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A smartphone-based intervention to enhance functional occupation and mood in people with neurodevelopmental disorders: A research extension

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Abstract

This study extended the assessment of a smartphone-based intervention designed to support occupational engagement, provide an opportunity of physical exercise, and promote personal enjoyment in people with significant neurodevelopmental disorders. Six participants were included in the study. A Samsung Galaxy J4 Plus smartphone with Android 8.1 operating system and near-field communication function was automated through the MacroDroid application to fit the intervention conditions. The participants were required to place cards with frequency identification tags into an elevated box with an embedded smartphone.

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Ethical Approval: Approval for the study was obtained from the Ethics Committee of the Lega F. D'Oro, Osimo, Italy. 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.

Informed Consent: Written informed consent for the participants' involvement in the study was obtained from their legal representatives.

The smartphone identified each of the cards the participant placed into the box and played preferred song segments matching those cards. The smartphone also provided a verbal prompt/encouragement to respond if preset time intervals elapsed without any card response. All participants showed significant increases in their frequency of card responses, in their heart rates, and in their indices of enjoyment during the intervention sessions as opposed to baseline or control sessions. The results were discussed in relation to previous data in the area and in terms of their apparent relevance for daily contexts.

Keywords: Smartphone-based intervention; Neurodevelopmental disorders; Occupational engagement; Heart rates; Indices of enjoyment.

1. Introduction

People with serious neurodevelopmental disorders, such as moderate to severe intellectual disability combined with motor impairment, may experience extended periods of limited occupation or passivity during the day (Blain-Moraes & Chau, 2012; Whalley Hammell & Iwama, 2012; Lancioni, O'Reilly, Singh, Green, Oliva, Campodonico *et al*., 2013; Channon, 2014; Hunt & McKay, 2015; Munde & Vlaskamp, 2015; Whalley Hammell, 2015). They (a) may be unable to independently engage in functional daily activities, (b) may have no direct access to conventional tools used for occupation and leisure and/or fail to manage those tools on their own, and (c) may not receive sufficiently high levels of staff supervision aimed at supporting their positive occupational engagement (Leopold, Lourie, Petras, & Elis, 2015; Lancioni, O'Reilly, Singh, Sigafoos, Boccasini, La Martire *et al*., 2016; Lancioni, Singh, O'Reilly, Sigafoos, Alberti, Perilli *et al*., 2017; Lancioni, Singh, O'Reilly, Sigafoos, Alberti, Perilli *et al.*, 2018a).

Extended periods of limited occupation or passivity may be considered deleterious as they reduce the persons' opportunities of stimulation control and physical activity/exercise, hinder their social image, and depress their mood with generally negative implications for their well-being and quality of life (Green & Reid, 1999; Segibaeva, Pogodin, Lavrova, Balykin, & Aleksandrova, 2011; Lin, Chen, & Cho, 2012; Shih, Shih, & Luo, 2013; Taylor, Taylor, Gamboa, Vlaev, & Darzi, 2016). Technology-aided interventions have been indicated as a possible means to counter this situation and reduce the aforementioned drawbacks in a reasonably affordable manner (Shih *et al.*, 2013; Taylor *et al.*, 2016; Davies, Stock, Herold, & Wehmeyer, 2018; Raspa, Fitzgerald, Furberg, Wylie, Moultrie, DeRamus *et al.*, 2018). Indeed, those interventions are typically set up with the objective of promoting the persons' engagement with reduced staff involvement and thus with limited time costs. To ensure that engagement is successful and lasts over time, the interventions are set to target suitable responses and to follow each response emission with contingent stimulation, that is, with the occurrence of positive events such as brief periods of preferred music (Tam, Phillips, & Mudford, 2011; Lancioni, Singh, O'Reilly, Sigafoos, Campodonico, Oliva *et al.*, 2018b).

The interventions may vary depending on the characteristics of the participants, the forms of occupation pursued with them, and the technology used. For example, interventions may be directed at helping the participants

to perform a simple response (e.g., screen or microswitch touching) to access brief periods of prearranged stimulation (Tam *et al*., 2011; Shih, Chiang, Wang, & Chen, 2014). Interventions may also target responses that are potentially suitable for providing the participants with a mild form of physical exercise (e.g., arm or leg stretching) (Lancioni *et al*., 2018b; Lancioni, Singh, O'Reilly, Sigafoos, Alberti, Campodonico *et al.*, 2019b).

The technology may include (a) specifically built combinations of microswitches (i.e., sensors triggered by participants' responses) and computers programmed to deliver stimulation contingent on those responses (Lancioni *et al*., 2018b), (b) commercial touch-screen devices set up to enable the participants to manage the *occurrence* of stimulation events through simple hand responses (Kagohara, van der Meer, Ramdoss, O'Reilly, Lancioni, Davis *et al*., 2013; Joddrell & Astell, 2016), and (c) everyday devices such as a smartphone set up to allow the participants to access preferred stimulation events through the manipulation of small objects/cards (Lancioni, O'Reilly, Sigafoos, Alberti, Campodonico & Chiariello, 2019a).

The last form of technology was recently used with seven participants who presented with intellectual disability ranging from moderate/severe to severe/profound and visual impairment (i.e., blindness in six of the seven cases). The participants could activate brief periods of preferred stimulation by placing special, rigid cards fitted with radio frequency identification (RFID) tags (Irani, Gunasekaran, & Dwivedi, 2010) into an elevated box with an embedded smartphone. The smartphone was programmed to read the cards' tags and provide the stimulation matching them. This technology was effective in promoting a response (arm stretching to place the card into the box) that represented a mild form of physical exercise and in improving the participants' mood. The same technology might also be considered suitable for allowing participants with functional vision to choose their stimulation input. For example, the cards could be of different colors (with each color related to a singer or a song) or could be placed in boxes marked with the pictures of different singers, thus allowing the participant to decide what to select (i.e., what music/song to listen to) (Mitchell, 2015). While the preliminary results reported with this last form of technology are quite encouraging, only a few participants with intellectual and visual disabilities were involved in the evaluation. This study was aimed at extending the use of such technology with six new participants who were diagnosed with intellectual disability and motor impairment.

2. Method

2.1. Participants

Table 1 lists the six participants by their pseudonyms and reports their chronological ages, their intellectual and motor conditions, and their age equivalents for receptive communication on the second edition of the Vineland Adaptive Behavior Scales (Sparrow, Cicchetti, & Balla, 2005; Balboni, Belacchi, Bonichini, & Coscarelli, 2016).

Table 1 - *Participants' pseudonyms, chronological ages, intellectual and ambulation conditions, and Vineland Age Equivalents for Receptive Communication*

Participants	Chronological Ages (years)	Intellectual and Ambulation conditions	Vineland Age Equivalents[1] (years; months)
David	70	Moderate to severe intellectual disability; ambulation with some staff assistance	3; 1
Alec	30	Severe to profound intellectual disability; ambulation with some staff assistance	1; 9
Emil	32	Moderate intellectual disability; no ambulation	3; 4
Mitch	39	Severe to profound intellectual disability; no ambulation	1; 7
Larry	57	Moderate to severe intellectual disability; no ambulation	2; 7
Glen	74	Moderate to severe intellectual disability; ambulation with a walker	2; 5

[1] The Vineland age equivalents are based on the Italian standardization of the Vineland scales (Balboni *et al.*, 2016).

Their chronological ages varied between 30 and 74 (M = 50) years. Three of them were non-ambulatory (Emil, Mitch, and Larry), one could move with a walker (Glen), and the other two walked with some assistance from staff. Two participants could utter a number of sentences (Emil and Glen), while the others did not have any functional expressive skills. All participants could discriminate basic colors, and two of them (Emil and Glen) were able to discriminate images of preferred singers. Their Vineland age equivalents for receptive communication ranged from slightly above 1

and a-half years to over 3 years. Their levels of intellectual disability had been estimated (by the psychological services of the rehabilitation and care centers that they attended) to range from moderate to severe/profound. No IQ scores were available for them due to the difficulties of conducting formal testing.

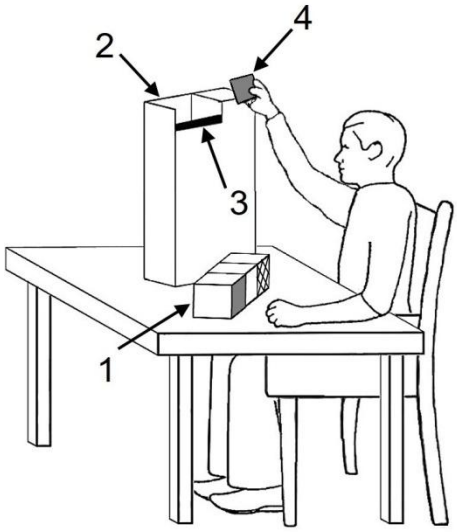
The participants were included in the study based on the following criteria. First, they were known to be generally passive (i.e., failing to engage in activities). Second, they possessed the response scheme targeted within the study (i.e., the response of placing an object into an elevated box) and the performance of such scheme was viewed as beneficial/desirable by physiotherapists. Third, they were known to be interested in specific types of music stimulation and to respond to such stimulation with positive expressions such as smiles and excited vocalizations. Their interest in music suggested that they (a) would enjoy an intervention program such as the one set up in this study (i.e., allowing them access to music), and thus (b) would be quite willing to participate in such a program. Fourth, they generally complied with verbal prompts/encouragements to carry out simple, familiar responses. Fifth, staff and families supported the use of the intervention (which had been explained to them in advance). Given the participants' inability to sign a consent form for the study, their legal representatives had done so for them. The study complied with the 1964 Helsinki declaration and its later amendments and was approved by a relevant Ethics Committee.

2.2. Setting, Sessions, Target Response, and Stimuli

The setting for the study consisted of quiet areas of the rehabilitation and care centers that the participants attended. The study included baseline, control, and intervention sessions. Sessions lasted 5 min and were carried out for each participant individually. During baseline and intervention sessions, the participants sat at a desk in front of a container divided into three compartments each including a group of 10 cards. For Emil and Glen, the outside of every compartment was marked with the photo of a preferred singer, and the cards inside the compartment produced song segments from that singer when placed into the elevated box (i.e., in contact with the smartphone; see below). For the other participants, the outside of every compartment and the cards inside it were of a specific color (e.g., red, yellow, or green) and each color was linked to a singer. Figure 1 provides a diagram illustrating the participants' position, the container with the compartments, and the response the participants were to perform (i.e.,

bringing cards into an elevated box, which encompassed a smartphone). Given that the performance of the response required some physical exertion, it was assumed that response engagement during the sessions could constitute a mild/beneficial form of physical exercise for the participants. During the control sessions, the participants sat without any material or activity. The control sessions served to measure the participants' heart rates and mood (i.e., indices of enjoyment such as smiles and vocalizations) outside the intervention sessions.

Figure 1 - *Participant's position and materials*



Note: The diagram represents a participant sitting at a desk in front of a container with three different compartments marked with different colors (1), and an elevated box (2) with a smartphone (3). The participant is bringing a card (4) to the box's opening to activate the smartphone.

Song segments were the stimuli used contingent on the participants' responses. The songs, which had been recommended by staff as the participants' favorites, were selected for the study following a preference screening procedure. The screening procedure consisted of presenting two or three 10-s segments of each song for about 10 non-consecutive times over several assessment occasions (Hagopian, Long, & Rush, 2004; Lancioni *et al.*, 2018b). A song was retained for use during the intervention sessions if the research assistant and staff member carrying out the screening procedure concurred in reporting that the participant had positive reactions (e.g.,

orientation or indices of enjoyment; see below) during about or more than 50% of the presentations.

2.3. Smartphone, Cards, and Wristwatches

A Samsung Galaxy J4 Plus smartphone (i.e., a very common and fairly inexpensive model) with Android 8.1 operating system and near-field communication function was specifically automated through the MacroDroid application so it could suit the intervention conditions (see below). The smartphone was fitted with audio files containing segments of the participants' preferred songs as well as prompts/encouragements, and was equipped with a mini speaker. The cards that the participants were expected to place into the elevated box were pieces of hard cardboard of 6 x 8 cm, which were coated with plastic and fitted with RFID tags (Irani *et al.*, 2010). The tags made the cards recognizable by the smartphone and so the smartphone could reliably deliver song segments matching the cards (i.e., song segments of the singer linked to those cards).

In practice, placing a card into the elevated box (i.e., making the card touch the back of the smartphone embedded in the box; see Figure 1) caused the smartphone's near-field function to discriminate the tag attached to the card and the MacroDroid to open a file matching the card. The MacroDroid was also programmed to ensure that (a) a smartphone verbal prompt occurred if there was no new response after about 10 s from the end of the previous song segment (i.e., during intervention), and (b) responses and prompts were recorded automatically.

Wristwatches with built-in heart-rate monitor (i.e., TomTom Runner Cardio or Garmin Vivosmart HR) were employed for recording the participants' heart rates during a number of intervention sessions and the control sessions preceding them. This use of wristwatches was consistent with that reported in previous studies in this area (Lancioni *et al.*, 2019a, b).

2.4. Measures

The measures recorded included: the card responses, smartphone prompts, heart rates, and mood (i.e., indices of enjoyment). The number of card responses (i.e., of cards brought into the elevated box, in contact with the smartphone) and of smartphone prompts were automatically recorded by the smartphone. Heart rates were recorded as mean rates per session via a wristwatch with heart-rate monitor, which the participants wore. Recording

was carried out for each participant over 18-29 pairs of sessions. A pair included an intervention session and the control session that preceded it. Indices of enjoyment (i.e., smiling, singing, music-related vocalizations or body movements, and positive verbal statements; Lancioni *et al.*, 2019a) were recorded by research assistants during 12-25 control sessions and 38-64 intervention sessions. A partial interval recording system was used, in which 10-s observation intervals were followed by 5-s scoring periods (Kazdin, 2012). Reliability observers joined the research assistants in at least 20% of the sessions to check interrater agreement on this last measure. Agreement was calculated for the single sessions (by dividing intervals with the same scoring by the total number of intervals and multiplying by 100%). The percentages of agreement were in the 80-100 range, with means for the single participants greater than 90.

2.5. Experimental Conditions and Data Analysis

A non-concurrent multiple baseline design across participants (Barlow, Nock, & Hersen, 2009) was used to determine the effects of the smartphone-based intervention. The participants were initially provided with baseline sessions. Then, they received intervention sessions during which the automated smartphone worked as described in the *Smartphone, Cards, and Wristwatches* section. Control sessions were also available. They were scattered through the intervention phase (see below). The participants' card responses during baseline and intervention were summarized as means per session over blocks of sessions and reported in graphic form. The participants' heart rates and indices of enjoyment were summarized as means per session across the intervention sessions and the control sessions, in which these measures were recorded, and were reported in tables. The Kolmogorov-Smirnov (i.e., a nonparametric) test was used to determine whether the differences in the data distribution for card responses and indices of happiness differed significantly between the intervention and the baseline or control sessions (Siegel & Castellan, 1988). The paired t-test was used to assess the differences across the pairs of intervention and control heart rate values of each participant (Peacock & Peacock, 2010).

2.6. Baseline Sessions

During the baseline sessions (whose number varied from four to eight consistent with the design requirements), the participants were provided

with the elevated box containing the smartphone as well as the cards (i.e., as previously described; see Figure 1). The smartphone recorded the participants' card responses but did not produce (a) any stimulation (i.e., song segments) in relation to the card responses or (b) any prompts if the participants failed to respond. At the start of the sessions, the research assistant led the participants to perform a response (i.e., place a card into the elevated box) through verbal and physical guidance.

2.7. Intervention Sessions

During the intervention sessions (whose number varied from 52 to 102 based on participants' availability), the smartphone delivered (a) a 10-s segment of a preferred song after each card response, and (b) a verbal prompt to respond after about 10-s of no responding had elapsed from the end of the previous song segment. The smartphone also recorded responses and prompts. Heart rates and indices of enjoyment were recorded during 18-29 and 38-64 intervention sessions, respectively (see *Measures* section). There was partial overlap between the two groups of sessions, as a number of those sessions were used for recording both measures. The intervention sessions were preceded by three to seven introductory sessions during which the participants practiced (with the research assistant's verbal and physical guidance, if needed) the response and experienced the song stimulation.

2.8. Control Sessions

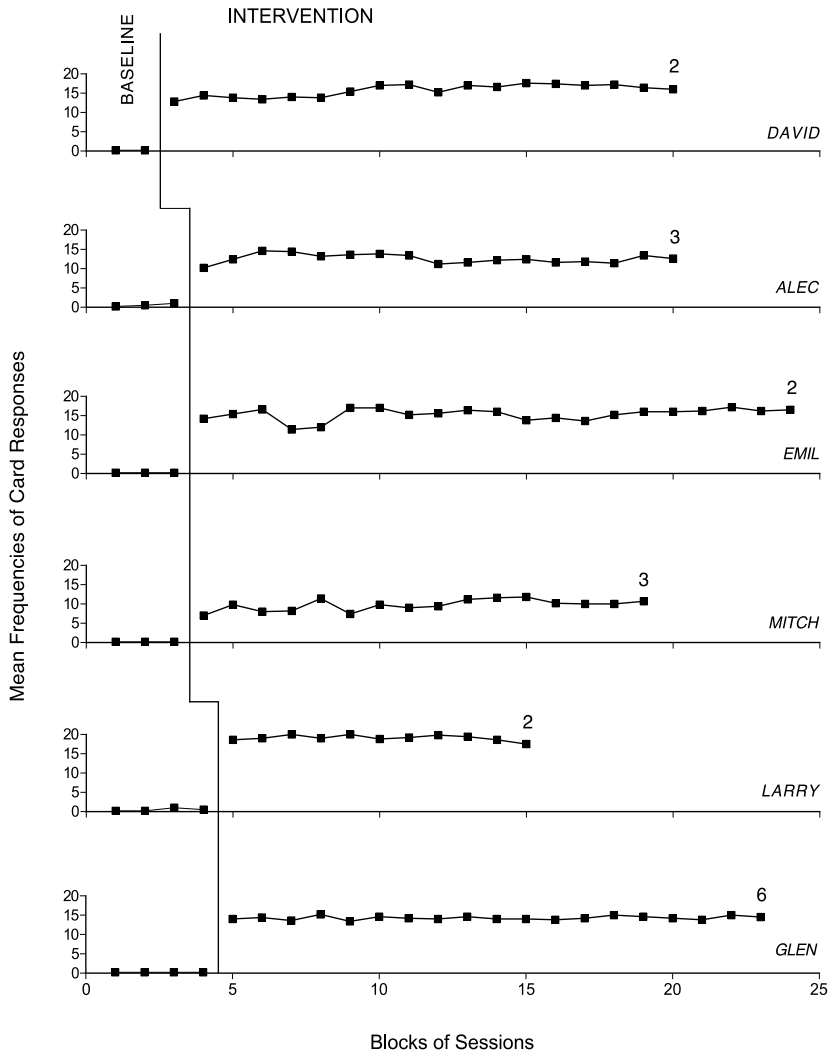
Control sessions, as mentioned earlier (see *Measures* section), served for recording the participants' heart rates and indices of enjoyment outside the intervention sessions. The two measures were recorded in 18-29 and 12-25 control sessions, respectively. During the control sessions, the participants were sitting without any specific stimulation or activity.

3. Results

The six panels of Figure 2 summarize the participants' baseline and intervention data concerning card responses. The figure does not report the introductory sessions preceding the start of the intervention. Data points represent mean frequencies of responses per session computed over blocks of two sessions (during baseline) and blocks of five sessions (during

intervention). The only exception concerns the last block of the intervention phase. The numeral on that block indicates the number of sessions included.

Figure 2 - *Participants' baseline and intervention mean frequencies of card responses per session*



During the baseline sessions, the participants' mean frequencies of card responses per session was zero or close to zero. During the intervention phase, the mean frequencies of responses per session increased for all participants to between near 10 (Mitch) and about 19 (Larry). The Kolmogorov-Smirnov test showed that the differences between the baseline

and intervention session frequencies were significant ($p < .01$) for all participants. The frequency of smartphone prompts per session ranged from virtually zero (Larry) to over six (Mitch).

Table 2 reports the participants' heart-rate values (i.e., means and ranges) for the 18-29 pairs of control and intervention sessions. The mean heart rate values per session varied between 67 (Emil) and 82 (Alec) during the control sessions and between 71 (Emil) and 91 (Glen) during the intervention sessions. The mean heart rate increases during the intervention ranged from 4 to 14 ($M = 10$) points. The paired t-tests performed for the single participants indicated that the differences between their control and intervention heart rate values were significant ($p < .01$), with t values ranging from 3.79 to 13.35.

Table 2 - *Participants' mean heart-rate values (and session ranges) across the control and intervention sessions whose number (No.) is specified*

Participants	Control sessions			Interventions sessions		
	No.	*Mean*	*Range*	*No.*	*Mean*	*Range*
David	22	78	71-85	22	87	77-99
Alec	19	82	71-93	19	89	77-102
Emil	20	67	61-73	20	71	65-77
Mitch	29	68	62-79	29	82	74-89
Larry	18	73	62-83	18	87	69-105
Glen	21	80	66-95	21	91	74-109

Note: Mean heart rates are rounded to the nearest full number values.

Table 3 - *Participants' mean percentages of intervals with indices of enjoyment (and session percentage ranges) across the control and intervention sessions whose number (No.) is specified*

Participants	Control sessions			Interventions sessions		
	No.	*Mean*	*Range*	*No.*	*Mean*	*Range*
David	24	4	0-25	64	48	5-75
Alec	18	2	0-15	61	37	0-85
Emil	20	19	10-35	56	5	20-80
Mitch	25	4	0-25	52	56	30-70
Larry	12	17	10-30	38	33	5-70
Glen	22	10	0-30	55	41	15-65

Note: Mean percentages are rounded to the nearest full number values.

Table 3 reports the participants' data on indices of enjoyment for the 12-25 control sessions and the 38-64 intervention sessions. In particular, the table reports for each participant (a) the number of control and intervention sessions, in which indices of enjoyment were recorded, and (b) the mean and range percentage values for the two sets of sessions. The mean percentages of intervals with indices of enjoyment were between 2 (Alec) and 19 (Emil) during the control sessions, and between 33 (Larry) and 56 (Mitch) during the intervention sessions. The Kolmogorov-Smirnov test showed that the differences between the baseline and intervention data values were significant ($p < .01$) for all participants.

4. Discussion

The results of this study indicate that the smartphone-based intervention was effective in fostering card responses (i.e., occupational engagement), increasing heart rates, and enhancing indices of enjoyment for all participants. These results support and strengthen the findings of the previous study using the same smartphone-aided intervention (Lancioni *et al.*, 2019a) and, at the same time, provide an additional demonstration of the relevance of technology-aided strategies for improving the overall performance and pleasure of people with extensive neurodevelopmental disorders (Dillon & Carr, 2007; Sunderland, Catalano, & Kendall, 2009; Stasolla, Perilli, Di Leone, Damiani, Albano, Stella *et al.*, 2015; Lancioni *et al.*, 2019b). In light of these results, a number of considerations may be in order.

First, the positive results obtained with the six participants may be particularly relevant in light of the fact that the intervention was based on easily accessible and relatively inexpensive commercial technology. Indeed, the smartphone, the MacroDroid application, and the tags to attach to the cards can be acquired without any difficulty and are affordable for most daily contexts. In spite of the aforementioned accessibility/affordability aspects, it should be noted that the technology, as available on the market, is not ready for use. The two most important operations required for making the technology functional concern the smartphone. One operation is to supply the smartphone with a variety of files containing the participants' preferred song segments and the prompts. The other operation is to program the smartphone through the MacroDroid application. Programming is essential to (a) enable the smartphone to read the cards (i.e., their tags) and activate the matching files, (b) monitor the time gaps between the end of a

stimulus event and the following card response, (c) activate a prompt when the gap exceeds a preset limit, and (d) record responses and prompts.

Second, the participants' consistent responding through the intervention sessions can be explained by the fact that (a) responses were followed by preferred song segments and (b) lack of responding for a preset period led to the occurrence of smartphone prompts (Pierce & Cheney, 2008; Kazdin, 2012). The song segments alone appeared responsible for ensuring performance continuity for a participant like Larry (who virtually received no prompts). On the other hand, prompts seemed to have a role for other participants, in particular for Mitch (i.e., the participant with the largest prompt frequency). The latter participants might have developed and maintained their responding with the use of song segments only, but they would have probably displayed pauses (breaks) in performance and a consequent reduction in the overall response frequency (Kazdin, 2012).

Third, the increases in heart rates and indices of enjoyment during the intervention sessions are important evidence that supports the use of an approach such as that adopted in this study. Indeed, helping the participants to replace periods of passivity with smartphone-mediated occupational sessions can be viewed as a relevant objective by itself. The relevance of this objective increases when there are signs that response engagement can positively impact the participants' physical condition and level of pleasure, as it was observed in this study.

With regard to the increase in heart rates, it is difficult at this point to make specific comments given that no certain parameters exist for determining possible effects (benefits) of small changes such as those reported (Fernhall, McCubbib, Pitetti, Rintala, Rimmer, Millar *et al.*, 2001; Gellish, Goslin, Olson, McDonald, Russi, & Moudgil, 2007; Waninge, Van der Putten, Stewart, Stenberg, van Wijck, & van der Schans, 2013). New research will hopefully shed some light on this issue and eventually identify correlations between heart rates and physiological measures (Bartlo & Klein, 2011; Wen, Wai, Tsai, Yang, Cheng, Lee *et al.*, 2011; Hill, Gardiner, Cavalheri, Jenkins, & Healy, 2015). With regard to the increases in indices of enjoyment, one can argue that they contribute to enhance the social image of the participants and possibly also their quality of life (Dillon & Carr, 2007; Verdugo, Navas, Gomez, & Schalock, 2012; Brown, Hatton, & Emerson, 2013; Copeland, Luckasson, & Shauger, 2014).

Fourth, while the study was focused on determining the effects of the intervention on the participants' occupational level, heart rates and enjoyment, the intervention setup also offered the participants choice

opportunities. Indeed, the participants had a container divided into three compartments with three sets of cards representing songs of different singers and could use the cards in any order depending upon their preferences or momentary desires. This setup may be considered adequate to support choice in people with moderate or moderate to severe intellectual disability and informal reports suggested that two of the participants of this study (i.e., Emil and Glen) were particularly careful in picking the cards and using them, suggesting that they were making choices. Obviously, choice should be assessed in a formal manner. For example, one could provide cards linked to preferred songs/singers as well as cards connected to music that the participants do not prefer and determine whether they choose the former and skip the latter (Lancioni, Singh, O'Reilly, Sigafoos, Oliva, Alberti *et al.*, 2014; Stasolla *et al.*, 2015).

Fifth, several limitations of the study need to be mentioned. One limitation is represented by the relatively small number of participants involved and the fact that they were provided with fairly limited amounts of short sessions. Additional research is needed to determine the robustness of the present data and clarify whether it is possible to extend the length of the sessions and their use over time (Kazdin, 2011; Brandt, Ijzerman, Dijksterhuis, Farach, Geller, Giner-Sorolla *et al*., 2014; Makel & Plucker, 2014). Another limitation is the lack of any direct, data-based investigation of the participants' choice in their use of the cards (Stenhoff, Davey, & Lignugaris/Kraft, 2008; Kazdin, 2012; Mitchell, 2015). An answer to this question may be useful to determine the suitability of the container's compartments with the images of preferred singers or different colors for promoting choice patterns. A third limitation is the lack of a social validation of the intervention. A social validation would need to include staff and caregivers and identify their opinion about the effects of the intervention and its applicability within daily contexts (Luiselli, Bass, & Whitcomb, 2010; Dickson, McDonald, Mansfield, & Ahearn, 2014).

In conclusion, the results of this study are encouraging as to the possibility of using a simple smartphone-based intervention to (a) support occupational engagement, (b) provide an opportunity for mild physical exercise, and (c) promote personal enjoyment among people with significant neurodevelopmental disorders. New research will need to address the limitations of this study so as to determine the robustness and reliability of this approach and its level of acceptability within daily contexts. Response and stimulation variations should also be explored to build intervention alternatives suitable for people with different needs.

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