The Effect of Various Sensory Feedbacks in Motor Skill Training: A VR-based Study

Fady S. Alnajjar*** Qi An*** Mohit Saravanani**** Khaled Khaliif**** Shingo Shimodaa**

* College of Information Technology (CIT), The United Arab Emirates University, UAE (Tel: 971-3767-3333; e-mail: fady.alnajjar@uaeu.ac.ae).
** Intelligent Behaviour Control Unit, CBS-TOYOTA Collaboration Centre, RIKEN, Nagoya, Japan
*** Graduate School of Engineering, The University of Tokyo, Tokyo, Japan.
**** University of Toronto, Toronto, Canada.

Abstract: In this study, we investigated the effects of auditory, cognitive, tactile, and visual feedback systems in motor skill training. A Virtual Reality (VR) interface was built to facilitate the study and to better motivate the participants to complete their assigned tasks. Twelve young healthy adults were recruited to interact with the designed VR. During the interaction, various feedback systems, including visual, auditory, tactile and cognitive, were tested, as a unit or in-group, on the participants throughout different sessions. We have then examined the influence of these feedbacks to enforce the recruitment of particular muscle patterns on the participants. Initial results reveal that combining visual and tactile feedback methods achieves marked superiority over the speed of learning relative to other methods.

Keywords: BioFeedback, Motor Training, Rehabilitation

1. INTRODUCTION

Stroke survivors, involuntarily, often employ abnormal muscle patterns which results in limited range of motion and weak muscle strength (Alnajjar et al., 2019). This can be apparent in their arm movements and/or hand gripping, the most common difficulties among these patients. In the conventional rehabilitation, physiotherapists mainly target to discourage these muscle pattern abnormalities at the early stage by proposing manual guidance and feedback to redirect the correct movement of the patient limbs (Alsinglawi et al., 2018).

Technological advancements in wearable rehabilitation robots and rehabilitation gaming are proving to be a way forward in offering modern and promising advanced rehabilitation technologies (Tamayo-Serrano et al., 2018). Such development is largely aimed at enhancing the level of home-based stroke rehabilitation (Ekerete et al., 2018), for instance, RAPAEI (Song, et al., 2016) is a wearable rehabilitation robot supported by interactive game to motivate the patient to utilize their stroke-affect hand. Augmented reality (AR) as well as virtual reality (VR) have also been examined in different forms of motor training, especially that which target home-based rehabilitation (Saposnik, 2016). However, most of these approaches are more suitable for patients in clinical or under-controlled environment; and whether they sustain user’s motivation is not immediately apparent. One of the main challenges in this area is to achieve effective and motivational home rehabilitation techniques by providing a quick, accurate, informative, and easy-to-understand guidance and feedback to the patient during the therapy, thus to speed up the recovery (Alsinglawi et al., 2018).

Various sensory cues such as visual, auditory, tactile, etc. have been used for guidance and/or feedback in many researches related to rehabilitation and motor training (Kearney et al., 2018). For guidance, the cues aim to steer the attention of the user to specific factors that can help to obtain a certain movement. For feedback, the cues target to assess the user actions and represent it back to him in a simple representation, in a form of reward or punishment, to enhance his/her next actions. Yet, a comparison between existing cues and their level of influence in the recruitment of a group of muscle patterns to excite or inhibit a particular movement is still a subject of research.

In this paper, we have investigated different feedback systems in healthy adults and looked at their effect on providing adequate feedback capable to speed up the recruitment of the desired muscle patterns.

2. METHOD

2.1 Participants

Twelve volunteered young healthy adults participated in this study: four males, eight females, mean age (SD) was 20.6 (0.7) years old. All participants were right-handed and no one had experienced any motor disability or fine motor problems. All participants were assigned to various groups. Two of the participants were assigned to a Group-A, used to build the desired motor patterns for various movements, while the remaining groups were requested to take part in the training sessions that uses the guidance and feedback system. Each group can only experience one type of feedback, thus the participants won't be able to guess the required movement based on the past feedback experiences.

To build the database of muscle patterns for the desired movements, we asked Group-A to do five types of wrist and elbow movements using their left arm, and then we monitored the main muscles that contributed to each of these movements, Fig. 1. As from the figure, movements of the wrist-flexion, the wrist-extension, and the wrist-ulnar-deviation require a muscle pattern consisting of at least four
main muscles. The movement of the elbow flexion and extension requires a muscle pattern of two main muscles. We used these recorded muscle patterns to guide and feedback the other participants, Groups-B to -F, during their training sessions.

2.2 Procedure

To facilitate our experiment motivating the participants, and guide and assess their movements, a virtual environment (VE) developed by Unity3D was used to build the VR system, Fig. 2. Oculus Rift headset was used to display the VE. A leap motion was mounted on the Oculus Rift headset to capture the user’s hand motion. Low-Poly 3D hand model was used to represent the user hand in the VE (sketchfab.com). Muscles on the hand were represented using a customized muscle model. By the VE, participants can go through the various tasks, review the tasks’ instructions, monitor their scores, and review the guidance and feedback. The system also allows the operator to monitor, in real-time, the training development of the participants.

2.3 Guidance and Feedback

Using the VR system and the collected muscles database from Group-A, we developed and tested multimodal guidance and feedback related to the desired and executed movement, see the whole control system in Fig. 3. During the training sessions, we asked the participants to sit on a chair and move freely the left arm following the guidance on the VR. The condition is to always start from the same initial position (a virtual marker were set) and perform one movement at a time. A complete movement was considered every two seconds starting from the time the participant moves his/her arm. The guidance and feedback presented to each group during the training are as follow:

Auditory feedback: This group gets no guidance before their arm movement. However, positive or negative auditory feedbacks are given to the participants immediately after each complete movement. To meet the general knowledge of participants and to facilitate their understanding of the meaning of the given sound, we used the existing windows built-in sound themes to represent the auditory feedback. Windows Unlock.wav scheme is used to represent the positive feedback and the Windows_critical_strop.wav is used as for the negative feedback.

Visual guidance and feedback: Before the participant starts each movement, a visual guide highlights in green the muscles that the participant needs to activate to achieve the desired movement. Immediately after each movement, the incorrectly activated muscles will be highlighted in “Red”, and the correctly activated muscles will be highlighted in “blinking green”.

Tactile guidance and feedback: As a tactile guidance, an Arduino-based vibrator was placed on the desired muscles to guide the participant’s movement. One second continuous vibration was given before the participant starts the movement to indicate which muscles he/she needs to activate. Immediately after completing each movement, an interrupted form of vibration will be activated on the incorrectly recruited muscles followed by a second of continuous vibration on the desired muscles.

Cognitive feedback: A scoring system was developed to report a feedback to the participants after each of their arm movement. A one positive score (+1) was given every time the participant activates correctly a desired muscle. A negative score of (-1) was given every time the participant activates undesired muscles.

3. Results and Discussion

We have instructed the participants from each group to follow the guidance and the feedback given to them by the VR system, and to keep trying various movements until they reach the desired movement and their associated muscles activities patterns. All the groups have completed successfully the assigned tasks.

Figure 4 illustrates the number of trials required by each group to successfully reach the desired muscle patterns. From the figure, it is obvious that movements that involve more than one muscle activity, e.g., wrist ulnar deviation; takes longer to be accomplished than the one with simple movement, e.g., elbow flexion and extension. Results show that the cognitive training requires the larger number of trials to reach the desired movement, followed by the tactile
feedback and then the visual feedback. The model, which merge the visual and the tactile feedback requires the less number of trials.

To collect the participant feedback about the experiment, we have interviewed each participant after the training session. Participants who experienced the tactile feedback alone reported that, at some point, the vibrators cues were confusing and difficult to interpret. The other groups did not report such complaints. However, participants who experienced the merged model reported that they felt comfortable and more guided when the vibrators and visual feedback cues were given together. All the participants have reported that having the auditory feedback in addition to other feedbacks was helpful.

**Fig. 3.** A scheme represent the whole scenario of the developed system: 1) The user review the guidance in the VR, then perform the arm movement. 2) EMG data is recorded from the six muscles, and compared to the desired muscle pattern. 3) A feedback is given to the user. The process is repeated until the desired muscle pattern is achieved.

**Fig. 4.** Number of trials required by each group to reach the desired muscle pattern. Each bar in the figure is an average of the results of two participants.

4. Conclusion

This pilot study explores multimodal guidance and feedback and their impact on the speed of employing a certain movement through activation or inhibition of a specific muscle pattern. Participants were perceiving the provided sensory guidance and/or feedback, integrating it into mental representation, and plan motor action depending on it. Five muscles patterns, represented by six muscles, were used to assess the participants’ actions during the training in the VR system. Results reveal that a model that merges both visual and tactile guidance and feedback appears to be useful as a motor training tool compared to the other feedbacks. Proposing such a merged-biofeedback system could be a promising research direction for post-stroke rehabilitation. Although this study has been conducted on healthy adults not directly on post-stroke patients; we have showed previously that there is a kind of similarity underlying the neuromuscular strategies for both adaptation in healthy individuals, and the recovery of motor function after stroke (Alnajjar et al., 2019), therefore, our results here can still can offer a contribution.

The main limitation of this study is the small number of participants, which did not allow us to randomize the participants, the movements, and the guidance and feedback. The Auditory feedbacks to be given to all the groups are also a feedback. Future work will, therefore, focus on increasing the sample size and overcome some of the current limitations. Investigating the feasibility of using muscle synergies for designing the feedback is also planned for future direction, since it may encode a larger amount of useful information than a single muscle especially when performing complex movements (Alnajjar et al., 2015). Using such guidance and feedback system at early stage of post-stroke rehabilitation may prevent the use of abnormal muscle patterns. Scaling up the movement complexity and conducting are also planned in the future.

**REFERENCES**


