Assessing Exertions: How an increased level of immersion unwittingly leads to more natural behavior

Kevin Ponto* Karen Chen† Ross Tredinnick‡ Robert G Radwin§

University of Wisconsin - Madison

ABSTRACT

This paper utilizes muscle exertions as a means to effect and study the behavior of participants in a virtual environment. Participants performed a simple lifting task both physically using an actual weight and virtually. In the virtual environment participants were presented with two different types of virtual presentation methods, one in which the weights were shown as a 3D model in the Immersive Visuals scenario and one in which the weights were shown as a simple line in the bland scenario. In the virtual scenario, the weight is only lifted when the participant's muscle activity, measured by surface EMG, exceeds a calibrated minimum level as described in previous literature. We found that while participants were able to perceive the difference for various weights both physically and virtually, we found no significant differences in the perceived efforts between the presentation methods. However, while the participants subjectively indicated that their effort was the same for each of these presentation methods, we found significant differences in the muscle activity between the two virtual presentation methods. For all primary mover muscle groups and weights, the more immersive virtual presentation method led to exertions that were much more approximate to the exertions used for the physical weights.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Input devices and strategies;

1 INTRODUCTION

This study builds on the concept of virtual exertions, which was first demonstrated by Ponto et al. [1] extended upon by Radwin et al. [2]. In the current study, participants lifted physical weights and virtual weights in a CAVE. Virtual weights were moved when participant's muscle activity, measured by surface EMG, exceeded a calibrated minimum level as described in previous literature. Two different virtual conditions were used to test the effects of immersion on behavior. In the first condition, labeled *Immersive Visuals (IV)*, subjects were presented 3D visuals that were meant to mimic the physical environment as shown in Figure 1. In the second condition, labeled *bland*, minimal visuals were presented in 2D but still provided users the same instructional information as in the IV condition. In the third condition, labeled *physical*, the users lifted physical dumbbells of unknown mass as shown in Figure 1.

If there is a correlation between immersion and behavior for this lifting task we would hypothesize that: (1) An increase of the lifted weight should produce an increase for both the muscle activity and the rated perceived exertion. (2) The IV condition should be significantly different from the bland condition. (3) The IV condition should be more similar to the physical condition than the bland condition is the physical condition.

*e-mail:kbponto@wisc.edu
†e-mail:kbchen@wisc.edu
‡e-mail:rdtredinnick@wisc.edu
§e-mail:radwin@bme.wisc.edu

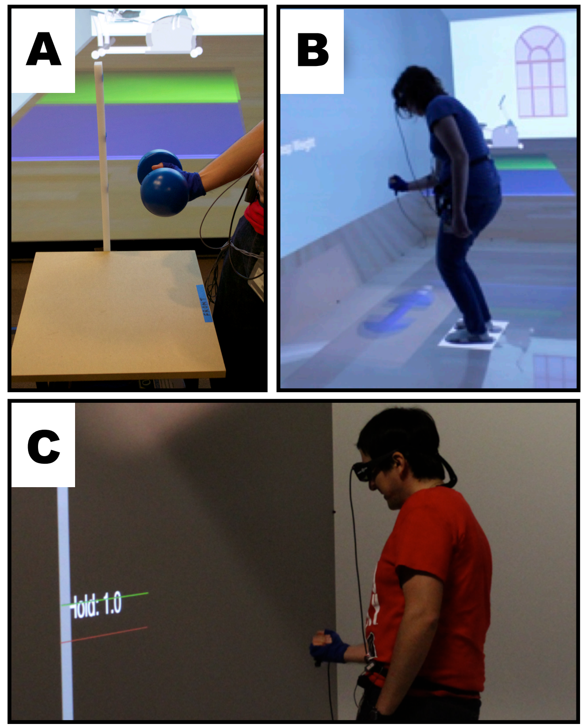

Figure 1: Three different Virtual Exertion environmental conditions: A. (Physical Condition) Participants lifted dumbbells of unknown weight. B. (Immersive Visuals Condition) Participants lifted virtual weights, rendered as 3D models, through muscle activation. C. (Bland Condition) Participants lifted virtual weights, rendered as a 2D line, through muscle activation.

2 METHODS

Informed consent and IRB approval were obtained for eleven participants (8 females and 3 males, mean age=24.5 with 3.53 SD). The exclusion criteria were neuromotor impairment or injuries, inability to stand for 20 minutes, claustrophobic in small spaces, prior occurrence of epileptic seizure or blackout, high tendency for motion sickness, sensitivity to flashing lights, Lasik eye surgery, and taking prescribed perception-altering medications.

A complete experiment comprised three 1.5 hour sessions and each session corresponded to the three environments that were counterbalanced, with the environments being physical, immersive visual (IV), and bland. Bipolar surface EMG electrodes were affixed over the biceps and triceps brachii, flexor and extensor carpi radialis (FCR and ECR, respectively). The EMG signals were rectified and integrated (RMS). To calibrate the system, participants held various weights (1.36, 2.27, and 4.54 kg) at controlled vertical heights (76, 91, 107, 122, and 137 cm) during all sessions. Following the weight lifting calibration, participants performed maximum voluntary contractions (MVC) at three different heights (91, 107, and 122 cm), which served for data normalization purposes.

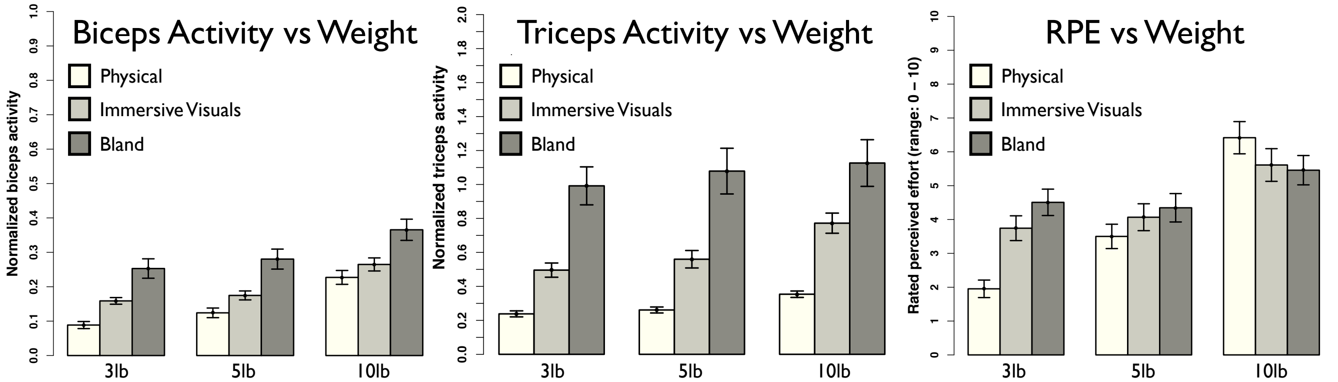

Figure 2: Graph of muscle activity and RPE vs weight. The bland condition was shown to be significantly different from the IV condition for the Biceps and Triceps activity while no significance difference was found for the RPE. The error bars represent standard error of the mean.

For the lifting task performed in the virtual environments, twelve practice trials were administered prior to the actual data collection to avoid practice effect. The within-subject independent variables were: environment (3 levels), weight (3 levels), and height (3 levels). The dependent variables were biceps and triceps activities, FCR and ECR activities, and rated perceived effort (RPE) on a scale of 0 to 10. All muscle activities were normalized against the participants MVC. Data were analyzed using repeated measures ANOVA using the free statistical software R. The significance level was set at 0.05.

3 Results

Muscle activity was affected by environmental condition and weight, while RPE was only affected by weight. In general, activities of the pair of prime movers (e.g., biceps and triceps) were significantly greater in the bland condition.

Muscle activity: Biceps activity in the bland condition was 0.105 normalized units greater ($F(1,9.43)=5.92$, $p=.037$) than the IV condition, and the IV condition was 0.053 normalized units greater ($F(1,10)=7.09$, $p=.024$) than the physical condition. Triceps activity in the bland condition was 0.521 normalized units greater ($F(1,9.80)=5.40$, $p=.043$) than the IV condition, and the IV condition was 0.324 normalized units greater ($F(1,10)=14.69$, $p=.003$) than the physical condition. Across the 3 conditions, for every 1 kg increase in weight, the biceps were expected to increase by 0.038 normalized units ($F(1,9.97)=76.77$, $p < .001$), triceps were expected to increase by 0.055 normalized units ($F(1,9.99)=6.18$, $p = .032$), FCR was expected to increase by 0.060 normalized units ($F(1,9.95)=36.11$, $p < .001$), and ECR was expected to increase by 0.077 normalized units ($F(1,9.98)=42.66$, $p < .001$).

RPE: For every 1 kg increase in weight, RPE increased 1.385 units ($F(1,10)= 97.66$, $p<.001$) in the physical condition, increased 0.636 units ($F(1,10)= 29.27$, $p<.001$) in the IV condition, and increased 0.334 units ($F(1,9.64)= 9.44$, $p=.012$) in the bland condition. RPE was not affected by condition.

4 Discussion

This study attempts to examine physical activities in virtual environments in a means to assess if immersive environments would lead to more natural human performance. For all of the conditions, we found a significant main effect of weight while statistically controlling for the height. As the effect of weight was observed in both physiological and subjective measures, we can assert that subjects were able to perceive the weights and the differences between them.

While the biceps and triceps showed significant differences between the three conditions, the RPE showed no significant difference between the physical, IV and bland conditions. One interpretation of this result is that the participants did not perceive that they were doing anything different between these different conditions, i.e., lifting the 4.54kg weight in the IV condition took just as much effort as in the physical condition. Yet, the muscle activities paint a very different picture with the IV and bland conditions causing significantly higher exertions.

This result raises many questions. It is unclear why increased muscle activity was not accompanied by an increase in RPE. One possibility is that given a lack of familiar visual cues, participants tended to approach lifting tasks more forcefully out of uncertainty. It is also possible that the bland condition caused participants to move differently and in a less efficient manner. Yet, it seems surprising that the extra muscle activity was not “felt” by the participants.

This result also raises interesting questions of how to assess behavior for physical activities in virtual environments. From the RPE values one could argue that the participants were behaving the same way across the conditions where as from the muscle activity one would argue their behavior was quite different. In this regard, assessment of physical activities in virtual environments should utilize both physiological as well subjective assessments as these measures may not be harmonious.

5 Conclusion

This paper studies physical activities in virtual environments through a simple lifting activity. It was found when visuals were presented with greater degree of immersion, the muscle activity was significantly different between the two virtual environmental conditions and participant muscle activity in the IV condition was closer to the physical muscle activity. However, while participants were able to perceive the weight differences between various dumbbells both physically and virtually, there was no significant difference in rated perceived exertion between environment conditions. The results of this study pose interesting questions for researchers attempting to study human performance and behavior in virtual environments. Future work will aim to understand the differences between the two virtual scenarios and to understand what visual factors contribute to the differences in muscle activation.

References

[1] K. Ponto, R. Kimmel, J. Kohlmann, A. Bartholomew, and R. G. Radwin. Virtual exertions: a user interface combining visual information, kinesthetics and biofeedback for virtual object manipulation. In *3D User Interfaces (3DUI), 2012 IEEE Symposium on*, pages 85–88. IEEE, 2012.

[2] R. G. Radwin, K. B. Chen, K. Ponto, and R. D. Tredinnick. Virtual exertions physical interactions in a virtual reality cave for simulating forceful tasks. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 57, pages 967–971. SAGE Publications, 2013.