Reducing Simulator Sickness with Perceptual Camera Control - Supplementary Material

S1 ACCELERATION THRESHOLD COMPUTATION

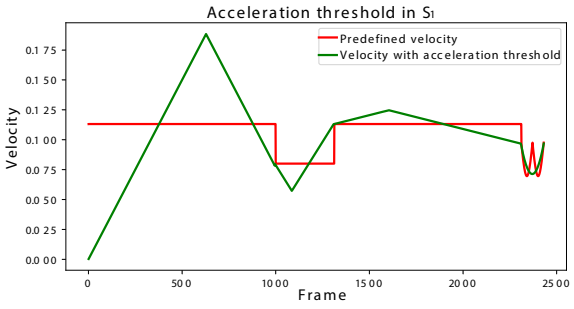

Fig. S1. *Velocity in baseline T.*

To compare with challenging cases in our S_1 and S_2 scenes, the predefined camera movements are designed to move smoothly for most of the time. The entire path is composed of several segments, divided by specified *PoI*s. Large velocity changes only occur around the start of the path and around each *PoI*. As shown in Figure S1, the baseline T minimizes the maximum value of $\|a_T\|$ within $[t_0, t_0 + H]$. Given the distance of one segment, s, and the velocities at the specified *PoI*s, v_{t_0} and v_{t_0+H}, the acceleration a_T along this segment is computed as

$$\begin{aligned} &\underset{a_T \in [t_0, t_0+H]}{\text{minimize}} && \max \|a_T\| \\ &\text{subject to} && s = \int_{t_0}^{t_0+H} v_t \, dt, \\ & && v_{t_0+H} = v_{t_0} + \int_{t_0}^{t_0+H} a_T \, dt \end{aligned} \tag{1}$$

where H is the time duration for this segment, t_0 and $t_0 + H$ are specified time points.

Table S1. *Study results of factor "depth" in Section 3.1.* SPHERES, FOREST, and TOWN represent the three scenes in Figure 2, and indices 1, 2, 3 indicate the animations with increasing camera distances. One participant's two trials in the scene SPHERES were dropped due to Trypophobia. The poll indicates the amount of votes supportive for alternative hypothesis out of the total amount of votes. Our null hypothesis in this study is: depth is not related to sickness perception in VR.

Scene comparison	Poll
SPHERES_1 vs. SPHERES_2	6 / 7
SPHERES_1 vs. SPHERES_3	7 / 7
SPHERES_2 vs. SPHERES_3	8 / 8
FOREST_1 vs. FOREST_2	8 / 8
FOREST_1 vs. FOREST_3	7 / 8
FOREST_2 vs. FOREST_3	5 / 8
TOWN_1 vs. TOWN_2	6 / 8
TOWN_1 vs. TOWN_3	6 / 8
TOWN_2 vs. TOWN_3	6 / 8

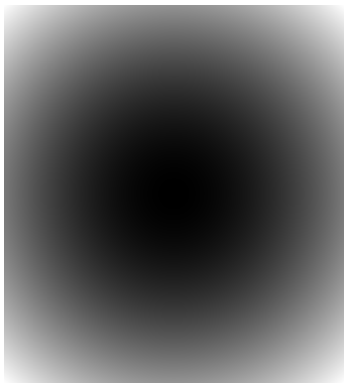

Fig. S2. *Computed Gaussian-based weight on each pixel.* The grayscale value on each position of the view illustrates the approximated weight, $w(i, j)$, of motion perception eccentricity in Equation (6). The larger grayscale values represent higher pixel weight. This weight mask is applied when computing perceived VIMS in our camera motion optimization.

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Table S2. *Cross validation data for Section 3.3.*

Fold ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Error	0.62	0.44	0.42	0.94	1.00	0.56	0.53	0.73	0.72	1.24	1.29	0.85	0.82	0.53
Fold ID	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Error	1.05	1.10	0.66	0.63	1.03	1.09	0.65	0.62	1.61	1.17	1.14	1.22	1.19	0.75

Table S3. *The user study results in S_1 and S_2.* The first column shows the two conditions which the subjects need to compare. We use P to represent the predefined navigation, O to represent our optimization result, U to represent uniform-speed navigation, and T to represent acceleration-thresholding navigation.

Preference \ Subject / Comparison		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
S_1	P vs. O	O	O	O	O	O	O	O	O	P	O	O	P	O	P	P	O
	U vs. O	U	O	O	O	U	U	O	O	U	U	O	O	O	O	U	O
	T vs. O	O	T	O	O	O	O	T	O	O	O	O	T	O	O	O	O
S_2	P vs. O	O	O	P	P	O	O	O	O	O	O	O	O	O	P	O	O
	U vs. O	O	O	U	O	O	O	O	U	O	O	U	U	O	O	O	U
	T vs. O	O	O	T	T	O	O	O	O	O	O	T	O	O	T	O	O

Table S4. *The user study result in S_3 and S_4.* The two rows sequentially show the comparisons in S_3 and S_4. We use P to represent the original active navigation and O to represent our optimized active navigation.

Preference \ Subject / P vs. O	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
S_3	O	O	P	P	O	O	O	P	O	O	O	O
S_4	O	O	P	O	O	P	O	O	P	O	O	O