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IMPACT - A Serious Game in Virtual and Augmented Reality to Enhance Mirror Therapy

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The Mirror therapy (MT) is the main non-pharmacological treatment for Phantom Limb Pain (PLP) in amputees and it is also used in stroke rehabilitation. It consists in placing a mirror between the healthy limb and the compromised one. The reflection creates the illusion that both limbs are healthy and that the patient is able to move them symmetrically. This proved to be helpful in restoring the normal body image and alleviate pain [1]. To overcome the limitations of an optical mirror (e.g., partial immersion, limited exercises, etc.), researchers are currently proposing to use Virtual Reality (VR) [2] or Augmented Reality (AR) [3] to improve the MT. However, to the best of our knowledge, none of the existing works proposed a system that, only using relatively low-cost and off-the-shelf technologies:

- Is able to deal with lower- and upper-limbs amputations.
- Could be used in both AR and VR.
- Offers full immersion with a first-person point of view.
- Proposes serious games specially developed to make MT more engaging.

While the whole system is presented in [4], in this paper, we focus on one of the serious games that we developed: the “IMPACT Music game”.
The game has two goals: first, it should help to make the treatment more engaging and less tiring; second, it should lead the patient intuitively through the treatment.
The conception of the game started from a scenario created with occupational therapists at CHUV. The game that we present focuses on a specific type of exercises, in which the patient has to perform movements with both arms or both legs simultaneously.
In terms of gameplay, we took inspiration from the famous game “Guitar hero”. When the game starts, pairs of virtual objects move towards the patient and the patient has to hit them with symmetric limb movements at the right time (in synchronization with the tempo of the music). The shape and color of the objects specify the body part that the patient has to use to hit them (e.g., golden spheres are associated to the feet, blue cubes to the knees, etc.). In addition, while the height from the ground depends on the targeted body parts, the horizontal distance between the objects varies randomly (therefore requiring wider or narrower movements).
Currently, it is possible to play the game with three difficulty levels. The levels can be used to lead patients through progressively harder rehabilitation steps. Currently, the difficulty level changes the frequency and the speed of the objects; in the future, it could be used to modify other parameters of interest for the therapists (such as the required precision, the amplitude of movements, etc.). At the end of the game session, the game gives a score to the user that is proportional to the number of “hits” and the difficulty level.
From the point of view of the customization, the system allows adding new songs to the system. In this way, patients can do the exercises while listening to their favorite songs.

Finally, we tested the game with 6 healthy users (1 woman) with heights ranging from 165 to 198 cm. The goal of these preliminary tests was to detect possible usability problems (formative usability).

Even if the tracking system could be improved in terms of precision and reaction, the participants felt that the application was easy to use, the gameplay intuitive and that the virtual elements were easy to detect and locate (to help the users in the task of spatially locating the objects, we cast on the ground their virtual shadows).
The AR experience was in average perceived as slightly worse than the experience in VR. During previous tests, we noticed that AR caused higher motion sickness. To prevent this problem, we reduced the resolution of the stereo cameras (from 950x650 to 640x480 pixels) while increasing the fps (from 60 to 90 Hz). This seemed to successfully reduce the motion sickness but, on the other hand, it created a very obvious contrast between real objects (blurry because of the low resolution) and virtual objects (with sharp shapes and vivid colors).

To conclude, AR and VR may help to make the MT more immersive and, therefore, more effective. We believe that introducing our serious game may play an important role to make this treatment not only more engaging but, in combination with low-cost and off-the-shelf technologies, also available for future home care by leading the patient through the different rehabilitation steps. In the next months, the system will be part of clinical trials to evaluate the use of AR for the treatment of PLP.

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