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Documenting the use of a musical virtual space environment in the rehabilitation of young adults with congenital motor disabilities

PEDRO LOPES-DOS-SANTOS (*)
ARMANDO NANIM (*)
HELENA FERNANDES (**)
JORGE LEVI (***)

This paper focuses on the application of a musical virtual space environments in the rehabilitation of individuals with motor disabilities. It is contended that the use of such environments has the potential of enhancing performance through engagement of the person in meaningful and functional activities. Our study describes and evaluates the use of a musical virtual space generated by Soundbeam 2™ to increase the quality of movement and improve gross motor functioning in four young adults with congenital hemiparesis. Results showed that immersion episodes in the musical virtual environment provided highly engaging experiences that fostered body movement and social interaction. After twenty immersive sessions, participants revealed gains in the aesthetic quality of gestures performed in dancing responses to music. There were also significant improvements regarding gross motor functions, namely in parameters such as stability, coordination, flow, effort, and mobility.

Key words: *Environment, Motor disabilities, Rehabilitation, Social interaction, Virtual music.*

Cet article presente l'utilisation d'environnements d'espaces musicaux virtuels dans la réhabilitation d'individus atteints de handicaps moteurs. On y défend que l'utilisation de tels environnements permette d'augmenter la performance dans les activités significatives et fonctionnelles dans laquelle la

(*) Universidade do Porto.
(**) ISS-IP, UADIP/Centro de Campo Lindo, Porto.
(***) Balleteatro, Porto.

personne s'est engagée. Notre étude décrit et évalue l'utilisation d'un espace de musique virtuelle généré par Soundbeam 2™ et dont le but est d'accroître la qualité des mouvements et d'améliorer les fonctions motrices globales chez quatre jeunes adultes atteints d'hémiparésie congénitale. Les résultats ont montré que les moments d'immersion dans l'environnement musical virtuel génèrent des expériences hautement motivées favorisant les mouvements corporels et les interactions sociales. Après vingt sessions d'immersion, on note chez les participants une amélioration de la qualité esthétique de leurs gestes à travers des réponses dansées à la musique. De même, on a pu noter des améliorations significatives concernant les fonctions motrices globales, nommément dans des paramètres comme la stabilité, la coordination, la fluidité, l'effort et la mobilité.

Mots clé: *Environnements, Handicap moteur, Interactions sociales, Rehabilitation, Virtuel musique.*

Introduction

Traditional rehabilitation practices focus on treatment of specific impaired skills thought to underlie the functional limitations of people with disabilities. This perspective builds on an *interventionist-centred* model that regards disabled persons as in need of services from a professional who can provide specialized therapy to reduce or "correct" impairments caused by given dysfunctions. Most impairment-based interventions rely on the belief that people with disabilities should be trained as much as possible to perform activities and tasks "normally". Therefore, "normality" becomes the key guiding reference for decisions about what is recommended and prescribed in each case (Ravaud & Stiker, 2001).

Highlighting the achievement of discrete goals and outcomes, *interventionist-centred* practices provide an organizing structure for interpersonal processes in which the therapist becomes the sole controlling agent of action. Such orientation does not factor in or take advantage of the preferences for activities that clients might want to do, or to avoid. While ignoring these aspects, the *interventionist-centred* model disregards the importance of personal choices, concerns, appeals, likes and dislikes of the individuals whose disabilities are being addressed in therapy programs (e.g., Rosenbaum et al., 1998).

During the past few years, views on rehabilitation have been moving from an *interventionist-centred* framework to a *whole person* approach, which places a special emphasis on the dynamic interaction between the individual and its environment (Williams, 2001).This notion of person-environment interaction is echoed in a change of focus from strict documentation and

treatment of impairments, to a wider approach that emphasises the therapeutic significance of engaging disabled people in meaningful and functional activities (Simeonsson, Pereira, & Scarborough, 2003). One of the fundamental premises underlying such perspective is that individuals are more likely to participate in activities in which they are interested and in which they elaborate on existing assets (Dunst, 2004). When truly involved in an activity, they have opportunities to practice current abilities and use their often-residual capabilities to acquire new skills. Individuals may try out new possibilities, exploring and finding out how their behaviours can make things happen. In this way, they have the chance to learn about their own abilities, strengthening their sense of mastery and self-efficacy (Raab & Dunst, 2006).

Two types of interest are likely to influence individuals' engagement in activities: *personal interests* and *situational interests* (Renninger, 2000). Personal interests are specific to individuals and involve their knowledge of positive feelings about an experience or activity. On the other hand, situational interests refer to enjoyment evoked by the appealing quality of situations or contexts. Thus, a situational interest emerges when the characteristics of an activity or event draw the individual's attention and curiosity, inviting him or her to become involved. Conditions that have ingredients of novelty, surprise, and exploration can originate situational interests (Krapp et al., 1992).

Musicological aspects of human functioning have been historically neglected in comparison with other capabilities revealed by members of our species. Yet, musicality – an attribute that encompasses aspects such as sensitivity for music, expression of music skills, or predispositions for processing and enjoying musical experiences – might have evolved even before speech in the human evolutionary process (Papoušek, 1996). Related to the inherited architecture of the mind, human musicality has universal presence across age, sex, or culture, and fosters a strong intrinsic motivation for its manifestation. Therefore, it is not surprising that activities associated with music tend to evoke both personal and situational interests.

Our study lies on the assumption that musical virtual spaces are valuable contexts for promoting engagement in action. The concept of musical virtual space refers to an environment where human physical movements are translated into real time auditory feedback provided through appropriated stimuli for music-making (e.g., percussive sounds, notes from different scales, and chords delivered by distinct "instruments"). While interacting with such environments, immediate "musical" responses to gestures are likely to be so pleasing that make individuals unaware of the effort involved in the generation of movement (Brooks et al., 2002). Pleasurable experiences resulting from immersion in musical virtual spaces increase the motivation to move and stimulate the

performance of motor activities. On the other hand, if embedded in meaningful interpersonal contexts, movements produced in relation with technology may acquire a communicative value, developing into expressive gestures. These gestures, taken as social valued bodily expressions, are likely to be analysed through their creative aesthetical sense.

The aim of the present paper was to explore the use of a musical virtual space environment as a therapeutic tool in the rehabilitation of individuals with hemiparesis. Participants were invited to take part in a "dancing workshop" where they were free to explore the sonic effects of their movements within a musical virtual space. During the "workshop" sessions, the facilitator stimulated them to develop themes using expressive "dance" movements as a way to avoid a potential sterile "technology-led" approach. Since the fundamental principle of the intervention was to engage participants in meaningful dance-related activities, assessment outcomes were primarily focused on improvements regarding the aesthetic quality of gestures produced in response to music. Although the intervention was not explicitly designed to treat or correct their specific impairments, we expected that promoting participants engagement in "dancing" activities would induce some positive changes in impaired functions. Therefore, typical aspects of gross motor functioning were also addressed in the assessment procedures.

Method

Participants

Participants were four young adults (2 males and 2 females) with congenital hemiparesis associated with intellectual and language impairments. Their ages ranged from 19 to 25 years old and they were all attending full-time rehabilitation services in an occupational unit for persons with severe disabilities. Inclusion criteria included moderate to less than mild difficulties in changing body positions (from sitting down to standing up or lying down), walking, jumping, moving both upper and lower limbs, understanding verbal instructions, and perceiving contingencies between one's own gestures and the delivered auditory feedback. Furthemore, participants had no significant visual or hearing impairments. Their legal carers signed the informed consent.

The musical virtual space

The musical virtual space environment was created using Soundbeam 2™. This device was chosen because it can be operated by anyone without musical skills and with minimal motor capabilities.

Applying a movement tracking technology, Soundbeam emits ultrasonic invisible beams inaudible to human ears. The emitted pulses activate sensors so that any physical movement performed in the range of a beam, generates data, which are immediately translated by digital systems into auditory signals. Moving a limb in space can result in the sound of a harp, an ensemble of voices, or bells for example. Although it is possible to incorporate visual components, in our study only sonic feedback responses were programmed.

Each participant's tracked gesture controlled the pitch variation of a MIDI instrument. Several modes were selected with different sorts of variables: (1) the number of generated notes, (2) the relationships between those notes – i.e., scales, chords, and arpeggios – (3) the required articulation for activate the notes – i.e., movement dynamics in relation to the sensor –, and (4) secondary information pertaining aspects such as velocity, pitch-bend, and depth modulation. The choice of program was left as an option in the interface, as well as the possibility of shifting or lowering the register of each instrument. Four sensors were attached to the MIDI, creating a three-dimensional playing space of around nine squared meters where "players" had the opportunity to move expansively. Each sensor was positioned in a specific angle so that beams could adequately "capture" participants' movements generated by their upper or lower parts of the body.

Procedure and measures

The four young adults agreed to participate in a 3-month "dancing workshop". During the first three sessions, they were presented with two kinds of music pieces: one symphonic (excerpts from the "Dance of the Swans" of Tchaikovsky's Swan Lake) and the other disco-sound type ("Come on Eileen" performed by the Dexys Midnight Runners & Kevin Rowland). Both pieces had acoustic resemblances with the sound templates used within the musical virtual space. Each participant was then invited to hear those pieces and to "dance" freely in response to the music. Their performance was videotaped in order to be analysed as pre-test data.

After these first sessions, participants were introduced in the musical virtual space environment. These sessions took place three times a week and lasted approximately one hour and a half. Participants were all present and seated in face of the virtual space. During the initial immersion experiences, they were invited to explore individually the environment. With time and following the indications of the facilitator, they were encouraged to elaborate musical patterns. They were also stimulated to develop narrative themes using expressive "dance" movements to generate sounds, which should be congruent with the feelings or ideas that they were trying to convey. After some sessions,

group activities were introduced with the intent of exploring new sonic effects and "composing musical themes" together. Experiences of immersion in the musical virtual space environment involved a total of twenty sessions and they were all video recorded.

For evaluation purposes, the same pre-test procedures were adopted in three additional sessions, following immersion experiences. "Dancing" activities during these last sessions were video recorded in order to be analysed as post-test data.

Regarding the so-called pre-test and post-test sessions, we extracted from the video records several samples (of 3/4 minutes). These samples were divided in two main groups according to the type of music that was being danced. At the pre-test, three samples of disco sound music and four samples of symphonic music were randomly chosen for each participant. At the post-test phase, we followed the same procedure. Thus, the seven pre-test samples were matched to the seven post-test samples in relation to the type of music that was being played. In each sample, the aesthetical quality of the dancing gestures was rated with a global score by a professional dancer using a coding scheme with several parameters and components mentioned in Table 1 (full descriptions and rating procedures are available from the authors). Ratings for each participant ranged from 0 to 5 points.

Table 1

Parameters used to assess the quality of the dancing movements

Parameters	Components
Improvisation	Movement development; Textures and efforts; Structured improvisation
Elements of movement	Space; Time; Energy/dynamics; Fluidity; Variety; Weight balance
Spatial relationships	Foreground/background; Symmetry; Levels; Planes
Mass movement	Movement phrases
Harmony	Opposition; Succession; Gestural
Themes	Rhythmic
Choreographic intent	Ordering and sequencing; The "felt" moment; Shape and Form

In order to assess gross motor functions, the same video samples were rated using five scales adapted from the *Video Documentation of Motor Behavior* – VDMB (Camargo et al., 1998). Scales are succinctly described in Table 2 (full definitions are available from the authors) and ratings extended from 1 to 6 points.

Hence, for each participant, pre and post-test measures comprehended a total of fourteen scores regarding the aesthetic dimension, and a sum of seventy

scores concerning gross motor functions (fourteen ratings in five scales), corresponding to a full amount of eighty four scores.

Table 2

Description of the rating scales used in the assessment of gross motor functions

Categories	Summary description
Stability	Maintains trunk control and balance while in gross motor activity, such that there is no evidence of transient propping or loss of balance that affects performance
Coordination	Uses two or more body parts together while performing moving activities such as walking, shaking...
Flow	Uses smooth and fluid arm and hand movements when performing activities that involve the use of upper limbs
Effort	Regulates or grades the speed and extent of movement while performing moving activities
Mobility	Actively flexes, rotates or twists the trunk in manner and direction appropriate to the moving activity

Participants' involvement during immersion sessions in the musical virtual space was assessed through the Engagement Assessment Scale – EAS – (Lopes-dos-Santos & Nanim, 2008). The EAS is an assessment tool specifically designed to evaluate levels of engagement in activity settings where individuals are invited to express themselves with movement or body postures in reaction to music. Scores are assigned considering that engagement behaviour results from a conjunction of responses implying attention, interest, enjoyment, and action. According to the EAS rating system, levels of engagement are scored in a range of 1 (nonengaged) to 7 (very intensively engaged) points. Likewise, a scale specifically designed for the current study evaluated social behaviours in the same immersion sessions. This scale focuses on positive social behaviour that indicates participants' willingness to engage in social interactions while performing within the musical virtual space environment. It considers behaviours that occur between peers, but not those that may take place between participants and the facilitator. For assessment purposes, a distinction was made between situations where participants were acting alone or performing in-group. Therefore, each participant could have two separate ratings within the same session. Participants' behaviours were rated within time sampling intervals of three minutes each. Since, during the same session, a participant was likely to be observed across several time sampling intervals, means were computed to obtain an overall rating of his or her behaviour throughout the session. According to the coding scheme (available from the first author), rates could vary between 1 point (no interaction) and 7 points (very active and persistent in social interactions).

Results

Data analysis

Due to the small sample size, results are presented for each participant. Ratings of engagement and social behaviours during every one of the first seven immersion sessions (first set) were compared, subject by subject, with the ratings assigned to each of the last seven sessions (second set). On the other hand, individual participants' scores obtained in each of the seven matched pre-test and post-test video samples were also analysed. For that purpose we employed non-parametric statistics. Rather than aiming inferential purposes, the use of these statistics intended to provide a basis for a better appreciation of individual data trends.

Engagement and social behaviours in immersion sessions

Figure 1 presents medians of engagement behaviour ratings for each subject in the first seven and the last seven immersion sessions. Results show that there has been a slight improvement from the first set to the second set of sessions, but none of the differences was statistically significant.

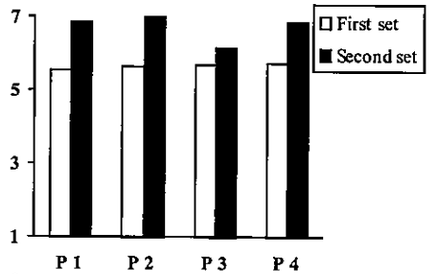

Figure 1. Medians of engagement behaviour ratings for each participant in the seven first and the seven last immersion sessions

Concerning the occurrence of social behaviours, results showed a general increase across the sessions. The fact that group activities were more frequent during the last sessions may explain this finding. However, watching the videos it seemed that the quantity of social interchanges tended to grow (laughs, verbal comments, etc.) even when participants were individually performing in front of their peers within the musical virtual space environment. Thus, we also compared for each subject ratings of social behaviour in the first seven sessions with ratings in the last seven sessions while they were individually acting.

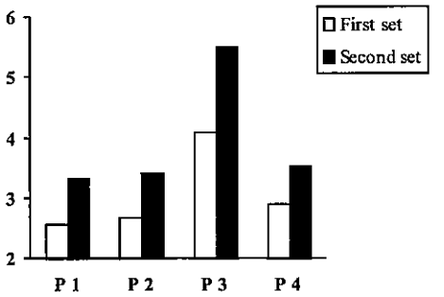

Figure 2. Medians of social behaviour ratings in the seven first and in the seven last immersion sessions for each participant while they were individually performing within the musical virtual space environment

Figure 2 shows the obtained medians in the two observation sets. These results, suggest that the amount of social interchanges grew from the first to the second set. The one-tailed Wilcoxon Signed Ranks Test (with alpha defined at .10) indicated that increases were significant for participant 1 (Z=-2.04; p<.04), participant 2 (Z=-1.65; p<.10), and participant 3 (Z=-2.41; p<.04). Regarding participant 4 the difference was not statistically significant (Z=-0.74; p>.29).

Dancing performance assessments before and after the immersion sessions

As above explained, ratings of the aesthetical quality of dancing were assigned to each participant in seven video samples from the pre-test sessions and in other matched seven samples from the post-test sessions. Medians are presented in Figure 3.

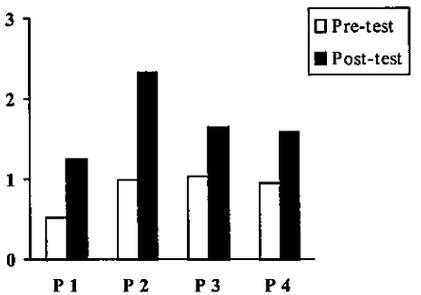

Figure 3. Median scores assigned to the quality of dancing performances of each participant at the pre and the post-test

The one-tailed Wilcoxon Signed Ranks Test showed that difference between the pre-test and the post test ratings were significant for participant 1 (Z=-2.37; p<.01), participant 2 (Z=-2.36; p<.01), participant 3 (Z=-2.36; p<.01), and participant 4 (Z=-2.36; p<.01).

Gross motor function assessments before and after the immersion sessions

During the so-called pre-test and post-test sessions, five gross motor function parameters were assessed while participants were involved in dancing activities. Figure 4 presents, for each participant, the medians of the scores assigned to the five gross motor parameters at the pre and at the post-test assessments.

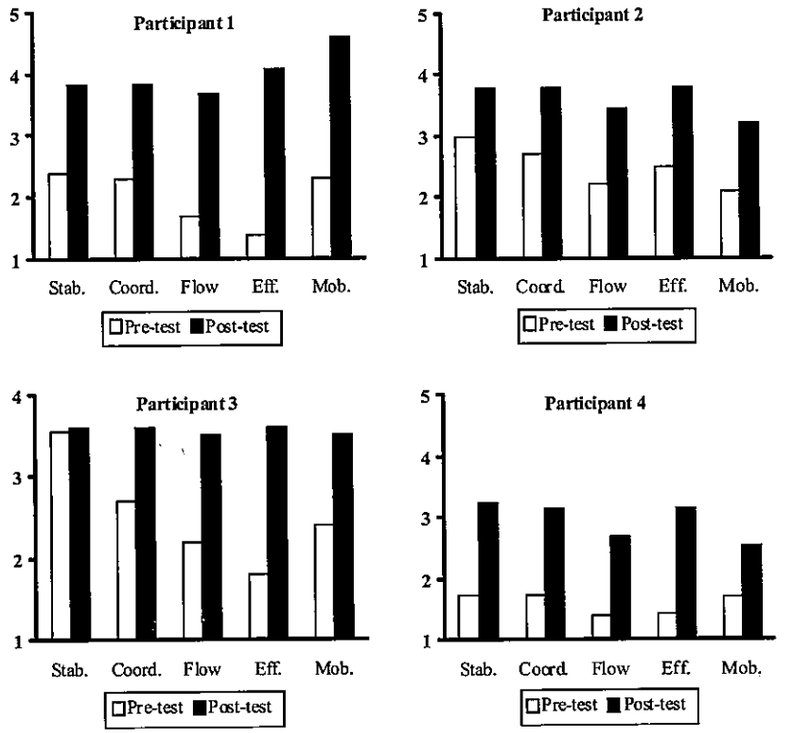

Figure 4. Median scores assigned to Stability (Stab.), Coordination (Coord.), Flow, Effort (Eff.), and Mobility (Mob.) for each participant at the pre-test and the post-test sessions

Graphic representations suggest that there was a general increase of motor gross performance after participants' experiences within the musical virtual space environment. The one-tailed Wilcoxon Signed Ranks Test results (pre-test *versus* post-test) for each subject are presented in Table 3.

Table 3

Results of the Wilcoxon Signed Ranks Test (pre-test versus post-test)

	Stability	Coordination	Flow	Effort	Mobility
Participant 1	Z=-2.27; p<.02	Z=-2.41; p<.01	Z=-2.23; p<.02	Z=-2.39; p<.01	Z=-2.46; p<.01
Participant 2	Z=-2.12; p<.03	Z=-1.84; p<.07	Z=-1.99; p<.04	Z=-2.42; p<.01	Z=-2.06; p<.04
Participant 3	Z=-1.00; p>.31	Z=-2.07; p<.04	Z=-1.63; p<.10	Z=-2.39; p<.01	Z=-2.12; p<.04
Participant 4	Z=-2.43; p<.01	Z=-2.27; p<.02	Z=-2.26; p<.02	Z=-2.20; p<.02	Z=-2.12; p<.04

With alpha value set at .10, differences were all statistically significant except for participant 3 whose stability scores did not show important gains between the pre and the post-test.

Discussion

The conceptual basis for providing intervention services to persons with disabilities has significantly evolved during the past few years. Indeed, contemporary views on rehabilitation shifted from an *interventionist-centred* orientation to a *whole person* approach in which therapy plans are designed to provide opportunities for interest-based involvement in meaningful and functional activities. Such involvement is likely to promote engagement and to encourage the practice of existing abilities. As individuals use their current assets to participate in activities, they are able to build upon them new skills and capabilities (Browder, 2001).

Assuming that music-related activities tend to elicit both personal and situational interests, the present study immersed four young adults with hemiparesis in a musical virtual space. Results showed that immersion experiences were highly engaging. As reported, participants revealed a remarkable persistence in interacting with the acoustic virtual space, exploring its potentialities for extended lengths of time. This finding is consistent with the assertion that individuals' interests are more likely to be evoked by

situations or environments in which elements of novelty, surprise, and exploration are prevalent (Krapp et al., 1992).

Social interchanges between participants increased across the immersion sessions. Such circumstance is seen as a direct consequence of the progressive introduction of group "tasks" in the performed activities. However, the increasing number of social interactions could be documented even when participants were acting alone in front of their peers. With time, the interactive "solitary play" with sounds gave place to frequent displays of behavioural patterns in which the willingness to receive social feedback was quite evident. Smiles, laughs, verbal comments, gazing exchanges became gradually more frequent and were particularly likely to occur when performed actions produced interesting sound feedback responses. This growing tendency to incorporate activities in the context of interpersonal processes probably reflects the effects of practice and learning. It was obvious that participants acquired a progressive capacity to interact creatively within the musical virtual space. Since social behaviour is fuelled by feelings of efficacy following self-recognized achievement of mastery (Shonkoff & Philips, 2000), the enhanced sense of control might have encouraged involvement in social interactions.

Comparing "dancing" performances at the pre and at the post-intervention sessions, our findings suggest that immersion experiences in the musical virtual space environment increased participants' sense of aesthetical awareness. Actually, results documented significant gains regarding the overall quality of expressive movements produced in response to music.

On the other side, assessments of gross motor functions revealed net improvements in aspects such as balance, fluency, amplitude of gesture, and coordination of both upper and lower limbs. Concerning this last observation, it is important to stress that our intervention was not specifically focused on impairments. However, the fact of engaging participants in dance-related activities brought up functional benefits. It is likely that movements required by performance of "dancing" activities have instigated improvements in underlying motor functions.

A fundamental premise of the *whole person* approach is that rehabilitation practices should concentrate on enhancing activities that involve a broad range of competencies. Individuals with disabilities have fewer opportunities to take part in common life experiences (Simeonsson, McMillen, & Huntington, 2002). Such restrictions are likely to reduce their capacity to learn from physical and social environments and to operate as disability-amplifying factors. Concerning the motor domain, movement has many functions; it enables growth and expression across several domains (e.g., cognitive, emotional, social), supports relationships, and is a major source of joy (Linder,

2008). Thus, it is not surprising that research studies document how specific neuromotor disorders may be the starting point for the development of disablement processes that affect several other domains of human functioning (Bruyère et al., 2005).

Although further research is needed, our findings support the hypothesis that musical virtual space environments can have the potential to address multiple skills within the same activity. On the other hand, previous studies conducted in the context of the *Soundbeam Project* suggest that experiences with the "invisible, elastic keyboard in space" provide important foundations for fostering development of abilities pertaining domains such as attention, imagination, mastery motivation, self-reliance, spatial orientation, motor planning, memory, reflective cognition, language, and social-skills (e.g., Ellis, 1997; Russell, 1996). Therefore, the use of musical virtual space environments may be a valuable therapeutic tool in intervention practices inspired by conceptual assumptions of the *whole person* approach.

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