Supplementary Material

CHI2022 Papers

Kuiper Belt: Utilizing the "Out-of-natural Angle" Region in the Eye-gaze Interaction for Virtual Reality

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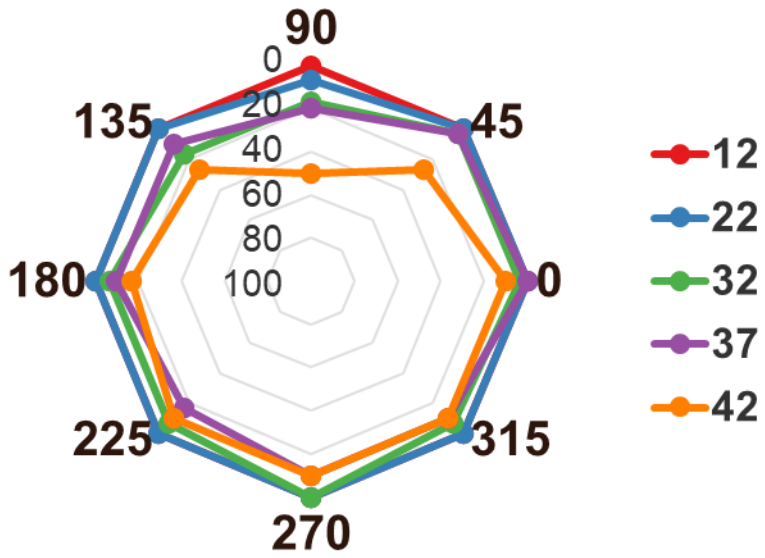
This pdf file shows details of statistical data of:

- Study #1
  - Error Rate
  - Physical Comfort
  - Mental Comfort
  - NASA Task Load Index (NASA-TLX)
  - Appropriate Sphere diameter: The target size required to enable robust interaction
- Study #2
  - Trial Time
  - Error Rate
  - Midas Touch Rate
  - Visual Search Error Rate
  - System Usability Scale (SUS)
  - NASA Task Load Index (NASA-TLX)

Study #1: Error Rate



iDistance	iDirection	Mean (%)	# of error	# of all tasks
12	0	0	0	30
12	45	0	0	30
12	90	0	0	30
12	135	0	0	30
12	180	0	0	30
12	225	0	0	30
12	270	0	0	30
12	315	0	0	30
22	0	0	0	30
22	45	0	0	30
22	90	6.67	2	30
22	135	0	0	30
22	180	0	0	30
22	225	0	0	30
22	270	0	0	30
22	315	0	0	30
32	0	3.33	1	30

32	45	3.33	1	30
32	90	16.67	5	30
32	135	16.67	5	30
32	180	6.67	2	30
32	225	6.67	2	30
32	270	0	0	30
32	315	6.67	2	30
37	0	0	0	30
37	45	3.33	1	30
37	90	20.00	6	30
37	135	10.00	3	30
37	180	10.00	3	30
37	225	16.67	5	30
37	270	10.00	3	30
37	315	10.00	3	30
42	0	10.00	3	30
42	45	26.67	8	30
42	90	50.00	15	30
42	135	26.67	8	30
42	180	16.67	5	30
42	225	10.00	3	30
42	270	10.00	3	30
42	315	10.00	3	30

Significant main effects of iDistance and iDirection on error rate.

Independent variable	F value	p.value
iDisatnce	F(4, 1151)=165.36	<.001 *
iDirection	F(7, 1151)=31.23	<.001 *
iDistance× iDirection	F(28, 1151)=11.59	<.001 *

Post-hoc comparisons for iDistance.

iDistance	t.ratio	p.value
12-22	-14.49	<.001 *
12-32	-16.95	<.001 *
12-37	-9.53	<.001 *

12-42	-24.48	<.001 *
22-32	-2.46	0.100
22-37	4.96	<.001 *
22-42	-10.00	<.001 *
32-37	7.42	<.001 *
32-42	-7.53	<.001 *
37-42	-14.96	<.001 *

Post-hoc comparisons for iDirection.

iDirection	t.ratio	p.value
0-45	-8.84	<.001 *
0-90	-12.35	<.001 *
0-135	-7.59	<.001 *
0-180	-4.91	<.001 *
0-225	-4.91	<.001 *
0-270	-2.80	0.097
0-315	-2.56	0.17
45-90	-3.50	0.013 *
45-135	1.26	0.091
45-180	3.94	0.0022 *
45-225	3.94	0.0022 *
45-270	6.047	<.001 *
45-315	6.28	<.001 *
90-135	4.76	<.001 *
90-180	7.44	<.001 *
90-225	7.44	<.001 *
90-270	9.55	<.001 *
90-315	9.78	<.001 *
135-180	2.68	0.13
135-225	2.68	0.13
135-270	4.79	<.001 *
135-315	5.03	<.001 *
180-225	0	1.000
180-270	2.11	0.41
180-315	2.34	0.27

225-270	2.11	0.41
225-315	2.34	0.27
270-315	0.23	1.00

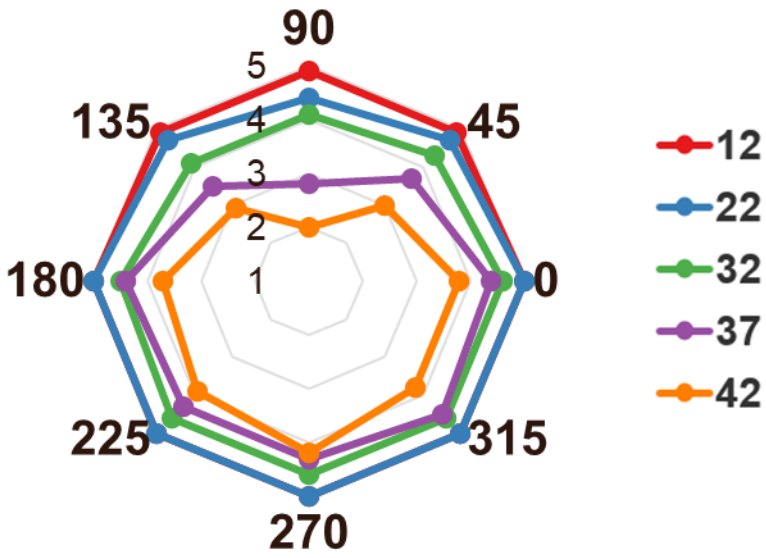
Cross-factor pair-wise comparison. Some results were omitted because a Wilcoxon signed rank test cannot be performed when all pairwise differences equal zero.

iDistance	iDirection	Z.score	p.value
22	0-90	-1.41	1.00
22	45-90	-1.41	1.00
22	90-135	1.41	1.00
22	90-180	1.41	1.00
22	90-225	1.41	1.00
22	90-270	1.41	1.00
22	90-315	1.41	1.00
32	0-45	0	1.00
32	0-90	-1.63	1.00
32	0-135	-2.00	1.00
32	0-180	-0.58	1.00
32	0-225	-0.58	1.00
32	0-270	1.00	1.00
32	0-315	-0.58	1.00
32	45-90	-1.63	1.00
32	45-135	-1.63	1.00
32	45-180	-0.58	1.00
32	45-225	-0.58	1.00
32	45-270	1.00	1.00
32	45-315	-0.58	1.00
32	90-135	0	1.00
32	90-180	1.73	1.00
32	90-270	1.73	1.00
32	90-315	2.24	1.00
32	135-180	1.73	1.00
32	135-225	1.73	1.00
32	135-270	1.73	1.00
32	135-315	2.24	1.00

32	180-270	1.41	1.00
32	225-270	1.41	1.00
32	270-315	-1.41	1.00
37	0-45	-1.00	1.00
37	0-90	-2.45	0.78
37	0-135	-1.73	1.00
37	0-180	-1.73	1.00
37	0-225	-2.24	1.00
37	0-270	-1.73	1.00
37	0-315	-1.73	1.00
37	45-90	-1.89	1.00
37	45-135	-1.00	1.00
37	45-180	-1.00	1.00
37	45-225	-2.00	1.00
37	45-270	-1.00	1.00
37	45-315	-1.00	1.00
37	90-135	-1.34	1.00
37	90-180	-1.34	1.00
37	90-225	-0.38	1.00
37	90-270	-1.34	1.00
37	90-315	-1.34	1.00
37	135-225	-1.41	1.00
37	135-270	0	1.00
37	180-225	-1.41	1.00
37	180-270	0	1.00
37	225-270	0.71	1.00
37	225-315	1.41	1.00
37	270-315	0	1.00
42	0-45	-1.89	1.00
42	0-90	-3.46	0.012 *
42	0-135	-1.89	1.00
42	0-180	-1.41	1.00
42	0-270	1.00	1.00
42	45-90	-1.81	1.00
42	45-135	0	1.00

42	45-180	1.13	1.00
42	45-225	1.89	1.00
42	45-270	1.51	1.00
42	45-315	1.89	1.00
42	90-135	2.11	1.00
42	90-180	2.67	0.27
42	90-225	3.46	0.012 *
42	90-270	3.46	0.012 *
42	90-315	3.46	0.012 *
42	135-180	1.00	1.00
42	135-225	1.89	1.00
42	135-270	1.89	1.00
42	135-315	1.89	1.00
42	180-225	1.41	1.00
42	180-270	0.71	1.00
42	180-315	1.41	1.00
42	225-270	0	1.00
42	270-315	0	1.00

Study #1: Physical Comfort



iDistance	iDirection	Mean	S.D.
12	0	5.0	0
12	45	4.9	0.30
12	90	4.9	0.30
12	135	4.9	0.30
12	180	5.0	0
12	225	5.0	0
12	270	5.0	0
12	315	5.0	0
22	0	5.0	0
22	45	4.7	0.46
22	90	4.4	0.66
22	135	4.7	0.46
22	180	5.0	0
22	225	5.0	0
22	270	5.0	0
22	315	5.0	0
32	0	4.6	0.66

32	45	4.3	0.78
32	90	4.1	0.94
32	135	4.1	0.94
32	180	4.5	0.67
32	225	4.6	0.49
32	270	4.6	0.49
32	315	4.6	0.66
37	0	4.4	1.02
37	45	3.7	0.90
37	90	2.8	0.98
37	135	3.5	0.81
37	180	4.4	1.02
37	225	4.3	0.64
37	270	4.3	0.64
37	315	4.5	0.67
42	0	3.8	0.98
42	45	3.0	1.00
42	90	2.0	1.18
42	135	2.9	1.14
42	180	3.7	1.10
42	225	3.9	1.14
42	270	4.2	0.75
42	315	3.8	1.17

Significant main effects of iDistance and iDirection on physical comfort.

Independent variable	F value	p.value
iDistance	F(4, 351)=111.94	<.001 *
iDirection	F(7, 351)=20.18	<.001 *
iDistance× iDirection	F(28, 351)=2.84	<.001 *

Post-hoc comparisons for iDistance.

iDistance	t.ratio	p.value
12-22	4.06	<.001 *
12-32	9.76	<.001 *
12-37	14.88	<.001 *

12-42	18.17	<.001 *
22-32	5.70	<.001 *
22-37	10.82	<.001 *
22-42	14.10	<.001 *
32-37	5.12	<.001 *
32-42	8.41	<.001 *
37-42	3.28	<.001 *

Post-hoc comparisons for iDirection.

iDirection	t.ratio	p.value
0-45	4.55	<.001 *
0-90	7.66	<.001 *
0-135	5.42	<.001 *
0-180	0.97	0.98
0-225	0.45	1.00
0-270	-0.67	1.00
0-315	-0.51	1.00
45-90	3.11	0.042 *
45-135	0.88	0.99
45-180	-3.57	0.010 *
45-225	-4.10	0.0013 *
45-270	-5.22	<.001 *
45-315	-5.05	<.001 *
90-135	-2.24	0.33
90-180	-6.68	<.001 *
90-225	-2.24	0.33
90-270	-8.33	<.001 *
90-315	-8.16	<.001 *
135-180	-4.45	<.001 *
135-225	-4.98	<.001 *
135-270	-6.09	<.001 *
135-315	-5.93	<.001 *
180-225	-0.53	1.000
180-270	-1.64	0.72
180-315	-1.48	0.82

225-270	-1.12	0.95
225-315	-0.95	0.98
270-315	0.17	1.00

Cross-factor pair-wise comparison. Some results were omitted because a Wilcoxon signed rank test cannot be performed when all pairwise differences equal zero.

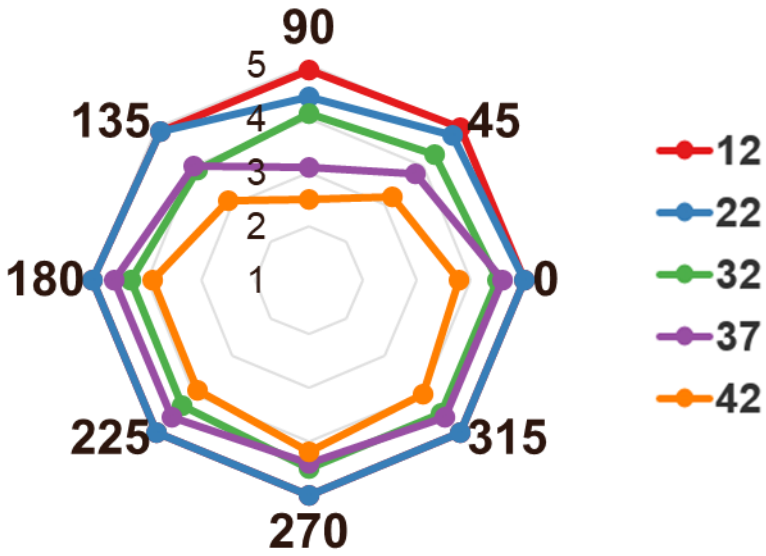
iDistance	iDirection	Z.score	p.value
12	0-45	1.00	1.00
12	0-90	1.00	1.00
12	0-135	1.00	1.00
12	45-180	-1.00	1.00
12	45-225	-1.00	1.00
12	45-270	-1.00	1.00
12	45-315	-1.00	1.00
12	90-180	-1.00	1.00
12	90-225	-1.00	1.00
12	90-270	-1.00	1.00
12	90-315	-1.00	1.00
12	135-180	-1.00	1.00
12	135-225	-1.00	1.00
12	135-270	-1.00	1.00
12	135-315	-1.00	1.00
22	0-45	1.73	1.00
22	0-90	2.12	1.00
22	0-135	1.73	1.00
22	45-90	1.34	1.00
22	45-135	0	1.00
22	45-180	-1.73	1.00
22	45-225	-1.73	1.00
22	45-270	-1.73	1.00
22	45-315	-1.73	1.00
22	90-135	-1.34	1.00
22	90-180	-2.12	1.00
22	90-225	-2.12	1.00
22	90-270	-2.12	1.00

22	90-315	-2.12	1.00
22	135-180	-1.73	1.00
22	135-225	-1.73	1.00
22	135-270	-1.73	1.00
22	135-315	-1.73	1.00
32	0-45	1.73	1.00
32	0-90	2.24	1.00
32	0-135	1.63	1.00
32	0-180	0.45	1.00
32	0-225	0	1.00
32	0-270	0	1.00
32	45-90	1.41	1.00
32	45-135	0.82	1.00
32	45-180	-0.71	1.00
32	45-225	-1.34	1.00
32	45-270	-1.73	1.00
32	45-315	-1.73	1.00
32	90-135	0	1.00
32	90-180	-1.08	1.00
32	90-225	-1.67	1.00
32	90-270	-1.89	1.00
32	90-315	-2.24	1.00
32	135-180	-1.63	1.00
32	135-225	-1.89	1.00
32	135-270	-1.89	1.00
32	135-315	-1.63	1.00
32	180-225	-1.0	1.00
32	180-270	-0.45	1.00
32	180-315	-0.45	1.00
32	225-270	0	1.00
32	225-315	0	1.00
32	270-315	0	1.00
37	0-45	2.07	0.94
37	0-90	2.71	0.098
37	0-135	2.25	0.59

37	0-225	0.45	1.00
37	0-270	0.45	1.00
37	0-315	-0.58	1.00
37	45-90	2.26	0.59
37	45-135	1.00	1.00
37	45-180	-2.07	0.94
37	45-225	-1.90	1.00
37	45-270	-1.90	1.00
37	45-315	-2.53	0.33
37	90-135	-2.12	0.94
37	90-180	-2.71	0.098
37	90-225	-2.91	0.053
37	90-270	-2.71	0.098
37	90-315	-2.86	0.053
37	135-180	-2.25	0.59
37	135-225	-2.53	0.33
37	135-270	-2.13	0.88
37	135-315	-2.64	0.17
37	180-225	0.45	1.00
37	180-270	0.45	1.00
37	180-315	-0.58	1.00
37	225-270	0	1.00
37	225-315	-1.41	1.00
37	270-315	-1.41	1.00
42	0-45	2.13	0.71
42	0-90	2.69	0.098
42	0-135	2.46	0.30
42	0-180	0.58	1.00
42	0-225	-0.45	1.00
42	0-270	-1.63	1.00
42	0-315	0	1.00
42	45-90	2.46	0.30
42	45-135	0.58	1.00
42	45-180	-1.93	1.00
42	45-225	-2.71	0.16

42	45-270	-2.81	0.098
42	45-315	-2.53	0.30
42	90-135	-2.26	0.47
42	90-180	-2.70	0.098
42	90-225	-2.84	0.055
42	90-270	-2.83	0.055
42	90-315	-2.85	0.055
42	135-180	-2.27	0.47
42	135-225	-2.64	0.16
42	135-270	-2.75	0.098
42	135-315	-2.46	0.30
42	180-225	-1.0	1.00
42	180-270	-2.24	0.81
42	180-315	-0.58	1.00
42	225-270	-1.34	1.00
42	225-315	1.00	1.00
42	270-315	1.63	1.00

Study #1: Mental Comfort



iDistance	iDirection	Mean	S.D.
12	0	5.0	0
12	45	5.0	0
12	90	4.9	0.30
12	135	4.9	0.30
12	180	5.0	0
12	225	5.0	0
12	270	5.0	0
12	315	5.0	0
22	0	5.0	0
22	45	4.8	0.60
22	90	4.4	0.80
22	135	4.9	0.30
22	180	5.0	0
22	225	5.0	0
22	270	5.0	0
22	315	5.0	0
32	0	4.5	0.81
32	45	4.3	0.78

32	90	4.1	0.94
32	135	3.9	1.30
32	180	4.3	0.90
32	225	4.3	0.90
32	270	4.5	0.81
32	315	4.5	0.81
37	0	4.6	0.66
37	45	3.8	0.98
37	90	3.1	1.14
37	135	4.0	1.00
37	180	4.6	0.66
37	225	4.6	0.66
37	270	4.4	0.66
37	315	4.6	0.66
42	0	3.8	1.25
42	45	3.2	1.33
42	90	2.5	1.36
42	135	3.1	1.51
42	180	3.9	1.37
42	225	3.9	1.37
42	270	4.2	1.08
42	315	4.0	1.26

Significant main effects of iDistance and iDirection on mental comfort.

Independent variable	F value	p.value
IDistance	F(4, 351)=59.95	<.001 *
IDirection	F(7, 351)=10.77	<.001 *
IDistance×IDirection	F(28, 351)=2.11	0.0011 *

Post-hoc comparisons for iDistance.

IDistance	t.ratio	p.value
12-22	2.78	0.045 *
12-32	7.65	<.001 *
12-37	10.41	<.001 *
12-42	13.42	<.001 *

22-32	4.87	<.001 *
22-37	7.63	<.001 *
22-42	10.63	<.001 *
32-37	2.77	0.047 *
32-42	5.77	<.001 *
37-42	3.00	0.024 *

Post-hoc comparisons for iDirection.

iDirection	t.ratio	p.value
0-45	3.52	0.011 *
0-90	5.30	<.001 *
0-135	3.32	0.022 *
0-180	0.53	0.99
0-225	0.53	1.00
0-270	-0.89	0.99
0-315	-0.97	0.98
45-90	1.78	0.64
45-135	-0.20	1.00
45-180	-3.00	0.058
45-225	-3.00	0.058
45-270	-4.41	<.001 *
45-315	-4.49	<.001 *
90-135	-1.98	0.50
90-180	-4.77	<.001 *
90-225	-4.77	<.001 *
90-270	-6.19	<.001 *
90-315	-6.26	<.001 *
135-180	-2.79	0.10
135-225	-2.79	0.10
135-270	-4.21	<.001 *
135-315	-4.29	<.001 *
180-225	0	1.00
180-270	-1.41	0.85
180-315	-1.49	0.81
225-270	-1.41	0.85

225-315	-1.49	0.81
270-315	-0.078	1.00

Cross-factor pair-wise comparison. Some results were omitted because a Wilcoxon signed rank test cannot be performed when all pairwise differences equal zero.

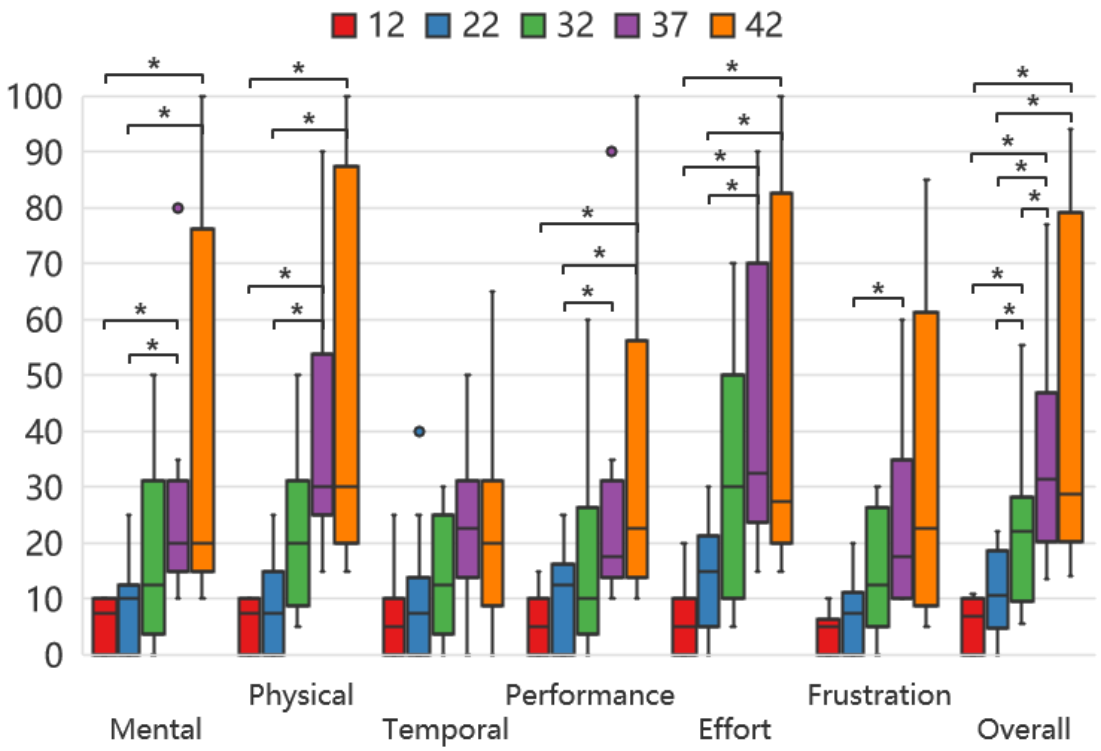
iDistance	iDirection	Z.score	p.value
12	0-90	1.00	1.00
12	0-135	1.00	1.00
12	45-90	1.00	1.00
12	45-135	1.00	1.00
12	90-135	0	1.00
12	90-180	-1.00	1.00
12	90-225	-1.00	1.00
12	90-270	-1.00	1.00
12	90-315	-1.00	1.00
12	135-180	-1.00	1.00
12	135-225	-1.00	1.00
12	135-270	-1.00	1.00
12	135-315	-1.00	1.00
22	0-45	1.00	1.00
22	0-90	1.86	1.00
22	0-135	1.00	1.00
22	45-90	1.30	1.00
22	45-135	-0.45	1.00
22	45-180	-1.00	1.00
22	45-225	-1.00	1.00
22	45-270	-1.00	1.00
22	45-315	-1.00	1.00
22	90-135	-1.52	1.00
22	90-180	-1.86	1.00
22	90-225	-1.86	1.00
22	90-270	-1.86	1.00
22	90-315	-1.86	1.00
22	135-180	-1.00	1.00
22	135-225	-1.00	1.00

22	135-270	-1.00	1.00
22	135-315	-1.00	1.00
32	0-45	1.41	1.00
32	0-90	2.00	1.00
32	0-135	1.34	1.00
32	0-180	1.00	1.00
32	0-225	1.00	1.00
32	45-90	1.41	1.00
32	45-135	0.82	1.00
32	45-180	0	1.00
32	45-225	0	1.00
32	45-270	-1.41	1.00
32	45-315	-1.41	1.00
32	90-135	0	1.00
32	90-180	-0.70	1.00
32	90-225	-0.70	1.00
32	90-270	-2.00	1.00
32	90-315	-2.00	1.00
32	135-180	-1.41	1.00
32	135-225	-1.41	1.00
32	135-270	-1.34	1.00
32	135-315	-1.34	1.00
32	180-270	-1.00	1.00
32	180-315	-1.00	1.00
32	225-270	-1.00	1.00
32	225-315	-1.00	1.00
37	0-45	2.07	1.00
37	0-90	2.72	0.086
37	0-135	1.86	1.00
37	0-270	1.41	1.00
37	45-90	1.67	1.00
37	45-135	-1.00	1.00
37	45-180	-2.07	1.00
37	45-225	-2.07	1.00
37	45-270	-1.56	1.00

37	45-315	-2.07	1.00
37	90-135	-2.33	0.53
37	90-180	-2.72	0.086
37	90-225	-2.72	0.086
37	90-270	-2.56	0.14
37	90-315	-2.72	0.086
37	135-180	-1.86	1.00
37	135-225	-1.86	1.00
37	135-270	-1.19	1.00
37	135-315	-1.86	1.00
37	180-270	1.41	1.00
37	225-270	1.41	1.00
37	270-315	-1.41	1.00
42	0-45	1.39	1.00
42	0-90	2.36	0.49
42	0-135	1.59	1.00
42	0-180	-0.45	1.00
42	0-225	-0.45	1.00
42	0-270	-1.63	1.00
42	0-315	-1.00	1.00
42	45-90	2.07	1.00
42	45-135	0.58	1.00
42	45-180	-1.93	1.00
42	45-225	-1.93	1.00
42	45-270	-2.43	0.37
42	45-315	-2.27	0.63
42	90-135	-2.12	1.00
42	90-180	-2.56	0.20
42	90-225	-2.75	0.11
42	90-270	-2.70	0.11
42	90-315	-2.72	0.11
42	135-180	-2.27	0.63
42	135-225	-2.27	0.63
42	135-270	-2.43	0.37
42	135-315	-2.46	0.37

42	180-225	0	1.00
42	180-270	-1.73	1.00
42	180-315	-1.00	1.00
42	225-270	-1.34	1.00
42	225-315	-1.00	1.00
42	270-315	1.41	1.00

Study #1: NASA Task Load Index (NASA-TLX)



Statistical significance: *p<.05, **p<.01.

Mental Workload	iDistance	Mean	Median	S.D.
Mental	12	6.00	7.50	4.36
Mental	22	9.50	10.00	7.89
Mental	32	18.00	12.50	15.68
Mental	37	26.00	20.00	19.34
Mental	42	39.00	20.00	33.45
Physical	12	6.00	7.50	4.36
Physical	22	9.00	7.50	8.00

Physical	32	22.00	20.00	13.64
Physical	37	39.50	30.00	21.50
Physical	42	45.50	30.00	32.21
Temporal	12	7.00	5.00	7.14
Temporal	22	10.50	7.50	12.13
Temporal	32	14.00	12.50	10.20
Temporal	37	23.45	22.50	13.45
Temporal	42	22.00	20.00	17.92
Performance	12	6.00	5.00	4.90
Performance	22	10.00	12.50	8.94
Performance	32	16.50	10.00	17.18
Performance	37	26.00	17.50	22.67
Performance	42	35.50	22.50	28.76
Effort	12	6.50	5.00	5.94
Effort	22	14.00	15.00	8.89
Effort	32	30.00	30.00	20.62
Effort	37	42.00	32.50	24.21
Effort	42	46.50	27.50	31.07
Frustration	12	4.50	5.00	3.50
Frustration	22	7.50	7.50	6.42
Frustration	32	14.50	12.50	10.11
Frustration	37	24.50	17.50	17.10
Frustration	42	35.00	22.50	28.81
Overall Workload	12	6.00	6.83	4.39
Overall Workload	22	10.90	10.67	7.00
Overall Workload	32	21.83	22.00	14.03
Overall Workload	37	35.23	31.33	18.25
Overall Workload	42	41.87	28.67	28.40

Significant main effects of iDistance and iDirection on NASA-TLX.

Mental Workload	χ^2_2-value	p-value
Mental	23.33	<.001 *
Physical	31.01	<.001 *
Temporal	16.98	0.0020 *
Performance	22.88	<.001 *

Effort	29.80	<.001 *
Frustration	18.62	<.001 *
Overall Workload	30.67	<.001 *

Post-hoc comparisons for Mental Workload.

Mental Workload	iDistance	Z-value	p-value
Mental	12-22	-1.63	0.50
Mental	12-32	-2.21	0.19
Mental	12-37	-2.68	0.039 *
Mental	12-42	-2.67	0.039 *
Mental	22-32	-1.87	0.28
Mental	22-37	-2.68	0.039 *
Mental	22-42	-2.68	0.039 *
Mental	32-37	-1.85	0.28
Mental	32-42	-1.89	0.28
Mental	37-42	-0.92	0.50
Physical	12-22	-1.38	0.44
Physical	12-32	-2.50	0.070
Physical	12-37	-2.81	0.020 *
Physical	12-42	-2.81	0.020 *
Physical	22-32	-2.39	0.078
Physical	22-37	-2.83	0.020 *
Physical	22-42	-2.81	0.020 *
Physical	32-37	-2.44	0.078
Physical	32-42	-2.11	0.12
Physical	37-42	0.071	0.99
Temporal	12-22	-0.82	1.00
Temporal	12-32	-1.87	0.31
Temporal	12-37	-2.37	0.14
Temporal	12-42	-2.21	0.25
Temporal	22-32	-1.16	1.00
Temporal	22-37	-2.20	0.25
Temporal	22-42	-2.21	0.25
Temporal	32-37	-2.64	0.078
Temporal	32-42	-1.86	0.50

Temporal	37-42	0.95	1.00
Performance	12-22	-1.51	0.56
Performance	12-32	-1.90	0.38
Performance	12-37	-2.53	0.055
Performance	12-42	-2.84	0.020 *
Performance	22-32	-1.28	0.16
Performance	22-37	-2.50	0.020 *
Performance	22-42	-2.67	0.027 *
Performance	32-37	-1.97	0.12
Performance	32-42	-2.39	0.12
Performance	37-42	-1.19	0.85
Effort	12-22	-1.62	0.23
Effort	12-32	-2.37	0.094
Effort	12-37	-2.81	0.020 *
Effort	12-42	-2.81	0.020 *
Effort	22-32	-1.96	0.16
Effort	22-37	-2.81	0.020 *
Effort	22-42	-2.68	0.027 *
Effort	32-37	-2.26	0.12
Effort	32-42	-2.25	0.12
Effort	37-42	0.21	0.85
Frustration	12-22	-1.51	0.50
Frustration	12-32	-2.21	0.19
Frustration	12-37	-2.53	0.070
Frustration	12-42	-2.50	0.094
Frustration	22-32	-2.23	0.19
Frustration	22-37	-2.67	0.039 *
Frustration	22-42	-2.44	0.11
Frustration	32-37	-1.70	0.38
Frustration	32-42	-1.90	0.25
Frustration	37-42	-1.19	0.50
Overall Workload	12-22	-1.82	0.156
Overall Workload	12-32	-2.55	0.039 *
Overall Workload	12-37	-2.80	0.020 *
Overall Workload	12-42	-2.80	0.020 *

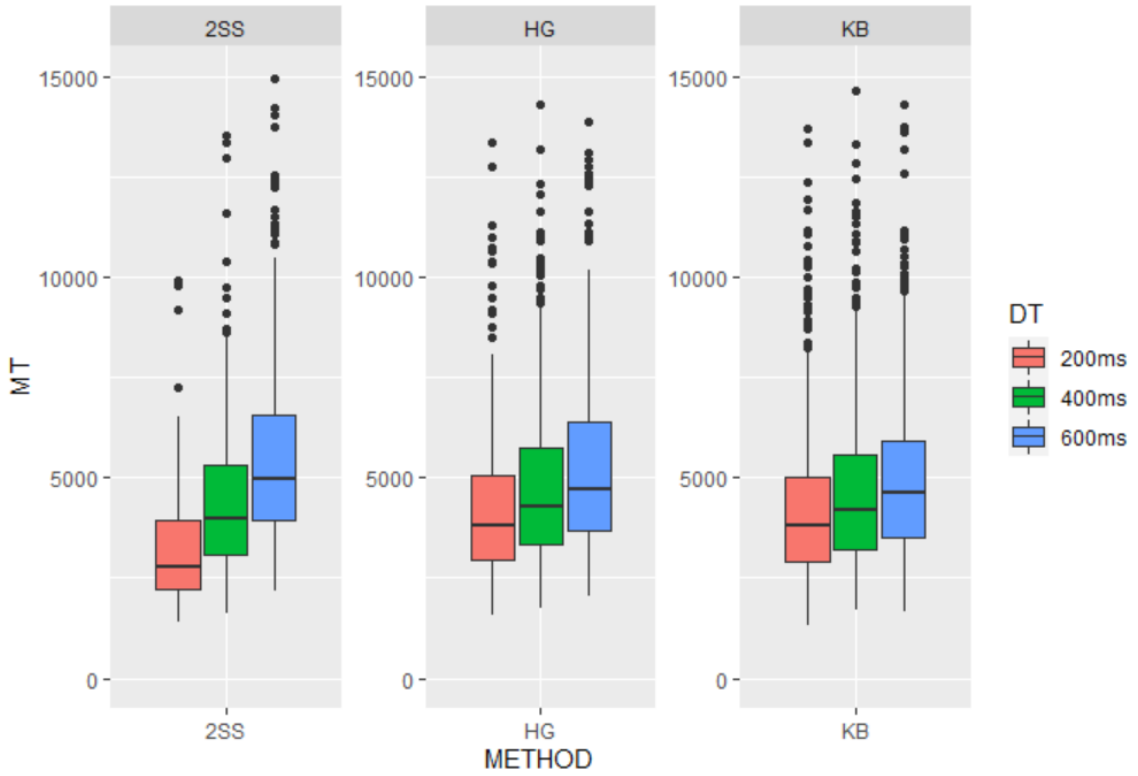
Overall Workload	22-32	-2.43	0.047 *
Overall Workload	22-37	-2.80	0.020 *
Overall Workload	22-42	-2.80	0.020 *
Overall Workload	32-37	-2.60	0.035 *
Overall Workload	32-42	-2.29	0.059
Overall Workload	37-42	-0.36	0.77

Study #1: Appropriate Sphere diameter: The target size required to enable robust interaction (°)

		Percentile				
iDistance	iDirection	25%	50%	75%	90%	95%
12	90	1.34	2.70	3.99	5.73	6.08
12	45	1.79	3.10	4.38	6.14	7.27
12	0	1.43	2.49	4.08	4.96	6.37
12	315	1.12	1.68	2.75	3.79	4.61
12	270	0.92	1.62	2.18	2.74	3.60
12	225	1.43	2.29	2.96	4.21	4.82
12	180	1.61	2.66	4.80	6.49	8.27
12	135	2.07	2.88	4.59	6.02	6.82
22	90	2.43	4.71	7.14	11.75	12.26
22	45	2.60	3.87	5.59	7.85	8.62
22	0	2.46	3.76	5.82	7.67	8.31
22	315	2.24	3.02	4.03	5.48	7.00
22	270	2.17	2.98	4.17	5.48	5.83
22	225	2.62	3.52	4.54	6.07	6.98
22	180	4.02	6.10	7.19	8.97	10.12
22	135	3.47	4.91	6.85	9.25	10.59
32	90	3.59	6.34	11.68	25.49	34.79
32	45	3.32	5.89	9.15	11.13	12.58
32	0	1.69	3.09	5.17	8.48	11.48
32	315	2.76	3.91	6.25	8.01	15.20
32	270	3.42	4.60	6.28	7.44	8.33

32	225	3.35	4.86	7.07	10.24	12.17
32	180	1.96	4.67	7.87	11.78	12.54
32	135	4.09	5.91	8.13	16.23	21.59
37	90	3.40	6.37	10.36	13.02	39.25
37	45	3.15	4.98	6.80	9.38	12.09
37	0	1.93	3.31	7.84	9.66	10.24
37	315	3.65	5.16	7.36	12.91	16.40
37	270	2.47	3.86	6.63	9.06	22.51
37	225	4.02	6.72	10.18	15.14	21.36
37	180	2.80	4.19	7.96	12.66	16.44
37	135	4.98	7.60	9.64	19.00	21.15
42	90	5.51	9.76	15.66	18.98	21.47
42	45	5.23	8.14	12.53	15.95	17.81
42	0	3.74	5.59	8.83	13.26	17.30
42	315	4.08	6.57	8.39	13.18	25.04
42	270	2.64	5.16	8.69	10.26	13.42
42	225	4.61	7.07	11.87	18.16	23.39
42	180	3.45	7.74	12.09	19.37	20.66
42	135	4.53	7.76	10.74	13.65	14.58

Study #2: Trial Time



Method	DT (ms)	Mean (s)	Median (s)	S.D.
2SS	200	3.44	2.79	2.01
2SS	400	4.58	4.01	2.75
2SS	600	5.77	5.05	3.07
HG	200	4.37	3.85	2.32
HG	400	4.84	4.29	2.09
HG	600	5.54	4.76	3.26
KB	200	4.43	3.81	2.37
KB	400	4.81	4.23	2.51
KB	600	5.28	4.67	3.05

Significant main effects of Method and DT on trial time.

Independent variable	F value	p.value
Method	F(2, 4032.4)=9.70	<.001 *
DT	F(2, 4032.5)=75.04	<.001 *
Method ×DT	F(4, 4032.0)=11.61	<.001 *

Post-hoc comparisons for Method.

Method	z.ratio	p.value
2SS-HG	1.95	0.13
2SS-KB	3.90	<.001 *
HG-KB	3.10	0.0054 *

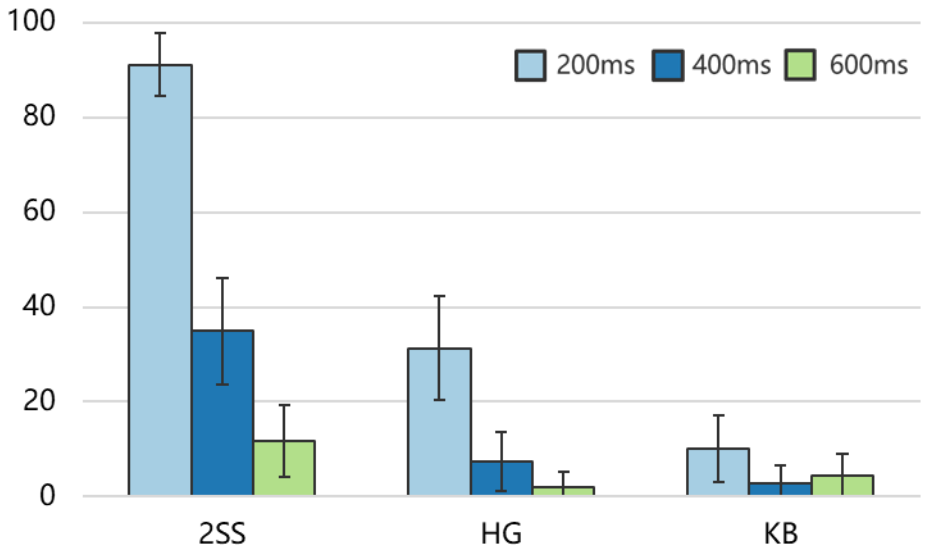
Post-hoc comparisons for DT.

DT (ms)	z.ratio	p.value
200-400	-4.28	<.001 *
200-600	-10.27	<.001 *
400-600	-9.42	<.001 *

Cross-factor pair-wise comparison.

DT (ms)	Method	Z.score	p.value
200	2SS-HG	-2.00	0.13
200	2SS-KB	-1.30	0.20
200	HG-KB	1.80	0.14
400	2SS-HG	-1.69	0.18
400	2SS-KB	-1.25	0.42
400	HG-KB	0.91	0.36
600	2SS-HG	1.69	0.090
600	2SS-KB	3.57	0.0012 *
600	HG-KB	1.71	0.18

Study #2: Error Rate



Method	DT (ms)	Mean (%)	# of error	# of all tasks
2SS	200	91.15	525	576
2SS	400	34.90	201	576
2SS	600	11.81	68	576
HG	200	31.25	180	576
HG	400	7.47	43	576
HG	600	1.91	11	576
KB	200	10.07	58	576
KB	400	2.78	16	576
KB	600	4.34	25	576

Significant main effects of Method and DT on trial time.

Independent variable	F value	p.value
Method	F(2, 5158)=2321.23	<.001 *
DT	F(2, 5158)=2519.50	<.001 *
Mehotd ×DT	F(4, 5158)=571.56	<.001 *

Post-hoc comparisons for Method.

Method	z.ratio	p.value
2SS-HG	38.45	<.001 *

2SS-KB	67.94	<.001 *
HG-KB	29.49	<.001 *

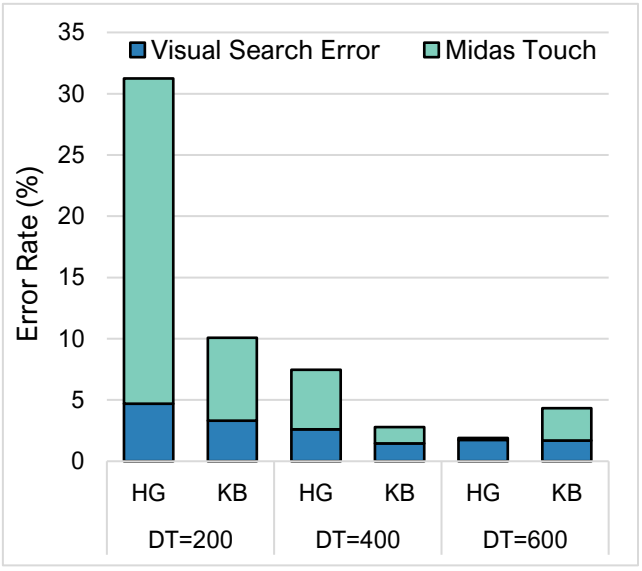
Post-hoc comparisons for DT.

DT (ms)	z.ratio	p.value
200-400	43.15	<.001 *
200-600	70.39	<.001 *
400-600	27.24	<.001 *

Cross-factor pair-wise comparison.

DT (ms)	Method	Z.score	p.value
200	2SS-HG	18.11	<.001 *
200	2SS-KB	21.52	<.001 *
200	HG-KB	9.14	<.001 *
400	2SS-HG	11.12	<.001 *
400	2SS-KB	12.86	<.001 *
400	HG-KB	3.58	<.001 *
600	2SS-HG	6.58	<.001 *
600	2SS-KB	4.61	<.001 *
600	HG-KB	-2.33	0.029 *

Study #2: Midas Touch Rate

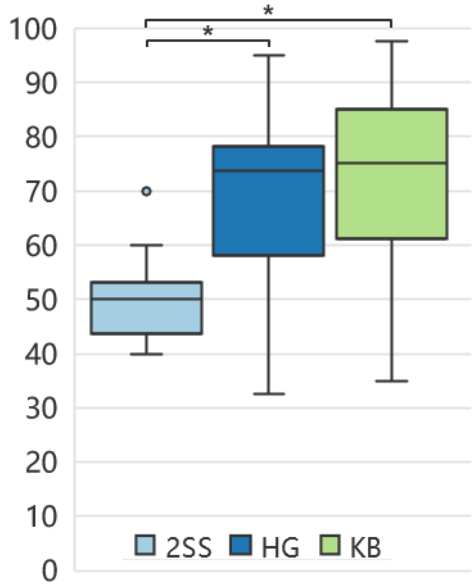


Method	DT (ms)	Mean (%)	# of error	# of all tasks
HG	200	26.56	153	576
HG	400	4.86	28	576
HG	600	0.17	1	576
KB	200	6.77	39	576
KB	400	0.087	5	576
KB	600	1.74	10	576

Study #2: Visual Search Error Rate

Method	DT (ms)	Mean (%)	# of error	# of all tasks
HG	200	4.69	27	576
HG	400	2.60	15	576
HG	600	1.74	10	576
KB	200	3.30	19	576
KB	400	1.91	11	576
KB	600	2.60	15	576

Study #2: System Usability Scale (SUS)



Statistical significance: *p<.05, **p<.01.

Method	Mean	Median	S.D.
2SS	49.44	50.00	7.62
HG	69.31	73.75	15.70
KB	71.53	75.00	15.32

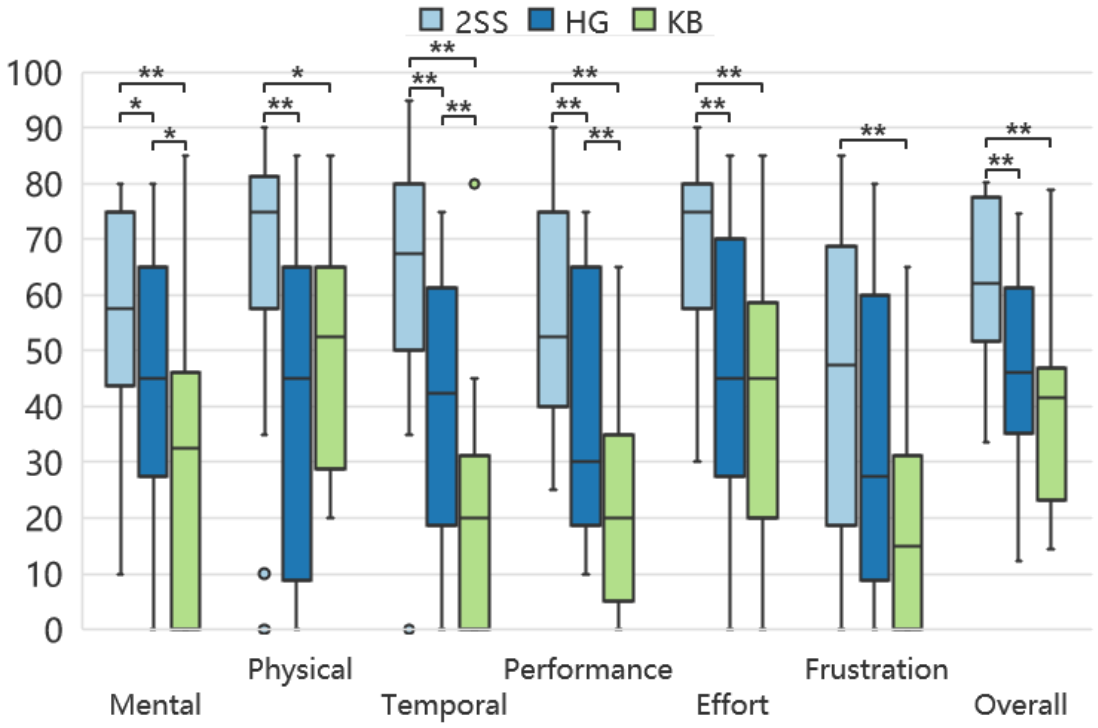
Significant main effects on SUS score.

SUS	χ^2_2-value	p-value
Overall	17.77	<.001 *

Post-hoc comparisons for Method.

SUS	Method	Z-value	p-value
Overall	2SS – HG	-3.34	<.001 *
Overall	2SS – KB	-3.60	<.001 *
Overall	HG – KB	-1.17	0.26

Study #2: NASA Task Load Index (NASA-TLX)



Statistical significance: *p<.05, **p<.01.

Mental Workload	Method	Mean	Median	S.D.
Mental	2SS	55.28	57.50	21.18
Mental	HG	43.89	45.00	23.31
Mental	KB	30.00	32.50	24.66
Physical	2SS	65.00	75.00	25.22
Physical	HG	41.11	45.00	28.70
Physical	KB	49.17	52.50	21.23
Temporal	2SS	61.11	67.50	27.31
Temporal	HG	40.28	42.50	24.41
Temporal	KB	19.72	20.00	20.91
Performance	2SS	57.50	52.50	18.28
Performance	HG	38.61	30.00	22.66
Performance	KB	21.94	20.00	17.65
Effort	2SS	68.89	75.00	16.04
Effort	HG	45.56	45.00	25.10

Effort	KB	43.33	45.00	23.09
Frustration	2SS	45.00	47.50	27.18
Frustration	HG	32.50	27.50	25.12
Frustration	KB	18.89	15.00	19.33
Overall Workload	2SS	62.85	62.17	14.13
Overall Workload	HG	46.28	46.17	18.10
Overall Workload	KB	37.91	41.67	16.38

Significant main effects on mental workload.

Mental Workload	χ^2_2-value	p-value
Mental	16.60	<.001 *
Physical	10.21	0.0061 *
Temporal	23.43	<.001 *
Performance	23.91	<.001 *
Effort	10.64	0.0049 *
Frustration	9.76	0.0076 *
Overall Workload	12.76	0.0017 *

Post-hoc comparisons for Method.

Mental Workload	Method	Z-value	p-value
Mental	2SS-HG	2.00	0.045 *
Mental	2SS-KB	2.90	0.0066 *
Mental	HG-KB	2.30	0.038 *
Physical	2SS-HG	2.56	0.025 *
Physical	2SS-KB	2.30	0.038 *
Physical	HG-KB	1.08	0.30
Temporal	2SS-HG	2.76	0.0032 *
Temporal	2SS-KB	3.42	<.001 *
Temporal	HG-KB	3.27	<.001 *
Performance	2SS-HG	2.72	0.0046 *
Performance	2SS-KB	3.63	<.001 *
Performance	HG-KB	2.85	0.0058 *
Effort	2SS-HG	2.80	0.0097 *
Effort	2SS-KB	2.83	0.0058 *
Effort	HG-KB	0.48	0.65

Frustration	2SS-HG	1.88	0.12
Frustration	2SS-KB	3.39	<.001 *
Frustration	HG-KB	1.79	0.077
Overall Workload	2SS-HG	2.85	0.0056 *
Overall Workload	2SS-KB	3.34	<.001 *
Overall Workload	HG-KB	1.76	0.080