Embodied Navigation in Immersive Abstract Data Visualization: Is Overview+Detail or Zooming Better for 3D Scatterplots?

This document includes detailed statistic results for the submitted paper.

$p \leq 0.05$ is highlighted with

As described in the submission, we use the *linear mixed modeling* when the normality assumption is met. We model with/without overview and with/without zooming as two effects in our models. For the Distance task, we also model the difficulty (i.e., close vs. far, short for Diff). For the Count task, we do not have the level of difficulty. We include all interactions between effects in our models.

We use the *Friedman* test when the data did not meet the normality assumption.

1 Performance

1.1 Distance Task

1.1.1 Time

The results of linear mixed modeling are:

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)	
baseline	3	1855.4	1867.9	-924.71	1849.4				
zoomModel	4	1857.4	1874.1	-924.71	1849.4	0.0043	1	0.9475878	
overviewModel	5	1846.8	1867.6	-918.38	1836.8	12.6621	1	0.0003731	***
diffModel	6	1808.3	1833.4	-898.16	1796.3	40.4274	1	2.041e-10	***
zoomOverview	7	1809.6	1838.8	-897.78	1795.6	0.7649	1	0.3818079	
zoomDiff	8	1807.9	1841.3	-895.95	1791.9	3.6699	1	0.0554026	.
overviewDiff	9	1808.6	1846.2	-895.30	1790.6	1.2899	1	0.2560603	
interModel	10	1805.5	1847.2	-892.74	1785.5	5.1286	1	0.0235349	*

We can see the highest interaction level, i.e., interModel (with/without overview X with/without zooming X Diff) is statistically significant. We then conducted pair-wise comparisons with Tukey's HSD post-hoc tests:

contrast	estimate	SE	df	t.ratio	p.value
NoZoom,NoOverview,1 - Zoom,NoOverview,1	-0.6939	0.271	453	-2.560	0.1737
NoZoom,NoOverview,1 - NoZoom,Overview,1	-0.7803	0.271	453	-2.878	0.0794
NoZoom,NoOverview,1 - Zoom,Overview,1	-0.6253	0.271	453	-2.307	0.2921
NoZoom,NoOverview,1 - NoZoom,NoOverview,2	-1.2964	0.271	453	-4.783	0.0001
NoZoom,NoOverview,1 - Zoom,NoOverview,2	-0.8594	0.271	453	-3.171	0.0345
NoZoom,NoOverview,1 - NoZoom,Overview,2	-1.7732	0.271	453	-6.541	<.0001
NoZoom,NoOverview,1 - Zoom,Overview,2	-1.7092	0.271	453	-6.305	<.0001
Zoom,NoOverview,1 - NoZoom,Overview,1	-0.0864	0.271	453	-0.319	1.0000
Zoom,NoOverview,1 - Zoom,Overview,1	0.0686	0.271	453	0.253	1.0000
Zoom,NoOverview,1 - NoZoom,NoOverview,2	-0.6025	0.271	453	-2.223	0.3400
Zoom,NoOverview,1 - Zoom,NoOverview,2	-0.1656	0.271	453	-0.611	0.9987
Zoom,NoOverview,1 - NoZoom,Overview,2	-1.0793	0.271	453	-3.982	0.0020
Zoom,NoOverview,1 - Zoom,Overview,2	-1.0153	0.271	453	-3.745	0.0050
NoZoom,Overview,1 - Zoom,Overview,1	0.1550	0.271	453	0.572	0.9992
NoZoom,Overview,1 - NoZoom,NoOverview,2	-0.5162	0.271	453	-1.904	0.5487
NoZoom,Overview,1 - Zoom,NoOverview,2	-0.0792	0.271	453	-0.292	1.0000
NoZoom,Overview,1 - NoZoom,Overview,2	-0.9930	0.271	453	-3.663	0.0067
NoZoom,Overview,1 - Zoom,Overview,2	-0.9289	0.271	453	-3.427	0.0152
Zoom,Overview,1 - NoZoom,NoOverview,2	-0.6711	0.271	453	-2.476	0.2085
Zoom,Overview,1 - Zoom,NoOverview,2	-0.2342	0.271	453	-0.864	0.9890
Zoom,Overview,1 - NoZoom,Overview,2	-1.1479	0.271	453	-4.235	0.0007
Zoom,Overview,1 - Zoom,Overview,2	-1.0839	0.271	453	-3.999	0.0019
NoZoom,NoOverview,2 - Zoom,NoOverview,2	0.4370	0.271	453	1.612	0.7429
NoZoom,NoOverview,2 - NoZoom,Overview,2	-0.4768	0.271	453	-1.759	0.6483
NoZoom,NoOverview,2 - Zoom,Overview,2	-0.4128	0.271	453	-1.523	0.7950
Zoom,NoOverview,2 - NoZoom,Overview,2	-0.9138	0.271	453	-3.371	0.0183
Zoom,NoOverview,2 - Zoom,Overview,2	-0.8497	0.271	453	-3.135	0.0384
NoZoom,Overview,2 - Zoom,Overview,2	0.0640	0.271	453	0.236	1.0000

We are not interesting in the comparison of different visualizations in different difficulties (e.g., NoZoom,NoOverview,1 vs. Zoom,NoOverview,2 which is Rm in close vs. Zm in far). After deleting these results, we have significant comparisons within:

NoZoom,NoOverview,1 - NoZoom,NoOverview,2 => **Rm** in close vs. far
NoZoom,Overview,1 - NoZoom,Overview,2 => **RmO** in close vs. far
Zoom,Overview,1 - Zoom,Overview,2 => **ZmO** in close vs. far
Zoom,NoOverview,2 - NoZoom,Overview,2 => **Zm** vs. **RmO** in far
Zoom,NoOverview,2 - Zoom,Overview,2 => **Zm** vs. **ZmO** in far

1.1.2 Accuracy

We used Friedman test for comparing the accuracy.
For the Distance-Close task:

```
  Asymptotic Friedman Test

data:  accuracy by Vis (Rm, RmO, Zm, ZmO)
   stratified by UserName
chi-squared = 10.114, df = 3, p-value = 0.01762
```

The Post-hoc test:

```
$PostHoc.Test

RmO - Rm  0.03334459
Zm - Rm   0.99984650
ZmO - Rm  0.76092218
Zm - RmO  0.02670443
ZmO - RmO 0.30607470
ZmO - Zm  0.71674455
```

For the Distance-Far task:

```
  Asymptotic Friedman Test

data:  accuracy by Vis (Rm, RmO, Zm, ZmO)
   stratified by UserName
chi-squared = 0.15909, df = 3, p-value = 0.9839
```

1.2 Count Task

1.2.1 Time

We use the linear mixed modeling.

```
              Df    AIC    BIC  logLik deviance   Chisq Chi Df Pr(>Chisq)
baseline       3 1039.6 1050.9 -516.81   1033.6
zoomModel      4 1022.2 1037.3 -507.11   1014.2 19.3919      1  1.065e-05 ***
overviewModel  5 1018.2 1037.0 -504.10   1008.2  6.0191      1    0.01415 *
interModel     6 1013.7 1036.3 -500.87   1001.7  6.4672      1    0.01099 *
```

We then conduct pair-wise comparison:

```
$contrasts
 contrast                           estimate    SE  df t.ratio p.value
 NoZoom,NoOverview - Zoom,NoOverview -0.88320 0.176 297 -5.014  <.0001
 NoZoom,NoOverview - NoZoom,Overview -0.62575 0.176 297 -3.552  0.0025
 NoZoom,NoOverview - Zoom,Overview   -0.87523 0.176 297 -4.969  <.0001
 Zoom,NoOverview - NoZoom,Overview    0.25745 0.176 297  1.462  0.4621
 Zoom,NoOverview - Zoom,Overview      0.00798 0.176 297  0.045  1.0000
 NoZoom,Overview - Zoom,Overview     -0.24947 0.176 297 -1.416  0.4901
```

We have significant comparisons within:

NoZoom,NoOverview - Zoom,NoOverview => **Rm** vs. **Zm**
NoZoom,NoOverview - NoZoom,Overview => **Rm** vs. **RmO**
NoZoom,NoOverview - Zoom,Overview => **Rm** vs. **ZmO**

1.2.2 Accuracy

The Post-hoc test:

```
  Asymptotic Friedman Test

data:  accuracy by Vis (Rm, RmO, Zm, ZmO)
   stratified by UserName
chi-squared = 2.1579, df = 3, p-value = 0.5403
```

2 Interaction

2.1 Camera moving distance

2.1.1 Distance task

We use the linear mixed modeling:

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)	
baseline	3	1115.31	1127.68	-554.66	1109.31				
zoomModel	4	939.65	956.14	-465.83	931.65	177.6627	1	< 2.2e-16	***
overviewModel	5	939.61	960.22	-464.81	929.61	2.0402	1	0.15319	
diffModel	6	913.95	938.69	-450.98	901.95	27.6586	1	1.447e-07	***
zoomOverview	7	889.51	918.36	-437.75	875.51	26.4456	1	2.711e-07	***
zoomDiff	8	887.02	920.00	-435.51	871.02	4.4893	1	0.03411	*
overviewDiff	9	888.30	925.40	-435.15	870.30	0.7218	1	0.39555	
interModel	10	885.49	926.72	-432.75	865.49	4.8045	1	0.02839	*

We then conducted post-hoc test:

```
$contrasts
 contrast                                    estimate    SE  df t.ratio p.value
 NoZoom,NoOverview,1 - Zoom,NoOverview,1       0.9477 0.113 430   8.390 <.0001
 NoZoom,NoOverview,1 - NoZoom,Overview,1       0.2111 0.113 430   1.869 0.5732
 NoZoom,NoOverview,1 - Zoom,Overview,1         0.8133 0.113 430   7.200 <.0001
 NoZoom,NoOverview,1 - NoZoom,NoOverview,2     -0.6029 0.113 430  -5.337 <.0001
 NoZoom,NoOverview,1 - Zoom,NoOverview,2       0.8306 0.113 430   7.353 <.0001
 NoZoom,NoOverview,1 - NoZoom,Overview,2      -0.0498 0.113 430  -0.441 0.9999
 NoZoom,NoOverview,1 - Zoom,Overview,2         0.5457 0.113 430   4.831 0.0001
 Zoom,NoOverview,1 - NoZoom,Overview,1        -0.7366 0.113 430  -6.521 <.0001
 Zoom,NoOverview,1 - Zoom,Overview,1          -0.1344 0.113 430  -1.190 0.9346
 Zoom,NoOverview,1 - NoZoom,NoOverview,2      -1.5506 0.113 430 -13.727 <.0001
 Zoom,NoOverview,1 - Zoom,NoOverview,2        -0.1171 0.113 430  -1.037 0.9686
 Zoom,NoOverview,1 - NoZoom,Overview,2        -0.9974 0.113 430  -8.831 <.0001
 Zoom,NoOverview,1 - Zoom,Overview,2          -0.4020 0.113 430  -3.559 0.0098
 NoZoom,Overview,1 - Zoom,Overview,1           0.6022 0.113 430   5.331 <.0001
 NoZoom,Overview,1 - NoZoom,NoOverview,2      -0.8140 0.113 430  -7.206 <.0001
 NoZoom,Overview,1 - Zoom,NoOverview,2         0.6195 0.113 430   5.485 <.0001
 NoZoom,Overview,1 - NoZoom,Overview,2        -0.2609 0.113 430  -2.309 0.2908
 NoZoom,Overview,1 - Zoom,Overview,2           0.3346 0.113 430   2.962 0.0634
 Zoom,Overview,1 - NoZoom,NoOverview,2        -1.4161 0.113 430 -12.537 <.0001
 Zoom,Overview,1 - Zoom,NoOverview,2           0.0173 0.113 430   0.153 1.0000
 Zoom,Overview,1 - NoZoom,Overview,2          -0.8630 0.113 430  -7.641 <.0001
 Zoom,Overview,1 - Zoom,Overview,2            -0.2676 0.113 430  -2.369 0.2593
 NoZoom,NoOverview,2 - Zoom,NoOverview,2       1.4335 0.113 430  12.691 <.0001
 NoZoom,NoOverview,2 - NoZoom,Overview,2       0.5531 0.113 430   4.897 <.0001
 NoZoom,NoOverview,2 - Zoom,Overview,2         1.1485 0.113 430  10.168 <.0001
 Zoom,NoOverview,2 - NoZoom,Overview,2        -0.8804 0.113 430  -7.794 <.0001
 Zoom,NoOverview,2 - Zoom,Overview,2          -0.2849 0.113 430  -2.523 0.1887
 NoZoom,Overview,2 - Zoom,Overview,2           0.5954 0.113 430   5.271 <.0001
```

We again deleting the comparisons of different visualizations in different difficulties. We have significant comparisons within:

NoZoom,NoOverview,1 - Zoom,NoOverview,1 => **Rm** vs. **Zm** in close
NoZoom,NoOverview,1 - Zoom,Overview,1 => **Rm** vs. **ZmO** in close
Zoom,NoOverview,1 - NoZoom,Overview,1 => **Zm** vs. **RmO** in close
NoZoom,Overview,1 - Zoom,Overview,1 => **RmO** vs. **ZmO** in close
NoZoom,NoOverview,2 - Zoom,NoOverview,2 => **Rm** vs. **Zm** in far
NoZoom,NoOverview,2 - NoZoom,Overview,2 => **Rm** vs. **RmO** in far
NoZoom,NoOverview,2 - Zoom,Overview,2 => **Rm** vs. **ZmO** in far
Zoom,NoOverview,2 - NoZoom,Overview,2 => **Zm** vs. **RmO** in far

NoZoom,Overview,2 - Zoom,Overview,2 => **RmO** vs. **ZmO** in far

NoZoom,NoOverview,1 - NoZoom,NoOverview,2 => **Rm** in close vs. far

2.1.2 Count task

We use the linear mixed modeling.

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)	
baseline	3	512.31	523.46	-253.16	506.31				
zoomModel	4	334.26	349.13	-163.13	326.26	180.0494	1	<2e-16	***
overviewModel	5	334.53	353.12	-162.26	324.53	1.7295	1	0.1885	
interModel	6	336.05	358.36	-162.03	324.05	0.4762	1	0.4901	

We can see with/without zooming significantly affects the camera moving distance. The highest level of interaction model is not significant. The pair-wise comparisons reveal the same information: whether being able to zoom significantly affects the camera moving distance.

$contrasts

contrast	estimate	SE	df	t.ratio	p.value
NoZoom,NoOverview - Zoom,NoOverview	0.7634	0.0654	282	11.674	<.0001
NoZoom,NoOverview - NoZoom,Overview	-0.0289	0.0654	282	-0.442	0.9712
NoZoom,NoOverview - Zoom,Overview	0.6710	0.0654	282	10.261	<.0001
Zoom,NoOverview - NoZoom,Overview	-0.7923	0.0654	282	-12.115	<.0001
Zoom,NoOverview - Zoom,Overview	-0.0924	0.0654	282	-1.413	0.4924
NoZoom,Overview - Zoom,Overview	0.6999	0.0654	282	10.702	<.0001

We have significant comparisons within:

NoZoom,NoOverview - Zoom,NoOverview => **Rm** vs. **Zm**

NoZoom,NoOverview - Zoom,Overview => **Rm** vs. **ZmO**

Zoom,NoOverview - NoZoom,Overview => **Zm** vs. **RmO**

NoZoom,Overview - Zoom,Overview => **RmO** vs. **ZmO**

2.2 Number of interactions

2.2.1 Number of interactions

For the Distance task, we use the linear mixed modeling:

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)	
baseline	3	1151.1	1163.5	-572.57	1145.1				
zoomModel	4	1150.0	1166.5	-571.01	1142.0	3.1204	1	0.07732	.
overviewModel	5	1148.3	1168.9	-569.15	1138.3	3.7233	1	0.05366	.
diffModel	6	1149.9	1174.6	-568.93	1137.9	0.4341	1	0.51001	
zoomOverview	7	1145.6	1174.5	-565.81	1131.6	6.2452	1	0.01245	*
zoomDiff	8	1142.1	1175.1	-563.06	1126.1	5.4935	1	0.01909	*
overviewDiff	9	1144.1	1181.2	-563.06	1126.1	0.0001	1	0.99219	
interModel	10	1142.1	1183.3	-561.06	1122.1	4.0109	1	0.04521	*

We then conducted post-hoc test:

$contrasts

contrast	estimate	SE	df	t.ratio	p.value
NoZoom,NoOverview,1 - Zoom,NoOverview,1	-0.00174	0.149	430	-0.012	1.0000
NoZoom,NoOverview,1 - NoZoom,Overview,1	0.18517	0.149	430	1.244	0.9183
NoZoom,NoOverview,1 - Zoom,Overview,1	0.10544	0.149	430	0.708	0.9967
NoZoom,NoOverview,1 - NoZoom,NoOverview,2	-0.37144	0.149	430	-2.495	0.2003
NoZoom,NoOverview,1 - Zoom,NoOverview,2	0.27207	0.149	430	1.828	0.6016
NoZoom,NoOverview,1 - NoZoom,Overview,2	0.10871	0.149	430	0.730	0.9961
NoZoom,NoOverview,1 - Zoom,Overview,2	0.08136	0.149	430	0.547	0.9994
Zoom,NoOverview,1 - NoZoom,Overview,1	0.18691	0.149	430	1.255	0.9144
Zoom,NoOverview,1 - Zoom,Overview,1	0.10718	0.149	430	0.720	0.9964
Zoom,NoOverview,1 - NoZoom,NoOverview,2	-0.36970	0.149	430	-2.483	0.2053
Zoom,NoOverview,1 - Zoom,NoOverview,2	0.27381	0.149	430	1.839	0.5936
Zoom,NoOverview,1 - NoZoom,Overview,2	0.11045	0.149	430	0.742	0.9956
Zoom,NoOverview,1 - Zoom,Overview,2	0.08310	0.149	430	0.558	0.9993
NoZoom,Overview,1 - Zoom,Overview,1	-0.07972	0.149	430	-0.536	0.9995
NoZoom,Overview,1 - NoZoom,NoOverview,2	-0.55661	0.149	430	-3.739	0.0051
NoZoom,Overview,1 - Zoom,NoOverview,2	0.08690	0.149	430	0.584	0.9991
NoZoom,Overview,1 - NoZoom,Overview,2	-0.07646	0.149	430	-0.514	0.9996
NoZoom,Overview,1 - Zoom,Overview,2	-0.10381	0.149	430	-0.697	0.9970
Zoom,Overview,1 - NoZoom,NoOverview,2	-0.47689	0.149	430	-3.203	0.0313
Zoom,Overview,1 - Zoom,NoOverview,2	0.16663	0.149	430	1.119	0.9524
Zoom,Overview,1 - NoZoom,Overview,2	0.00327	0.149	430	0.022	1.0000

```
Zoom,Overview,1 - Zoom,Overview,2          -0.02408 0.149 430 -0.162  1.0000
NoZoom,NoOverview,2 - Zoom,NoOverview,2     0.64351 0.149 430  4.323  0.0005
NoZoom,NoOverview,2 - NoZoom,Overview,2     0.48015 0.149 430  3.225  0.0293
NoZoom,NoOverview,2 - Zoom,Overview,2       0.45281 0.149 430  3.042  0.0506
Zoom,NoOverview,2 - NoZoom,Overview,2      -0.16336 0.149 430 -1.097  0.9572
Zoom,NoOverview,2 - Zoom,Overview,2        -0.19071 0.149 430 -1.281  0.9056
NoZoom,Overview,2 - Zoom,Overview,2        -0.02735 0.149 430 -0.184  1.0000
```

We have significant comparisons within:

NoZoom,NoOverview,2 - Zoom,NoOverview,2 => **Rm** vs. **Zm** in far.

NoZoom,NoOverview,2 - NoZoom,Overview,2 => **Rm** vs. **RmO** in far.

For the Count task.

```
              Df    AIC    BIC  logLik deviance   Chisq Chi Df            Pr(>Chisq)
baseline       3 847.24 858.39 -420.62   841.24
zoomModel      4 744.79 759.66 -368.39   736.79 104.446      1            < 2.2e-16  ***
overviewModel  5 746.05 764.64 -368.03   736.05   0.736      1               0.3909
interModel     6 724.92 747.22 -356.46   712.92  23.131      1          0.000001513 ***
```

Pair-wise comparisons:

```
$contrasts
 contrast                              estimate    SE  df t.ratio p.value
 NoZoom,NoOverview - Zoom,NoOverview     -1.395 0.119 282 -11.691 <.0001
 NoZoom,NoOverview - NoZoom,Overview     -0.337 0.119 282  -2.824 0.0560
 NoZoom,NoOverview - Zoom,Overview       -0.908 0.119 282  -7.609 <.0001
 Zoom,NoOverview - NoZoom,Overview        1.058 0.119 282   8.867 <.0001
 Zoom,NoOverview - Zoom,Overview          0.487 0.119 282   4.082 0.0003
 NoZoom,Overview - Zoom,Overview          -0.571 0.119 282  -4.785 <.0001
```

We have significant comparisons within:

NoZoom,NoOverview - Zoom,NoOverview => **Rm** vs. **Zm**

NoZoom,NoOverview - Zoom,Overview => **Rm** vs. **ZmO**

Zoom,NoOverview - NoZoom,Overview => **Zm** vs. **RmO**

Zoom,NoOverview - Zoom,Overview => **Zm** vs. **ZmO**

NoZoom,Overview - Zoom,Overview => **RmO** vs. **ZmO**

2.2.2 Number of teleportation

For the Distance task, we use linear mixed modeling:

```
              Df     AIC     BIC  logLik deviance    Chisq Chi Df Pr(>Chisq)
baseline       3 1207.90 1220.27 -600.95  1201.90
zoomModel      4  982.11  998.60 -487.06   974.11 227.7892      1  < 2.2e-16 ***
overviewModel  5  984.09 1004.70 -487.04   974.09   0.0275      1    0.86826
diffModel      6  984.63 1009.37 -486.32   972.63   1.4551      1    0.22771
zoomOverview   7  955.62  984.47 -470.81   941.62  31.0157      1  2.559e-08 ***
zoomDiff       8  951.57  984.55 -467.79   935.57   6.0439      1    0.01395 *
overviewDiff   9  951.12  988.22 -466.56   933.12   2.4528      1    0.11732
interModel    10  952.32  993.55 -466.16   932.32   0.7979      1    0.37173
```

If we check the zoomOverview model with pair-wise comparisons:

```
$contrasts
 contrast                              estimate    SE  df t.ratio p.value
 NoZoom,NoOverview - Zoom,NoOverview      1.429 0.086 433  16.622 <.0001
 NoZoom,NoOverview - NoZoom,Overview      0.333 0.086 433   3.869 0.0007
 NoZoom,NoOverview - Zoom,Overview        1.076 0.086 433  12.510 <.0001
 Zoom,NoOverview - NoZoom,Overview       -1.096 0.086 433 -12.753 <.0001
 Zoom,NoOverview - Zoom,Overview         -0.353 0.086 433  -4.112 0.0003
 NoZoom,Overview - Zoom,Overview           0.743 0.086 433   8.641 <.0001
```

We have significant comparisons within:

NoZoom,NoOverview - Zoom,NoOverview => **Rm** vs. **Zm**

NoZoom,NoOverview - NoZoom,Overview => **Rm** vs. **RmO**

NoZoom,NoOverview - Zoom,Overview => **Rm** vs. **ZmO**

Zoom,NoOverview - NoZoom,Overview => **Zm** vs. **RmO**

Zoom,NoOverview - Zoom,Overview => **Zm** vs. **ZmO**

NoZoom,Overview - Zoom,Overview => **RmO** vs. **ZmO**

For the Count task, we use linear mixed modeling:

```
             Df    AIC    BIC  logLik deviance   Chisq Chi Df Pr(>Chisq)
baseline      3 686.35 697.50 -340.17   680.35
zoomModel     4 609.72 624.59 -300.86   601.72 78.6232      1  < 2.2e-16 ***
overviewModel 5 582.27 600.85 -286.13   572.27 29.4565      1  5.718e-08 ***
interModel    6 584.07 606.37 -286.03   572.07  0.1988      1     0.6557
```

We can see both with/without overview and with/without zooming affect the number of teleportation. Pair-wise comparisons also confirm:

```
$contrasts
 contrast                              estimate     SE  df t.ratio p.value
 NoZoom,NoOverview - Zoom,NoOverview    0.688 0.0934 282   7.364 <.0001
 NoZoom,NoOverview - NoZoom,Overview   -0.337 0.0934 282  -3.606 0.0021
 NoZoom,NoOverview - Zoom,Overview      0.292 0.0934 282   3.130 0.0103
 Zoom,NoOverview - NoZoom,Overview     -1.025 0.0934 282 -10.970 <.0001
 Zoom,NoOverview - Zoom,Overview       -0.396 0.0934 282  -4.233 0.0002
 NoZoom,Overview - Zoom,Overview        0.629 0.0934 282   6.736 <.0001
```

We have significant comparisons within:

NoZoom,NoOverview - Zoom,NoOverview => **Rm** vs. **Zm**
NoZoom,NoOverview - NoZoom,Overview => **Rm** vs. **RmO**
NoZoom,NoOverview - Zoom,Overview => **Rm** vs. **ZmO**
Zoom,NoOverview - NoZoom,Overview => **Zm** vs. **RmO**
Zoom,NoOverview - Zoom,Overview => **Zm** vs. **ZmO**
NoZoom,Overview - Zoom,Overview => **RmO** vs. **ZmO**

2.2.3 Number of zooming interactions

For the Distance task, we use linear mixed modeling:

```
             Df    AIC    BIC  logLik deviance  Chisq Chi Df Pr(>Chisq)
baseline      3 582.45 592.74 -288.23   576.45
overviewModel 4 583.76 597.48 -287.88   575.76 0.6920      1     0.4055
diffModel     5 585.11 602.26 -287.56   575.11 0.6464      1     0.4214
interModel    6 585.08 605.66 -286.54   573.08 2.0308      1     0.1541
```

For the Count task, we use linear mixed modeling as well:

```
             Df    AIC    BIC  logLik deviance  Chisq Chi Df   Pr(>Chisq)
baseline      3 413.75 422.82 -203.87   407.75
overviewModel 4 388.58 400.67 -190.29   380.58 27.169      1 0.0000001864 ***
```

There is a significant difference between **ZmO** and **Zm**.

2.3 Overview usage

2.3.1 Percentage of time looking at the overview

For the Distance task, we use linear mixed modeling:

```
           Df     AIC     BIC  logLik deviance    Chisq Chi Df Pr(>Chisq)
baseline    3  79.985  90.273 -36.992   73.985
visModel    4 -52.453 -38.736  30.226  -60.453 134.4376      1    < 2e-16 ***
diffModel   5 -51.865 -34.719  30.933  -61.865   1.4123      1    0.23467
interModel  6 -55.437 -34.861  33.719  -67.437   5.5718      1    0.01825 *
```

Pairwise comparisons reveal:

```
$contrasts
 contrast      estimate     SE  df t.ratio p.value
 RmO,1 - ZmO,1   0.2997 0.0368 206   8.136 <.0001
 RmO,1 - RmO,2  -0.0926 0.0368 206  -2.515 0.0605
 RmO,1 - ZmO,2   0.3299 0.0368 206   8.958 <.0001
 ZmO,1 - RmO,2  -0.3923 0.0368 206 -10.652 <.0001
 ZmO,1 - ZmO,2   0.0302 0.0368 206   0.821 0.8444
 RmO,2 - ZmO,2   0.4226 0.0368 206  11.473 <.0001
```

For the Count task, we also use the linear mixed modeling:

```
         Df     AIC     BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
baseline  3 -203.64 -194.57 104.82  -209.64
visModel  4 -240.01 -227.91 124.00  -248.01 38.368      1  5.859e-10 ***
```

The result indicates a significant difference between **RmO** and **ZmO**.

3 User rankings and ratings

3.1 Ranking

For the Distance task, we use the Friedman test:

```
      Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
       stratified by user
chi-squared = 12.06, df = 3, p-value = 0.00718
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.049722415
Zm - Rm   0.005363617
ZmO - Rm  0.203561935
Zm - RmO  0.883087957
ZmO - RmO 0.928187875
ZmO - Zm  0.532752114
```

For the Count task, we again use the Friedman test:

```
      Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
       stratified by user
chi-squared = 15.66, df = 3, p-value = 0.001331
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.6110631288
Zm - Rm   0.0008571373
ZmO - Rm  0.0419198741
Zm - RmO  0.0496862951
ZmO - RmO 0.6881364555
ZmO - Zm  0.4559519472
```

3.2 Overall usability

We use Friedman test:

```
      Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
       stratified by user
chi-squared = 19.732, df = 3, p-value = 0.0001929
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.002310403
Zm - Rm   0.000212506
ZmO - Rm  0.026041899
Zm - RmO  0.950659143
ZmO - RmO 0.883035785
ZmO - Zm  0.582421851
```

3.3 Ratings

3.3.1 Confidence

For the Distance task, we use the Friedman test:

```
  Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
   stratified by user
chi-squared = 11.265, df = 3, p-value = 0.01038
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.008155308
Zm - Rm   0.092222825
ZmO - Rm  0.078024309
Zm - RmO  0.832565609
ZmO - RmO 0.865691589
ZmO - Zm  0.999874506
```

For the Count task, we again use Friedman test:

```
  Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
   stratified by user
chi-squared = 5.3636, df = 3, p-value = 0.147
```

3.3.2 Physical demanding

For the Distance task, we use the Friedman test:

```
  Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
   stratified by user
chi-squared = 17.891, df = 3, p-value = 0.0004633
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.0160951833
Zm - Rm   0.0005098434
ZmO - Rm  0.0079289380
Zm - RmO  0.7711237171
ZmO - RmO 0.9961436807
ZmO - Zm  0.8809787869
```

For the Count task, we again use Friedman test:

```
  Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
   stratified by user
chi-squared = 32.419, df = 3, p-value = 0.0000004271
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.193350052196
Zm - Rm   0.000044940036
ZmO - Rm  0.000004655783
Zm - RmO  0.045553502612
ZmO - RmO 0.017381216517
ZmO - Zm  0.986207801596
```

3.3.3 Mental demanding

For the Distance task, we use the Friedman test:

```
  Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
   stratified by user
chi-squared = 3.8466, df = 3, p-value = 0.2785
```

For the Count task, we again use Friedman test:

```
  Asymptotic Friedman Test

data:  rank by vis (Rm, RmO, Zm, ZmO)
   stratified by user
chi-squared = 8.6978, df = 3, p-value = 0.03359
```

Post-hoc comparisons:

```
$PostHoc.Test

RmO - Rm  0.64250194
Zm - Rm   0.04961030
ZmO - Rm  0.04249676
Zm - RmO  0.59571749
ZmO - RmO 0.50203770
ZmO - Zm  0.99887033
```