Preliminary Results on the Evaluation of Different Feedback Methods for the Operation of a Muscle-Controlled Serious Game

Julia Habenicht[1] and Elsa Andrea Kirchner[1,2]
[1]*University of Duisburg-Essen, Bismarckstraße 81 47057 Duisburg, Germany*
[2]*Robotics Innovation Center, German Research Center for Artificial Intelligence, Robert-Hooke Straße 1, 28359 Bremen, Germany*

Keywords: Muscle-Controlled Serious Game, Motor Learning, Auditory Feedback, Visual Feedback, Electromyogram.

Abstract: Muscle-controlled serious games can improve the ability of a targeted muscle control. This aspect is important for controlling muscle-controlled prostheses or for (re-)learning motor movements. Although there are more options, all muscle-controlled serious games are using visual feedback for providing information of the current muscle activity. The aim of this study is to compare the feedback methods visual, auditory and haptic feedback for motor learning with a muscle-controlled serious game. Due to the current status of the study, in this paper only the results of visual and auditory feedback will be analysed. Subjects were divided into two groups – visual or auditory feedback. A muscle-controlled serious game was played on three days in a row by three subjects in each group. For the visual group the game provided only visual and for the auditory group it provided only auditory feedback. At the end of each session one set without any feedback was played to control the learning status. Preliminary results show a slightly better performance of the auditory group. As the results aren't significant, more subjects are needed to get further information about the most promising feedback method for motor learning with muscle-controlled serious games.

1 INTRODUCTION

Serious games are games, which aren't there just for fun but also to have positive effects on the player (Olgers, de Weg, & Ter Maaten, 2021). In muscle-controlled serious games the game is used to provide biofeedback (in this case the muscle activity) in form of a game. With those games the targeted control of muscle activity can be practiced (Ghassemi, et al., 2019).

There are two primary target groups for muscle-controlled serious games. One target group consists of people with muscle-controlled prostheses, for whom a better prothesis control is aimed. Studies investigated the effect of practicing with muscle-controlled serious games with the aim to reach a better control of muscle-controlled prostheses. The results show a significant positive effect on fine motor movements with prostheses (Radhakrishnan, Smailagic, French, Siewiorek, & Balan, 2019, van Dijk et al. 2016) and also for the targeted control of individual muscles (Winslow, Ruble, & Huber, 2018).

The other target group consists of stroke patients. The results of studies show that playing muscle-controlled serious games can help the patients re-learning fine motor movements (Hung, et al., 2021) and can also help to build muscle mass, which got lost due to the stroke (Garcia-Hernandez, Garza-Martinez, & Parra-Vega, 2018).

The results of these studies show consistently positive effects on learning the control of muscle activity. According to our research, all of these games work with visual feedback. Serious games which are controlled by movements in general not only muscle activity often use different types of feedbacks. A study of Schättin et al. (2022) investigated the likability of visual, auditory and haptic feedback while playing a serious game. The results of the interviews revealed that the subjects liked the haptic feedback as well as the combination of haptic feedback and auditory feedback the most (Schättin, et al., 2022).

When it comes to the correct execution of movements, auditory feedback in the form of alarms has also proven to be a useful feedback method. (Riskowski, Mikesky, Bahamonde, & Burr, 2009; Underwood, 2009; Clarkson, James, Watkins, & Foley, 2013 ;Riskowski, Mikesky, Bahamonde, & Burr, 2009; Baudry, Leroy, Thouvarecq, & Choller, 2006).

Habenicht, J. and Kirchner, E.
Preliminary Results on the Evaluation of Different Feedback Methods for the Operation of a Muscle-Controlled Serious Game.
DOI: 10.5220/0012309600003657

In *Proceedings of the 17th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2024) - Volume 1*, pages 721-725
ISBN: 978-989-758-688-0; ISSN: 2184-4305

The goal of studies that used auditory alarms was to signal the subject when they were not performing a movement correctly. These results showed an immediate positive effect (Riskowski, Mikesky, Bahamonde, & Burr, 2009) but also effects up to two weeks (Baudry, Leroy, Thouvarecq, & Choller, 2006).

Haptic feedback just like vibration alone isn't very common in serious games. It is mainly added as a supporting feedback method (Kaul, Meier, & Rohs, 2017). Outside serious games it is often used to improve orientation in order to reduce the workload of the visual and auditory system (van Erp, Saturday, & Jansen, 2006).

As auditory and haptic feedback got positive results regarding serious games in general, they could also be a possible feedback method in muscle-controlled serious games. The aim of this study is to evaluate the feedback methods of visual, auditory and haptic feedback while playing a muscle-controlled serious game. Due to the current status of the study only the first results of the visual and auditory modality will be presented.

2 METHODS

2.1 Participants

In the experiment 6 healthy subjects (3 male and 3 female; average age 24.5 ±2.9) voluntarily participated. All subjects were righthanded in accordance to the Edinburgh handedness inventory (Oldfield, 1971). They gave their written informed consent to the experiment and were told that they could stop the experiment at any time without any consequences. Information about the ethic vote can be found in the section *Ethics Statement* at the end of the paper. The six subjects were divided into either the visual group or the auditory group resulting in two groups of three subjects. The group selection was randomized.

2.2 Data Acquisition

2.2.1 Electromyography

Before the experiment started subjects were prepared with a surface EMG electrode to measure the muscle activity of the right *m. flexor digitorum* (Figure 1.). The bipolar 16 channel waveplus pico blue EMG system from Cometa was used to measure the muscle activity. Skin preparation included the cleaning with alcohol. The electrode was placed in accordance to the SENIAM guidelines (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000).

Figure 1: Location of the *m. flexor digitorum* (alamy, n.d).

2.2.2 Serious Game

For the visual group the game consists of a column divided into four areas (Figure 2.). These areas can be reached by a bar, which is controlled by the contraction of the muscle. Next to the areas the digits 0, 1, 5, 10 are shown. The goal of the game is to reach the areas of the digit displayed in randomized order as accurately as possible with the muscle-controlled bar. The digit to be reached is clearly visible above the column. The bar must be in the area of the displayed digit for at least three seconds. If the bar is in the correct range, a countdown of three seconds appears. After the three seconds, the target is reached and the bar must be steered into the zero range by relaxing the muscle. After another three seconds in this area, the next target appears.

The auditory group was placed behind a movable wall so they weren't able to see the screen. For this group the goal was to hear the sound of music instruments which are connected to a certain muscle activity. The ranges for the muscle activity of the instruments correspond to the ranges of the numbers from the visual group. The subjects were told an instrument and the task was to find the muscle contraction which is connected to the before heard instrument. When they could hear the sound of the instrument, they knew they were in the right range. Otherwise, there was no sound. When they lasted in the right range for at least three seconds a bubble sound was played and they had to relax. When the muscle activity was under a pre-defined value the next instrument was announced.

Before playing the game, it had to be calibrated. For this, the maximum muscle activity and the relaxed muscle activity was measured. Based on these values the ranges for the game were calculated. A detailed description of which number/ instrument correspond to which muscle activity can be seen in Table 1.

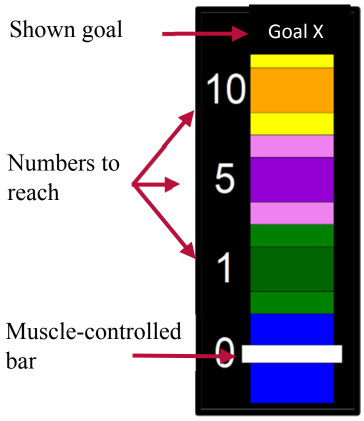

Figure 2: Muscle-controlled Serious Game for visual feedback.

Table 1: Explanation of the game calibration. Goals with the corresponding muscle activity of the maximal voluntary contraction (MVC).

Goals		Muscle activity
Goal 1	Number 1/ Instrument 1	20%-40% of MVC
Goal 2	Number 5/ Instrument 2	40%-60% of MVC
Goal 3	Number 10/ Instrument 3	60%-80% of MVC

2.2.3 Experimental Design

Seven sets of the game were played with a following learning control set on three days in a row. In each set every number/ instrument had to be reached three times. The order was randomized. The learning control set consists of a set in which the subjects didn't receive any feedback of the game. The game just showed/told the target and the subjects had to contract the muscle the right way out of their memory. After they thought they were in the right range for at least three seconds they had to relax the muscle and the next target was shown/told. A detailed description of the experimental design is depicted in Figure 3.

To evaluate the different feedback methods, the learning control set data was used to determine the percentage of the time the muscle activity was in the right range for each of the goals. The analysis was made for each goal in both groups. For the comparison between the feedback methods a Wilcoxon Test was performed between the visual and auditory data of all results of all subjects (Figure 4). The significance value was set at $p < 0.05$.

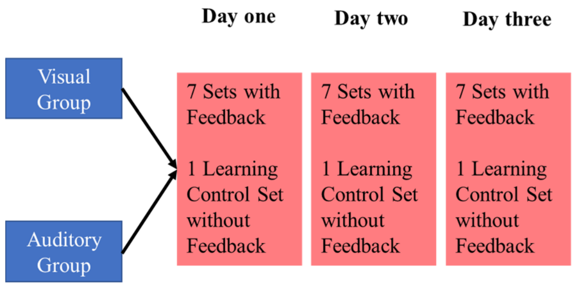

Figure 3: Experimental Design.

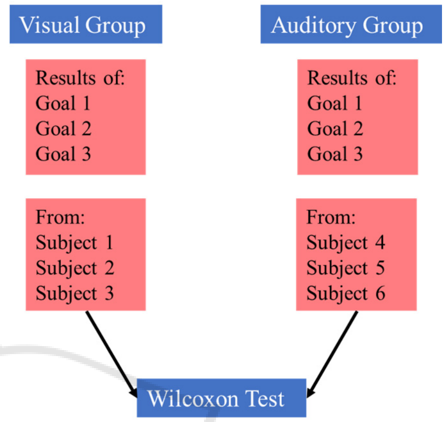

Figure 4: Description of statistical analysis.

3 RESULTS

Over all, the auditory group achieved a higher performance than the visual group although this difference was not significant. Table 2. shows the results of each subject for each goal. The values in the table represent the mean results of all three days for

Table 2: Percentage of time the muscle activity was in the right range per goal. The results of the learning control set of all three days are depicted.

Visual Feedback			
	Subject 1	Subject 2	Subject 3
Goal 1	40.64%	32.03%	27.58%
Goal 2	22.04%	27.47%	14.96%
Goal 3	27.43%	27.68%	56.34%
Auditory Feedback			
	Subject 1	Subject 2	Subject 3
Goal 1	42.23%	47.57%	24.35%
Goal 2	23.40%	27.31%	27.57%
Goal 3	39.92%	40.32%	55.57%

each goal. In average both groups showed the lowest performance reaching goal 2 and the highest performance in reaching goal 3. Figure 5 represents the combined results of each subject per group of all three days for the three goals. Results show a higher performance in reaching each goal which leads to a higher performance in general for the auditory group (Figure 6).

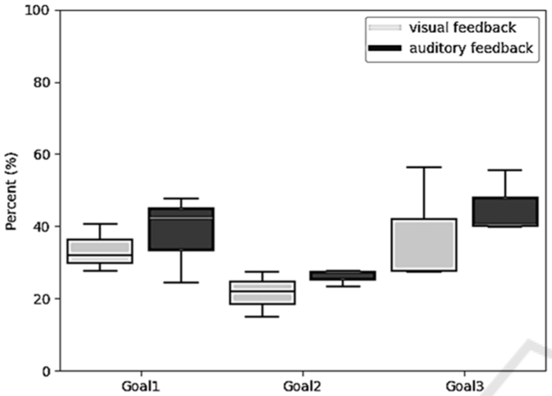

Figure 5: Achieved goals in the learning control sets of the visual and auditory group in percent. Each block combines the results of all three days of each subject.

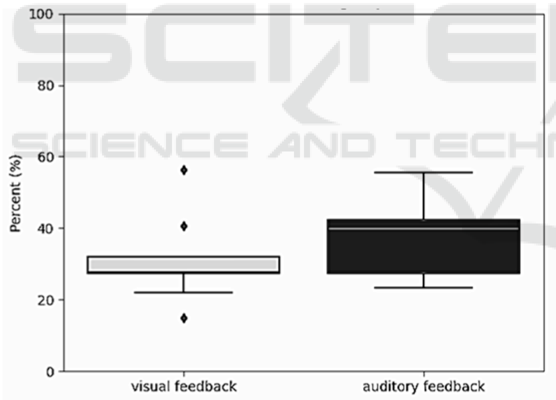

Figure 6: Comparison between visual and auditory group. Each block combines all achieved results of each subject for each goal of the learning control set on all three days.

4 DISCUSSION

The aim of the study was the evaluation of different feedback methods for a muscle-controlled serious game. In general, the results show a tendency for better performance of the auditory group in each goal which can be interpreted as a higher learning effect for the auditory group. Since the results are not significant, more subjects need to be studied.

An explanation for the better results of the auditory group could be the guidance hypothesis which states that the permanent feedback during acquisition leads to a dependency on the feedback (Salamin, Tadi, Blanke, Vexo, & Thalmann, 2010; Schmidt, Frequent Augmented Feedback Can Degrade Learning: Evidence and Interpretations, 1991; Schmidt, Young, Swinnen, & Shapiro, 1989). As the auditory group only received feedback when they where in the right range, no dependency on the feedback could be developed. That could be an explanation for the higher performance in the learning control set.

For the investigated subjects it is striking that for both groups the lowest performance was at goal 2. A reason could be that for goal 1 and goal 3 one could figure out that either the muscle activity should be very high or very low. To find the range in between is therefore more difficult.

Nevertheless, more subjects are needed to verify the presented results. For a right statement the experiments for the haptic feedback have to be performed and analysed as well.

5 CONCLUSIONS

This study should provide further insights into possible feedback methods in muscle-controlled serious games. However, individual adaptations may be necessary for the application in rehabilitation practice.

These first results show a tendency towards a higher learning effect in the auditory group. As these data are not statistically significant more subjects are needed for verification. Considering the current results so far, auditory feedback should be taken into account as a method for motor learning with muscle-controlled serious games.

ETHICS STATEMENT

The studies involving human participants were approved by the local Ethical Committee of the University of Duisburg-Essen, Germany. The participants provided their written informed consent to participate in this study.

REFERENCES

alamy. (n.d.). *alamy*. Retrieved from https://www.alamy.de/fotos-bilder/flexor-digitorum-superficialis-muscle.html?sortBy=relevant

Baudry, L., Leroy, D., Thouvarecq, R., & Choller, D. (2006, February 24). Auditory concurrent feedback benefits on the circle performed in gymnastics . *Journal of Sports Science*.

Clarkson, P. M., James, R., Watkins, A., & Foley, P. (February 2013). The Effect of Augmented Feedback on Foot Pronation during Barre Exercise in Dance. *Research Quarterly for Exercise and Sport*.

Garcia-Hernandez, N., Garza-Martinez, K., & Parra-Vega, V. (2018). Electromyography Biofeedback Exergames to Enhance Grip Strength and Motivation. *Games Health Journal*.

Ghassemi, M., Triandafilou, K., Barry, A., Stoykov, M. E., Roth, E., Mussa-Ivaldi, F. A., . . . Ranganathan, R. (27. February 2019). Development of an EMG-Controlled Serious Game for Rehabilitation. *IEEE Engineering in Medicine and Biology Society* .

Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000, October). Development of recommendations for SEMG sensors and sensor placement procedures . *Journal of Electromyography and Kinesiology*.

Hung, N. T., Paul, V., Prakash, P., Kovach, T., Tacy, G., Tomic, G., Slutzky, M. W. (2021, August 21). Wearable myoelectric interface enables high-dose, home-based training in severely impaired chronic stroke survivors. *Annals of Clinical and Translational Neurology*.

Kaul, O. B., Meier, K., & Rohs, M. (2017, September 21). Increasing Presence in Virtual Reality with a Vibrotactile Grid Around the Head. *Lecture Notes in Computer Science*.

Oldfield, R. C. (1971, March). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologie*.

Olgers, T. J., de Weg, A. A., & Ter Maaten, J. C. (2021, January 25). Serious Games for Improving Technical Skills in Medicine: Scoping Review. *JMIR Serious Games*.

Radhakrishnan, M., Smailagic, A., French, B., Siewiorek, D. P., & Balan, R. K. (2019). Design and Assessment of Myoelectric Games for Prosthesis Training of Upper Limb Amputees.

Riskowski, J. L., Mikesky, A. E., Bahamonde, R. E., & Burr, D. B. (2009, September). Design and Validation of a Knee Brace With Feedback to Reduce the Rate of Loading. *Journal of Biomechanics*.

Salamin, P., Tadi, T., Blanke, O., Vexo, F., & Thalmann, D. (2010, October). Quantifying Effects of Exposure to the Third and First-Person Perspectives in Virtual-Reality-Based Training. *IEEE Transactions on Learning Technologies*.

Schättin, A., Pickles, J., Flagmeier, D., Schärer, B., Riederer, Y., Niederecken, S., . . . Martin_Niederecken, A. L. (2922, December). Development of a Novel Home-Based Exergame With On-Body Feedback: Usability Study. *JMIR Serious Games*.

Schmidt, R. A. (1991). Frequent Augmented Feedback Can Degrade Learning: Evidence and Interpretations. *Tutorials in Motor Neuroscience*.

Schmidt, R. A., Young, G. E., Swinnen, S. E., & Shapiro, D. C. (1989). Summary Knowledge of Results for Skill Acquisition: Support for the Guidance Hypothesis. *Journal of Experimental Psychology Learning Memory and Cognition*.

Underwood, S. M. (2009). Effects of Augmented Real-Time Auditory Feedback on Top-Level Precision Shooting Performance.

van Erp, J. B., Saturday, I., & Jansen, C. (2006). Application of tactile displays in sports: where to, how and when to move.

Winslow, B. D., Ruble, M., & Huber, Z. (11. July 2018). Mobile, Game-Based Training for Myoelectric Prosthesis Control. *Frontiers Bioengeneering and Biotechnology*.