# A comparison of upper limb movement profiles when reaching to virtual and real targets using the Oculus Rift: implications for virtual-reality enhanced stroke rehabilitation

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## ABSTRACT

Recent innovations in the field of virtual reality, such as the Oculus Rift head mounted display, provide an unparalleled level of immersion in the virtual world at a cost which is rapidly approaching mainstream availability. Utilising virtual reality has been shown to improve many facets of the rehabilitation process, including patient motivation and participation. These systems, however, do not enable the user to receive feedback when interacting with virtual objects, which may influence the movement profile of a patient. Therefore, to investigate how a virtual environment influences movements during stance, participants were required to reach to a real and a virtual target. Their movements were quantified using a motion capture suit, and the virtual target was generated using the Oculus Rift. The motions to both targets were compared using a number of measures calculated to characterize the velocity profiles.

## 1. INTRODUCTION

Virtual reality (VR) systems have been demonstrated to be applicable to many forms of rehabilitation, improving patient motivation, and overall rehabilitation efficacy. Henderson et al. (2007) found evidence that increased levels of immersion in a virtual system provide advantages in upper limb motor skill reacquisition. They concluded that high immersion added meaningfulness to exercise movements, which increased the patient's motivation and participation in training. Rand et al. (2012) demonstrated a significant increase in the usage of the affected upper extremities when using commercial video games as compared to traditional therapy. They found that providing patients with a more enjoyable and motivating experience resulted in higher frequency and intensity of movement - which is understood to be a primary contributor to the promotion of synaptogenesis, and therefore recovery (O'Dell et al. 2009).

The Oculus Rift is a ground-breaking VR device, capable of providing an unparalleled level of immersion in a virtual world. Combining the Oculus Rift with motion capture allows a user to see through the eyes of a virtual avatar, and interact with a virtual world using their movements. However, the display latency and lack of haptic feedback may cause disturbances in the velocity profiles when performing simple movements. Indeed, recent studies (Epure et al, 2014) have suggested that the use of head mounted displays (HMDs), such as the Oculus Rift, leads to a degree of postural instability.

Reaching to objects is a fundamental activity performed in daily life, and the ability to do so during standing is often diminished for the elderly or those with neurological disorders. During stance, there are significant restraints placed upon human voluntary movement, which are absent in the seated position, involving the complex coordination between movement and balance performed by the central nervous system (CNS) (Hua et al, 2013). The activation and recruitment of muscles when reaching to a real target is understood, but the effect of a non-physical virtual target is unknown. In particular, it is unknown how much perceived support humans use when reaching to fixed targets to program their movement patterns. The use of VR enables a direct comparison between fixed and virtual targets in terms of the human movements produced.

Virtual reality provides an excellent opportunity to train these skills in patients, but the differences in movement patterns that are produced when moving in a virtual world are poorly understood. This study aims to investigate the effects of VR on human movement, by comparing the underlying structure of movements (velocity profiles of the hand) during stance when reaching to real and virtual targets.

## 2. METHOD

### *2.1 Procedure*

Four healthy adult male participants, three healthy adult female participants, and one stroke-affected adult male participant were included in this study, each with varying degrees of experience in virtual reality.

A physical target was set up at 1.3 times the length of the person's reach when feet are flat on the floor. The participants repeatedly reached for the target with their preferred hand, held that position for 5 seconds, retracted their hand to their chest, and held that position for 5 seconds (non-VR Trial).

The same task was performed while wearing the Oculus Rift (VR-Trial). A virtual target was placed in an environment, which was calibrated to be exactly at the same location as the physical target by having the participant reach for the physical target, then setting the location of the virtual target to the in-game location of the hand. The physical target was then removed. The only cue given concerning performance was the colour of the virtual target, which changed from green to red upon contact with the virtual avatar's hand.

### *2.2 Motion-Capture/VR System Setup*

Participants' movements were recorded using an XSENS MVN BIOMECH inertial motion capture suit. The suit was calibrated at the beginning of each session, to ensure that the readings for the real and the virtual tests were captured using the same calibration values. Recordings were captured by the associated software MVN Studio PRO, which provides the velocity data in x, y and z directions for 23 body segments at a capture rate of 120Hz.

The motion capture data was streamed in real-time into the Unity game engine as a number of quaternion rotations, representing each segment of a 23 point kinematic map. This was then used to cause an avatar to reproduce the same movement.

The Oculus Rift HMD became the virtual eyes of the user. This HMD provided rotational information, which controls the orientation of the avatar's head in Unity, so that the user was able to freely look around the virtual world. Looking down, the user could see his/her virtual avatar's body, which was moving to match the person's own movements.

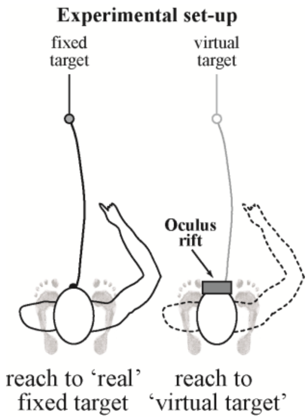


**Figure 1.** *Reaching to real and virtual target.*

### *2.3 Quantifying the Data*

The motion data for each reach movement was exported from MVN Studio. Only the initial component of the reach movement to the target (fixed or virtual) was included, the motion data for return of the finger to the initial starting point being discarded. The beginning of the motion was specified as the point where the velocity magnitude of the hand reached 5% of the maximum achieved velocity.

All data sets exhibited a similar basic shape: a period of acceleration (activation) to maximum velocity, then deceleration (settling) towards the target (Fig.1).

A number of variables were extracted from the data:

1. $V_{Max}$. The maximum movement velocity.

2. *Act$_{Grad}$.* Gradient for the acceleration phase: how quickly the maximum velocity was achieved.
3. *Time to Target.* The time used to reach the target.
4. *Symmetry Ratio.* The ratio between the acceleration and deceleration phases
5. *Settle MSE.* The amount of variation in the settling segment.
6. *Holding MSE.* The amount of variation while holding position at the target

## 3. RESULTS

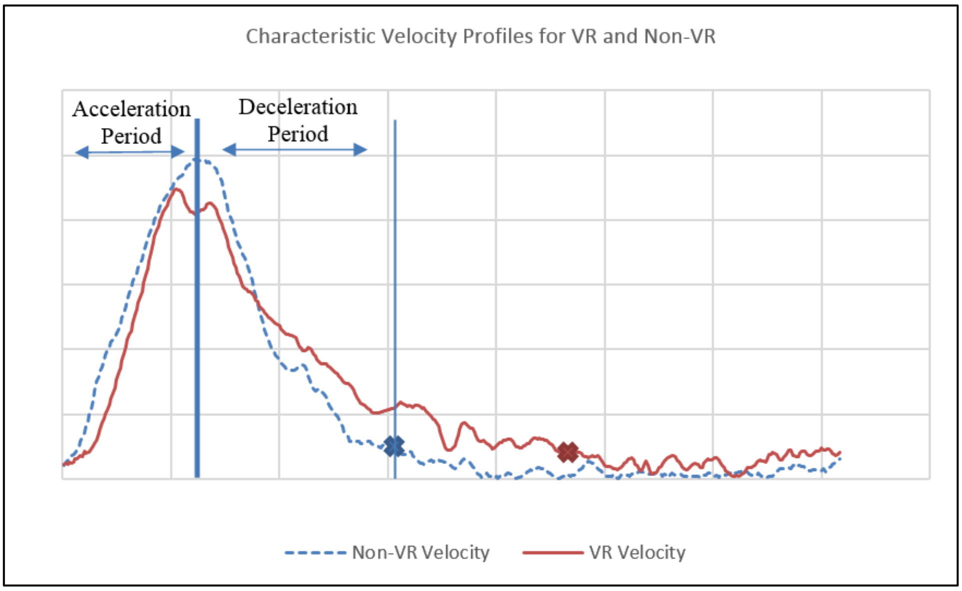


**Figure 2.** *Velocity profiles of characteristic results, X marks where the target was reached.*

The velocity profiles recorded showed significant differences in shape between the VR and non-VR trials (Fig.2). The time to reach the target in VR trials took, on average, 0.64 seconds longer than non-VR trials for the healthy participants, and 1.21 seconds longer for the stroke-affected participant. The VR trials showed significant oscillation during the settling period ($V_{Max}$ to target contact) for the healthy participants, while the stroke affected participant showed a much higher level of oscillation, independent of whether it was a VR or a non-VR trial.

The MSE was calculated against a reconstruction of a stereotypical movement profile, created using the assumption that an ideal motion would accelerate and decelerate smoothly towards the target. The MSE calculated for all phases of the movement was significantly higher for the VR trials.

## 4. DISCUSSION

The results show that the movement profile of reaching to a virtual profile resembled that of reaching to a real target; however the deceleration phase took significantly longer, resulting in a longer time to complete the movement. The level of experience with VR did not seem to have a noticeable effect on the results, however this was the first time any of the participants had used motion capture in combination with an HMD. Participants did, however, seem to slightly improve their VR symmetry ratio over the trial, indicating that the subjects could possibly be trained through repetition so that their movements in VR more accurately resemble those in reality. This suggests that VR could potentially be used to enhance traditional movement retraining.

Upon inspection of the velocity profiles of other body segments, it was found that in general the VR movements recruited other segments significantly more that the non-VR movements. Fig. 3 shows the velocity profile of the pelvis of one of the participants over 7 reaches. The non-VR movement registered almost no activation of the pelvis, while the VR movement shows significant pelvis activation.

The fourfold increase in settling MSE indicated that subjects experienced uncertainty in the position of both their hand and the target. The lack of physical target to rest against for the 5 second hold accounted for the increased hold MSE.

**Table 1.** *Non-VR vs. VR results for stroke-affected participant and average of healthy participants.*

| | $V_{Max}$ | $Act_{Grad}$ | Time To Target | Settle MSE | Holding MSE | Symmetry Ratio |
|---|---|---|---|---|---|---|
| Avg. Non-VR trial | **0.94** | **0.08** | **1.48s** | **0.01** | **0.0007** | **0.68** |
| Avg. VR trial | **0.81** | **0.02** | **2.46s** | **0.04** | **0.003** | **0.29** |
| Non-VR trial (stroke) | **1.18** | **0.03** | **1.76s** | **0.06** | **0.001** | **0.26** |
| VR trial (stroke) | **0.99** | **0.02** | **2.97s** | **0.06** | **0.003** | **0.15** |

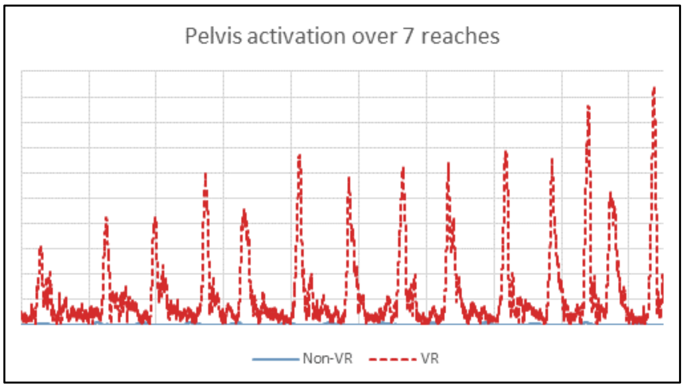


**Figure 3.** *Pelvis Velocity profile of 7 reaches in VR and non-VR trial.*

## 5. CONCLUSIONS

Differences between the VR and non-VR trials were observed. In particular, reaching during standing to a VR target required a greater degree of control of the arm during the deceleration phase than reaching to a fixed target. These results must be considered in any further research into VR-enhanced rehabilitation, particularly when utilising HMDs such as the Oculus Rift, because moving in a virtual world does not produce the same movement patterns as moving in the real world. In general, actions in VR took longer to accomplish than their real counterparts, and displayed a higher level of variance in motion, indicative of a degree of uncertainty and instability. VR movements appeared to recruit more body segments in the movement than non-VR. Further study is required to determine if these phenomena are limited to subjects inexperienced with VR, which would mean that subjects could be trained and their movements improved through repetition. Whether this effect has an impact on the efficacy of motor rehabilitation remains to be seen.

## 6. REFERENCES

Henderson, A, Korner-Bitensky, N, and Levin, M, (2007), Virtual Reality in Stroke Rehabilitation: A Systematic Review of its Effectiveness for Upper Limb Motor Recovery, *Top. in Stroke Rehabilitation*, **14**, 2, pp.52-61.

Rand, D, Givon, N, Zeilig, G, Nota, A, and Weingarden, H, (2012), Counting Repetitions of Upper Extremity Movements While Playing Video Games Compared to Traditional Therapy: Implications for Stroke Rehabilitation, *ICDVRAT*, Laval, pp. 487-490.

O'Dell, M, Lin, CD, and Harrison, V, (2009), Stroke Rehabilitation: Strategies to Enhance Motor Recovery, *Annual Review of Medicine*, **60**, pp.55-68.

Epure, P, Gheorghe, C, Nissen, T, Toader, LO, Macovei, AN, Nielsen, SSM, and Rosengren Christensen, DJ, (2014), The Effect of Oculus Rift HMD on postural stability, *ICDVRAT 2014*[1], pre-review document available at http://vbn.aau.dk/en/publications/.

Hua, S, Leonard, JA, Hilderley, AJ, and Stapley, PJ, (2013), Postural configuration does not alter unperturbed or perturbed reach movement kinematics, *Exp Brain Res.*, **227**, 1, pp. 63-78.

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