Motor learning in a mixed reality environment

Alexandru Dancu
t2i Lab, Dept. of Applied IT
Chalmers University of Technology, Göteborg
alexandru.dancu@gmail.com

ABSTRACT
The traditional method for acquiring a motor skill is to focus on ones limbs while performing the movement. A theory of motor learning validated during the last ten years is contradicting the traditional method. The new theory states that it is more beneficial to focus on external markers outside the human body and predicts acquiring the motor skill better and faster. Using a mixed reality environment, we tested if the new motor learning approach is also valid using a virtual trainer and virtual markers.

Author Keywords
Motor learning; voice instructions; markers; coaching movement; post-stroke rehabilitation; natural interface; gaming technology; Kinect; OpenNI; OGRE.

ACM Classification Keywords
H.5.1 Multimedia Information Systems

General Terms
Design; Experimentation; Human factors; Artificial, augmented, and virtual realities.

INTRODUCTION

Sports textbooks on motor learning say that when learning a movement one should focus on the limbs. The theory of motor learning that we are exploring in our application consists in the hypothesis that external focus of attention (effects of the performer on the environment) is more beneficial in motor learning than internal focus of attention (concentration on performer's own body movements) [8]. Gabriele Wulf, the author of the Constrained Action Hypothesis, states that when one tries to control the limbs it affects the normal, automatic, unconscious processes that regulate movement coordination. This theory was tested and proven during the last ten years with different sports like golf, basketball, dart throwing, American football, and volleyball, and with tasks like jumping and balancing. A virtual or mixed reality environment would give the possibility to alter the targets instantly according to the exercise [3] . Correct feedback on body pose and movements in such an environment would reduce the need for real trainers and require less time to acquire a skill independently. When implemented in a medical setting, this type of application could help stroke patients recover and potentially save their lives since only 50% currently receive sufficient support to recover during the first months [1].

Natural user interfaces (NUI) have stirred excitement with the Kinect sensor being the fastest selling consumer electronics device. Gestures are a powerful mode of input, but learning how to use them is difficult since feedback is not straightforward. Gesture-based input introduces issues such as learning, timing, and dynamics [6].

This paper addresses these issues through an application employing NUI technology and also evaluates the effect of learning a movement through voice instructions and animation as it compares conditions with and without virtual markers.

Figure 1: Motor learning environment screenshot (OpenNI sample application extension). The left character is the trainer, the right one represents the tracked user whose silhouette is in the bottom right corner. In the bottom left corner the score (large 0) and Frames Per Second (FPS) are shown. The red dot in front is the virtual marker.

RELATED WORK

In 1998 the Personal Aerobics Trainer (PAT) developed at MIT was detecting subject movements using infrared technology and played back corresponding videos of a human aerobics coach [4]. In Second Skin, an infrared 3D tracking system insensitive to lighting conditions and vibrotactile feedback was proposed for motor learning [5]. An advanced virtual trainer robotic system was developed recently for the task of rowing [7]. The rowing trainer measures physiological parameters of its user, classifies movement errors, and provides auditory, haptic, and visual feedback. A related setup is a robotic manipulandum corresponding to a virtual marker displayed on an LCD screen in real-time [2]. A 2D rectangle representation of the arm and marker reduced interference in the motor learning task of object grasp. Our work draws on elements of these projects [2, 4, 5, 7].

DESIGN AND IMPLEMENTATION

We suggest a motor learning application with these four components:

- Body tracking system based on images only
- Representation of hand movements of the exercise that is currently executed and of next ones needed to be performed
- Method of recording and analyzing user movements
- Real-time feedback mechanism informing the user whether the correct movement is being performed

As tracking system, we used the Kinect sensor and the cross platform OpenNI[1] library paired with an OpenNI sample application rendering an avatar in a 3D environment using OGRE. This rendering engine was employed to create the motor learning application that recorded the hand location and guided users to perform a movement through voice instructions and virtual markers. Fig. 1 shows two characters, the left one representing the trainer performing the correct movement, and the right one showing the user. The red shape in the bottom right corner is the user's silhouette.

The feedback mechanism in our application consists in dividing the whole movement into shorter movements, so-called sub-movements, and repeating the correct trainer sub-movement until the target is hit. The sub-movements' goal is hitting the virtual marker. They are performed consecutively and help in analyzing and simplifying the complete movement. In the instruction-based condition, recorded voice instructions were played back, providing additional guidance and helping users making sense of the teacher animation. In the marker-based condition, additional red spheres appeared along the movement path. In both conditions, the exercise consisted of a 360° rotation of the right hand that was modeled through animations of the virtual trainer. These animations were played in the same order, each of them being a smaller part of the complete hand movement.

EXPERIMENT AND RESULTS

The experiment was a between-groups design: one group performing instruction-based and one group performing marker-based motor learning. In the instruction-based condition, subjects were instructed to observe the teacher's movements and follow the voice instructions. In marker-based motor learning, we explained that subjects have to hit a red sphere triggering the next marker to appear. In both conditions, the goal was to achieve a minimum score of 5 and repeat the movement until they feel comfortable. Table 1 shows the results. Increasing the score displayed in bottom left corner (Fig. 1), combined with an audio cue when hitting the target gave useful affective feedback contributing to understanding and retention of the movement.

[1]http://www.openni.org/

Table 1: Duration and accuracy means of the movement.

	Instruction-based	Marker-based
Mean duration (s)	221.8	87.4
Mean accuracy (cpo)	2615.9	1277.2

The accuracy of the whole hand movement was computed for three smaller parts. It was calculated as the cumulated pixel offset (cpo) from the correct path (lower offset means higher accuracy). Fig. 2 shows accuracy improving by duration.

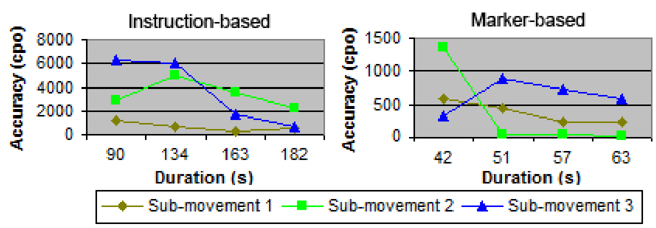

Figure 2: Examples of accuracy progress of the movement for the instruction-based (left) and marker-based (right) motor learning conditions.

FUTURE WORK AND CONCLUSIONS

Based on the experiment, we can improve future feedback mechanisms, partly visually by showing where the the hand is off course and tracking other body parts, partly by playing an error audio cue with volume or frequency proportional to the distance from the correct path.

Based on our observations and in line with the experimental results, we conclude that our work may have bearing on the design of clinical applications and instructional games. Our work proposes and validates ways to employ virtual markers in the design for time-efficient and accurate motor learning. In a clinical setting such use could permit significant decrease in the time needed for patients to recover.

REFERENCES

1. UK Department of Health. National stroke strategy, 2007.
2. Cothros N, Wong J, G. P. Visual cues signaling object grasp reduce interference in motor learning. *Journal of Neurophysiology* (2009).
3. Dancu, A. Instruction- vs. marker-based motor learning in a mixed reality environment. Master's thesis, University of Southampton, 2012.
4. Davis, J. W., Bobick, A. F. . Virtual PAT: A Virtual Personal Aerobics Trainer. *MIT Media Laboratory Proc. Workshop on Perceptual User Interfaces* (1998), 13–18.
5. Miaw, D. R., and Raskar, R. Second Skin: Motion Capture with Actuated Feedback for Motor Learning. In *Proc. of Human factors in computing systems* (2009), 4537–4542.
6. Norman, D. Natural user interfaces are not natural. *Interactions 17* (2010).
7. Rauter, G. R. Sigrist, K. Baur, L. Baumgartner, R. Riener, P. Wolf. A virtual trainer concept for robot-assisted human motor learning in rowing. *BIO Web of Conferences 1* (2011), 72.
8. Wulf, G. Attentional focus and motor learning: A review of 10 years of research. Bewegung und Training E-journal, 2007.