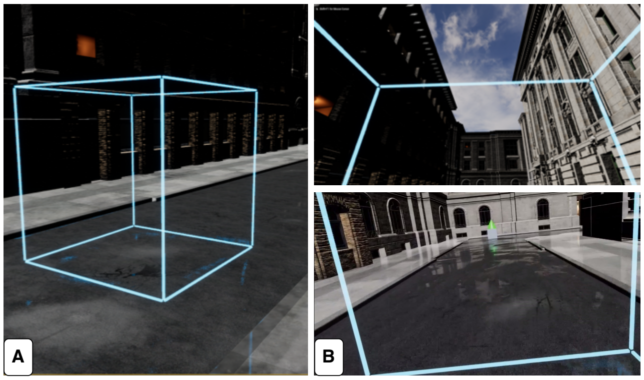

Figure 3: Simulated CAVE - A wireframe cube following the user's position. A) Third Person Perspective B) First Person Perspectives

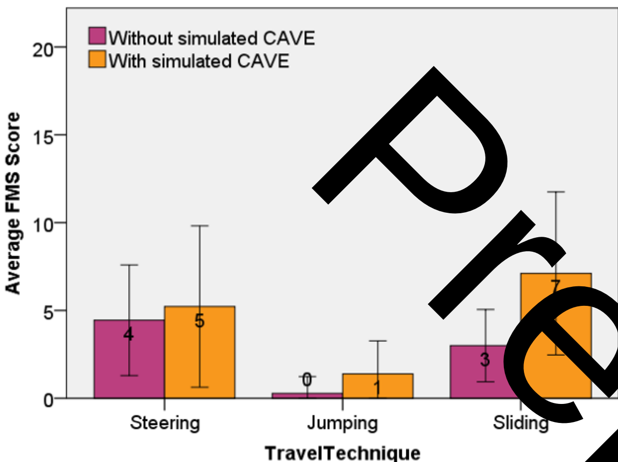

Figure 4: Average Sickness Scores (with Standard Deviation)

The *Steering* technique is based on continuous control and movement of the view point by manipulating the orientation of a tracking device attached to body parts. We implemented a hand-directed steering [11]. In this variation, the user indicates the travel direction by hand pointing and controlling the travel speed via an analogue stick.

The *Jumping* technique is a teleportation but limited to a location you can see [13]. It is using a parabolic ray for target indication and implicit orientation specification (i.e. orientation is determined by user's head orientation).

The *Sliding* is an *manipulation-based* technique combining the advantageous parts of steering and jumping: *Steering* maintains the spatial awareness better than *Jumping*, while *Jumping* induces less simulator sickness than *steering*. This technique is based on viewpoint manipulation with fixed-object. User initiates the movement and its speed by a short grabbing-releasing hand movement similar to pulling oneself along an elastic rope. This inspired by the *rope metaphor* [10] whereby the users can pull themselves through the environment hand-over-hand, like climbing a rope. However, here the overall effect is to move like sliding inside a water slide.

The virtual environment and task is a replication of Weissker et al. experiment [13]. The experimental task simply required participants to travel along a given route (i.e. a single street) and point to its origin after they have reached the terminal location. Each participant performed the task three times. First, with a very small route (the baseline), then two times with a longer route (first and second trial).

3 Results

Overall 36 participants participated in the study (six per condition) with 20 males and 16 females ($M_{age} = 25.36$, $SD_{age} = 8.48$). This study used an Oculus Rift Consumer Version with a three-sensor room scale tracking setup and the *Oculus Touch* controllers. The system used the Unreal Engine 4 and its *Robo Recall Modkit*.

- *Spatial Awareness*: A two-way ANOVA revealed no significant difference point-to-origin error angles between all conditions.
- *Motion Sickness*: As visible on figure 4, the addition of a *simulated CAVE* tended to increase sickness for every technique. The *Jumping* produced significantly lower scores ($M = 0.5$, $SD = .798$) with or without simulated CAVE ($F(2,30) = 7.77$, $p = .002$, $d = 0.323$) compared to *Sliding* ($M = 5.17$, $SD = 4.38$, $p = .003$), and *Steering* ($M = 4.67$, $SD = 3.86$, $p = .01$).

4 Conclusion

In this paper we measured the effects of adding a simulated frame of references to *Steering*, *Jumping* and *Sliding* techniques. No significant differences were found regarding spatial awareness between all techniques with or without a simulated frame of reference. Our preliminary results showed negative impact of the *Simulated-CAVE* on motion sickness for every technique, while showing lower sickness scores for the *Jumping*. Our future work will verify our results with a larger participant sample, and different navigation tasks.

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