APPENDIX A

STANDARD USER QUESTIONNAIRE

Please tell us about your background by answering these questions. Feel free to add comments to clarify your answers. If you need extra space, you may use the back of the page.

1. Specify your job title, if any. If you are a student, indicate your class and major.

2. What is your age? _____

3. Are you:

a) male b) female

4. Are you:

a) right-handed b) left-handed c) ambidextrous

5. How often do you use a computer? (Circle the best answer)

a) Daily b) A few times a week c) A few times a month d) Rarely or never

6. What computer platform(s) are you familiar with? (Circle all that apply)

a) PC
b) Macintosh
c) UNIX workstations
d) Other _____

7. Which, if any, of these input devices are you familiar with? (Circle all that apply)

a) keyboard
b) mouse
c) joystick
d) touch screen

e) pen/stylus (e.g. Apple Newton, PalmPilot)
f) drawing tablet
g) 3D input devices (e.g. trackers, 3D mice)
h) Other _____

8. Have you ever used virtual reality (VR) or a virtual environment (VE) which used a head-mounted display? _____

If so, please describe the system and the input devices used below (use back if necessary):

APPENDIX B

COMFORT RATINGS FORM

1 = normal conditions (comfortable)
5 = moderate discomfort
10 = extreme discomfort

After VE familiarization:

arm strain:	1	2	3	4	5	6	7	8	9	10
hand strain:	1	2	3	4	5	6	7	8	9	10
dizziness:	1	2	3	4	5	6	7	8	9	10
nausea:	1	2	3	4	5	6	7	8	9	10

After initial practice:

arm strain:	1	2	3	4	5	6	7	8	9	10
hand strain:	1	2	3	4	5	6	7	8	9	10
dizziness:	1	2	3	4	5	6	7	8	9	10
nausea:	1	2	3	4	5	6	7	8	9	10

After segment 1:

arm strain:	1	2	3	4	5	6	7	8	9	10
hand strain:	1	2	3	4	5	6	7	8	9	10
dizziness:	1	2	3	4	5	6	7	8	9	10
nausea:	1	2	3	4	5	6	7	8	9	10

After segment 2:

arm strain:	1	2	3	4	5	6	7	8	9	10
hand strain:	1	2	3	4	5	6	7	8	9	10
dizziness:	1	2	3	4	5	6	7	8	9	10
nausea:	1	2	3	4	5	6	7	8	9	10

After segment 3:

arm strain:	1	2	3	4	5	6	7	8	9	10
hand strain:	1	2	3	4	5	6	7	8	9	10
dizziness:	1	2	3	4	5	6	7	8	9	10
nausea:	1	2	3	4	5	6	7	8	9	10

APPENDIX C

COMPLETE RESULTS OF THE TRAVEL TESTBED EXPERIMENT

Table C.1 Results of Primed Search Task

Condition	Technique	Mean ThT	Std Dev ThT	Mean TrT	Std Dev TrT
R5V0	Gaze-directed	1.64	0.63	0.11	0.03
	Pointing	2.11	1.35	0.11	0.02
	Torso	2.29	1.16	0.25	0.21
	HOMER	3.88	2.17	0.23	0.08
	Map	23.92	12.69	0.26	0.11
	Ray-casting	2.57	2.48	0.35	0.24
	Go-Go	3.38	1.81	0.20	0.11
R5V1	Gaze-directed	1.35	0.63	0.05	0.01
	Pointing	2.04	1.06	0.05	0.01
	Torso	1.49	0.34	0.06	0.01
	HOMER	2.96	1.58	0.15	0.07
	Map	12.55	2.66	0.16	0.07
	Ray-casting	1.85	1.79	0.11	0.09
	Go-Go	1.84	1.12	0.05	0.01
R10V0	Gaze-directed	1.73	1.11	0.10	0.05
	Pointing	2.49	2.23	0.10	0.04
	Torso	3.61	2.59	0.21	0.18
	HOMER	3.82	1.43	0.30	0.15
	Map	17.24	12.51	0.24	0.07
	Ray-casting	1.61	0.48	0.24	0.13
	Go-Go	1.95	1.18	0.15	0.09
R10V1	Gaze-directed	1.62	0.90	0.05	0.01
	Pointing	2.02	1.28	0.06	0.01
	Torso	1.30	0.13	0.06	0.01
	HOMER	2.38	1.98	0.12	0.04
	Map	15.48	10.93	0.21	0.12
	Ray-casting	1.98	0.56	0.16	0.08
	Go-Go	1.61	0.81	0.06	0.03

Notes: For naïve search results, see table 4.3. R5 refers to trials with required accuracy radius of 5 m; R10 refers to trials with required accuracy radius of 10 m. V0 refers to trials with target not visible from start location; V1 refers to trials with target visible from start location. ThT refers to cognitive/perceptual processing (or thinking) time. TrT refers to travel time. Travel time is normalized: time per 100 meters of travel.

Table C.2 Demographic and Comfort Rating Summary

Technique	Gaze	Pointing	Torso	HOMER	Map	Ray-cast	Go-Go
# Left-Handed	0	0	0	0	0	0	0
# Females	0	1	2	0	0	0	2
Avg. Age	18	20.2	20.2	20	19	18.8	21
# Experienced VEs	1	0	1	1	1	1	0
Avg. SA score	7	8.8	9.4	9.8	8.8	8.4	12.6
Arm 1	1.6	1.2	1	2.4	1.4	1	1.6
Hand 1	1.2	1.2	1	1.4	2.6	1	1.4
Dizzy 1	3.6	2	3	2.6	2.6	1.2	2.4
Nausea 1	1	1.8	1.2	1.8	2.2	1	2
Arm 2	2.4	1	1	2.2	1.8	1.2	2.2
Hand 2	1.8	1	1	1.6	2.6	1	1.8
Dizzy 2	2.8	2	2.8	2.2	3.2	1.2	3
Nausea 2	1.4	1.6	1.4	1.8	3	1.2	2.4
Arm 3	2.4	1	1	2.8	2	1.4	2.2
Hand 3	2.4	1	1	1.6	2.6	1.2	1.4
Dizzy 3	2.8	1.8	2.2	2.6	3.4	1.2	3.2
Nausea 3	1.8	1.4	1.4	2.2	3.4	1.2	2.8
Arm 4	2	1.2	1	3.2	2.4	1.2	2.2
Hand 4	1.8	1.2	1	2	2.8	1	1.4
Dizzy 4	3.6	1.8	2.8	2.8	3.8	1.4	3
Nausea 4	2.2	1.2	1.4	2	3.4	1.4	2.6

Notes: VE Experience refers to any use of an immersive VE system prior to the experiment. SA score refers to the average score on the cube comparison test of spatial ability (maximum score 21).

APPENDIX D

COMPLETE RESULTS OF THE SELECTION/MANIPULATION TESTBED EXPERIMENT

Table D.1 Speed Results for Selection Task

Condition	Selection Technique	Selection Time	Standard Deviation of Time
D0S0N0	Go-Go	6.89	1.68
	Ray-casting	3.78	1.62
	Occlusion	2.77	1.44
D0S0N1	Go-Go	5.33	1.54
	Ray-casting	3.88	1.27
	Occlusion	3.82	1.26
D0S1N0	Go-Go	3.85	0.96
	Ray-casting	2.19	0.57
	Occlusion	2.34	0.57
D0S1N1	Go-Go	3.41	0.89
	Ray-casting	2.69	1.40
	Occlusion	2.67	0.86
D1S0N0	Go-Go	8.60	4.45
	Ray-casting	3.43	1.30
	Occlusion	4.11	1.81
D1S0N1	Go-Go	5.74	1.75
	Ray-casting	4.08	1.72
	Occlusion	4.18	1.41
D1S1N0	Go-Go	5.09	1.62
	Ray-casting	3.32	1.94
	Occlusion	4.32	2.88
D1S1N1	Go-Go	4.43	0.94
	Ray-casting	2.68	0.88
	Occlusion	3.05	1.24
D2S0N0	Go-Go	12.34	10.05
	Ray-casting	4.02	1.57
	Occlusion	4.18	1.09
D2S0N1	Go-Go	11.70	10.80
	Ray-casting	3.34	1.08

	Occlusion	3.98	1.21
D2S1N0	Go-Go	4.38	1.59
	Ray-casting	2.75	1.31
	Occlusion	3.61	2.16
D2S1N1	Go-Go	7.06	1.30
	Ray-casting	3.19	1.37
	Occlusion	5.83	7.30

Notes: D0, D1, D2 refer to the three levels of distance of the objects from the user. S0 and S1 refer to the two sizes of objects. N0 and N1 refer to the two levels of density of the object array.

Table D.2 Speed Results for Manipulation Task

Condition	Attach/Manip Technique	Manipulation Time	Std. Dev. for Time
D0S0F0	Go-Go	5.43	1.50
	Move hand/linear mapping	5.28	1.04
	Move hand/buttons	6.38	3.80
	Scale user/linear mapping	10.44	6.95
	Scale user/buttons	7.43	3.53
	Move hand/linear mapping	5.95	2.75
	Move hand/buttons	6.18	2.01
	Scale user/linear mapping	4.18	1.32
	Scale user/buttons	4.20	1.09
D0S0F1	Go-Go	30.63	19.33
	Move hand/linear mapping	31.48	18.75
	Move hand/buttons	38.34	15.71
	Scale user/linear mapping	42.24	28.33
	Scale user/buttons	59.34	70.53
	Move hand/linear mapping	31.38	17.09
	Move hand/buttons	49.74	41.97
	Scale user/linear mapping	22.79	16.30
	Scale user/buttons	21.27	12.11
D0S1F0	Go-Go	8.19	4.78
	Move hand/linear mapping	5.38	2.02
	Move hand/buttons	5.19	1.10
	Scale user/linear mapping	8.50	3.23
	Scale user/buttons	10.90	8.13
	Move hand/linear mapping	11.58	7.82
	Move hand/buttons	5.97	2.53
	Scale user/linear mapping	5.55	2.11
	Scale user/buttons	4.68	1.01
D0S1F1	Go-Go	4.59	37.36
	Move hand/linear mapping	36.96	19.22
	Move hand/buttons	44.05	16.55
	Scale user/linear mapping	59.57	36.07
	Scale user/buttons	61.09	29.07
	Move hand/linear mapping	62.02	42.35

	Move hand/buttons	35.02	30.17
	Scale user/linear mapping	61.95	33.77
	Scale user/buttons	51.58	15.34
D1S0F0	Go-Go	8.92	4.49
	Move hand/linear mapping	9.41	3.45
	Move hand/buttons	6.68	1.89
	Scale user/linear mapping	14.97	13.97
	Scale user/buttons	12.61	1.04
	Move hand/linear mapping	6.91	3.37
	Move hand/buttons	9.29	2.93
	Scale user/linear mapping	6.08	2.71
	Scale user/buttons	8.12	2.85
D1S0F1	Go-Go	44.71	26.45
	Move hand/linear mapping	52.57	28.11
	Move hand/buttons	47.20	29.19
	Scale user/linear mapping	70.09	19.92
	Scale user/buttons	42.61	22.88
	Move hand/linear mapping	43.93	34.87
	Move hand/buttons	29.94	21.15
	Scale user/linear mapping	21.69	12.84
	Scale user/buttons	24.79	15.45
D1S1F0	Go-Go	17.89	13.60
	Move hand/linear mapping	11.16	3.94
	Move hand/buttons	12.33	8.83
	Scale user/linear mapping	15.63	5.04
	Scale user/buttons	15.52	6.52
	Move hand/linear mapping	14.34	7.33
	Move hand/buttons	6.66	1.22
	Scale user/linear mapping	11.81	6.73
	Scale user/buttons	9.52	3.26
D1S1F1	Go-Go	40.51	19.78
	Move hand/linear mapping	53.94	28.02
	Move hand/buttons	39.17	31.56
	Scale user/linear mapping	65.39	34.52
	Scale user/buttons	75.01	39.85
	Move hand/linear mapping	60.39	21.78
	Move hand/buttons	23.74	12.75
	Scale user/linear mapping	36.29	9.52
	Scale user/buttons	24.88	19.90
D2S0F0	Go-Go	13.92	4.92
	Move hand/linear mapping	29.61	23.05
	Move hand/buttons	16.50	5.27
	Scale user/linear mapping	37.75	13.95
	Scale user/buttons	28.79	8.73
	Move hand/linear mapping	13.70	6.36
	Move hand/buttons	9.06	2.98
	Scale user/linear mapping	10.81	1.73
	Scale user/buttons	10.89	6.70
D2S0F1	Go-Go	19.63	8.20

	Move hand/linear mapping	67.02	49.78
	Move hand/buttons	48.25	39.98
	Scale user/linear mapping	45.41	36.11
	Scale user/buttons	52.75	32.71
	Move hand/linear mapping	41.54	25.48
	Move hand/buttons	33.71	12.50
	Scale user/linear mapping	45.30	38.19
	Scale user/buttons	33.56	22.66
D2S1F0	Go-Go	14.43	8.44
	Move hand/linear mapping	22.28	11.31
	Move hand/buttons	21.14	14.34
	Scale user/linear mapping	29.63	10.42
	Scale user/buttons	26.18	12.73
	Move hand/linear mapping	27.91	13.18
	Move hand/buttons	11.28	4.64
	Scale user/linear mapping	26.37	24.15
	Scale user/buttons	17.74	12.21
D2S1F1	Go-Go	69.68	30.90
	Move hand/linear mapping	59.50	23.01
	Move hand/buttons	86.39	47.19
	Scale user/linear mapping	88.58	21.99
	Scale user/buttons	85.97	13.74
	Move hand/linear mapping	61.96	32.07
	Move hand/buttons	49.84	29.68
	Scale user/linear mapping	44.53	18.69
	Scale user/buttons	35.08	16.00

Notes: D0, D1, and D2 refer to the three levels of distance from the object to the target. S0 and S1 refer to the two sizes of the target. F0 and F1 refer to the 2 DOF and 6 DOF conditions, respectively.

Table D.3 Demographic and Comfort Rating Summary

Technique	1	2	3	4	5	6	7	8	9
# Left-Handed	0	1	0	1	0	0	0	0	0
# Females	1	2	0	5	1	1	2	4	1
Avg. Age	21.2	19.8	19.4	18.6	19.6	21.8	20.6	18.4	23.6
# Experienced VEs	3	1	4	1	2	4	1	0	0
Avg. SA score	12.4	8	12.6	5.4	9.4	11	10.8	12.2	8.2
Arm1	1	1.2	1	1	1	1	1	1.2	1
Hand1	1	1	1	1	1	1	1	1.2	1
Dizzy1	1.6	1.2	2.4	1	1	1	1.4	1.6	1.4
Nausea1	1	1	1	1	1	1	1	1	1
Arm2	1.8	1.2	1	1	1	1.4	1.4	1.6	2.2
Hand2	1.4	1.2	1	1	1.2	1	1.2	1.4	1.4
Dizzy2	1.4	1.2	1.6	1.4	1.2	1.2	1.4	1.6	1.2
Nausea2	1	1	1	1	1	1	1	1	1
Arm3	3.4	1.6	1.4	1	1.2	3	1.8	2.4	3.8
Hand3	1.8	1.4	1.4	1	1.8	1.2	1.6	2	1.6
Dizzy3	1.2	1.8	1.8	3	1.4	1.4	1.6	2	1.8
Nausea3	1	1	1.2	1.6	1.2	1	1	1.2	1
Arm4	5.8	1.8	1.6	1	1.2	4.4	3	3.2	4.8
Hand4	2.4	1.6	1.4	1	1.6	1.2	2	2.4	1.8
Dizzy4	2	2	1.8	4	1.6	1.4	1.4	2.8	1.8
Nausea4	1.8	1	1.6	2.8	1.2	1	1	1.8	1
Arm5	5	2	1.6	1	1.4	3.4	1.8	2.6	3.8
Hand5	2.2	1.4	1.6	1	1.8	1.2	1.4	1.8	1.4
Dizzy5	1.8	1.8	1.8	3.6	1.8	1.4	1.2	2	1.6
Nausea5	1.8	1.2	1.2	2.6	1.2	1	1	1.4	1
Arm6	5.2	2	1.4	1	1.2	4.8	3.4	3.4	4.6
Hand6	2.6	1.6	1.6	1	1.8	1.2	1.8	2	1.4
Dizzy6	1.6	1.8	1.8	3.6	2.2	1.4	1.2	2.2	2
Nausea6	1.4	1.2	1.2	2.6	1.4	1	1	1.6	1

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