Detection of Translation Gain is Decreased When Virtual Reality Users Are Unaware of Its Presence

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Abstract

The prevalent evaluation methods used to estimate detection of redirected walking are based on methods from psychophysics that require users to know their virtual movements are being manipulated. However, this higher-than-normal level of attention toward their movements yields conservative detection thresholds. We find that participants who were unaware that redirected walking (translation gain) was applied detected the technique at a significantly higher gain than users who were aware (at gains of 1.73 and 1.38, respectively). We provide evidence that redirected walking-based navigation solutions may be able to leverage gain values that are larger than the current threshold guidelines would suggest.

CCS Concepts

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

Keywords

virtual reality, locomotion, redirected walking, human perception, human attention

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1 Introduction

Modifactions of the mapping between a user's real and virtual motions have been applied to enhance various aspects of VR interaction, such as facilitation walking with redirected walking (RDW) [3, 4]. The most common RDW methods include translation gain, rotation gain, curvature gain, and bending gain [3]. A large body work has applied methods from classical psychophysics to evaluate RDW for *when* users can detect the technique, such as two-alternative forced-choice (2AFC) and Yes/No classification [2]. Many techniques have been evaluated for detection, including but not limited to: translation gain [5], rotation gain [5], and curvature gain [5]. While these classical psychophysical methods have been applied to establish conservative detection thresholds, the high level of user awareness and vigilance in these studies may lead to stricter results than what would be seen in real-world applications. Users in these studies are explicitly told to observe for changes, whereas in typical VR usage, they may not focus on such details. This lack of awareness regarding the redirected interaction was investigated by Benda et al. [1], for scaling of a user's hand movements who identified that inattententive users were less likely to detect the amplified reach, and detected it at higher levels of scaling than the threshold whenever they did detect it. However, this consideration has not been considered for redirections of a user's view as is leverage by RDW, and is the focus of our work presented in this paper.

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2 Experiment

Adapting the methodology outlined by Benda et al. [1], we frame our conditions as a user-centered level of *AWARENESS* towards the technique being evaluated rather than as a measure of experimental design bias:

- *UNAWARE*: Participants were given a "dummy" task and not informed of any changes to their movement speed.
- *GUESS:* Participants were informed that something about the experiment was being kept from their knowledge but not what it was, and asked to try to figure out what was being withheld.
- *AWARE* Participants were told explicitly that their movement speed would be changed during the trials and were asked, in Yes/No format, if they felt their movement speed was normal or not after every trial.

Our measure is a user's **Earliest Detected Value**, the level of gain applied when the participant first detected the translation gain as estimated by think aloud comments. We evaluate a form of *translation gain*, where a user's movements in VR are amplified by a given *gain* value. In our implementation, **only movement in the horizontal plane is amplified**; movement forward, backward, or side-to-side will be increased while movement up or down is not increased. Gain values ranged from 1.0 to 2.0, in increments of 0.05.

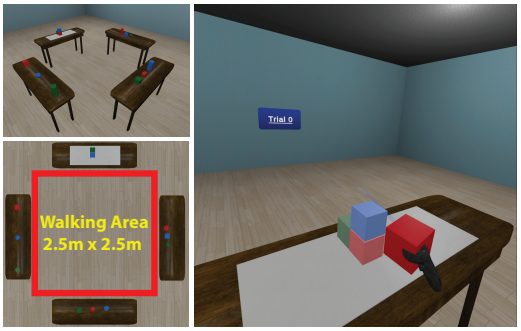

Figure 1: Top Left: A perspective view of the arrangement and layout of the tables. Bottom Left: A top-down view of the tables and walking area, with dimensions. Right: The user's perspective in the environment.

Our methodology adapts the method from [1], with minor modifications made to better evaluate translation gain specifically. The core features of this design are **(1)** using a deceptive task (moving blocks to match a pattern) while **(2)** gradually increasing translation gain to determine a lower bound for detection and **(3)** having participants think-aloud with **(4)** some intentionally included oddities to encourage robust think-aloud comments.

We recruited 68 participants for this study, a total of 60 participants (self-reported as 36 male, 23 female, and 1 non-binary/third gender) (20 for each condition) are included in the analysis, with 8 excluded for a combination of pilot testing, technical errors, and data quality issues (low engagement from participants).

3 Results

We first conducted a standard threshold analysis on our *AWARE* condition to establish a point of comparison for the other conditions. The fit curve yields a threshold at a gain value of 1.38 and has a 95% confidence interval of [1.33, 1.42].

Then, we evaluated *when* users in different *AWARENESS* conditions detected the translation gain based on utterances (using a similar method to Benda et al. [1]). Here, we only analyze data when the participant *did detect* the technique. A table summarizing the detected translation gains per condition is displayed in Table 1. A Kruskal-Wallis identified a significant effect ($H = 22.602$, $df = 2$, $p < 0.001$) suggesting that detection did vary between groups. To determine differences between conditions, pairwise Nemenyi testing was used; *AWARE* and *GUESS* were both detected at significantly lower speeds than *UNAWARE* ($p < 0.0001$) with no difference detected between the two ($p = 0.96$). Finally, we compared each distribution to the estimated threshold of 1.38 using independent Wilcoxon signed rank tests. Both *UNAWARE* ($V = 55$, $p < 0.01$) and *GUESS* ($V = 78$, $p < 0.01$) were significantly higher than than the threshold while *AWARE* was not different ($V = 58$, $p = 0.08$).

4 Conclusion

In our experiment, some users were made aware that their movements would be sped up while others were not. We found that these unaware users often never detected the technique (15 out of 40) even at our maximum gain value of 2.0 (see Figure 2). Compared

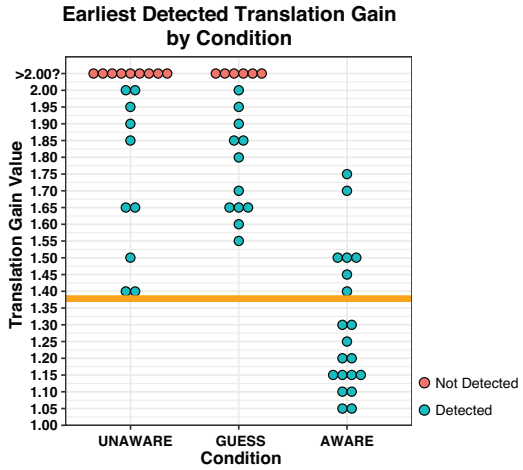

Figure 2: The earliest detected translation gain per participant in each condition. The orange horizontal line represents the detection threshold estimated by analyzing the *AWARE* users (1.38).

Table 1: Means, Medians, Standard Deviations, and 95% Confidence Intervals of Earliest Detected Translation Gains per Condition.

	Mean	Median	SD	95% CI
UNAWARE	1.73	1.75	0.24	[1.58, 1.87]
GUESS	1.76	1.75	0.15	[1.68, 1.85]
AWARE	1.30	1.225	0.21	[1.21, 1.39]

to the detection threshold (1.38), these users on average detected the translation gain at a significantly higher value of 1.73. These findings show that in cases where a user's attention is not focused on their movements, like for hand redirection [1], redirected walking techniques may be able to be used at more extreme values than previously suggested by detection thresholds.

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