

by the augmented reality environment, in which they felt satisfaction when progressing through the gameplay. All members were able to understand how these games are focusing on specific muscles and movements so that they can be applied for therapeutic applications.

The responses given for the games were positive in terms of usability. One of the main advantages of using an augmented reality gaming system for rehabilitation is the increased motivation provided by the interactive game play. This claim was supported by consistent comments from the healthy test subjects.

The most common negative feedback given from the volunteers was that the gameplay wasn't smooth. More specifically, the marker object tends to flicker, which made the game unresponsive at times. Also, when the games are played without the roller-ball device i.e. playing the game with the arm in the air, the volunteers complained that their arm was getting fatigued after prolonged game play.

With the colour ball game, two subjects felt that the speed at which the ball travelling was too slow and made the game boring. However, the design choice for this is due to the fact that real stroke victims will need much more time to react to visual cues.

Below is the list of questions that answered by each volunteer immediately after they played each game. Each question is ranked on a scale of 1 (strongly disagree) to 5 (strongly agree).

The user was also asked to give any general comments or feedback.

1. I am familiar with AR technology and systems
2. I felt the game was intuitive and enjoyable
3. I was able to play the game correctly
4. I would play this game again
5. I felt pain/discomfort during the game
6. I can recognise the exercise application of the game

Table 1. Usability Questionnaire

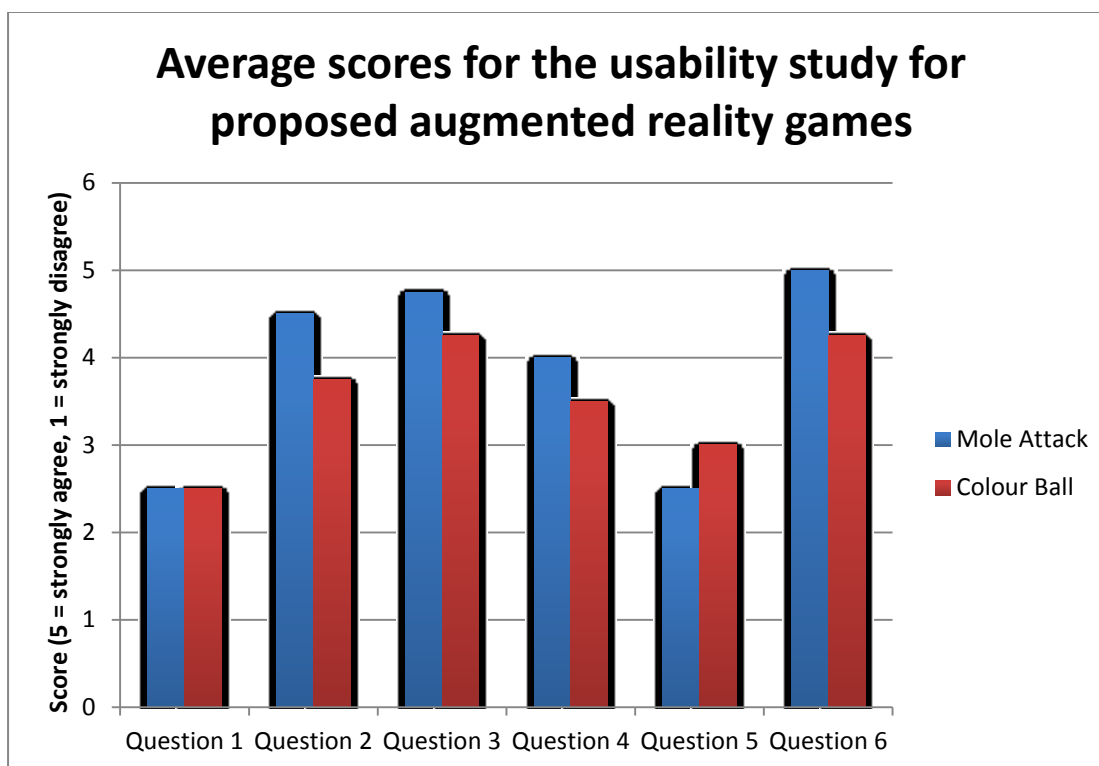


Figure 9. Results for the usability study

VI. CONCLUSIONS AND FUTURE WORK

In this paper, two augmented reality based games have been presented. They have been specifically modified to focus on specific upper limb movements for the purpose of stroke rehabilitation. The games have been developed using libraries from the FLARManager framework. The games can be easily accessed using a PC with Flash installed and a simple webcam. The optional use of a hand held roller-ball device allows each game to focus on different movements and muscles, thus increasing the effectiveness of the games. These games aim to improve the user's participation by presenting an interactive way of rehabilitation.

As simple as these games are in design, they still capture the proposed idea that stroke rehabilitation can be enhanced using augmented reality games. The games have been modified to force the user to perform specific movements that are strongly linked with current physical therapy techniques.

The marker tracking capabilities of the FLARManager have proved to not be very robust as the marker tends to flicker at times, thus not providing smooth gameplay. The marker would successfully activate 70% of the time. Future work can involve the use of other augmented reality libraries in order to find the most robust object tracking process to provide smooth gameplay in a variety of lighting conditions. Also, since these games are in 2D, it would be interesting to explore the possibility of working with 3D models to further add depth and interactivity to the gameplay. The future work will include a stroke patients test.

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