The Effect of Increased Body Motion in Virtual Reality on a Placement-Retrieval Task: Supplemental

Details about Equipment Used

The VR headset used for the experiment was the (first generation) Oculus Quest, with two screens at 1440×1600 pixels each, 72 Hz refresh rate, a mass of 571 g, and a FoV of at least 90° both horizontally and vertically (the precise FoV depends on the measurement method). This headset is untethered, and runs application code on an embedded processor with the Android (version 7.1.1) operating system. It uses accelerometers and cameras to achieve 6 DoF inside-out tracking within a 7×7 meter area. The user held two "Oculus Touch" controllers in their hands, which are tracked with 6 DoF. Each controller has the same buttons available on it, of which we made use of the A, B, and Trigger buttons, as we mention below. The headset also streamed video wirelessly to a tablet, allowing the researchers to monitor the user's progress during the study.

Details about Figure 2 in the main paper

The quantities shown in Figure 2 of the main paper are listed in bold below, where sd, se, and ci are the standard deviation, standard error, and 95% confidence interval, respectively.

Placement: time (seconds)
Stationary: **11.3805** (sd=5.570718, se=1.39268, **ci=2.968426**)
Locomotion: **13.61547** (sd=6.194329, se=1.548582, **ci=3.300725**)
Stationary minus Locomotion: **-2.234965** (sd=4.6057, se=1.151425, **ci=2.454204**)

Visible Recall: RecallTime (seconds)
Stationary: **7.67385** (sd=3.184388, se=0.7960969, **ci=1.69684**)
Locomotion: **6.481019** (sd=2.701612, se=0.675403, **ci=1.439587**)
Stationary minus Locomotion: **1.192831** (sd=3.306841, se=0.8267102, **ci=1.762091**)

Blind Recall: EuclideanErrorDistance (meters)
Stationary: **0.5283793** (sd=0.2757055, se=0.06892637, **ci=0.1469131**)
Locomotion: **0.6468581** (sd=0.6279782, se=0.1569946, **ci=0.334626**)
Stationary minus Locomotion: **-0.1184788** (sd=0.5398303, se=0.1349576, **ci=0.2876552**)

Blind Recall: NormalizedErrorDistance
Stationary: **0.3209415** (sd=0.1768233, se=0.04420583, **ci=0.09422249**)
Locomotion: **0.1880574** (sd=0.186365, se=0.04659126, **ci=0.09930691**)
Stationary minus Locomotion: **0.1328841** (sd=0.1693932, se=0.0423483, **ci=0.09026325**)

Blind Recall: ItemsCloserToCorrectOne
Stationary: **12.15625** (sd=8.817631, se=2.204408, **ci=4.698584**)
Locomotion: **7.728125** (sd=9.337237, se=2.334309, **ci=4.975462**)
Stationary minus Locomotion: **4.428125** (sd=9.092066, se=2.273016, **ci=4.84482**)

More Details about Time and Errors

As explained in the main paper, each user experienced both MOVEMENT conditions (*Stationary* and *Locomotion*) in counterbalanced order, performing one block of trials for each condition. Thus, each user experienced a block 1 and block 2 of trials, which comprise the "1st half" and "2nd half" of the experiment. For half of the users, their "1st half" of trials was *Stationary* and their "2nd half" was *Locomotion*, and the opposite was true for the other half of users. We computed average performance (Table 1) broken down by MOVEMENT condition and by the half of the experiment involved.

In almost all measures, the averages suggest an improvement from the 1st half to the 2nd half, suggesting that users are converging toward more expert performance. In addition, within the 2nd half, the *Locomotion* condition appears superior to the *Stationary* condition in terms of average RECALLTIME and ITEMSCLOSERTOCORRECTONE. As explained in the main paper, we argue that ITEMSCLOSERTOCORRECTONE is a better way to quantify small errors for the purposes of comparing the two MOVEMENT conditions.

Table 1: Mean dependent measures per window, for each condition, broken down by trials completed in the first half and the second half of the experiment.

Condition:	*Stationary*		*Locomotion*	
Half:	1st	2nd	1st	2nd
Placement time (seconds)	12.0	10.7	13.1	14.1
Visible Recall				
RECALLTIME (seconds)	8.4	6.9	7.6	5.4
Blind Recall				
EUCLIDEANERRORDISTANCE (meters)	0.625	0.432	0.829	0.465
NORMALIZEDERRORDISTANCE	0.380	0.262	0.243	0.133
ITEMSCLOSERTOCORRECTONE	14.9	9.4	10.6	4.8

Subjective Measures

Prior to the experiment, 7/16 users reported that they had used standing desks in the past, and 13/16 reported that they would like the option of using a standing desk in their normal work.

After the experimental tasks, users were asked which of the conditions they would prefer if they had to perform similar tasks on a regular basis. 3/16 preferred *Stationary*, 6/16 preferred *Locomotion*, and 7/16 reported they would prefer a mix of the two. Likert ratings (Table 2) suggest that users found the *Locomotion* condition required more physical effort, but the *Stationary* condition required more mental effort and was more frustrating, perhaps due to excessive overlap or crowding between windows.

Table 2: Subjective ratings on a scale of 1 to 7.

	Locomotion	*Stationary*
Mental effort required?	3.5	4.8
Physical effort required?	3.6	2.8
The UI allowed you to accomplish the task	6.1	5.5
Frustration felt?	2.1	3.6

Users were also asked: if they had to work with windows in VR, would they prefer the ability to freely position the windows or to have windows snap to a virtual wall? 12 users preferred the ability to freely position the windows. Finally, users were asked if they would prefer to work in VR seated, standing, or having the ability to alternate, and 11 users preferred the ability to alternate.

Window Layouts

Figures 1 and 2, below, show the positioning given to windows by each user. In all cases, the x axis is right, y axis up, z axis forward, and θ results from a cylindrical projection.

The colors shown in the figures do not match the colors of screenshots that were textured on the windows. These false colors nevertheless help to understand the correspondence between the top-down and cylindrical projections. Some windows that were positioned close to the y axis (directly above or below the user) are very elongated in the cylindrical projection.

The figures make it clear that, in the *Stationary* condition, users placed windows following the surface of a sphere, whereas in the *Locomotion* condition, users placed windows usually following the surface of a cylinder, but sometimes departing from the shape of a cylinder.

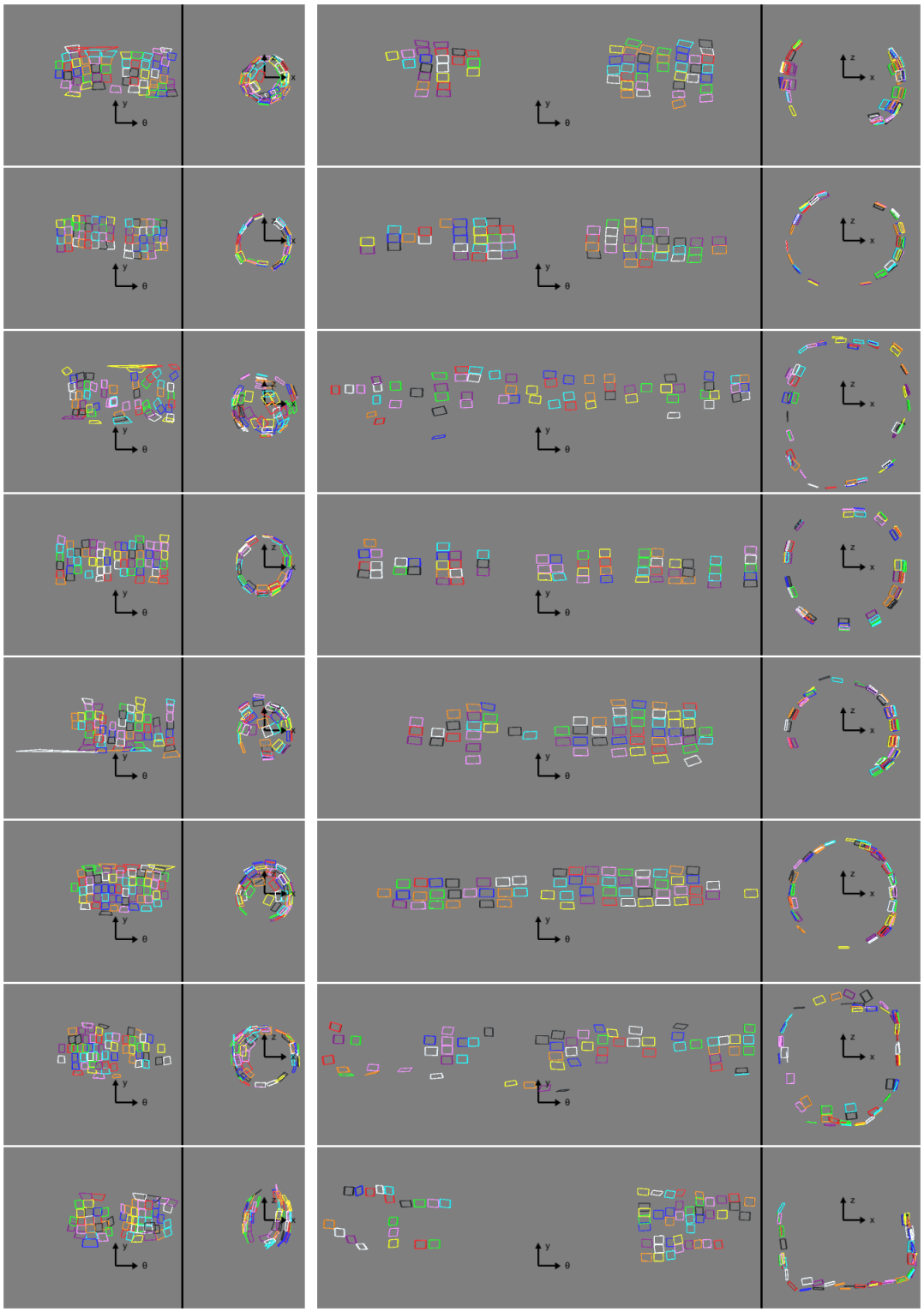

Figure 1: The windows positioned by 8 users (one for each row) who underwent the *Stationary* condition first (left column), followed by the *Locomotion* condition (right column).

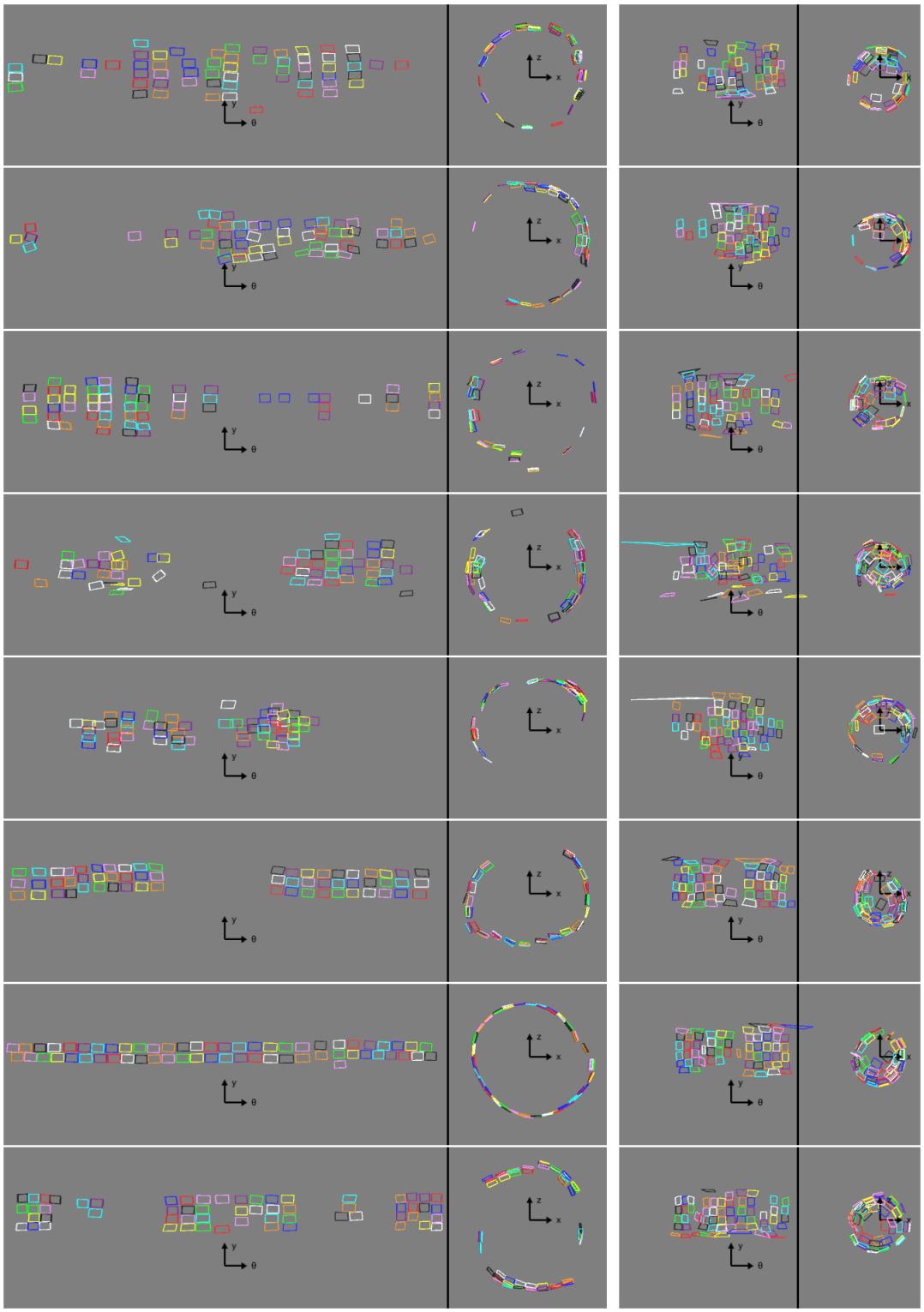

Figure 2: The windows positioned by 8 users (one for each row) who underwent the *Locomotion* condition first (left column), followed by the *Stationary* condition (right column).