Impact of Game Mode on Engagement and Social Involvement in Multi-User Serious Games with Stroke Patients

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Abstract—The use of novel technologies for rehabilitation has been intensely researched in the last decades. As technology evolved, it has become usual to exploit virtual reality and serious games as tools for motor and cognitive rehabilitation. However, despite the increasing use of games in rehabilitation, evidence of the impact of their use in multi user settings remains scarce. To our knowledge, there are no comparative studies on stroke patients assessing the specific benefits of Competitive, Cooperative and Collaborative gaming modes for motor rehabilitation. In this study we propose to use a multiplayer motor rehabilitation gaming system, and evaluate the impact that these different game modes can have on patient's engagement and social involvement, and also to research the influence that different motor and cognitive skill levels can produce in those three different multiplayer settings. To that end, we developed a multiplayer setup – using tangible objects and a large screen interactive table – for upper limb rehabilitation purposes. We implemented a game that, while keeping the same basic mechanics, can be played on the three different multiplayer modes (Competitive, Cooperative and Collaborative). We performed a preliminary study with 11 stroke patients, and results show that behavioral involvement and positive affect is promoted more effectively with the Collaborative mode, specifically with participants with less motor and cognitive difficulties.

Keywords—Game mode, Serious games, Engagement, Social involvement, Rehabilitation, Elderly.

I. Introduction

The use of novel technologies for neurorehabilitation has increased in recent times, leading to new ways of approaching rehabilitation. These technologies can support therapists on their work in very different but significant ways, according to their specific characteristics. Depending on the technology, we can have benefits concerning personalization (ability to be personalizable to patient's individual needs), the ability to measure with objectivity, or providing visual, haptic or auditory real-time feedback [1]. However, aspects such as the environment, changes on assistive devices or individual preferences, play a role in the experience that is delivered through the use of these novel technologies [1].

Additionally, Virtual Reality (VR) can provide an enriched environment for stroke survivors to engage in problem-solving challenges and therefore develop new skills. Moreover, besides the effect of technology itself, the use of non-immersive VR through a serious game approach offers attractive rehabilitation options, as the motor learning principles underlying neuroplasticity, such practice, augmented feedback, motivation, and observational learning [2] are inherent features of VR systems [3].VR allows to define goal-oriented tasks and promotes more task repetitions than conventional therapy, which have been repeatedly shown to be important for neurological rehabilitation [4], [5]. Indeed, these properties of VR have been found more interesting and enjoyable than standard care, being one of the contributors for the higher engagement verified when using VR [6].

From the many characteristics serious games have that can influence rehabilitation, the type of game mode is an important one. The context of gaming can influence the social impact and the engagement of the users during rehabilitation. Literature commonly identifies three game modes: *Competitive*, *Cooperative* and *Collaborative*. Although the *Competitive* mode is well known, Mueller et al. made a distinction within this game mode [7]. They subdivide the *Competitive* game mode in *combat competition* and *object competition*. In combat competition, one of the players can have control over the other player, while in object competition it does not happen. According to Verhoeven et al. combat gameplay can lead to more physical effort, which can be important according to the goal of the game in rehabilitation [8].

Cooperative and *Collaborative* are many times misused to define the same idea. Some authors state that they have similar roots, but Roschelle et al. [9] defines collaboration as "to work together," which requires coordination of efforts to solve a problem and establishing a synergic relationship. In the other side, cooperation means "to operate together," which means to divide the work among different operators, each one being responsible for a portion of a problem. A review study identifies that some modes found in the literature should be termed co-active instead of *Cooperative*, as an individual player can solve the task [10]. However, according to the authors, their definition of *Cooperative* (*"playing in the same team with the different roles according to own individual skills, thus, a role being either "supported" or "supportive"*), is not considered in the reviewed studies. In our context, cooperation has great potential for rehabilitation systems. The role of "supported" and "supportive" can be and is used in therapy, specifically, in the strategy a therapist assumes during a therapeutic exercise [11].

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Interestingly, no studies in rehabilitation are comparing the three game modes, being that most of them compare the *Cooperative* mode versus *Competitive* mode [10]. Baur et al. identified 9 studies where multiplayer modes positively affects game experience [10]. Also, the *Competitive* game mode seems to be more related to higher exertion and usually requires more skills, at least more than the opponent, to have satisfaction. It is also more related to higher enjoyment [12], [13]. However, there is also literature suggesting the opposite [14]. The authors also state that *Cooperative* modes can produce a better game experience than *Competitive* ones. According to Baur et al. [10], the *Collaborative* mode was referred in only four studies [15]–[18]. Interestingly, this is a game mode particularly suitable for therapy settings where the difficulty level of the rehabilitation tasks cannot be adapted to the individual, hence needing some level of assistance [16].

We developed an interactive table with a custom-made serious game intended to enhance the social impact and improve self-efficacy during motor rehabilitation of stroke survivors. We consider that this interactive table has some characteristics that can have a positive social impact on users, such as allowing several people to interact at the same time or enabling direct interaction with the virtual content. In this study, we aimed to understand if different game modes, namely, *Competitive*, *Cooperative* and *Collaborative* impact differently engagement and social involvement. For this purpose, we gathered people who suffered a stroke, joined them in pairs, and enrolled them in a game with the three game modes. We hypothesized that engagement would be higher in the *Competitive* mode when compared to *Cooperative* and *Collaborative* modes, as most literature identifies competitive modes as it is a common motivating strategy [19], however, no comparative studies between these two modes exist. Also, we expected social involvement to be higher in the *Collaborative* game mode when compared to *Competitive* and *Cooperative* modes, as this specific mode requires dependence on the co-player to reach the goal. Finally, we want to understand the impact of stroke survivors with different motor and cognitive skills on engagement and social involvement on the different multiplayer game modes.

II. Methods

A. Experimental Setup

The interactive table setup consisted of a PC (OS: Windows 10, CPU: Intel Coffee Lake Core I7-8700K 3.7Ghz 12 MB, RAM: 2x 8GB DDR4 2400Mhz, Graphics: Gigabyte Nvidia GTX 1070 Ti Gaming 8G GDDR5), a 55" LED TV screen and a 55" infrared multitouch sensitive layer (latency: <15ms panning, <25ms touchdown, reporting rate 100Hz), plus an auxiliary screen for the researcher (Fig. 1). Users were seated facing each other with the arms resting on the table and hands on the touch-sensitive screen. To interact with the game, users interacted with a plastic cone (5cm base diameter, 17,5cm height, and 3,8cm top diameter) – later referred as the handle - mounted on a soft conductive base. This base reduced friction and facilitated detection over the touchscreen. We also used chairs with adjustable height and a structure underneath the table to rest the feet in order to guarantee a proper posture while seated.

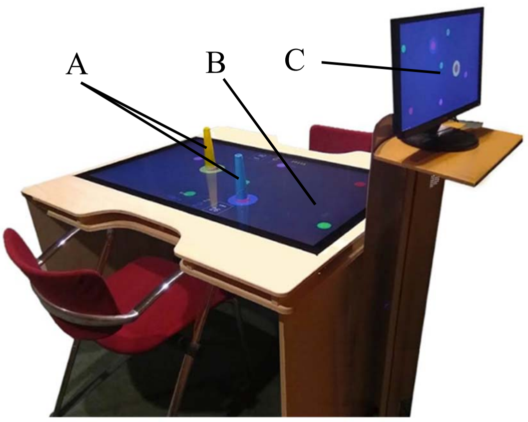

Fig. 1. Experimental Setup: Handles (A), the infrared touch sensitive layer (B), and the auxiliary screen for the researcher (C).

B. Task

The VR task was a two-player game with the primary objective of catching balls that appeared in random positions, in order to increase the variability of movements, otherwise, probabilities of the most of the balls being caught proximally would be high. Also, we opted to make the balls to move on a straight line, in order to allow for prediction and therefore allow easier planning. For that purpose, each user controlled a virtual ring on the screen by moving the handle over the screen. We implemented three different versions of the task, each one corresponding to a different game mode: *Competitive*, *Cooperative*, and *Collaborative* (Fig. 2). The different game modes relied on the same basic mechanics. In the *Competitive* mode (Fig. 2 - A), each participant had to catch the maximum number of balls, which accumulated to his/her personal score. The participant who scored more points (balls caught) would win the round. In the *Cooperative* (Fig. 2 – B) game mode, participants had to play as a team and catch balls, but points would accumulate to a

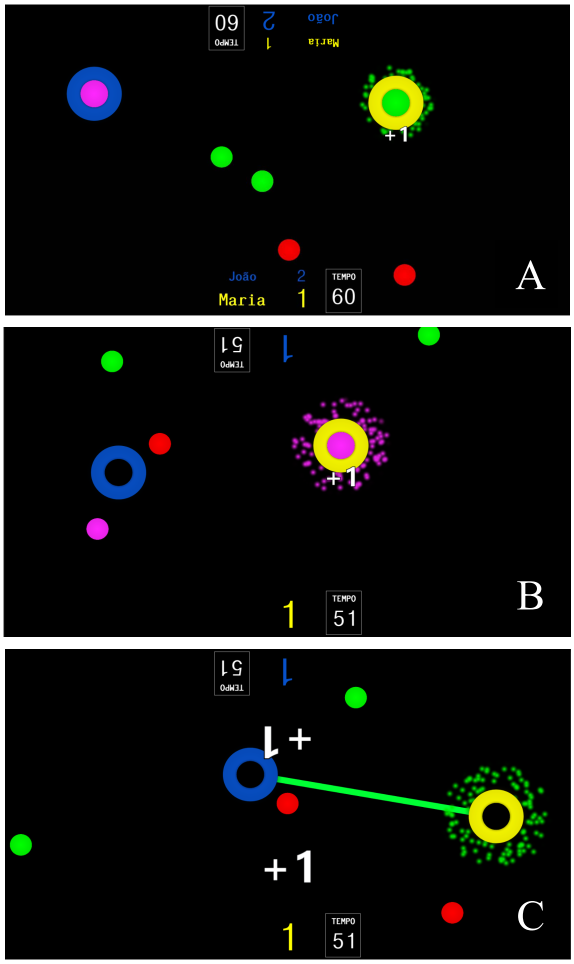

Fig. 2. *Competitive* (A), *Collaborative* (B) and *Cooperative* (C) game modes, from top to bottom, respectively. On the *Competitive* we have the round time left on a square and the name and score. On *Collaborative* and *Cooperative* we have only the time and score. The rings (yellow and blue) are used to catch the balls (inside they have the color of the last ball caught) and represent the color of the player (yellow or blue).

single combined team score. Finally, in the *Collaborative* (Fig. 2 – C) game mode, patients also played as a team but only scored if both players consecutively caught two balls of the same color.

C. Sample and recruitment

The sample was recruited on several health units of the regional health service (SESARAM) in Madeira Island, Portugal. It was a convenience sample, and the inclusion criteria included to have suffered a stroke and existence of motor upper limb impairment as a consequence of stroke. The exclusion criteria were the following: 1) Inability to hold the cone used as the interface; 2) No literacy; 3) Evident cognitive deficits that would interfere with the understanding of the game.

One hundred forty one potential participants were approached. Nine refused to participate, and 119 were excluded due to exclusion criteria. One participant was excluded after data collection due to a wrong criteria assessment, resulting in 11 participants included on data analysis, 6 females and 5 males, with a mean age of 61.2±12.2 years (range: 31-80 years) and 6.27±4.8 (range: 4-17) years of schooling. Only two participants reported having previous experience with video games. To get a profile of the participants, we used: 1) A brief questionnaire for demographic information; 2) The Montreal Cognitive Assessment (MoCA) for cognitive screening [20]; and 3) The Fugl-Meyer Assessment for Upper Extremity (FMA-UE) [21].

D. Outcome Measures

The Game Experience Questionnaire (GEQ) – Core Module [22] and the GEQ – Social Presence Module [23] were chosen to measure engagement and social involvement, respectively. The Core Module measures the players' thoughts and feelings through 7 components (Competence, Sensory and Imaginative Immersion, Flow, Tension/Annoyance, Challenge, Negative affect, and Positive affect) in a total of 33 items [22]. The Social Presence Module has three components (Psychological Involvement – Empathy, Psychological Involvement – Negative Feelings and Behavioral Involvement), and a total of 17 items. In both questionnaires, the items are rated from "0" (Not at all) to "4" (Extremely). These questionnaires are typically filled-in by the user, but because of the characteristics of the sample, the answers' scale was provided on an A4 sheet, always visible to the participants, and the questions were made verbally. The scale was translated from English to Portuguese by two experts in English-Portuguese translation.

E. Experimental Procedure

The study followed a repeated measures design with the three conditions: *Competitive, Cooperative,* and *Collaborative*. The order of the conditions was randomized using random.org. Data collection was conducted in two sessions of approximately 90 minutes for each pair of players. In the first session, participants had to sign the informed consent before starting the study, then they were checked against exclusion criteria, and at last motor function and cognitive level were assessed. An Occupational Therapist was responsible for the assessments. Sessions were conducted by two researchers trained on the system and on the assessment questionnaires. During the intervention, participants were arranged in pairs (6 in total), according to their motor skill level as assessed by Section A-Shoulder/Elbow/Forearm of FMA-UE, except subsections I-Reflex activity and V-Normal Reflex Activity. We limited the difference between paired participants to 10 (thetotal of 30) and pairs stayed the same during the whole study.

To introduce the system and to get familiarized with the interface and the game we allowed participants to play the game with no time limit until they understood how to play and the purpose of the game. Each condition consisted of 8 consecutive rounds of 1 minute with a 5-15 seconds interval between rounds. Between each round, the score was reset. At the end of each condition, participants answered the GEQ – Core Module and GEQ – Social Presence Module [22] in separate rooms.

F. Data Analysis

Because of the ordinal nature of the measures, non-parametric statistical tests were used for data analyses. Hence, the median was used as a measure of central tendency and the interquartile range (IQR) for dispersion. To test for differences across conditions, we used Friedman's test for each of the components of both modules from the GEQ. We tested for significant differences across game modes in the three groups. For pairwise comparisons, the Wilcoxon signed-rank test was used. No correction was done to account for the number of pairwise comparisons as we consider that non-parametric methods were already conservative. Data were analyzed using IBM Statistics for Mac, Version 25.0 (Armonk, NY: IBM Corp).

To understand the impact of motor function level, we divided the sample into two subgroups according to their FMA-UE score. Additionally, to analyze the impact of having different levels of motor function in multiplayer, we created two subgroups, one for those elements of the pairs with the lowest FMA-UE score and one with the highest, and Mann-Whitney U test was used.

III. Results

A. Engagement

Concerning engagement, when dividing the sample into groups according to their FMA-UE score, we found that there were significant differences among conditions for the 6 participants with the highest scores in FMA-UE($Fr(2)=7.500$, $p=0.024$) in Positive Affect. Pairwise comparisons revealed that engagement was significantly higher in the *Collaborative* mode (Mdn=3.8(0.95)) when compared to *Competitive* mode (Mdn=3.1(1.15)) ($Z=-2.032$, $p=0.042$) and *Cooperative* mode (Mdn=3.1(1.30)) ($Z=-2.032$, $p=0.042$).

To analyze the impact of the relative differences in motor function between participants in multiplayer modes, we divided the sample into two groups. The elements of each pair with the lower and higher FMA-UE scores constituted each group. A comparison of the two groups revealed that those opponents with higher FMA-UE scores showed a higher sense of Flow in the *Competitive* mode (Mdn=3.60(0.50)) than those with lower scores (Mdn=3.00(0.80)), $U=2.500$, $p=0.036$.

When we compared conditions, we found no significant differences when considering the whole sample, as well as no impact from having different cognitive skills. We can observe that on all conditions (*Competitive*, *Cooperative*, *Collaborative*), Flow (Mdn=3.40, 3.00, 3.20) and Positive

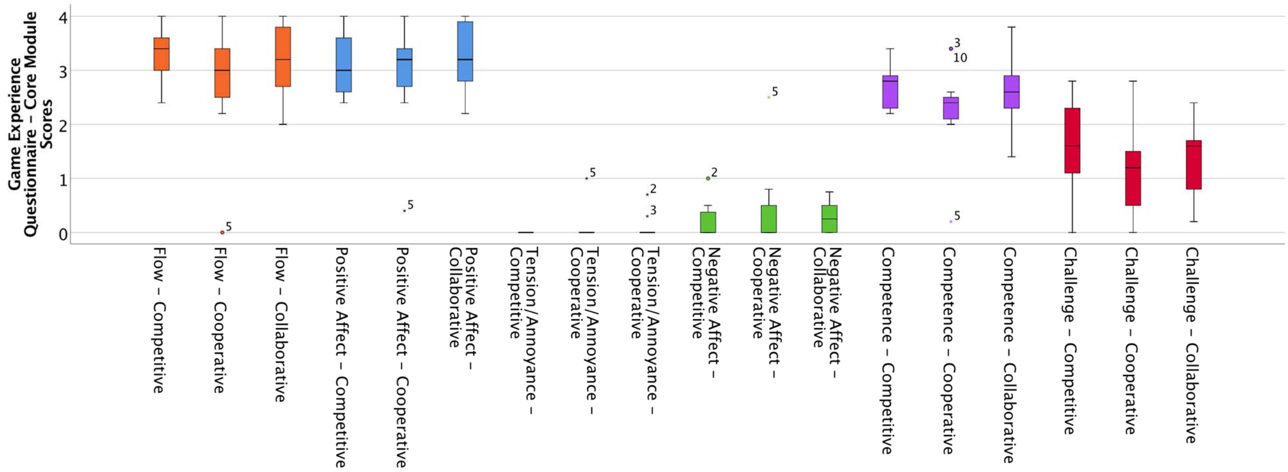

Fig. 3. Boxplots of the components Flow, Positive Affect, Tension/Annoyance, Negative Affect, Positive Affect, Competence and Challenge from the GEQ – Core Module per game mode, with all sample. On the Y Axis, the numbers '0, 1, 2, 3 and 4' represents answers 'Not at all, Slightly, Moderately, Fairly, Extremely', respectively.

Affect (Medians: 3.00, 3.20, 3.20) were found to be high, while Tension/Annoyance (Mdn=0.00, 0.00, 0.25) and Negative Affect (Mdn=0.00, 0.00, 0.25) were very low. The sense of Competence was positive (Mdn=2.80, 2.40, 2.60) and consistent with the reports on Competence, as data shows that tasks were not very challenging (Mdn=1.60, 1.20, 1.60) on neither game mode (Fig. 3).

B. Social Involvement

Regarding social involvement, we found a condition effect in the Behavioral Involvement component (Fr(2)=13.744, p=0.001). Pairwise comparisons revealed that Behavioral Involvement was significantly higher in the *Collaborative* mode (Mdn=2.30(2.30)) when compared to *Competitive* (Mdn=0.70(1.30)) (Z=-2.805, p=0.005) and *Cooperative* (Mdn=0.80(1.50)) (Z=-2.703, p=0.007).

In Fig. 4 we can verify that Empathy was similar in *Competitive* (Mdn=2.20) and *Collaborative* (Mdn=2.20) modes, while the *Cooperative* mode triggered more negative answers.

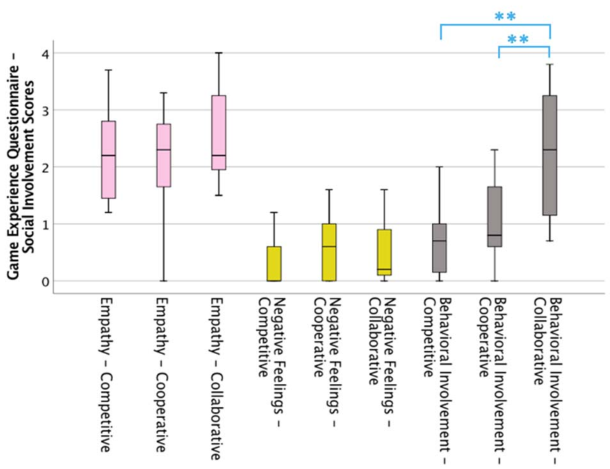

Fig. 4. Boxplots of the components Empathy, Negative Feelings, and Behavioral Involvement from the GEQ – Social Presence Module per game mode. We found significant differences in Behavioral Involvement component between *Collaborative* mode and *Competitive* mode, and *Collaborative* mode and *Cooperative* mode (**p<0.01). On the Y Axis, the numbers '0, 1, 2, 3 and 4' represents answers 'Not at all, Slightly, Moderately, Fairly, Extremely', respectively.

When dividing the sample by motor function, we identified significant differences in Behavioral Involvement across game modes only for those with the highest scores in FMA-UE (Fr(2)=10.300, p=0.006). Pairwise comparisons identified a significantly higher Behavioral Involvement for the *Collaborative* mode (Mdn=3.80(0.95)) when compared to the *Competitive* mode (Mdn=3.10(1.15)) (Z=-2.207, p=0.027) and *Cooperative* mode (Mdn=3.10(1.30)) (Z=-2.023, p=0.043).

When dividing participants by their cognitive profile (MoCA) into two groups, participants with larger cognitive deficits displayed a higher Behavioral Involvement in the *Collaborative* mode (Fr(2)=9.294, p=0.010). Pairwise comparisons show that the *Collaborative* mode (Mdn=2.50(2.50)) is more effective at generating Behavioral Involvement than *Competitive* (Mdn=1.30(1.45)) (Z=-2.023, p=0.043) and *Cooperative* modes (Mdn=1.30(1.60)) (Z=-2.032 p=0.042).

IV. Discussion

A. Engagement

Data regarding the 7 different components of GEQ-Core Module reflect the impact that the overal experience had on participants engagement. The most positive results were on the residual Tension/Annoyance the three different game modes triggered, which were close to zero. Also, the high levels of Flow and Positive Affect (higher than 3) described by the participants. Literature suggests that patients performing exercises with a co-player they already know and have a positive relationship with, maximize engagement and motivation within the activity [12]. Hence, these are encouraging results taking in account that in our experiment the participants did not know each other.

In the Positive Affect component, we found significant differences in favor of *Collaborative* mode for those stroke patients that had the highest scores in FMA-UE, that is, the group of participants with less motor impairment. This could be related to the more complex interactions with the partners this mode demands to be successful. This is supported by literature identifying higher levels of adherence when a game fosters support and communication between players [24]. However, the lack of differences in Positive Affect for the lower FMA-UE scores group, suggests that people with higher motor deficits have more difficulties to establish positive affect when engaged with a challenge, regardless of the multiuser component. Additionally, in group rehabilitation, where skills are different between participants, the *Collaborative* mode is indicated as a preferred one, since it can accommodate larger disimilarities in skill levels of participants and yet successfully achieve flow with all players involved, disregarding their motor skills. [16]. As the participants did not know each other previously, they were most of the time not communicating. However, as the *Collaborative* mode requires that they adopt an active role and interact with the co-player to score, we observed more verbal interaction and involvement for some pairs. On the Negative Affect component, all game modes induced very low responses, which is desirable, with no significant differences among conditions.

Regarding Competence and Challenge, results seem to be coherent. Data show high levels of Compentence and lower levels of Challenge. Although no statistical differences were found across conditions, the *Cooperative* mode is the one where participants felt less challenged.

As this study focuses on the impact of multiplayer games on patients that suffered a stroke, it is important to understand the impact that different motor skill levels can have within different game modalities. Results show that the co-player with better motor skills showed a statistically higher sense of flow only on the *Competitive* mode, which is expectable as the player with better skills has an advantage. Therefore, being that success plays an important role in motivation and consecutively within flow [25], alternatives to avoid dominance by one player should be avoided, as the experience may not result positive for both players.

B. *Social Involvement*

On what concerns social involvement, we measured Psychological Involvement, through Empathy and Negative Feelings, and Behavioral Involvement. Empathy was similar across game modes. When analyzing data regarding Negative Feelings across the three game modes, the *Cooperative* mode is the one that elicits more. However, no significant differences between game modes were identified.

Statistical analysis demonstrated that participants seem to benefit more from the *Collaborative* mode in what relates to Behavioral Involvement. This component measures the degree players feel their actions are dependent on their co-players actions [23]. This dependence can be positive as it can foster communication, which is essential to promote social interaction. This is important, as evidence highlights the weight of social engagement on health and well-being for a senior population [26], but also for rehabilitation, as it supports both higher levels of enjoyment during interaction and sense of self-efficacy [27]. These results seem to be particularly relevant to those participants with higher motor function, but also by those with a higher cognitive level, who benefited the most from this game mode.

As limitations of this study, the fact we used GEQ - Core Module, as outcome measure, did not allow us to compare our results with the ones from others studies. A possibile better option, would have been the *Intrisinc Motivation Inventory (IMI)*, even though it focuses on motivation, is widely used on research [12], [13], [17], [28]. Additionally, we missed the collection of qualitative data on the experience with the three game modes. Regarding the use of rehabilitation cones as interfaces, as they were the same for everyone, it can have impacted differently participants with higher and lower motor skills. However, the cone was chosen as their manipulation can be facilitated according to the ability and/or preference of patients. Regarding the sample sizeas it was relatively small (N=11), it is possible that other specific differences among modes, in particular those of the *Cooperative*, could not be identified. Also, it was not possible to verify if previous experience with video games had an impact on engagement and social involvement as only 2 of the participants reported previous experience. We are still collecting data and we expect to reach a sample of 20, and also to replicate the study with aged matched healthy controls. One next step of this study shall be to explore other variants of game modes, such combat or object competition in the competitive mode.

V. Conclusions

The results of this study show that *Collaborative* mode can potentially promote more Positive Affect and Behavioral Involvement when compared to *Cooperative* and *Competitive* modes. Specifically, this was identified for patients with higher motor and cognitive skills, being then the ones who can benefit more from this mode. Additionally, we identified that the *Competitive* mode induces higher levels of Flow, but only on those players with higher motor skills. Consequently, this mode should be avoided, in particularly when differences in motor skills between players are larger. To conclude, these data are important as suggest the use of a *Collaborative* mode as an effective strategy to promote social involvement and positive affect during motor rehabilitation training, with the potential of increasing adherence and the effectiveness of therapies.

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