Investigating the Impact of Perturbed Visual and Proprioceptive information in Near-Field Immersive Virtual Environment

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Abstract

We report the results of an empirical evaluation to examine the carryover effects of calibrations to one of three perturbations of visual and proprioceptive feedback: i) Minus condition (-20% gain) in which a visual stylus appeared at 80% of the distance of a physical stylus, ii) Neutral condition (0% gain) in which a visual stylus was co-located with a physical stylus, and iii) Plus condition (+20% gain) in which the visual stylus appeared at 120% of the distance of the physical stylus. Feedback was shown to calibrate distance judgments quickly within an IVE, with estimates being farthest after calibrating to visual information appearing nearer (Minus condition), and nearest after calibrating to visual information appearing further (Plus condition).

1 Introduction

Feedback representing the users' actions in *Virtual Reality* (VR) may consist of missing or maligned information in different visuo-motor sensory channels. This may be due to technological limitations such as latency, tracker drift, registration errors, or intentional offsets between visual and proprioceptive information in the performance of near-field 3D interaction. This kind of mismatch in human spatial perception could potentially degrade training outcomes, experience and performance. In this work, our empirical evaluation explores to what extent users are able to recalibrate their depth judgments during visually guided actions in *Immersive Virtual Envrionment* (IVEs), when given congruent or dissonant visual and proprioceptive information while performing manual dexterous tasks, during 3D interactions in near-field VR.

2 Related Work

To overcome the problem of seeing the world as compressed in VR, some suggested that users' visuo-motor calibration interactions with the *Virtual Environment* (VE) could improve distance estimation in relatively short amount of time [3]. Although, the rate of calibration (aka adaptation) has been shown to be constant despite the immediate calibration [1]. Ziemer et al. [5] showed that participants calibrate to a perturbed visual information or walking speed in either real world or IVE using blindfolded walking technique. In contrary, Nguyen et al. [4] found distance judgments were unaffected even by a significant scaling of the surrounding environment in IVE in action space. Bourgeois and Coello [2] showed that spatial perception can be modified by motor experience with a few interactions with perturbed environment, which cause adaptation to the new visuo-motor constraints in real world. Distance judgment have been shown to be affected in some cases and shown to be unaffected in others via visual perturbations. The explanation for these diverse results is still unclear and necessitates future research. Additionally, it is not well known how visual-motor alteration effects distance perception in IVEs with respect to near-field interactions.

In the following experiment, we investigated carryover effects of calibration to inaccurate visual feedback, with participants making reach estimates to near-field targets in the IVE. There were three conditions of perturbed visual feedback in an IVE. These perturbations were such that the participants' reach estimates were scaled to one of the three conditions. To test for calibration, a baseline measure in an IVE in which participants complete distance estimates without feedback will be compared to IVE estimates made after visual feedback was provided. *It is hypothesized that participants whose reaches appeared 20% closer during the calibration session will believe they are under reaching, and thus reach farther after the calibration. It is also hypothesized that participants who view their reach to be 20% farther during the calibration session will believe they are overreaching, and thus reach shorter after the calibration.*

3 Experiment Methodology and Procedure

36 participants (26 female, 10 male) were recruited from the student population of Clemson University and received course credit for their participation.

3.1 Apparatus and Materials

3.1.1 General Setup

Figure 1 depicts the apparatus used for this experiment. The target was enclosed within a 0.5 cm black border with a groove which was extended from the center of the base of a white rectangle. The physical target was only used to measure the arm length and eye height before the experiment started. Participants reached to a virtual target with a tracked stylus and were required to position the stylus tip in the groove of the virtual target during the experiment. Each trial began with the stylus back on top of the launch platform, which was located next to the participant's right hip.

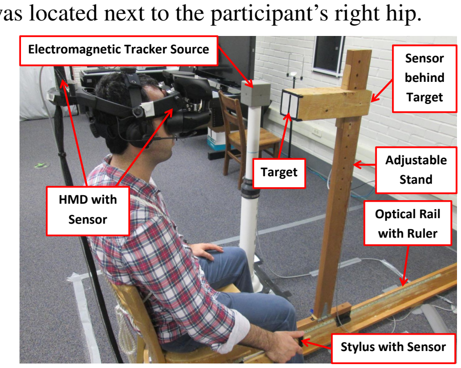

Figure 1: The near-field distance estimation apparatus.

3.1.2 Visual Aspects

Participants wore a NVIS nVisor SX111 HMD weighing 1.3 kg. The simulation was designed so that the stylus' tip would turn red when it was within a 1 cm radius of target's groove in the calibration session. Based on the visual information provided to participants in calibration session, they visually detected when the stylus intersected the target's face in the VE.

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3.2 Procedure

Participants were instructed on how to make a fast, ballistic motion to where they believe the virtual target had been before putting on the HMD. Each participant began with a baseline pretest session of distance estimates with no feedback. They first completed two practice trials followed by 30 recorded distance estimates. For each trial, with the HMD display turned off, the target distance was set, and the participant then viewed the target. Once they notified the experimenter that they are ready, the HMD video was turned off to eliminate visual feedback. The tracked position of the stylus (hand), target, and head was logged over the duration of the experiment.

3.3 Experiment Design

The experiment consists of three sessions; a baseline measure without feedback (pretest), a calibration session with visual feedback, and finally a post-interaction session without feedback (posttest). The experiment used a between subjects design where participants were randomly assigned to one of the three viewing conditions in the calibration session (Figure 2).

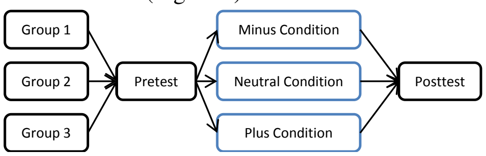

Figure 2: Experiment design.

The three viewing conditions for the calibration session were; Minus, Neutral, and Plus conditions where the visual stylus appeared at 80%, 100%, or 120% of the distance of the physical stylus respectively.

4 Results

The average slopes and intercepts of the functions predicting indicated target distance from actual target distance in the pretest, calibration and posttest sessions for the Minus, Neutral and Plus conditions are presented in Table 1. Our analyses will test for calibration to determine if the participants' performance improved as a function of the feedback received during the calibration session. Examination of Table 1 reveals that across all three conditions, the r^2 values tended to be higher in the posttest session compared to the pretest session. A paired t-test using the combined r^2 values from all three conditions confirmed that this increase was statistically significant, indicating that the intervening calibration session tended to cause the participants' reaches to become more strongly based on the target distances; t (34) = -7.2, $p < .0001$. The slopes of the simple regressions tended to increase in the posttest session compared to the pretest session, moving more closely to 1.0, and the intercepts decreased, moving more closely to 0. Paired t-tests using the combined r^2 values from all three conditions confirmed that this increase was statistically significant; t (34) = -5.8, $p < .0001$, for the slopes, and t (34) = 7.3, $p < .0001$, for the intercepts. In short, the results revealed an increase in the r^2 values and improvements in both slope and intercept, indicating a calibration effect that is characterized by an improved scaling of the reaches to the actual target distances.

Table 1: Average R^2, Slopes, and Intercepts of Simple Regressions Predicting Reach Distance from Actual Distance (cm) for Each Participant in the Minus, Neutral and Plus conditions (*Intercept)

	Pretest			Posttest		
	r2	**Slope**	**Intp.***	**r2**	**Slope**	**Intp.***
Minus	0.53	0.47	29	0.72	0.65	19.1
Neutral	0.46	0.49	25.4	0.68	0.67	12.8
Plus	0.54	0.53	25.2	0.68	0.65	12.4

Next, multiple regression techniques were used to determine if the slopes and intercepts differed between the pretest and posttest sessions within each of the calibration conditions. In sum, reaches improved after calibration in all 3 conditions. For the multiple regressions the r^2 for the Plus and Neutral conditions increased, the intercept lowered to become closer to zero, and the slope increased to become closer to 1. For the Plus condition the r^2 increased and the intercept lowered to become closer to zero. The slope increased in the Plus condition to become closer to 1, but this failed to reach statistical significance. The purpose of the multiple regressions was to separately compare the changes in the average slopes and intercepts for each calibration condition presented in Table 1, which only include the statistically significant simple regressions. The t-tests, however, included all of the participant data, and thus they compare the 36 individual slopes, intercepts and r^2 values, combining the data from the three calibration conditions. The t-tests for all three of these variables confirmed an increase in the r^2 values and improvements in both slope and intercept, indicating calibration, which is characterized by an improved scaling of the reaches to the actual target distances.

5 Discussion and Conclusions

We studied the effects of a visual distortion during a closed-loop physical reach task to near field targets in an IVE. Specifically, we investigated the effects of calibration on egocentric distance perception in an IVE using pretest, calibration and posttest viewing sessions. As reaches were manipulated to appear closer, participants believed they were underestimating, and thus they reached farther after feedback. Similarly, reaches became nearer after they were manipulated to appear farther. The tendency towards calibration to perturbation of visual distance observed in this study is consistent with a similar pattern observed by Bourgeois and Coello [2]. While Bourgeois and Coello [2] investigated the effects of feedback on near-field distance estimation in the real world, our contribution shows that in an IVE participants similarly scale their depth judgments to visual and proprioceptive information during 3D interactions in the near field. The results from this experiment support the notion that users of virtual environments adapt their behavior to adjust to visual feedback that conflicts with their physical movements. This is a particularly interesting finding, as it implies that users will likely be able to reasonably adapt to virtual reality systems that may not have tightly corresponding visual and physical movements.

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