THE EFFECT OF SERIOUS GAME TRAINING ON UPPER LIMB PROSTHESIS CONTROL IN THE HOME ENVIRONMENT

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ABSTRACT

Background: The focus of the field of upper limb prosthesis has primarily been on lab-based studies, while user-complaints do hardly change. Focus should shift to home use training and assessment. The current paper establishes whether training with serious games in the home setting affect upper limb prosthesis activation signals in Pattern Recognition controlled prostheses.

Method: Ten upper limb prosthesis users were measured for a period of two weeks and were instructed to play serious games for at least 45 minutes per week. The activation signals before and after a serious game was played during daily life were measured. The activation signals were classified in involuntary and voluntary activations.

Results**:** More involuntary activation signals than voluntary activation signals were recorded. Second, no effects of serious game training on activation signals in daily life were found.

Conclusion: Even though no effect of serious game training was found, our findings show that recording and analyzing data derived from prosthesis users' daily life is feasible. However, much has still to be learned about the storage, applicability and meaning of this data. Our research underlines the importance of transitioning from lab-based research to research in daily life.

INTRODUCTION

Upper limb prostheses have undergone substantial technological improvements in the last two decades. For instance, the number of degrees of freedom of the prosthetic hand has increased by creating multi-grip hands and control has advanced to Pattern Recognition (PR) control, where multiple electrodes measure patterns of muscle activation that are matched to a grip pattern, cf. [1]. However, user complaints about the control of the prosthesis in daily life situations have hardly changed in the last two decades, despite these technical advancements [2]–[4]. This might be partly due to the fact that technological improvements have mainly been assessed in lab-based studies with a limited number of users [5]. In lab-based studies, mostly tasks were used that only partly cover the tasks that users perform in activities of daily living. To improve the quality of lab-based training, serious games (games that are designed to develop a certain skill while playing) have been used as a training tool to enhance prosthesis control [6]–[8]. However, effectiveness of serious game training on prosthesis use has not been evaluated in home use. Hence, the current study aims to determine the effect of training serious games in the home setting on upper limb prosthesis activation signals in PR controlled prostheses.

METHOD

The data collection of the Coapt Complete Control System for this study was conducted by Coapt LLC. Each participant provided informed consent in accordance with the WCG-IRB.

Design

The activation signals of the participants' upper-limb prosthesis were measured in their home setting when the device was turned on during a period of 2 weeks. Participants were instructed to use their prosthesis as they would in their normal day-to-day life with the only additional requirement to train with serious games provided by the Coapt system for at least 45 minutes per week. Participants were free to choose when they would train with the games, however they were urged to train multiple days.

Serious games

The Coapt system provided users with two serious games, Simon Says and In The Zone. Simon Says is a Fitts'-Laws style serious game in which participants control a virtual arm in an attempt to match a target posture (Figure 1). The virtual arm is controlled by the same activation signals as the real prosthesis.

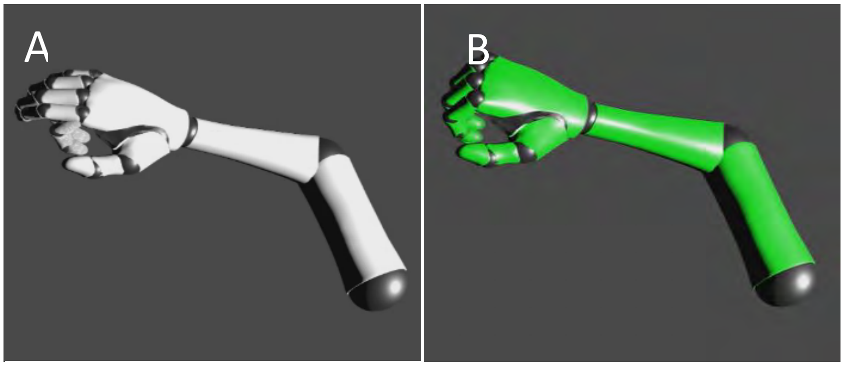

Figure 1. A) The user has to match the position of the 'shadow arm' (closed hand position) with the representation of their own prosthesis (solid arm, hand open position). B) When the user correctly matches their prosthesis position to the target position, the prosthesis turns green.

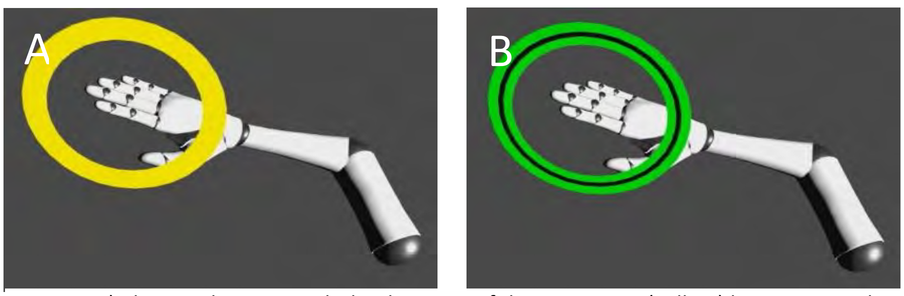

Figure 2. A) The user has to match the diameter of the target ring (yellow) by activating the joint with the correct amount of activation. B) When the user correctly matches the amount of activation (the black ring) with the target ring, the ring will turn green.

In The Zone is a serious game in which participants had to match a target intensity of muscle contraction levels. A virtual arm with a target ring around a specific joint and a ring which matched their actual contraction level (see Figure 2) was presented. By increasing the amount of muscle activation around that joint, participants were able to match the sizes of both rings.

Data storage and outcome measures

Data storage within the Coapt system was done in three steps. First, the system computed the number of consecutive time frames of 50 ms in which the user produced the same activation signal. Second, the system stored the data of each individual activation signal in one of two groups based on the number of consecutive time frames: involuntary activations (1-6 frames) and voluntary activations (<7 frames). Third, the system counted the frequency of each group of activation signals per individual motion of the system. As outcome measure we divided the number of activation signals per group by the total activations for all participants separate for each motion of the system. It was hypothesized that serious games would improve a user's prosthesis control, arguably resulting in more voluntary activation. When a user had more voluntary activation than involuntary activation after the serious games were played than before, it could be assumed that playing serious games improved that user's prosthesis control.

Statistical analysis

Due to the limited number of participants, a non-parametric Wilcoxon Signed Rank test was used to determine if there were differences in the ratio of the involuntary and voluntary activations of the Hand Open, Hand Close, Wrist Supination and Wrist Pronation modes before and after serious games were played.

RESULTS

Participant characteristics are presented in Table 1. The data show that there are more involuntary activation signals than voluntary activation signals for each prosthesis activation mode, see Figure 3. No significant differences were found between the ratio of involuntary and voluntary activations before and after the serious games were played (Figure 3) for both the Hand Open, Hand Close, Wrist Supination and Wrist Pronation modes.

Table 1. Characteristics of participants with transradial (TR) or transumeral (TH) defects

Participants	Sex	Age	Number of months of prosthesis use	Wear time (hours/2 weeks)	Number of games played/2 weeks (1 game = 5 minutes)
TR 1	Female	57	33	6.8	18 (90 min)
TR 2	Male	38	25	25.9	19 (95 min)
TR 3	Female	42	18	64.9	14 (70 min)
TR 4	Male	28	8	125.0	19 (95 min)
TR 5	Female	53	74	243.7	18 (90 min)
TR 6	Female	31	54	4.1	53 (265 min)
TR 7	Female	36	4	13.2	14 (70 min)
TH 1	Male	57	16	66.4	28 (140 min)
TH 2	Male	47	72	9.6	21 (105 min)
TH 3	Male	43	84	45.0	20 (100 min)

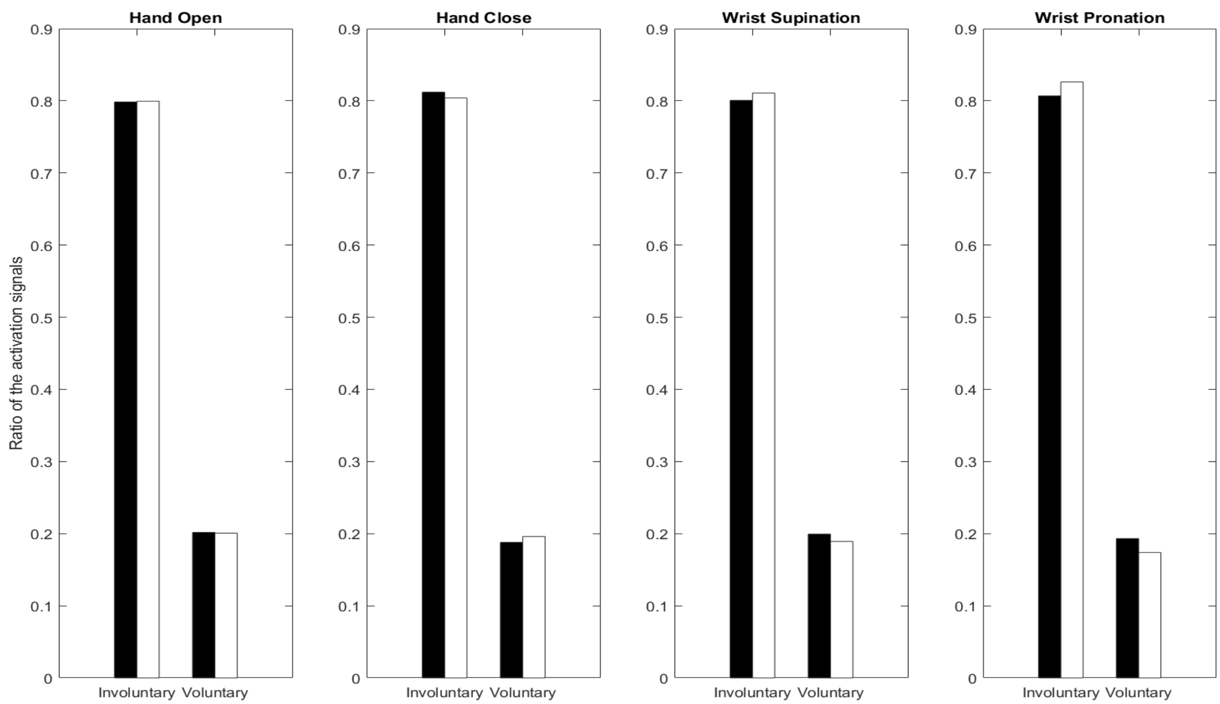

Figure 1. The average distribution of the activation signals for the Hand Open motion (first), Hand Close (second), Wrist Supination (third) and Wrist Pronation (fourth) are shown. The ratio of the activation signals (y-axis) was calculated (activation signals per group (x-axis) divided by the total) for all participants before a serious game was played (black bars) and after a serious game was played (white bars).

DISCUSSION AND CONCLUSION

Our main analysis of the effectiveness of serious games on activation signals in PR controlled upper limb prostheses showed no difference in the ratio of voluntary and involuntary activation signals when comparing before and after training. This null-finding may have different reasons that deserve further study. For instance, it might be that a training period of two weeks is too short to find an effect of the training with serious games (see for instance Tabor et al 2018), or that the training time of minimal 45 minutes was not long enough. Moreover, it might be that the users included in this study were already quite experienced in the use of PR controlled prosthesis.

Another issue that deserves further study is the choice of the games. In this study we used the games that were available in the Coapt system. However, other studies have shown effectiveness of serious games that were task-specific [7], [9]. It might be that the serious games currently used were not specific enough to improve use of the prosthesis in the home setting due to training and focused too much on the control of the myo-signal.

An unexpected result of the current study is that we found more involuntary activations that voluntary activations. The origin of this result is not clear. It might be that the short activation commands do not result in activation of the prosthesis and therefore these signals are not controlled by the users, which might explain their high occurrence. This finding underlines the importance of longer lasting studies in the home setting of the prosthesis users instead of short lab-based research.

To conclude, in a first study to examine the effectiveness of serious games in home usage of PR controlled upper limb prostheses we did not find an effect of the serious games. We argued that the step to measuring in the home situation is an important one to further improve the field. Our current findings show that a type of training (i.e., serious gaming) that had shown to be effective in the lab, was not effective in the home situation. Therefore, our findings, although a null finding, show the importance to shifting focus to studies in home settings to improve PR controlled upper limb control.

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