Travel Speed, Spatial Awareness, And Implications for Egocentric Target-Selection-Based Teleportation - A Replication Design

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ABSTRACT

Virtual travel in Virtual Reality experiences is common, offering users the ability to explore expansive virtual spaces. Various interfaces exist for virtual travel, with speed playing a crucial role in user experience and spatial awareness. Teleportation-based interfaces provide instantaneous transitions, whereas continuous and semi-continuous methods vary in speed and control. Prior research by Bowman et al. highlighted the impact of travel speed on spatial awareness demonstrating that instantaneous travel can lead to user disorientation. However, additional cues, such as visual target selection, can aid in reorientation. This study replicates and extends Bowman's experiment, investigating the influence of travel speed and visual target cues on spatial orientation.

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1 INTRODUCTION

Virtual travel in Virtual Reality (VR) experiences is ubiquitous, where the virtual spaces we explore exceed the physical ones we have access to. Interfaces for virtual travel are numerous and varied in many respects [2]. Some interfaces even include physical components, making them better described as hybrid. However, all interfaces have in common the fact that speed plays a significant role.

In teleportation-based interfaces, where the viewpoint shifts from the starting point to the destination instantaneously, the speed is effectively infinite. In continuous or semi-continuous interfaces, the speed varies, from constant to variable and user-controlled to automatic, from linear to user-input-driven to non-isometric, or even partially discontinuous [1, 8].

Bowman et al. [4] have demonstrated that the speed of movement has a direct impact on users' spatial awareness. Spatial awareness refers to the user's ability to understand their position, orientation, and movement in relation to the virtual environment and its objects. It is crucial to optimize navigation, enhance task performance, and deepen presence. In their experiment, Bowman et al. moved users to a target location and asked them to locate a reference point in the virtual scene. They isolated the speed component entirely, meaning the user had no other cues than path integration to orient themselves. Consequently, after an infinitely fast (teleport), which naturally does not allow for path integration, the user is left disoriented. Further, Bowman et al. tested three more methods: a slow, a fast, and a varying (accelerated: (slow-in, slow-out) travel speed and found no differences between these pairs.

However, applications typically include cues beyond path integration to help the user reorient themselves. For example, consider the Egocentric Target-Selection-Based Teleport, also referred to as Point-and-Teleport or simply teleportation. The latter is often used but potentially misleading as it is also used, as mentioned, for the pure form of instantaneous viewpoint transition. With this method, the user selects their target point usually with a parabolic selection technique on the ground. The potential target point is often visualized through a circle and the trajectory of the parabola. After confirmation, the transition occurs, which can vary from instantaneous to fade-to-black and other types [5].

The visualization and selection of the target should positively impact spatial awareness. For instance, an experiment by Weissker et al. [6] showed that 75% of the participants were able to achieve similar spatial updating accuracies in a pointing-based triangle completion task with an Egocentric Target-Selection-Based Teleport when compared to a Hand-controller-based Pointing-Directed Steering interface with the maximum speed of $13.\overline{8}$ m/s (50 km/h). Zielasko et al. [7] demonstrated significant differences even among different methods of instantaneous travel (rotation) techniques (iterative rotation via thumbstick vs. orientation selection via pointing), underscoring that the selection process alone impacts spatial awareness. These observations raise the question of the contributions of factors such as speed, mere knowledge of the destination point, and the process of selecting it to spatial awareness.

To address this question, we present a study design that replicates and extends the Spatial Awareness Experiment described by Bowman et al. [4]. We slightly adjust and repeat the original experiment based on the discussion of the original authors. Additionally, we use the same design but show users the destination point of their journey in the first step and allow them to select it by pointing in the second step.

2 STUDY DESIGN

In this work, we will conduct two studies. The first is a close replication of the original study, a design with one factor (*Speed*) and three levels (*slow*, *fast*, *infinite*). This means we will exclude one of the levels of the original study, specifically SISO (slow-in, slow-out) a

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method that implements acceleration. The original authors already discussed that this method falls somewhat outside the scope. In the original study, *fast* was defined as being 10 times faster than *slow*. Since the virtual environment is abstract, absolute speeds are relatively insignificant. We believe it is sensible to use relevant speeds for our study. For *slow*, we plan to use a speed comparable to human walking–scaled to its meaning in the used virtual environment–or running, and for *fast*, we plan to use very high speeds typical of semi-continuous methods like Dash [3] or Hyperjump [1]. We hypothesize that spatial awareness decreases with increasing speed, even from *slow* to *fast*, as path integration becomes more difficult with less time.

In the second study, we will compare different forms of *Target Cue*s given that the speed is set to infinite. The levels are *none*, *visual*, and visual + pointing *(pointing)*. Regarding the outcome of the study, we hypothesize that spatial awareness increases with the addition of cues. Furthermore, we still expect poorer performance compared to continuous movement methods.

Virtual Environment. The virtual environment in the original experiment is reduced to a minimum. The only objects in the environment are colored cubes that are part of the task, which involves memorizing their configuration and identifying one of the cubes after a movement. The layout of the cubes is 3D and not confined to a single plane. Furthermore, there is no ground or horizon. This design aims to isolate and maximize the potential effects of travel speed. In our replication, we intend to maintain this setup as we remain interested in the targeted isolation of individual components of human orientation capabilities in the VR travel context. As in the original experiment, this results in low ecological validity in exchange for high statistical power, which we prefer to understand the interplay of various cues in relation to spatial awareness.

Task. For the first study, we will replicate the task from the original study. Participants start in the virtual environment and can familiarize themselves with the surroundings from their initial viewpoint. A button press by the user initiates a movement in a straight line to another point in the virtual environment at the designated *Speed*. The transition will be user-initiated within a specified time frame to ensure comparability. Upon reaching the target point, the participant will be shown a color cue corresponding to one of the cubes present in the scene, and a stopwatch will start. When the participant finds and selects the correct cube, the timer stops. This time measurement serves as our primary metric, *Performance (Time)*.

In the second study, we use the same task design. However, in the condition *Target Cue (visual)*, the target point is visualized by a glowing sphere before the transition. In the condition *Target Cue (pointing)*, the participant additionally must select the target point using a simple pointing-based selection technique.

Apparatus. We plan to use an Oculus Quest 3, utilizing its built-in inside-out tracking and the accompanying handheld controllers. The participant will stand during the experiment and can freely rotate in place.

Procedure. In the original experiment, participants completed 4 blocks. In each of the 4 blocks, the participant performed a set of 20 trials per condition, with the first 10 trials serving as training. This training aimed to familiarize participants with the method and the environment, allowing them to build a mental map of the cube configuration. After each set, the virtual environment was reconfigured. Each participant completed 40 training trials and 40 measured trials per condition.

Given that the task remains identical across both of our panned studies and the conditions of *Speed (infinite)* and *Target Cue (none)* are identical, we will conduct a balanced and mixed sequence of the five conditions overall. This means we will exclude one condition (SISO) and include two others instead. We reserve the right to adjust the number of blocks to accommodate the duration of the study. We are discussing changing the ratio of training to measured trials from 1:1 to 1:3. We do not plan to make any further changes to the actual procedure.

Sampling & Analysis Plan. In the original study, a total of 10 participants took part, of whom 9 completed the study. Bowman et al. [4] found *Performance (Time)* significantly slower for *Speed (infinite)* over the other conditions and no further other differences. Based on the available results, we calculated effect sizes using Cohen's d of, $d = 1.30$ (strong) *slow* vs. *infinite*; $d = 2.42$ (strong) *fast* vs. *infinite*; and $d = 0.23$ (small) *slow* vs. *fast*.

Using GPower 3.1 for a paired-samples t-test with $\alpha = .05$, Power = .80, and an effect size of 0.23 results in a sample size of 119. Given that we plan to test 5 conditions, we intend to recruit 120 participants to also investigate a potential small effect between *Speed (slow)* and *Speed (fast)*. Furthermore, we aim to sample as diverse and representative a group as possible across genders and age groups. Study participants will be financially compensated for their participation.

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