Exploring a Dynamic Change of Muscle Perception in VR, Based on Muscle Electrical Activity and/or Joint Angle

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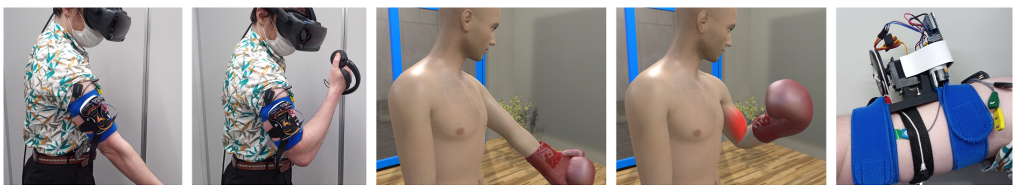

Figure 1: From left to right: A user doing the task (extension); A user doing the task (contraction); The virtual avatar (extension); The virtual avatar (contraction); The ad hoc haptic device with the EMG sensor.

ABSTRACT

We display a virtual avatar changing its biceps appearance to fit the user's biceps contraction. The avatar's biceps changes its size and color based on either: (EMG) the biceps activity (recorded with a electromyography [EMG] sensor); or (ANG) the elbow angle; or (EMG + ANG) the biceps activity and elbow angle. The users also wear an ad hoc haptic device around their biceps to give the illusion of stronger biceps contractions. In the Virtual Environment, the participants (N=10) look at their right biceps and do elbow flexion. They rate EMG, ANG and EMG + ANG (with and without the haptic device) along *Body Ownership* and *Agency*. We found that ANG (without the haptic device) was rated noticeably lower on the Agency than EMG and EMG + ANG (both without the haptic device). It is likely better to change the appearance of a muscle using the user's muscle contraction rather than the user's movement when considering the user's muscle ownership and agency. The addition of the ad hoc haptic device appeared to not affect the *Sense of Embodiment*.

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CCS CONCEPTS

• **Human-centered computing → Virtual reality**; *User studies*.

KEYWORDS

*Virtual Reality, Embodiment, Physical Activity, EMG

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1 INTRODUCTION

Virtual Embodiment (associating a virtual body as our own body) is a well studied subject in Virtual Reality (VR) [2, 5]. While most of Virtual Embodiment studies use a "static body shape" (i.e., that will not change its shape during the application's execution), a "dynamic body shape" might highlight different behaviors.

We want to know if there is a difference in the *Body Ownership* and *Agency* of a muscle depending of the method used to change its appearance: based on its muscle activity and/or based on its surrounding bones orientation. We also want to know if there is a difference in Body Ownership or Agency if we add a feeling of tightness around the muscle when the muscle is contracted. In a next step not shown in this work, we want to know if a change in muscle appearance when doing a physical activity (e.g. Active Video Games or VR Rehabilitation) led to higher performance and higher motivation.

In our setup the user is embodied in a virtual body whose virtual biceps changes its size and color depending on their biceps contraction and/or elbow angle, c.f., Sec. 2.

When looking at related works, previously Barenbrock et al. [1] dynamically changed an avatar's weight but did not see significant changes on motivation. We except to get better results, since we have a more localized effect. More recently Kocur et al. [3] showed that a muscular avatar can decrease the perception of effort and increase the physical performance.

2 SETUP DESCRIPTION

The user wears a Head Mounted Display (a Valve Index[1]), a tracker on their waist (a Vive Tracker[2]), and hold 2 controllers (Valve Index as well). We also attach to the user 1 electromyography (EMG) sensor (c.f. Fig. 1) on their right biceps (the Trigno Quattro[3]). The ad hoc haptic device (c.f. Fig. 1) is also attached to the right biceps, next to the EMG sensor. A servomotor (ref. G996R) tighten a band that surround the upper arm, therefore both the biceps and triceps are "tightened". A white noise is delivered to cover the noise of the servomotor. A couple of wireless emitter/receiver (XBee[4]) assure the wireless connection with the VR application. At rest there is no sensation of tightness and at max there is a "very tight" sensation, almost hurtful[5].

3 VIRTUAL ENVIRONMENT

The Virtual Environment (VE) is a gym (c.f. Fig 1) and was developed in Unity 2019[6]. The avatar (c.f. Fig. 1) follows the user's movements thanks to Inverse Kinematic and the FinalIK[7] package, using the head, hands and waist as control point. Because we want the user to focus on their biceps, we do not display the avatar's legs - Embodiment-wise, this is not an issue, since having a "normal body" or partially invisible body is not a requirement [4].

4 DYNAMIC CHANGE OF PERCEPTION

The avatar's right arm biceps increases its volume based on the right biceps activity and/or the right elbow angle. The biceps activity is recorded with a EMG sensor and the elbow angle is computed from the lower and upper right arm bones orientation. The change in volume is noticeably big, while still being realistic. We also apply a transparent to red color gradient to make it more visible. The virtual biceps volume can be linked to the haptic device band's tightness (bigger size = tighter).

5 EXPERIMENT DESIGN AND TASK

The "Biceps activation" variables are: (EMG) the biceps activity; or (ANG) the elbow angle; or (EMG + ANG) the biceps activity and elbow angle. The "Haptic" variables are: (HAPTIC) There is haptic feedback; (NOHAPTIC) there is no haptic feedback (device turned off). We have a total of (3×2) 6 conditions and use a within-subject design. The participants (N=10) do the conditions in a random partial counterbalanced order.

The experimenter setups and calibrates the EMG sensor and the ad hoc haptic device for the participant. Then the participant follows a quick training session. Then the participant does the conditions one by one. For each condition, the participant does elbow flexion for about a minute while looking at their biceps. The participant has the liberty to contract their biceps during the flexion. Then he/she answers the following questions on a 7-Likert scale: Q1 - I felt as if the virtual biceps was my biceps; Q2 - I felt as if the virtual biceps I saw was the biceps of someone else; Q3 - It felt like I could control the virtual biceps as if it was my own biceps; Q4 - The movements of the virtual biceps were caused by my actions; Q5 - It seemed as if the touch I felt was located somewhere between my physical biceps and the virtual biceps.

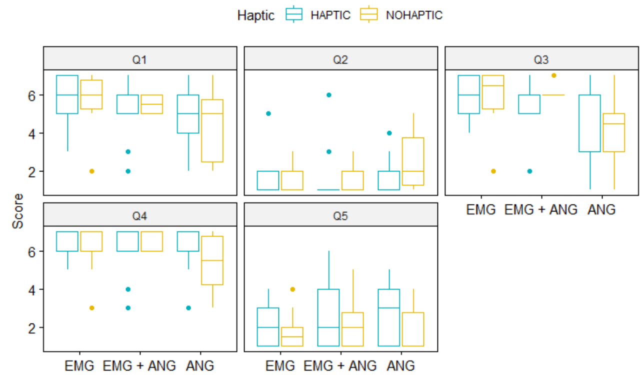

Figure 2: The questions scores.

Conditions		Questions. Median and SD score				
Haptic	Activation	Q1	Q2	Q3	Q4	Q5
Yes	EMG	6; 1.6	1; 1.3	6.5; 1.6	7; 1.3	2; 1.3
Yes	EMG+ANG	6; 1.6	1; 1.7	6; 0.32	7; 0.52	2;2.03
Yes	ANG	5; 1,8	1; 1.1	4.5; 1.8	5.5; 1.6	3; 1.6
No	EMG	6; 1.5	1; 0.71	6.5; 1.6	7; 1.3	1.5; 1.03
No	EMG+ANG	5.5; 0.53	1; 0.71	6; 0.32	7; 0.52	2; 1.40
No	ANG	5; 1.8	2; 1.4	4.5; 1.8	5.5; 1.6	1; 1.14

Table 1: The median and SD of the questions.

6 RESULTS AND CONCLUSION

Our results are promising and show that the use of muscle activation might led to a better Body Ownership and Agency over the muscle when comparing it to using only the joint angle (we can see it in Q1, Q2, Q3 and Q4). The haptic feedback appears to only have small differences in the different conditions. What we can say in the current state of this work, is that it is likely better to change the appearance of a muscle using the user's muscle contraction rather than the user's movement when considering the user's muscle ownership and agency. We however need to gather more participants to consolidate our findings, and to do a statistical analysis of our data.

[1] https://store.steampowered.com/valveindex
[2] https://www.vive.com/fr/vive-tracker/
[3] https://www.delsys.com/trigno-quattro/
[4] https://www.digi.com/xbee
[5] Although we do not go at max
[6] https://unity3d.com/
[7] http://www.root-motion.com/final-ik.html

ACKNOWLEDGMENTS

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