Preliminary Findings from BehCreative: Exploring the Potential of Extended Digital Music Instruments for Music Therapy and Rehabilitation

Elena Partesotti[1](✉), Gabriela Castellano[2,3], and Jônatas Manzolli[1]

[1] University of Campinas (UNICAMP), NICS, Campinas, Brazil
eparteso@unicamp.br
[2] University of Campinas (UNICAMP), GlebWataghin Institute of Physics, Campinas, Brazil
[3] University of Campinas (UNICAMP) Brazilian Institute of Neuroscience and Neurotechnology, Campinas, Brazil

Abstract. The usefulness of traditional musical instruments has already been demonstrated in music therapy and rehabilitation. In recent years, virtual reality systems have also been shown to promote good cognitive and motor rehabilitation results. Nevertheless, there are still few studies joining these things. The aim of this study was to demonstrate the application potential of an Extended Digital Musical Instrument (EDMI), BehCreative, in those areas, focusing on its ability to promote engagement, motivation, and confidence among users. For this, Gibson's concept of affordance to study users' creative behavior was used. Three healthy subjects participated in this study. Virtual Affordances (VAs) used by users during an exploratory phase and their Motion Development (jerk) were measured, and they answered the Affective Sliders self-assessment questionnaire. The results indicate a positive impact of BehCreative on emotional reactions, physical activities, and creative learning, opening avenues for future research and practical applications in the fields of motor learning and human-computer interaction in music therapy and rehabilitation.

Keywords: Extended DMI · Music Therapy · Creativity

1 Introduction

The use of Extended Digital Music Instruments in music therapy practice and rehabilitation is extremely limited or practically non-existent. In contrast, there exists a substantial body of literature on the application of music therapy in motor rehabilitation [1], including its use in Parkinson's [2] and post-stroke cases [3]. This can be attributed to the fact that music stimulates various brain reward systems, thereby enhancing the physical and cognitive performance of clients. Concurrently, the utilization of Virtual Reality (VR) in the realm of rehabilitation has witnessed a significant upsurge over the past decade [4].

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Music therapy, recognized internationally in the 80s as a discipline capable of enhancing clients' physical and psychological well-being [5], centers around the active incorporation of traditional musical instruments to accompany and engage in dialogue with clients during sessions. This involvement may be led by one or more music therapists, depending on the applied methodology. In recent years, music therapy has increasingly intersected with the field of neurotechnology, involving the utilization of new technologies to ameliorate users' quality of life [6].

Despite this interdisciplinary impetus, research and implementation of DMIs in music therapy and physiotherapy have remained limited, with only a few examples to date [8, 9]. Considering the demonstrated effectiveness of music as therapy and the growing use of VR in therapeutic contexts, this paper aims to showcase the potential benefits that an Extended DMI can offer in these areas.

Within an EDMI the user becomes the instrument, as "the interaction occurs through a correlation between the environment and the agent, making the distributive nature of the space offered to the user essential as its property of manipulation and incorporation" [7].

The implementation of these technologies, in fact, could represent an excellent tool both for research and for caregivers during the delicate task of post-session analysis of clients' improvements.

This paper presents preliminary results of an exploratory study that tested the hypothesis that using an EDMI would increase the creativity and expression of the users, as measured by their motion development (Jerk) and Virtual Affordances.

2 Background

In this Exploratory Study we propose BehCreative as an EDMI [10]. In particular, within this EDMI, we considered the perspective offered by Embodied Cognition (EC) in designing a mapping closely connected to the movement and gestures of the subject in the environment, in which the body itself becomes a musical instrument. Within the EC paradigm, in fact, the common denominator is the role played by the body in experiencing and perceiving both the inner and the outer world in an enactive continuum [11]. EC contains various theories within it, many of which have been studied in recent years and are developing further. When dealing with an EDMI, we should also keep in mind Gibson's theory of visual perception, in particular the concept of Affordance that refers to the characteristics of the environment offered to the subject [12]. Affordances represent the potential of an object to be used in a particular way and for a particular purpose, a kind of invitation to use an object in a specific way.

In BehCreative (Fig. 1) there are no physical objects, but rather virtual possibilities depending on audiovisual feedback decided *a priori* through mapping. From the point of view of mapping, this virtual gesture refers to the concept of Multiple Affordance (MA) and Sensorimotor Map (SM) - somewhere else described [9] - and are determined by the subject's exploration of the environment. While MAs are the possible paths made available to the subject depending on the interaction with the EDMI and defined *a priori* by the mapping, the user can change the type of interaction or the ways they are used, following a specific goal within the environment by creating always new SMs. And this

characteristic depends on the mapping of the EDMI. At the same time, this goal is linked to the Creative Empowerment that "happens when the subject gains full control over the technology and is therefore capable of creative expression, self-control, and awareness" [10]. Hence, giving these considerations, we believe that BehCreative is a potentially promising EDMI with creative and expressive possibilities, grounded on the explorative behavior of the users and Creative Empowerment.

This research was interrupted due to the COVID-19 pandemic; therefore, of the 10 volunteers who took part in the experiment, only 3 completed all sessions and their data are presented in this article.

Fig. 1. BehCreative EDMI usage during an experiment with two users.

3 Material and Methods

We conducted an exploratory study with 3 healthy volunteers, between 21 and 38 years old, 1 male. The project was approved by the Ethics Committee of University of Campinas and all subjects gave their written informed consent before entering the study. For the experiment, the subjects explored the BehCreative environment for 10 days (during two weeks, from Monday to Friday) for a maximum of 5 min, without receiving any particular instruction, on the contrary, having maximum freedom to interrupt the experiment if they wanted. Each subject had a different musical and physical background; they were selected having in mind a future formation of the following groups:

- Control Group - subject with no previous knowledge of music and a regular fitness style of life;
- Music Group - subject with basic music knowledge;
- Exercise Group - subject with dance or sport background, but preferably with no musical background.

Before and after each session, the subjects completed an evaluation using Affective Sliders. The arousal and pleasure values were derived using the Affective Sliders method developed by Betella and Verschure [13]. This method involves utilizing a set of sliders to quantify the emotional dimensions of arousal and pleasure experienced by subjects during interactions with a given stimulus or experience. Participants provide real-time feedback by adjusting the sliders along a continuum, reflecting their emotional states. The Affective Sliders provide a structured and quantifiable way to assess emotional responses, enabling the measurement of subjective emotional experiences in a controlled experimental setting.

3.1 Equipment

BehCreative (Behave Creatively) is an EDMI developed within the NICS laboratory (Interdisciplinary Nucleus for Sound Studies) and BRAINN (Brazilian Institute for Neuroscience and Neurotechnology), at University of Campinas. In the first version of this EDMI proposed here, BehCreative consisted of an immersive environment inside the NICS recording studio made up of an octophonic system for sound diffusion, and three screens in which visual feedback connected to the sound is projected (in front and to the sides of the user). For mapping, Kinect 2 made it possible to use several programs - Processing, Pure Data, Sadie - connected via OSC (Fig. 2).

The audiovisual feedback consisted of different types of sounds and visuals that changed according to the jerk of the subject. Jerk is the rate of change of acceleration and it is relevant for measuring the movement of the subjects because it reflects their speed, intensity, and direction. The sounds were synthesized using Pure Data and they varied in pitch, timbre, duration, and harmony. The visuals were generated using Processing and they varied in shape, size, color, and brightness. The mapping between the gestures, sounds, and visuals was based on the concept of MA and SM quoted above.

We implemented upper-limb gestures as MAs - that is to say, a specific gesture as a virtual command in order to play the instrument that is the user's body itself - and these were named Virtual Affordances (VAs) (Fig. 3). Thus, in the mapping, we added six VAs [8] - feedback connected to pre-established gestures of the subjects, which corresponded to certain sounds lasting a few seconds feedbacks and predetermined colors. At the same time more jerk corresponded to dissonance and black and white. Figure 3 shows an example of how the mapping worked for one VA.

3.2 Data Collection and Analyses

We collected data from three sources: Kinect 2, Pure Data, and a self-assessment questionnaire. Kinect 2 recorded the position and movement of the subjects' joints in three-dimensional space, with an acquisition rate of 1 Hz. Pure Data recorded the sounds

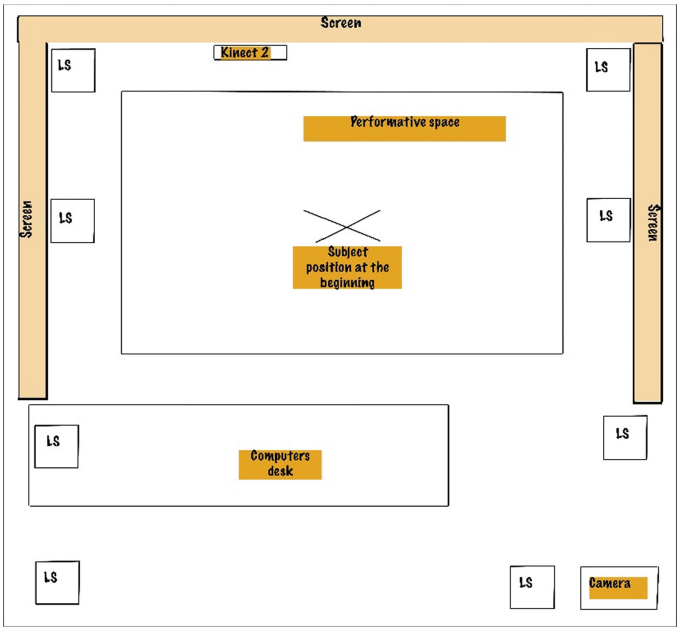

Fig. 2. BehCreative EDMI environment at NICS.

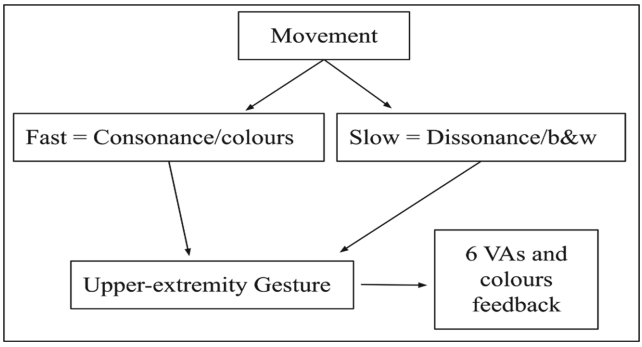

Fig. 3. Visual Mapping with correspondence of Movement. Fast movements correspond to consonant sounds and coloured particles screens. Slow movements correspond to dissonant sounds and black & white particles. Moreover, six VAs corresponds to six upper-limb gestures.

produced by the subjects and their corresponding jerk levels, also with an acquisition rate of 1 Hz. The sessions had a maximum duration of 5 min.

The self-assessment questionnaire consisted of two questions that asked the subjects to rate their experience with BehCreative using the Affective Slider scale from 1 to 5. The Affective Slider, developed by Betella and Verschure [13], is a tool to assess affective responses in participants during an interaction with a particular stimulus or experience. It is a continuous rating scale that allows individuals to express their emotional states or

affective experiences in real-time. The questions were related to their positive interaction self-assessment after the experience in a scale from 1 to 10. We named this measure as Experience Appreciation Index (EAI).

3.3 Data Analysis

We used descriptive statistics to summarize the data from each source. We calculated the mean and standard deviation of the jerk levels for each subject, each session and for both left and right hand. For the Virtual Affordance (VA), we employed the same approach, calculating the mean and standard deviation for each subject, each session and for both left and right hand. This allowed us to gain insight into the overall performance trends and variability of VA and Jerk levels within each subject over the 10 sessions. Next, we used the Matplotlib library in Python to plot the bar chart. We used different colors to distinguish between the subjects and the two performance measures (VA and Jerk), see Fig. 3.

In this way, we aimed to visualize and compare the mean VA and Jerk values across three types of participants: Control (C), Music (M), and Exercise (E) over the course of 10 sessions. This visual representation complemented the descriptive statistics, enhancing our understanding of the participants' performance across the 10 sessions.

4 Results

The graphs in Fig. 4 show the average values of VA and Jerk for the three participants: CS, MS, and ES. The data is divided into 10 sessions numbered from 1 to 10 on the x-axis.

Throughout the sessions, we can see how the values of VA and Jerk change among the different subjects, indicating performance differences between them.

The trend of CS shows opposite values in the first six sessions of VA and Jerk: a decrease (increase) for VA (Jerk), followed by an increase (decrease) and then another decrease (increase). From session 7 to 10, two peaks alternate with two drops, for both VA and Jerk, but Jerk displays less abrupt variations than VA.

MS exhibits a similar trend between VA and Jerk in the first four sessions, followed by some regularity in Jerk (sessions 4 to 10) not observed in VA, which instead, displays some extreme variations.

Finally, ES demonstrates consistent Jerk and VA patterns of values, except for larger VA values in sessions 5 to 7, nonetheless making ES the most consistent subject.

Regarding VA, the peaks may indicate moments of intense exploration, while lower values may suggest usage driven by learning between gestures and audiovisual feedback. In this perspective, CS continues exploration even in the last sessions, while MS and ES exhibit more stable behavioral learning.

Considering graphs in Figs. 5 and 6:

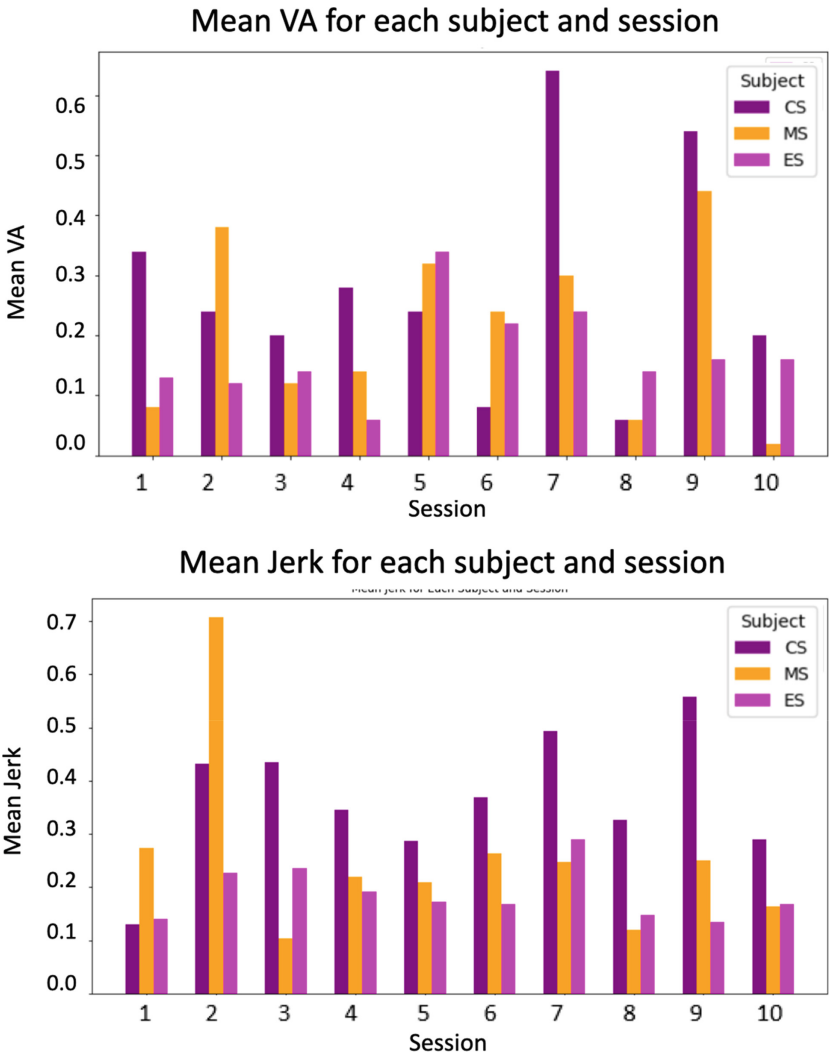

Fig. 4. Average values of VA (upper graph) and Jerk (lower graph) for the three participants: C, M, and E. The x-axis of the charts represents the 10 sessions, numbered from 1 to 10. The y-axis shows the range of mean values for each performance measures.

Arousal Trends

Prior to the experiment, participants exhibit varying levels of arousal. The control subject (C) shows a fairly wide range of arousal, with some sessions indicating higher excitement and others less. The musician subject (M) generally maintains elevated levels of arousal, suggesting emotional engagement and heightened attention. The exercise subject (E) initially displays high arousal levels, which could be associated with the anticipation of physical exercise, and then decreases in the later sessions.

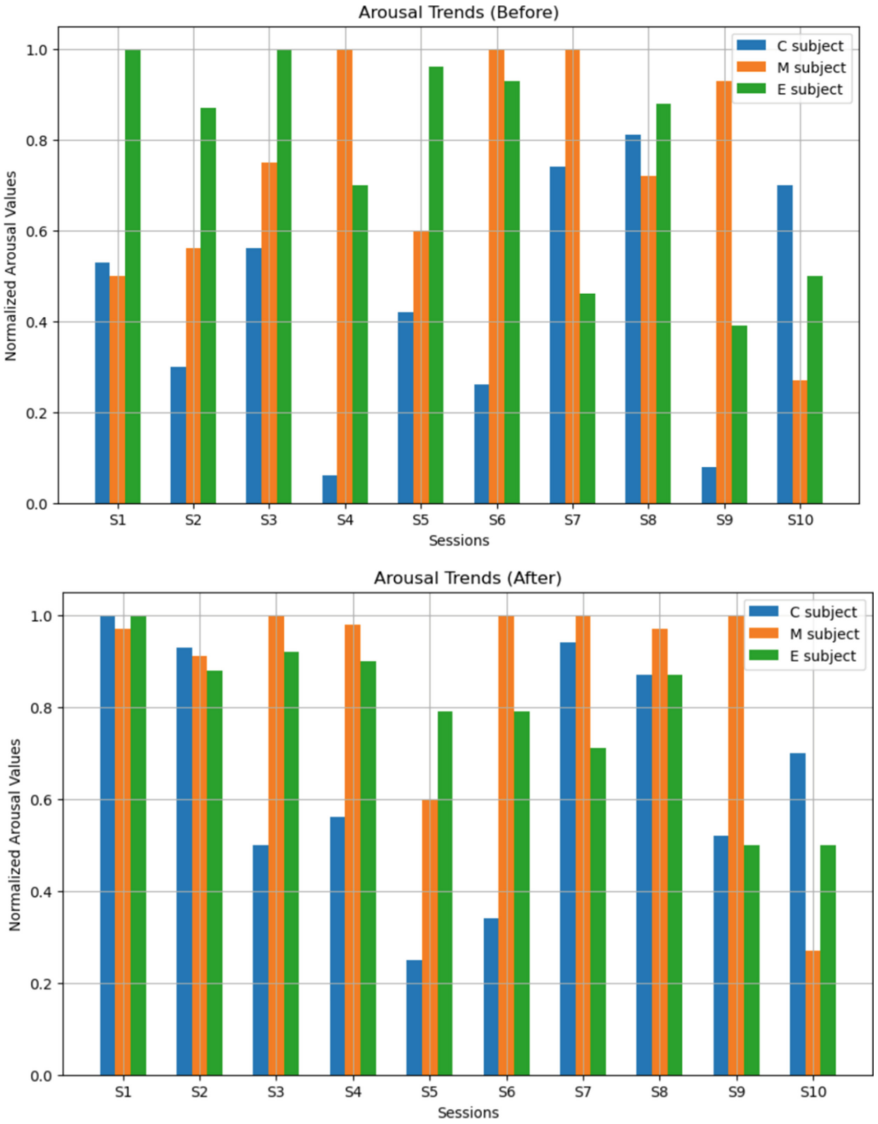

Fig. 5. Values of Arousal before and after the experiment, following the Affective Slider self-assessment.

Following the experiment, subjects appear to have regulated their arousal levels differently. The control subject shows a more consistent trend compared to the beginning, with higher excitement in 7 out of 10 sessions, possibly indicating increased stimulation. The musician subject (M) maintains elevated levels of arousal even after the experiment, implying sustained engagement. The exercise subject (E) seems to have balanced arousal regulation, likely in response to movement.

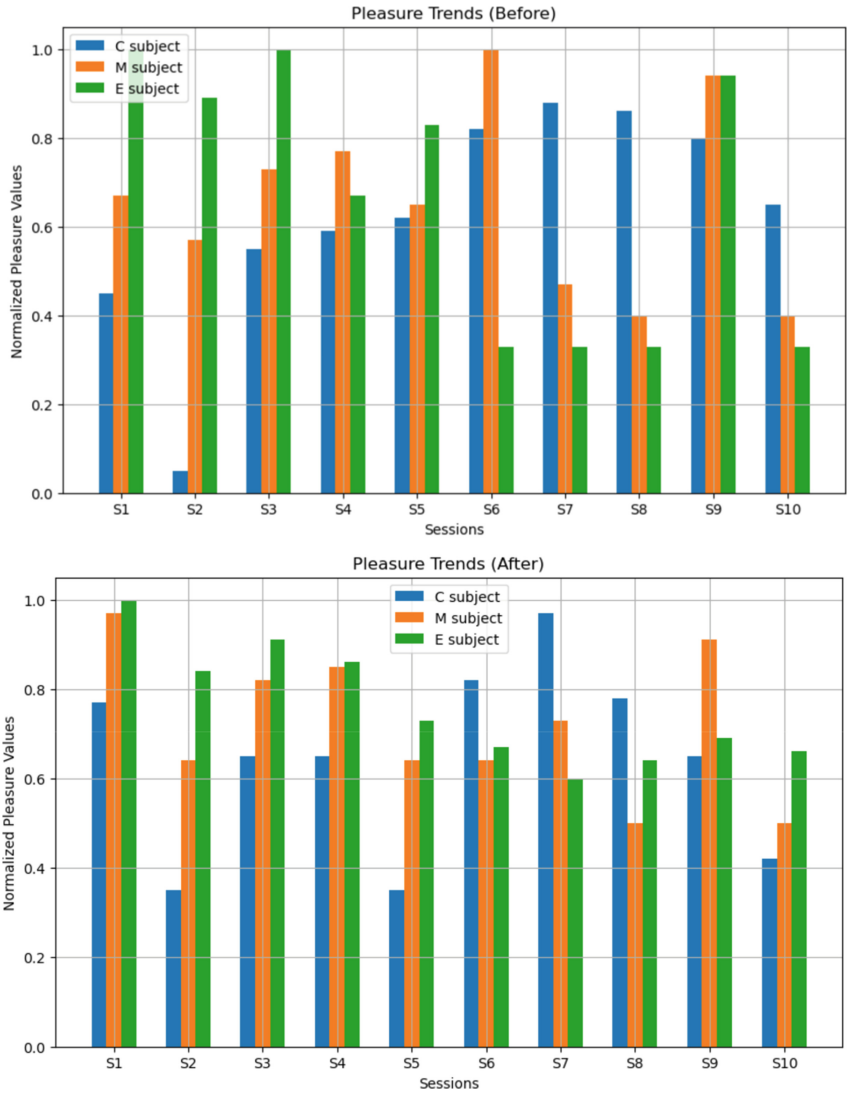

Fig. 6. Values of Pleasure before and after the experiment, following Affective Slider self-assessment.

Pleasure Trends

Before the experiment, pleasure levels vary among subjects. The control subject shows increasing pleasure values over sessions, while the musician subject and the exercise subject exhibit high values at the first sessions with an abrupt drop in the last sessions (with exception of session 9). This might reflect a positive expectation towards the experiment.

Post-experiment, pleasure levels tend to stabilize for the musician (M) and exercise (E) subjects. However, the control subject's pleasure increases only in half of the sessions, possibly linked to a more positive experience with EDMI usage. The musician (M) and exercise (E) subjects maintain a high level of pleasure, increasing the values in the last sessions, suggesting a rewarding experience. For E, this may indicate that the sensorimotor learning experience through movement has been positive.

The EAI (Fig. 7) provides subjective feedback from participants about their engagement with BehCreative. Looking at the EAI questionnaire results, we can observe certain trends and differences among the three subjects (C, M and E):

Control Subject: Participant C has scores for half of the sessions with low values (less than or equal to 3), indicating the most unstable response.

Music Subject: User M showed variations in ratings across the sessions. The user's positive self-assessment process showed some fluctuations. This could suggest that users with a musical background may have a more nuanced response to the technology, possibly due to higher expectations or specific preferences.

Exercise Subject: User E consistently rated their experience with BehCreative very positively, giving high scores throughout the sessions. The user's responses were relatively stable throughout the sessions, indicating a consistent level of positive experience with the EDMI.

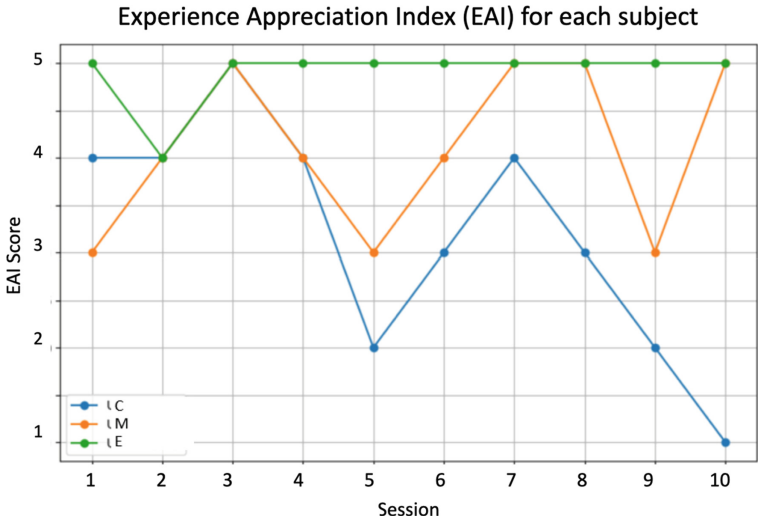

Fig. 7. The graph illustrates the participants' subjective feedback. The x-axis represents the different sessions (from S1 to S10) in which the participants interacted with BehCreative. The y-axis represents the Experience Appreciation Index (EAI) scores provided by the participants.

5 Discussion

From the analysis of the graphs, we can make some hypotheses about the effect of different experimental conditions on the variables VA and Jerk. Overall, the analysis of Mean Jerk values reveals varying trends in motor control and movement smoothness across the three subjects. The CS subject exhibits more irregular Jerk patterns, potentially reflecting challenges in motor coordination. On the other hand, the ES subject demonstrates more consistent and controlled movements, implying better motor performance. The MS subject falls in between, with sessions of both smoother and less smooth movements. These differences may indicate variations in motor learning and sensorimotor adaptation among the subjects.

The observed differences between subjects and the variations in VA and Jerk can be attributed to the participants' different movement experiences and needs, given their different backgrounds. C shows evident fluctuations in Mean VA values but less so for body acceleration (Jerk). M also shows fluctuations in Mean VA values but with smaller amplitudes, and an initial trend of growth in Mean Jerk values. On the other hand, E shows a steady increase in VA values and a (low amplitude) large stability in Mean Jerk values.

Correlating the results of pleasure with those of arousal, several interesting observations can be made. For instance, it can be noted that the increase in pleasure for participants M and E after the session (Fig. 6, bottom) appears to align with the rise in arousal (Fig. 5, bottom). This suggests a potential relationship between pleasurable experience and heightened arousal for M and E subjects.

From the results, indeed, it appears that emotional engagement and subjective experience during EDMI usage are influenced both by initial arousal levels and changes in pleasure during the experiment. Subjects responded differently to sensorimotor learning sessions, with the musician subject (M) displaying consistent engagement and the exercise subject (E) adjusting emotional levels in response to physical activities. The EDMI seems to have a positive impact on participants' emotional experience, contributing to their interaction and engagement in learning to use the body as a musical instrument.

The consistently positive ratings of EAI for the M and E subjects (and for half the sessions for the C subject) indicate that the EDMI has the potential to enhance users' engagement, expression and thus satisfaction. The user with a physical exercise background (E) appeared to have particularly positive experiences, which aligns with the paper's focus on therapeutic and music therapy applications.

The questionnaire (EAI) results also support the paper's discussion on the impact of musical experience and physical training on users' responses to the EDMI. Additionally, the variations in ratings suggest that the technology-based approach may cater differently to individuals with different backgrounds, emphasizing the need for personalized approaches in therapeutic settings. In conclusion, the data obtained from the experiment seem to suggest that the use of BehCreative has an impact on the emotional reactions and physical activities of the participants. The results indicate that there may be significant differences in responses among people with the three types of backgrounds analyzed during the interaction with the immersive musical experience. These differences may be relevant for the creative learning and musical expression of the subjects.

The results from this study contribute - despite the low statistical power of the data - to the growing body of research on motor learning and human-computer interaction, providing valuable implications for future studies and practical applications in related fields.

5.1 Future Perspectives

The interpretation of the results is an important aspect to understand the impact of EDMIs on subjects' behavior and for future directions. It could be interesting to analyze the differences in movement types and how they are linked to the internal MS (see Sect. 2). Furthermore, the Mean Jerk indicates the overall body acceleration during the experiment and could be correlated with the complexity of movements or the expressiveness of the subjects. Moreover, the audio and visual feedback provided by the EDMI may have had a significant impact on the subjects' behavior. For instance, the visual feedback projected on three screens might have influenced their perception of space and interaction with the surrounding environment. Regarding the impact of training and experience, the difference between C's and M's responses could be related to the musical training of subjects in the latter case. It could be interesting to examine how musical experience influences the interpretation and use of the EDMI in future research. Finally, regarding creative potential and learning, BehCreative appears to offer new opportunities for expressing Creative Empowerment and learning the EDMI. The ability to manipulate sound and visual feedback could stimulate artistic exploration and the learning of new musical techniques.

The study's limitations include the small sample size and the interruption due to the COVID-19 pandemic. Despite these limitations, results provide valuable insights that can inform future research with larger and more diverse populations.

To further understand the impact of the EDMI, future studies could explore correlations between EAI, Affective Sliders scores and users' creative output, motor learning progress, and emotional states. Additionally, incorporating qualitative interviews or focus groups could offer deeper insights into users' experiences and suggestions for improvement.

6 Conclusions

The results of the pilot study with the EDMI suggest that this technology can significantly influence the behavior of subjects belonging to different groups. The observed differences between the C, M, and E may indicate the impact of musical experience, physical training, and artistic skills on the response to the EDMI. The interaction between body movements, audiovisual feedback, and general motion development offers new perspectives for creative expression and musical learning. Furthermore, the Affective Sliders results on arousal and pleasure and the line plot of EAI scores connect the concept of Creative Empowerment and engagement with users' experiences while using BehCreative. The improved level of pleasure's responses after the experiment and the positive EAI scores indicate that the EDMI has the potential to empower users creatively and create an engaging musical experience, supporting its application in music therapy and

rehabilitation contexts. The variations in arousal and pleasure among users, furthermore, underscore the importance of personalized approaches to optimize the therapeutic benefits of the EDMI for different individuals.

However, with only three subjects, it is important to remember that the results are not representative of the general population. Further studies with a larger sample are currently being conducted and analyzed to confirm or delve deeper into the observations obtained from this experimental study.

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