ASSESSING CONTROL AND FEEDBACK IN VIRTUAL REALITY FOR MYO-ELECTRIC PROSTHESIS TRAINING

Samantha G. Rozevink[1], Bart Maas[1], Alessio Murgia[1], Raoul M. Bongers[1], Corry K. van der Sluis[2]

1. University of Groningen, University Medical Center Groningen, Department of Human Movement Sciences, Groningen, The Netherlands

2. University of Groningen, University Medical Center Groningen, Department of Rehabilitation Medicine, Groningen, The Netherlands

ABSTRACT

Training a myo-electric prosthesis could benefit from a virtual reality environment (VRE) as a training tool, however it should match the wishes and needs of prosthesis users and therapists. We investigated whether an existing VRE, developed for exploration of prosthesis use, complied with the needs and wishes of the end-users, regarding control and feedback. The VRE simulated a coffeehouse where different types of cups of coffee needed to be grasped. A preliminary sample of eight prosthesis users and eight therapists tried out the VRE and subsequently filled out a 7-item numeric rating scale questionnaire. Prosthesis users were not very satisfied with the control in the VRE, mainly due to the delay between the muscle impulse and the prosthesis movement. Therefore, they felt that the control did not correspond to a daily life experience with their own prosthesis. End-users agreed that sparse visual feedback was used and, then, only when needed. Negative feedback was however present in the game, which was only noted by therapists. Prosthesis users and therapists agreed with most items of the questionnaire, indicating that they experienced most factors of the framework in the VRE. However, the observed differences in experiences between end-users showed that both prosthesis users and therapists should be involved in the assessment of training tools.

INTRODUCTION

People with a limb deficiency can use a prosthesis to assist them in daily life tasks. From the majority of the available active prostheses, the myo-electric prostheses, which are controlled by the muscle signals of the user, are the most difficult to learn to control. Due to the lack of function and comfort, they are often abandoned [1]. Training can help a user to learn how to successfully control the prosthesis, however this is time consuming and often experienced as dull [2]. New ways of training are emerging due to the use of virtual reality environments (VRE), where a person can immerse themselves in a digital environment. VREs provide multiple advantages, such as adaptable environments, multiple possibilities in exercises, different types of feedback and the ability to include game elements in the training [3,4]. These can all help to improve the learning experience for prosthesis users.

Previous research from our group investigated the important design characteristics of a VRE to adhere to the needs and wishes of prothesis users and therapists [5]. Using a combination of a literature review and focus groups, the important characteristics of a VRE were detailed in a framework. The framework, consisting of four main domains and 46 factors, could be used during the development of a VRE or to verify whether an existing VRE adheres to the framework. The latter was explored for the first time in this study using the barista game (The Simulation Crew, Nijmegen). The framework was rewritten as a questionnaire to investigate the opinion of the user with regards to the current system. Here, we report on the domains control and feedback, since the use of feedback in VR could benefit the learning process for prosthesis control. Our research questions were as follows: 1) can the framework be used as a questionnaire to assess an existing VRE?; 2) does the VRE of the barista game include the needs and wishes of the end-users (users and therapists) according to the VRE framework domains control and feedback?

METHODS

The study was approved by the central ethics review board of the University Medical Center Groningen (RR1147). Participants signed an informed consent before participation.

The domains control and feedback, each containing 3 subdomains and 8 factors, were investigated in this study (Figure 1, A). We rephrased the factors of the framework into statements, where participants could indicate on a numeric rating scale from 1 (strongly disagree) to 10 (strongly agree) how much they agreed with the statement. Factors which either did not exist in the current game or were clearly available, were removed beforehand for conciseness of the questionnaire. The factors that were removed concerned co-contraction and switching commands, control for lack of weight, audio and vibration feedback, as these were not implemented in the current VRE and could therefore not be assessed. Factors regarding calibration in different arm positions, proportional control, feedback on electromyography (EMG) and force, and animation as instruction of movement were clearly evident in the VRE and therefore also removed. Descriptive data such as mean and standard deviation was reported. Due to the small sample size and explorative nature of the study, no statistics were performed.

The 7-item questionnaire was used to evaluate whether an immersive VRE, which was developed to provide myoelectric training, contained the factors of the framework. The commercially available Oculus Rift was used in combination with a Bluetooth-connected Myoband (Otto Bock Healthcare Products GmbH, Wien, Austria) containing four active electrodes (Figure 1, B). A calibration was performed in three different arm positions, where the user trained the system the muscle signals for hand-open and hand-close movements. In the VRE, the participant immersed themselves in a Mediterranean café to work as a barista, where coffee orders had to be completed (The Simulation Crew, Nijmegen). The task was to grasp the correct cup with the prosthetic hand, place it under the coffee machine and press the correct button for the right drink (Figure 1, B). The cup had to be placed on the serving tray, subsequently. Higher levels resulted in more difficult game play, such as breakable cups that had to be grasped using proportional control or cups placed on high and low shelves. Participants played for approximately 15 to 30 minutes, depending on how fast they could complete the orders. In the game, feedback was provided on the force and EMG signal.

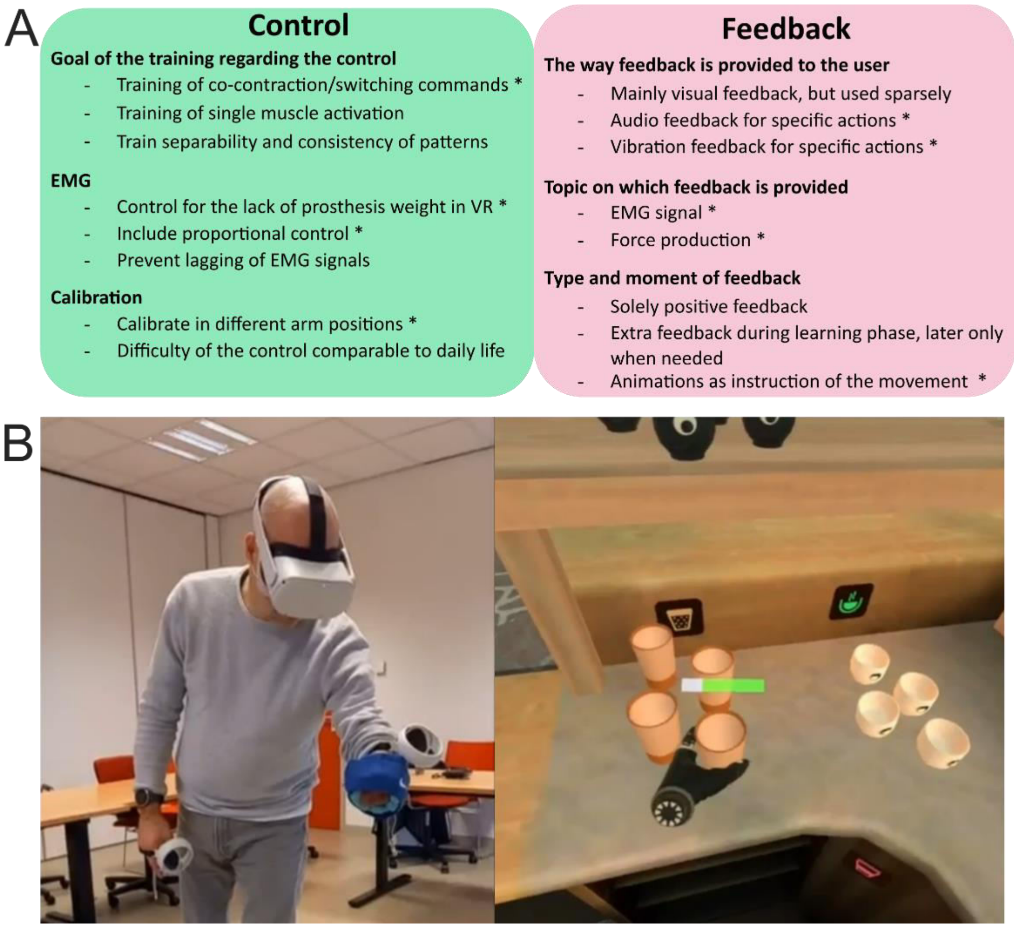

Figure 1: A: The domains 'Control' and 'Feedback' of the framework, which was developed based on a narrative review and focus groups with prosthesis users and therapists. Factors marked with an asterisk were not included in the questionnaire since they either did not exist of were clearly available in the VRE. B: the setup of a prosthesis user wearing the VR headset and Myoband around the stump (left photo). The task is to grasp cups to fulfil the coffee order (right photo).

RESULTS

A preliminary sample of eight prosthesis users (six males and two females, mean age 61.8 years) and eight therapists (one male and seven females, mean age 49.6 years) participated in the VR experience. The majority of the prosthesis users had a congenital deficit (N=5), the others (N=3) had an amputation due to trauma. Most of the participants had a previous VR experience (N=10).

Prosthesis users seemed to rate the control in the VRE lower than therapists, providing a mean score (±standard deviation) of all questions of 6.5±3.4 and 7.4±2.5, respectively (Figure 2). This was mainly visible in the items "lag between EMG and prosthesis movement" (prosthesis users=5.4±4.0; therapists=7.3±2.7) and "comparability to daily life prosthesis use" (prosthesis users=4.9±3.8; therapists=6.6±2.6). For the "control of a specific muscle" (prosthesis users=7.8±2.7; therapists=8.1±1.7) and "the training of separable muscle patterns" (prosthesis users=8±2.4; therapists=7.8±2.9), end-users generally agreed with these statements.

Prosthesis users provided a higher score on the feedback items (mean score of all questions=8.0±2.2) compared to therapists (mean score of all questions=7.0±2.4). Therapists noted that not only positive feedback was provided, since the waitress would respond displeased if participants did not prepare the right order (prosthesis users=7.9±2.4; therapists=5.3±2.7). All end-users seemed to agree that "the visual feedback was not too much" (prosthesis users=8.4±2.4; therapists=8.0±1.8) and that "extra feedback during the learning phase" (prosthesis users=7.6±2.1; therapists=7.9±2.0) were present.

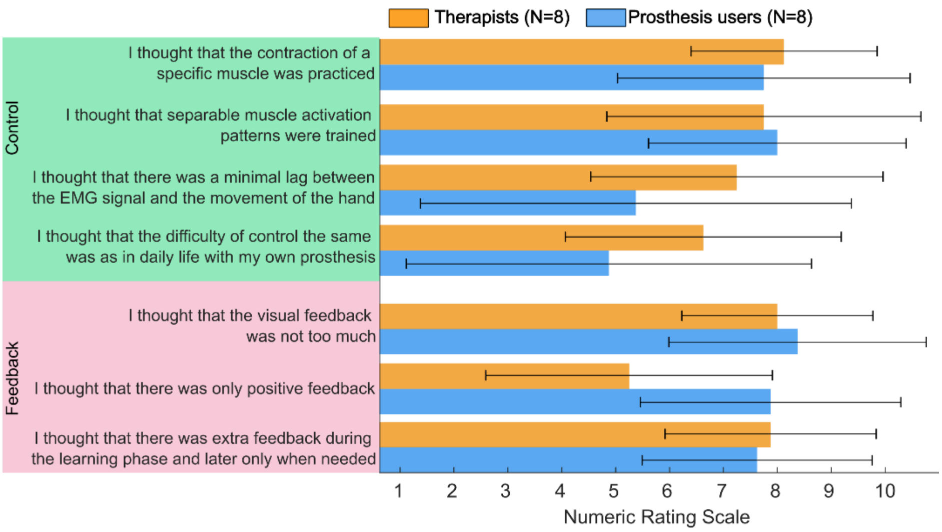

Figure 2: Questionnaire related to the framework of important design characteristics that should be part of a VRE to train prosthesis control, and the ratings of the therapists (orange) and prosthesis users (blue). Mean scores are represented by the bar graphs, whiskers represent the standard deviation

DISCUSSION

We investigated whether a previously developed framework describing the important design characteristics of a VRE for prosthesis control training could be used as a questionnaire and to investigate whether an existing VRE adhered to the framework. Results showed that the questionnaire could be used to assess adherence to the framework, although there were some limitations (see limitations). The prosthesis users and therapists agreed with most statements in the questionnaire, indicating that most factors were present in the barista game. We also noted that that the experiences of prosthesis users and therapists sometimes seemed to differ. Prosthesis users addressed that the control was often more difficult compared to their daily life prosthesis, in most cases this was caused by the delay between muscle activation and prosthesis movement. Note the large standard deviation in these questions, which indicates that some users agreed with the statements while others strongly disagreed. Furthermore, therapists might be less capable to judge whether control in VR is comparable to daily life, due to their lack of prosthesis experience.

Prosthesis users seemed to provide a higher score compared to therapists on the statement that "there was only positive feedback", a possible explanation is the unfamiliar term of positive feedback to patients. In the game, negative feedback would mean that the waitress would respond displeased with an incorrect order or when a glass was dropped, it shattered on the ground. These feedback visuals were negative, in the sense that they highlight something that the user did wrong.

According to the data logs, prosthesis users did encounter these experiences, but they were not perceived as negative. It is therefore questionable whether negative feedback should be avoided, as is mostly advised in learning studies [6]. The different experiences between prosthesis users and therapists shows that both types of end-users should be involved in the usability studies of training tools, since each group pays attention to different aspects of the system.

Limitations: The framework factors from previous research were translated into a questionnaire. Some questions could be interpreted in different ways. For example, the statement "control of the prosthesis is the same as daily life". A low score on this item could mean that prosthesis control was either easier or harder compared to their own prothesis. Therefore, the information in the questionnaire provides limited information. The formulation of the questionnaire should be formally validated to be more informative. Another limitation is that in this study we chose not to rate all the items from the framework, for the conciseness of the questionnaire. In the future, all items could be rated, leading to more information on how end-users experienced the VRE and where improvements can be made in the design. Future research could use the framework as a questionnaire to assess VRE, however, the factors that are incorporated and the framing of the questions are important to reconsider.

Conclusion: Prosthesis users and therapists agreed with most items in the questionnaire, indicating that they experienced most factors of the framework in the VRE.

ACKNOWLEDGEMENTS

We thank the following rehabilitation centres for their participation in this research: De Hoogstraat Revalidatie Utrecht, Libra Eindhoven, Rijndam Revalidatie Rotterdam and Revalidatiecentrum Roessingh Enschede.

REFERENCES

[1] Smail LC, Neal C, Wilkins C, Packham TL. Comfort and function remain key factors in upper limb prosthetic abandonment: findings of a scoping review. Disabil Rehabil Assist Technol 2021;16:821–30. https://doi.org/10.1080/17483107.2020.1738567.

[2] Franzke AW, Kristoffersen MB, Bongers RM, Murgia A, Pobatschnig B, Unglaube F, et al. Users' and therapists' perceptions of myoelectric multi-function upper limb prostheses with conventional and pattern recognition control. PLoS One 2019;14:1–13. https://doi.org/10.1371/journal.pone.0220899.

[3] Hashim NA, Abd Razak NA, Shanmuganathan T, Jaladin RA, Gholizadeh H, Abu Osman NA. On the use of virtual reality for individuals with upper limb loss: a systematic scoping review. Eur J Phys Rehabil Med 2022;58:612–20. https://doi.org/10.23736/S1973-9087.22.06794-6.

[4] Papaleo ED, D'Alonzo M, Fiori F, Piombino V, Falato E, Pilato F, et al. Integration of proprioception in upper limb prostheses through non-invasive strategies: a review. J Neuroeng Rehabil 2023;20:1–22. https://doi.org/10.1186/s12984-023-01242-4.

[5] Rozevink SG, Murgia A, Bongers R, van der Sluis C. Users ' and therapists ' perspectives on the design of a virtual reality environment to train prosthesis control : a narrative review and focus group study (preprint). Res Sq 2023:1–26. https://doi.org/10.21203/rs.3.rs-3675534/v1.

[6] Wulf G, Lewthwaite R. Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. Psychon Bull Rev 2016;23:1382–414. https://doi.org/10.3758/s13423-015-0999-9.