Transfer of Juggling Skills Acquired in a Virtual Environment

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Abstract: This paper explores whether motoric skills acquired within a virtual training environment can be successfully transferred to the real world by comparing a virtual environment with a traditional learning environment. Specifically, a system for learning juggling with virtual balls was designed with a focus on approximating natural interaction. We propose a method of evaluating the acquisition and transfer of motoric skills through a virtual environment, which is compared to a traditional learning environment. Each environment was evaluated using various criteria ranging from improvement in skills to observations of performance. The findings suggest that a transfer of motoric skills and knowledge takes place for users of the virtual system with only little difference between the environments. They also suggest that a virtual environment can create a less frustrating learning experience.

1 INTRODUCTION

Juggling is a sport that heavily involves motor skills in order to facilitate throws from one hand to the other without dropping a ball. It requires the user to learn the basic techniques and to understand the rhythm. Furthermore, the user has to anticipate coming events to organize current actions (Beek and Lewbel, 1995).

The goal of the virtual learning environment proposed in this work is to facilitate the acquisition of transferable juggling skills in as effective a way as possible. To this end, the physical motion of juggling balls is simulated and appropriately modified in order to allow for an improved learning experience.

The comparison of a virtual environment (VE) and a traditional environment for learning motor skills such as juggling can reveal whether training in a VE could substitute training with physical balls – or whether the loss of depth, spatial and tactile feedback when using the VE also means a loss in the transfer of motor skills. Apart from the transfer of knowledge, we also investigate how a well-designed learning VE compares to a more traditional learning environment; in particular, we compare the efficacy of the two environments.

The rest of the paper is structured as follows: After a review of previous work, the design of the VE is discussed. This is followed by a description of the experiment and a presentation of the results. Finally, the VE is discussed based on the obtained results.

2 PREVIOUS WORK

Prior research in the field of acquisition of knowledge in VEs has focused on virtual reality (VR) applications. This includes transfer of spatial knowledge (Peruch et al., 2000)(Witmer et al., 1996) and basic task-related knowledge (Kenyon and Afenya, 1995). This research suggests that virtual reality technology can facilitate acquisition of transferable knowledge. (Lagarde et al., 2012) focused on teaching timing through their VE. They found no significant difference between learning juggling in a virtual and a real environment. They also found that starting with balls at slow speed and increasing the speed allowed subjects to learn faster than with balls at normal speed.

However, VR equipment is not widely available and as such is primarily used in professional training simulators. The rise of computer-vision-based input devices such as the Microsoft Kinect for consumer use can bring the technology to a larger demographic that could potentially benefit from using a VE.

Using computer vision techniques, Charalambous facilitated the learning of juggling with virtual balls (Charalambous, 2005) and Marshall et al. studied the enhancement of the presentation of juggling performances with physical balls as well as advanced training by using juggling with physical balls as part of games (Marshall et al., 2007). Our work is similar to the work by Charalambous in that we also facilitate the learning of juggling in a VE; however, we observe the complete learning process. Moreover, we inte-

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grate game elements in the VE to improve the learning experience similar to the work by Marshall et al.

3 DESIGNING THE VIRTUAL ENVIRONMENT

The VE was implemented using the Unity3D game engine (Unity Technologies, 2011) and the Microsoft Kinect controller and SDK (Microsoft Corporation, 2011) to track each hand of the player.

In the VE the player's hands, are represented by 3D models such that the left hand appears on the left-hand side of the screen and the right hand on the right-hand side; see Figure 1.

Figure 1: A screenshot of a player juggling with 3 balls using the virtual training environment.

A basic button-trigger-based system was created to give users more control over releasing (i.e. throwing) the balls. Alternative solutions were investigated such as releasing the balls based on sudden deceleration of the hands; however, players reported problems with unintentional releases of balls. The motion of balls in the VE is restricted to a plane parallel to the view plane. Issues with using more degrees of freedom for the virtual balls have previously been identified by Charalambous (Charalambous, 2005).

An important part in the design of the VE was the dynamic difficulty adjustments during play. The training starts with reduced gravity and therefore slower motion of the balls. Furthermore, released balls are initially assigned the appropriate velocity so they reach the other hand. However, the player's control over the balls' velocity is gradually increased as his or her score rises. The difficulty level is computed by constantly checking the player's score.

If the player scores higher than his or her previous score, the difficulty will increase and vice versa. The difficulty is filtered; thus, dropping a single ball will not reset the difficulty but only reduce it slightly. If the player continues to drop several balls, the difficulty will decrease to help the player get back in the game. This dependency on the player's score results in a basic dynamic difficulty adjustment intended to challenge players without frustrating them, as suggested by flow theory (Csikszentmihalyi, 1997).

A level-based system in which new concepts are gradually introduced (in this case, more balls), provides a less steep learning curve compared to that of a traditional learning environment. To keep the attention of the players, flow theory (Csikszentmihalyi, 1997) was used in the design of the levels. Each level has a requirement containing a certain amount of juggles before the next level is reached. Throughout these levels, auditory cues are triggered when a ball is dropped, thrown or a new ball is on the way. The music also gradually changes based on the current score and increases from a lower pitch up to the normal speed of the music. Using a virtual system might also assist in increasing the automation of catching the balls, as the VE enables easy practicing. By increasing the amount of practice, the automation should also become faster (Logan, 1988). Failures were designed to be entertaining as suggested by Ravaja et al. (Ravaja et al., 2005). Thus, players are "rewarded" by visual and audio effects when they drop balls in order to encourage them to continue playing.

4 EXPERIMENT

The test subjects were mostly male and between 17 and 29 years. All were unable to juggle and had never received prior training in juggling.

To compare the VE with the traditional learning environment, test subjects were split into two groups. Group 1 consisted of 14 subjects who used the VE. Group 2 consisted of 15 subjects who used the traditional learning environment, i.e. physical balls. The test setup shown in Figure 2 consisted of recording equipment, the VE and a test facilitator to observe and take notes. Furthermore, an instructional juggling training CD-ROM (Duncan Toys Company, 2011) was available for use. The traditional learning environment was identical but without the screen and the Kinect controller.

For the first 5 minutes, the subjects of each group were asked to throw as many or as few physical balls from hand to hand as they were comfortable with. The goal of this was to evaluate the basic level of motor control and spatial awareness for each subject. After this, a period of 35 minutes was spent training juggling – 30 minutes for the users of the VE. During this time, subjects were allowed to watch training videos from a DVD. The DVD contained short videos with descriptions for juggling one up to four balls. The

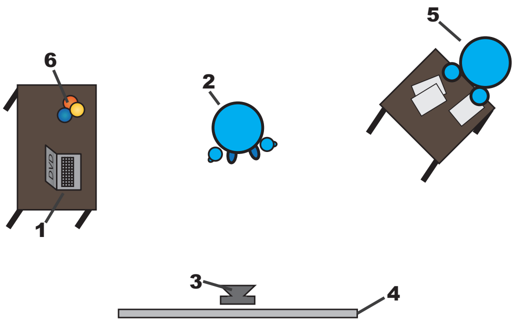

Figure 2: The test setup: laptop with instructional DVD (1), test subject (2), Kinect controller (3), screen (4), facilitator (5), spare balls (6), and recording equipment (7). In the traditional environment (3) and (4) were removed.

subjects using the VE were then given 5 minutes to adjust to throwing real balls. Finally, each group was asked to juggle as many or as few physical balls they could for 10 minutes in the same way they would do if they were supposed to learn to juggle.

After the performance test, users were asked to fill out a questionnaire. Questions ranged from performance self-assessment to rating their level of frustration during the test.

5 RESULTS

The performance score was created as an indication of how well the player performed during the test. The performance score was computed by first counting the number of throws from hand to hand per minute, which was divided by the number of drops per minute. This number x was then transformed by the function $(1-1/(x+1))/3$ resulting in a number between 0 (no successful throws) to $1/3$ (infinitely many successful throws). If the player was juggling with 2 balls instead of 1 ball, $1/3$ was added to the performance score in order to reflect the higher performance. If 3 balls were used, $2/3$ was added. The computation is illustrated in Figure 3. If a test subject juggled with different numbers of balls, only the score for the highest number of balls was considered in order to indicate that the subject is at the next level. This also ensures that a player, who only threw one ball, cannot have a better performance than a player who has trained with two balls.

Using a paired t-test it was possible to observe significantly better performances (probability level 0.05) of both groups after the training. Comparing the improvements between the groups with an independent t-test did not show a significant difference: the traditional environment had only a 1.52% higher score compared to the mean in the virtual environment. The

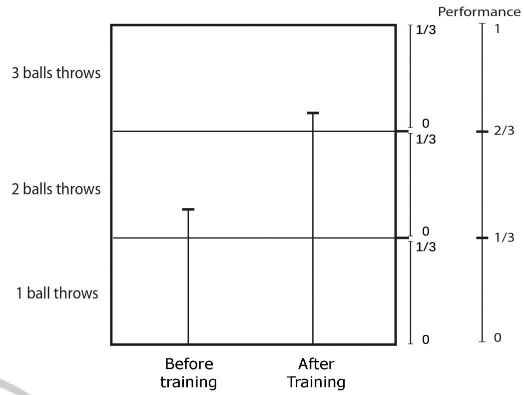

Figure 3: Model of how the performance is calculated.

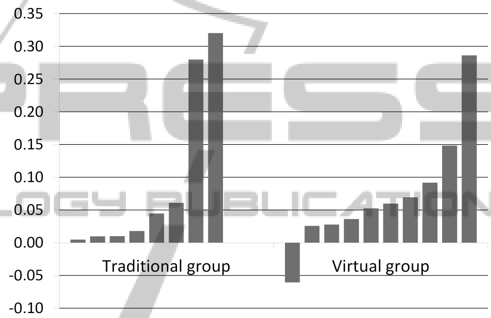

Figure 4: Individual difference in user performance for each learning environment (11 test subjects had to be culled from the data due to using an incorrect juggling technique).

performance differences of all test subjects can be seen in Figure 4.

When the virtual group answered the questionnaire, 57% of the subjects didn't feel they would be able to learn juggling by using the virtual environment. This shows that subjects were unaware of the improvement they made. As the subjects were using the virtual system they reported less frustration as opposed to the traditional learning environment, this was also reflected in the questionnaire answers as shown in Figure 5.

As depicted in Figure 6, subjects using the traditional learning environment felt it was difficult — as opposed to the subjects using the VE. 71% reported that the VE was not too hard.

6 DISCUSSION

The lack of a significant difference between the acquired skills of the two groups suggests that the virtual learning environment is comparable with the traditional learning environment as seen in Figure 4.

The results suggest that the acquisition of trans-

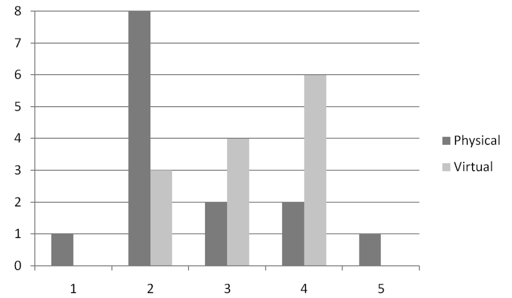

Figure 5: Number of subjects reporting a level of frustration from 1 (very frustrated) to 5 (very satisfied).1 test subject didn't fill out the questionaire.

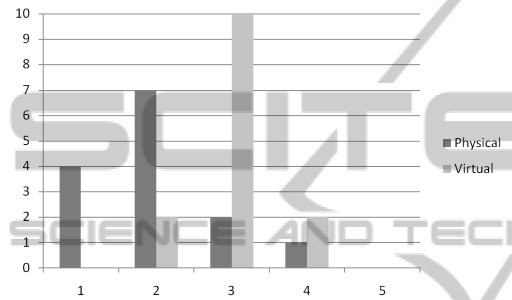

Figure 6: Number of subjects reporting a level of experienced difficulty ranging from 1 (too difficult) to 5 (too easy). 1 test subject didn't fill out the questionaire.

ferable motor skills is possible through training in a VE. User feedback indicates that the dynamic difficulty adjustments of gravity and velocity of thrown balls created an experience where players were less frustrated and provided a better training experience as shown in Figures 5 and 6.

This could be explored further by letting the training span several days to reduce mental and physical fatigue endured by subjects. Evaluating training over longer periods of time would have been beneficial as the short time makes the data more prone to be due to chance. The reason that it was not possible to find any difference between the two samples might also have been due to the small sample size.

7 CONCLUSIONS

The experiment showed that the use of game design can improve a training environment for juggling by helping learners to maintain focus and by keeping the learning experience engaging and interesting in spite of a repetitive training process. This confirms earlier research by Marshall et al. (Marshall et al., 2007).

Since these results and observations have all been gathered using juggling training, they can not be generalized to skills beyond juggling. In order to draw broader conclusions on the use and benefits of virtual training environments for transfer of motor skills, further research should be carried out across different fields relying on motor skill development.

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