

The Pointing and the Selecting System

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INTRODUCTION

This article discusses the process of designing and constructing a controlled experiment to analyze the pointing and the selecting system on a computer. This experiment intended to improve users' accuracy and efficiency using computer mice to select the target on their computer. Three techniques that might affect the selection were included in this experiment to determine whether the selection system was related to these factors. These techniques were selection method, real-time selection feedback (selection notification), and the number of targets on the screen. Each technique had three independent variables, respectively. This study involved three participants. After they completed the experiment, the result were analyzed and tested for further learning.

METHODOLOGY

First, I designed three techniques that I want to study in this experiment. They were selection method, real-time selection feedback (target color changes), and the number of targets on the screen.

The selection method stood for three different types of the mouse cursor: the point cursor, the area cursor, and the bubble cursor. The other selection method, the point cursor, was the traditional and the most common selection method in real life. Users needed to move the cursor to exactly where the targets were to make selection correctly. The area cursor provided a selection area for users. The target could be selected if it is covered in the area. Nevertheless, it worked as a point cursor if multiple targets were in the area. The bubble cursor gave users a dynamic selection area. The selection area would enlarge and shrink base on its distance to the target.

The second technique was the real-time selection feedback. It allowed targets to change its color while users were moving the cursor. I chose this technique because I wanted to study if the visibility of system status would affect selection accuracy and efficiency. Three independents variables were the same selection color, target click Change, and cursor select change. For the same color variable, the target's color would not change when the cursor can make the correct selection. The second variable, target click change, meant that only the accurate target color would be changed when users pointed the cursor to the target. The cursor selection change allowed users to have real-time feedback on which target they were pointing to. For circles that were not correct targets, the color would change to

green. If users were pointing to the correct target, the color changed to dark red.

I decided to change the number of the target on the screen. This technique was used to test whether the amount of information on a page could affect users' ability to choose the correct target. I categorized this technique into three independent variables: a few targets, a moderate number of targets, and a massive number of targets. Each of them had 10, 60, and 100 targets, respectively.

After designing three techniques that might affect target selection, I completed the JavaScript code to make a web page for the experiment and decided on the conditions' arrangement. Each condition would have five trials; five trials form a block. The experiment had 54 blocks in total. Rest breaks were allowed after one block had finished. I categorized these 27 conditions into three groups base on the selection method. Users were asked to fill in the current selection method in the experiment. Each selection method had nine conditions; these conditions would appear in the experiment randomly. After participants had finished 27 blocks, they were asked to complete this experiment again. This meant each selection method would be selected twice after they had finished 54 blocks. I designed the second round because participants' proficiency in the selection method might be changed. This might affect their reaction speed. Performing a second experiment could make the final result more accurate.

After participants had complete all the blocks, the data would be recorded automatically. The data recorded the participant number, the techniques and the trials for the current block, and their reaction time. The screen would also be recorded.

Three participants would participate in this experiment. It would take 15-20 minutes in total, and the experiment was done on a web page. They would be asked to sign a consent form in advance. The basic process of the experiment would be notified to the participants. These participants were randomly chosen, and they are all university students. They all had experience with the computer. I selected them randomly from one of my group chat. I thought they could participate in this study because young people are more receptive to new things. They were familiar with traditional selection methods, therefore changing the factors could determine whether the changes were efficient.

Three experiments were conducted online. I sent the participants a zip file, including the experiment website, the

consent form and a brief introduction to the experiment. I asked them to experiment with Zoom to keep track of their actions and take notes.

HYPOTHESIS

In this experiment, I guessed the selection method, selection notification, and the number of targets would affect users' reaction time to a certain extent. For instance, the number of targets on the screen might affect the reception time of information. Participants might spend more time finding the correct target, move the cursor to the target, etc. The number of targets also affected the cursor method. I thought the area cursor and the bubble cursor might be more efficient when there were few targets on a screen compared to many targets. It was because these two cursors would provide a broader selection area. Users did not need to point to the target accurately.

The color change might provide users with varying degrees of real-time feedback. For example, if the target was always the same color, users would not know whether they can click the target accurately. For bubble and area cursor, maybe the target was cover in the selection area already, and participants could not make the correct judgment. The color change for other circles that were not the proper target while moving might also cause the user to misjudge that the mouse has moved to the correct position. All these factors would cause delays in reaction time.

In brief, I thought the bubble cursor was the most efficient selection method, and the point cursor was the most accurate one. The bubble cursor allowed users to click the target in a larger area and reduced the cursor's moving time. In contrast, the preciseness of the point cursor minimized the risk of accidental clicks.

RESULTS AND ANALYSIS

Three files with the participant's number, techniques been used, trial number, and the reaction time had been recorded. The mean value for each condition has been calculated. The difference between the selected time was small; all the participant's reaction time was around 1 second. The third participant had a shorter reaction time; the time was less than 1 second for most conditions. The second participant took the longest time to select the correct target. Most of the reaction time was between 1-2 seconds, and a few of them had exceeded 2 seconds.

For the bubble cursor method, the average reaction time

Effect	df	SS	MS	F	p
Participant	2	2823502.673	1411751.336		
Selection method	2	653923.328	326961.664	1.195	0.3919
Selection method_x_Par	4	1094498.416	273624.604		
Selection notification	2	203676.479	101838.239	0.209	0.8194
Selection notification_x_Par	4	1945526.623	486381.656		
Number of targets	2	1929211.311	964605.656	5.629	0.0687
Number of targets_x_Par	4	685508.092	171377.023		
Selection method_x_Selection	4	412036.601	103009.150	1.454	0.3018
Selection method_x_Selection	8	566861.868	70857.734		
Selection method_x_Number of	4	26414.080	6603.520	0.254	0.8993
Selection method_x_Number of	8	208042.734	26005.342		
Selection notification_x_Num	4	691167.660	172791.915	0.581	0.6852
Selection notification_x_Num	8	2378970.730	297371.341		
Selection method_x_Selection	8	1387154.849	173394.356	1.861	0.1381
Selection method_x_Selection	16	1490364.283	93147.768		

Table 1. The ANOVA table for reaction time

was 1.30s, 1.72s, and 0.95s, respectively. The average reaction time for the point cursor was 1.1s, 1.04s, and 0.81s, respectively. It took 1.33s, 1.27s, and 0.90s to make a proper selection for the area cursor. Base on the result, the point cursor was the most efficient selection method for the participants (average 0.98s), followed by the area cursor (average 1.16s), and the bubble cursor took the longest time (average 1.32s). When participants received no real-time feedback for their pointing target, the average time was 1.01s, 1.46s, and 1.03s, respectively. If they were pointing at the correct target and the color changed, then the reaction time changed to 1.27s, 1.17s, and 0.92s. If all target color changed, the average reaction time became to 1.56s, 1.34s, and 0.87s. In general, the average selection time for three independent variables for the selection notification technique was 1.17s, 1.12s, and 1.26s. For the last technique: the number of targets on the screen, the average reaction time was 1.42s, 1.08s, and 1.04s. The result showed that when there were more targets on the screen, the reaction time decreased.

The rough data was then integrated into well-formatted data. The format was three-way with three within-subjects factors that could be analyzed in ANOVA. Method A, B, and C stood for three types of techniques. The average reaction time for the 27 conditions was formatted in the following order: A1B1C1, A1B1C2, A1B1C3, A1B2C1, A1B2C2, A1B2C3, A1B3C1, A1B3C2, A1B3C3, A2B1C1, A2B1C2, A2B1C3, A2B2C1, A2B2C2, A2B2C3, A2B3C1, A2B3C2, A2B3C3, A3B1C1, A3B1C2, A3B1C3, A3B2C1, A3B2C2, A3B2C3, A3B3C1, A3B3C2, A3B3C3. The number of participants was the number of rows of data. Detailed information can be found in the appendix.

According to table 1, the effect of selection methods ($F(2, 4) = 1.195, p > .05$), selection notification ($F(2, 4) = 0.209, ns$), and number of targets ($F(2, 4) = 5.629, p > .05$) on the reaction time were not statistically significant. This means that the differences between the results were large, and the results defied expectations. The difference between selection method and

selection notification was not statistically significant because the p-value was greater than 0.5 ($F(4, 8) = 1.454, p > .05$). Similar to the interaction between selection method and number of targets ($F(4, 8) = 0.254, ns$), and selection notification and number of targets ($F(4, 8) = 0.581, ns$), they were not statistically significant.

DISCUSSION

According to the result analysis, the experiment expectations were defied because the results were not statistically significant. The selection method, selection notification, and the number of targets did not affect participants’ reaction time.

I made several assumptions and tried to explain the result. Firstly, confounding variables might exist in the experiment. For example, participants’ personality might affect their reaction time. Some might move their mouse quickly; others might move their mouse to the target precisely. Moreover, due to the insufficient experimental samples, the results might be biased. Since all of the participants were familiar with the computer, their habits might affect their operations subconsciously. They would move the cursor to exactly where the target was even three types of selection methods were provided to participants. It was because they had used to the traditional cursor: point cursor.

It took a shorter time to react when there were more targets on the screen. In my perspective, this phenomenon formed because the distance between the targets was shorter. Participants could move their mouse to the next target quickly.

In summarize, the failure of the expectation might cause by several factors. The sample was not comprehensive, and confounding variables were not considered and controlled.

CONCLUSION

This report discuss the conduction of a controlled experiment to analyze the pointing and the selecting system on a computer. The format of the experiment was three-way with three within-subjects factors. Three techniques that might affect the selection time were conducted in the study: selection method, real-time selection feedback (selection notification), and the number of targets on the screen. Each techniques contained three independent variables. Therefore, there were 27 conditions.

Three participants were randomly chose online and completed the experiment through Zoom. All of the techniques were expected to have influence on computer mouse pointing and selecting. Nevertheless, the data and the ANOVA analysis

demonstrated that the effect of these techniques on the reaction time were not statistically significant. This indicated that the original hypothesis was defied.

There were several reasons which might be the cause of the incompatible result. Confounding variables might exist in the experiment. The number of participants were not sufficient so that the data was not comprehensive. Participants might have bias on the experiment because they were familiar to the computer operations. Their habits might affect their actions subconsciously, causing them to ignore the techniques in the experiment in some extent.

APPENDIX

● Appendix 1. ANOVA analysis

DV: Pointing and Selection
 F1: Selection method, Bubble, Point, Area
 F2: Selection notification, No change, Target Click Change, Cursor Selection Change
 F3: Number of targets, Few, Moderate, Many
 F4: ...
 F5: ...
 F6: ...
 F7: ...

911.9 874.2 1054.1 1189.4 1012.1 997.7 2938.4 1566.4 1012.8 1078.3 1088.9 1087.1 2270.5 871.5 1068.0 1741.8 1081.2 1014.5 1081.1 1118.9 1066.8 1488.8 1421.2 2079.9 1105.8 1019.4
 1001.4 1210.3 1039.1 1205.4 1112.4 1081.9 1081.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7 1101.7
 1105.4 949.0 877.3 897.4 835.1 895.6 894.8 774.5 806.9 1153.7 826.1 809.3 1011.7 879.3 742.7 822.3 920.8 777.5 1011.3 981.3 1066.1 1119.1 1058.4 842.8 811.3 901.1 909.7

ANOVA table for Pointing and Selection	df	SS	MS	F	p
Participant	2	2021902.473	1010951.236		
Selection method	2	433937.128	216968.564	1.195	0.3039
Selection method_x_Par	4	109408.416	27352.104		
Selection notification	2	209476.479	104738.239	0.209	0.8104
Selection notification_x_Par	4	134536.423	33634.106		
Number of targets	2	132921.111	66460.556	5.429	0.0007
Number of targets_x_Par	4	48508.092	12127.023		
Selection method_x_Selection	4	42380.401	10595.100	1.454	0.3008
Selection method_x_Selection_x_Par	8	94861.888	11857.736		
Selection method_x_Selection_x_Par	4	26545.908	6636.477	0.254	0.8995
Selection method_x_Selection_x_Par	4	20042.744	5010.686		
Selection notification_x_Selection	4	491167.668	122791.915	0.581	0.6852
Selection notification_x_Selection_x_Par	8	273899.798	34237.475		
Selection method_x_Selection_x_Par	8	1387154.649	173394.356	1.861	0.1381
Selection method_x_Selection_x_Par	4	449946.203	112487.550		

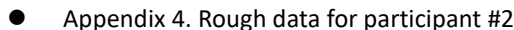
Sum of squares: Total: 2021902.473
 Error: 1010951.236
 Total: 3032853.709

Summary statistics:
 The effect of selection method on pointing and selection was not statistically significant ($F(2, 4) = 1.195, p > .05$).
 The effect of selection notification on pointing and selection was not statistically significant ($F(2, 4) = 0.209, p > .05$).
 The effect of number of targets on pointing and selection was not statistically significant ($F(2, 4) = 5.429, p > .05$).
 The selection method_x_selection notification interaction effect was not statistically significant ($F(4, 8) = 1.454, p > .05$).
 The selection method_x_number of targets interaction effect was not statistically significant ($F(4, 8) = 0.254, p > .05$).
 The selection notification_x_number of targets interaction effect was not statistically significant ($F(4, 8) = 0.581, p > .05$).

● Appendix 2. Rough data for participant #1

participant	trial	technique	time	1	0	BUBBLE	B3	C3	1192	1	0	POINT	B3	C1	1072		
1	0	AREA	B3	C1	1886	1	1	BUBBLE	B3	C3	1568	1	1	POINT	B3	C1	1088
1	1	AREA	B3	C1	2033	1	2	BUBBLE	B3	C3	688	1	2	POINT	B3	C1	736
1	2	AREA	B3	C1	1183	1	3	BUBBLE	B3	C3	1024	1	3	POINT	B3	C1	872
1	3	AREA	B3	C1	1155	1	4	BUBBLE	B3	C3	1052	1	4	POINT	B3	C1	698
1	4	AREA	B3	C1	1406	1	0	BUBBLE	B2	C2	903	1	0	POINT	B3	C2	1585
1	0	AREA	B1	C1	1136	1	1	BUBBLE	B2	C2	1329	1	1	POINT	B3	C2	918
1	1	AREA	B1	C1	840	1	2	BUBBLE	B2	C2	1097	1	2	POINT	B3	C2	760
1	2	AREA	B1	C1	1432	1	3	BUBBLE	B2	C2	1105	1	3	POINT	B3	C2	1112
1	3	AREA	B1	C1	984	1	4	BUBBLE	B2	C2	862	1	4	POINT	B3	C2	856
1	4	AREA	B1	C1	1016	1	0	BUBBLE	B1	C1	1153	1	0	POINT	B3	C3	815
1	0	AREA	B2	C1	1143	1	1	BUBBLE	B1	C1	864	1	1	POINT	B3	C3	1048
1	1	AREA	B2	C1	960	1	2	BUBBLE	B1	C1	912	1	2	POINT	B3	C3	986
1	2	AREA	B2	C1	857	1	3	BUBBLE	B1	C1	1183	1	3	POINT	B3	C3	727
1	3	AREA	B2	C1	1035	1	4	BUBBLE	B1	C1	784	1	4	POINT	B3	C3	681
1	4	AREA	B2	C1	1069	1	0	BUBBLE	B1	C2	815	1	0	AREA	B3	C1	13965
1	0	AREA	B2	C2	1327	1	1	BUBBLE	B1	C2	906	1	1	AREA	B3	C1	896
1	1	AREA	B2	C2	3052	1	2	BUBBLE	B1	C2	1031	1	2	AREA	B3	C2	885
1	2	AREA	B2	C2	2745	1	3	BUBBLE	B1	C2	768	1	3	AREA	B3	C1	938
1	3	AREA	B2	C2	1112	1	4	BUBBLE	B1	C2	840	1	4	AREA	B3	C1	1648
1	4	AREA	B2	C2	1816	1	0	BUBBLE	B1	C3	1224	1	0	AREA	B3	C2	961
1	0	AREA	B3	C2	2039	1	1	BUBBLE	B1	C3	1088	1	1	AREA	B3	C2	1208
1	1	AREA	B3	C2	1577	1	2	BUBBLE	B1	C3	1056	1	2	AREA	B3	C2	720
1	2	AREA	B3	C2	1000	1	3	BUBBLE	B1	C3	1216	1	3	AREA	B3	C2	1229
1	3	AREA	B3	C2	1198	1	4	BUBBLE	B1	C3	928	1	4	AREA	B3	C2	943
1	4	AREA	B3	C2	883	1	0	BUBBLE	B2	C3	1073	1	0	AREA	B2	C1	754
1	0	AREA	B3	C3	1704	1	1	BUBBLE	B2	C3	1071	1	1	AREA	B2	C1	1063
1	1	AREA	B3	C3	1376	1	2	BUBBLE	B2	C3	913	1	2	AREA	B2	C1	969
1	2	AREA	B3	C3	904	1	3	BUBBLE	B2	C3	864	1	3	AREA	B2	C1	950
1	3	AREA	B3	C3	1177	1	4	BUBBLE	B2	C3	736	1	4	AREA	B2	C1	1068
1	4	AREA	B3	C3	1144	1	0	POINT	B2	C1	13631	1	0	AREA	B3	C3	1088
1	0	AREA	B2	C3	1192	1	1	POINT	B2	C1	921	1	1	AREA	B3	C3	801
1	1	AREA	B2	C3	1584	1	2	POINT	B2	C1	859	1	2	AREA	B3	C3	840
1	2	AREA	B2	C3	2648	1	3	POINT	B2	C1	1084	1	3	AREA	B3	C3	681
1	3	AREA	B2	C3	1248	1	4	POINT	B2	C1	766	1	4	AREA	B3	C3	879
1	4	AREA	B2	C3	968	1	0	POINT	B2	C1	766	1	4	AREA	B3	C3	879
1	0	AREA	B1	C2	871	1	0	POINT	B1	C1	994	1	0	AREA	B1	C1	1024
1	1	AREA	B1	C2	928	1	1	POINT	B1	C1	897	1	1	AREA	B1	C1	952
1	2	AREA	B1	C2	1201	1	2	POINT	B1	C1	1229	1	2	AREA	B1	C1	944
1	3	AREA	B1	C2	800	1	3	POINT	B1	C1	1088	1	3	AREA	B1	C1	976
1	4	AREA	B1	C2	1015	1	4	POINT	B1	C1	1344	1	4	AREA	B1	C1	927
1	0	AREA	B1	C3	1920	1	0	POINT	B1	C2	993	1	0	AREA	B1	C2	809
1	1	AREA	B1	C3	1464	1	1	POINT	B1	C2	943	1	1	AREA	B1	C2	888
1	2	AREA	B1	C3	1016	1	2	POINT	B1	C2	993	1	2	AREA	B1	C2	952
1	3	AREA	B1	C3	840	1	3	POINT	B1	C2	751	1	3	AREA	B1	C2	1808
1	4	AREA	B1	C3	1008	1	4	POINT	B1	C2	769	1	4	AREA	B1	C2	869
1	0	AREA	B1	C3	1920	1	0	POINT	B1	C3	1064	1	0	AREA	B1	C3	833
1	1	AREA	B1	C3	1464	1	1	POINT	B1	C3	1036	1	1	AREA	B1	C3	846
1	2	AREA	B1	C3	1048	1	2	POINT	B1	C3	899	1	2	AREA	B1	C3	814
1	3	AREA	B1	C3	1136	1	3	POINT	B1	C3	817	1	3	AREA	B1	C3	882
1	4	AREA	B1	C3	976	1	4	POINT	B1	C3	823	1	4	AREA	B1	C3	1461
1	0	BUBBLE	B3	C1	20254	1	0	POINT	B1	C3	1064	1	0	AREA	B1	C3	833
1	1	BUBBLE	B3	C1	2032	1	1	POINT	B1	C3	1036	1	1	AREA	B1	C3	846
1	2	BUBBLE	B3	C1	1048	1	2	POINT	B1	C3	899	1	2	AREA	B1	C3	814
1	3	BUBBLE	B3	C1	1136	1	3	POINT	B1	C3	817	1	3	AREA	B1	C3	882
1	4	BUBBLE	B3	C1	976	1	4	POINT	B1	C3	823	1	4	AREA	B1	C3	1461
1	0	BUBBLE	B3	C2	1287	1	0	POINT	B2	C2	966	1	0	AREA	B2	C2	1128
1	1	BUBBLE	B3	C2	1079	1	1	POINT	B2	C2	1016	1	1	AREA	B2	C2	1056
1	2	BUBBLE	B3	C2	1491	1	2	POINT	B2	C2	1096	1	2	AREA	B2	C2	847
1	3	BUBBLE	B3	C2	968	1	3	POINT	B2	C2	832	1	3	AREA	B2	C2	864
1	4	BUBBLE	B3	C2	800	1	4	POINT	B2	C2	1040	1	4	AREA	B2	C2	967
1	0	BUBBLE	B2	C1	1057	1	0	POINT	B2	C3	864	1	0	AREA	B2	C3	1335
1	1	BUBBLE	B2	C1	2143	1	1	POINT	B2	C3	1058	1	1	AREA	B2	C3	793
1	2	BUBBLE	B2	C1	736	1	2	POINT	B2	C3	1286	1	2	AREA	B2	C3	1856
1	3	BUBBLE	B2	C1	1144	1	3	POINT	B2	C3	960	1	3	AREA	B2	C3	888
1	4	BUBBLE	B2	C1	899	1	4	POINT	B2	C3	1280	1	4	AREA	B2	C3	1708

- Appendix 3. Consent form for participant #1



Participant	trial	technique	time	time	2	0	POINT	B3	C2	908	2	0	AREA	B2	C3	1987	
2	0	BURBLE	B3	C1	2481	2	1	POINT	B3	C2	1007	2	0	AREA	B2	C3	1981
2	0	BURBLE	B3	C1	3175	2	0	POINT	B3	C2	999	2	1	AREA	B2	C3	981
2	2	BURBLE	B3	C1	2269	2	2	POINT	B3	C2	907	2	2	AREA	B2	C3	1089
2	3	BURBLE	B3	C1	3075	2	4	POINT	B3	C2	1255	2	4	AREA	B2	C3	1657
2	4	BURBLE	B3	C1	2598	2	0	POINT	B3	C2	1452	2	0	AREA	B3	C2	1790
2	0	BURBLE	B2	C1	2119	2	1	POINT	B3	C3	851	2	1	AREA	B3	C2	1072
2	1	BURBLE	B2	C1	1518	2	2	POINT	B3	C3	1064	2	2	AREA	B3	C2	1058
2	2	BURBLE	B2	C1	2267	2	3	POINT	B3	C3	1261	2	3	AREA	B3	C2	1022
2	3	BURBLE	B2	C1	1684	2	4	POINT	B3	C3	1395	2	4	AREA	B3	C2	1368
2	4	BURBLE	B2	C1	2080	2	0	POINT	B1	C2	1088	2	0	AREA	B3	C3	1846
2	0	BURBLE	B1	C1	2565	2	1	POINT	B1	C2	734	2	1	AREA	B3	C3	1551
2	1	BURBLE	B1	C1	1517	2	2	POINT	B1	C2	950	2	2	AREA	B3	C3	892
2	2	BURBLE	B1	C1	1584	2	3	POINT	B1	C2	947	2	3	AREA	B3	C3	1229
2	3	BURBLE	B1	C1	2053	2	4	POINT	B1	C2	1082	2	4	AREA	B3	C3	1138
2	4	BURBLE	B1	C1	1577	2	0	POINT	B1	C3	875	2	0	BURBLE	B1	C3	6278
2	0	BURBLE	B3	C2	2029	2	1	POINT	B1	C3	841	2	1	BURBLE	B1	C3	1188
2	1	BURBLE	B3	C2	2543	2	2	POINT	B1	C3	1031	2	2	BURBLE	B1	C3	965
2	2	BURBLE	B3	C2	3099	2	3	POINT	B1	C3	998	2	3	BURBLE	B1	C3	957
2	3	BURBLE	B3	C2	2492	2	4	POINT	B1	C3	1335	2	4	BURBLE	B1	C3	1230
2	4	BURBLE	B3	C2	2433	2	0	POINT	B2	C2	1023	2	0	BURBLE	B2	C1	1477
2	0	BURBLE	B2	C2	1808	2	1	POINT	B2	C2	998	2	1	BURBLE	B2	C1	1205
2	1	BURBLE	B2	C2	1361	2	2	POINT	B2	C2	973	2	2	BURBLE	B2	C1	1832
2	2	BURBLE	B2	C2	1863	2	3	POINT	B2	C2	1016	2	3	BURBLE	B2	C1	1369
2	3	BURBLE	B2	C2	1222	2	4	POINT	B2	C2	989	2	4	BURBLE	B2	C1	1394
2	4	BURBLE	B2	C2	1147	2	0	POINT	B2	C3	1377	2	0	BURBLE	B2	C2	1107
2	0	BURBLE	B3	C3	1317	2	1	POINT	B2	C3	1198	2	1	BURBLE	B2	C2	1247
2	1	BURBLE	B3	C3	817	2	2	POINT	B2	C3	1030	2	2	BURBLE	B2	C2	956
2	2	BURBLE	B3	C3	1526	2	3	POINT	B2	C3	1205	2	3	BURBLE	B2	C2	962
2	3	BURBLE	B3	C3	1120	2	4	POINT	B2	C3	810	2	4	BURBLE	B2	C2	1568
2	4	BURBLE	B3	C3	1188	2	0	AREA	B1	C1	6350	2	0	BURBLE	B1	C2	1478
2	0	BURBLE	B1	C1	1403	2	1	AREA	B1	C1	1057	2	1	BURBLE	B1	C2	1370
2	1	BURBLE	B1	C1	1073	2	2	AREA	B1	C1	1467	2	2	BURBLE	B1	C2	1237
2	2	BURBLE	B1	C1	1014	2	3	AREA	B1	C1	1311	2	3	BURBLE	B1	C2	835
2	3	BURBLE	B1	C1	1740	2	4	AREA	B1	C1	1090	2	4	BURBLE	B1	C2	1096
2	4	BURBLE	B1	C1	1130	2	0	AREA	B2	C1	1446	2	0	BURBLE	B2	C3	1509
2	0	BURBLE	B1	C3	1303	2	1	AREA	B2	C1	941	2	1	BURBLE	B2	C3	1023
2	1	BURBLE	B1	C3	1671	2	1	AREA	B2	C1	940	2	2	BURBLE	B2	C3	1402
2	2	BURBLE	B1	C3	1376	2	2	AREA	B2	C1	1147	2	3	BURBLE	B2	C3	1098
2	3	BURBLE	B1	C3	1262	2	3	AREA	B2	C1	1172	2	4	BURBLE	B2	C3	956
2	4	BURBLE	B1	C3	1197	2	0	AREA	B1	C2	1007	2	0	BURBLE	B1	C3	1304
2	0	BURBLE	B2	C3	1594	2	1	AREA	B1	C2	908	2	1	BURBLE	B1	C3	1114
2	1	BURBLE	B2	C3	1187	2	2	AREA	B2	C2	842	2	2	BURBLE	B3	C1	1664
2	2	BURBLE	B2	C3	834	2	3	AREA	B1	C2	1203	2	3	BURBLE	B3	C1	975
2	3	BURBLE	B2	C3	1453	2	4	AREA	B1	C2	915	2	4	BURBLE	B3	C1	1085
2	4	BURBLE	B2	C3	830	2	0	AREA	B1	C3	1611	2	0	BURBLE	B3	C2	1742
2	0	POINT	B1	C1	6112	2	1	AREA	B1	C3	1121	2	1	BURBLE	B3	C2	973
2	1	POINT	B1	C1	1057	2	2	AREA	B1	C3	1203	2	2	BURBLE	B3	C2	1254
2	2	POINT	B1	C1	1144	2	3	AREA	B1	C3	1484	2	3	BURBLE	B3	C2	1701
2	3	POINT	B1	C1	826	2	4	AREA	B1	C3	117	2	4	BURBLE	B3	C2	1518
2	4	POINT	B1	C1	823	2	0	AREA	B2	C2	1221	2	0	BURBLE	B3	C3	1208
2	0	POINT	B3	C1	1583	2	1	AREA	B2	C2	1007	2	1	BURBLE	B3	C3	1164
2	1	POINT	B3	C1	1254	2	2	AREA	B2	C2	1667	2	2	BURBLE	B3	C3	1131
2	2	POINT	B3	C1	865	2	3	AREA	B2	C2	1162	2	3	BURBLE	B3	C3	936
2	3	POINT	B3	C1	1948	2	4	AREA	B2	C2	1279	2	4	BURBLE	B3	C3	1448
2	4	POINT	B3	C1	816	2	0	AREA	B3	C1	1491	2	0	BURBLE	B1	C3	1518
2	0	POINT	B2	C1	957	2	1	AREA	B3	C1	943	2	1	BURBLE	B1	C3	1468
2	1	POINT	B2	C1	931	2	2	AREA	B3	C1	1162	2	2	BURBLE	B1	C3	1182
2	2	POINT	B2	C1	990	2	3	AREA	B3	C1	117	2	3	BURBLE	B1	C3	1228
2	3	POINT	B2	C1	1409	2	4	AREA	B3	C1	1286	2	4	BURBLE	B1	C3	1146
2	4	POINT	B2	C1	767	2	0	AREA	B3	C1	1286	2	0	BURBLE	B1	C3	1182

- Appendix 5. Consent form for participant #2



UNIVERSITY OF TORONTO

Toronto, Canada M5S 1G4

Research Consent Form

Course Instructor: Tovi Grossman (tovi@dgp.toronto.edu)

Student Investigator: Yufei Ye (yufei.ye@mail.utoronto.ca)

Affiliation: Department of Computer Science, University of Toronto

You are invited to participate in a controlled experiment to test an interactive system, as part of a course assignment for CSC428/2514. Your decision to participate is voluntary and you are free to withdraw at any time. You are not required to answer any questions you do not feel comfortable answering. You are not required to complete any task you do not feel comfortable completing. There will be no negative consequences for withdrawing or not completing any tasks or questions. There are no conditions for the withdrawal of your data if you do choose to withdraw.

I understand the following:

- The purpose of the study is to understand the performance an interactive system in supporting various tasks.
- I will be asked to participate in a controlled experiment requiring me to provide input to a typical computer system, such as a laptop, computer or mobile device.
- I have been asked to participate as someone who would exhibit typical behaviors with interactive technologies.
- I will be participating in a study lasting approximately 30 minutes.
- The study can take place either in person or remotely, a convenient location of my choosing. The study can only occur in person if the university is allowing in-person human research. More information on the current state of Human Research at University of Toronto can be found here: <https://www.utoronto.ca/ethics/online>
- The researchers do not foresee any risks or stresses beyond what one might experience in day-to-day living and interacting with typical computer systems.
- By participating in this study you will be helping me with my university education. No other direct benefits are associated with the study.
- I will not be compensated for participating in the study.
- All data collected about me will be kept secure. In all data files, my name and identifying features will be removed and replaced with a code in order to preserve my confidentiality. Only myself, the course instructor, and TAs, will have access to the information I provide. The data collected will be destroyed after the end of the current course semester.
- Video and audio recordings or frame grabs of the session may be used in my course assignment, which will be submitted to the course and seen by the course instructor and teaching assistants. I am free to consent or not consent to their usage without any negative consequences, as per the options provided below (check one option below):
 - ☐ Yes: Video and audio recordings or frame grabs of the session may be used
 - ☐ No: Video and audio recordings or frame grabs of the session may not be used

- Data collected will not be used for any purpose other than the preparation and submission of the associated course assignment. In the course assignment, my name will not be used and will be replaced with an identifier (e.g., Participant 1).
- I do not meet any of the exclusion criteria of the study – I am 18-65 years old, have normal or corrected to normal vision, and no major physical impairments.
- I am free to ask questions about the process at any time. I can ask questions in person, or by contacting the course instructor, Tovi Grossman at tovi@gdp.toronto.edu or by telephone at (416)974-7673.
- If requested, I will receive a copy of this form for my records.
- To learn more about the course I am taking, you can visit the website: <https://fas.calander.utoronto.ca/course/csc428b1>

The research study you are participating in may be reviewed for quality assurance to make sure that the required laws and guidelines are followed. If chosen, (a) representative(s) of the Human Research Ethics Program (HREP) may access study-related data and/or consent materials as part of the review. All information accessed by the HREP will be upheld to the same level of confidentiality that has been stated by the research team.

If you have any questions about your rights as a participant, please contact the Ethics Review Office at ethics.review@utoronto.ca or (416) 946-3273

Participant's Printed Name Yutong Han

Participant's Signature [Signature]Date 04/11/20 Participant # 2 Experimenter's Initials Y. J. Y.

- Appendix 6. Rough data for participant #3

Participant	trial	technique	C1	time30	z	0	POINT	B2	C1	730	z	0	AREA	B3	C1	1148	
3	0	BURBLE	B2	C1	1232	3	1	POINT	B2	C1	768	3	1	AREA	B3	C1	820
3	2	BURBLE	B2	C1	819	3	2	POINT	B2	C1	623	3	2	AREA	B3	C1	765
3	3	BURBLE	B2	C1	1451	3	3	POINT	B2	C1	665	3	3	AREA	B3	C1	980
3	4	BURBLE	B2	C1	1095	3	4	POINT	B2	C1	1112	3	4	AREA	B3	C1	729
3	4	BURBLE	B2	C1	1284	3	4	POINT	B2	C1	1112	3	4	AREA	B3	C1	729
3	0	BURBLE	B1	C1	2086	3	0	POINT	B1	C3	930	3	0	AREA	B3	C2	1634
3	1	BURBLE	B1	C1	986	3	1	POINT	B1	C3	1191	3	1	AREA	B3	C2	920
3	2	BURBLE	B1	C1	1081	3	2	POINT	B1	C3	959	3	2	AREA	B3	C2	942
3	3	BURBLE	B1	C1	896	3	3	POINT	B1	C3	892	3	3	AREA	B3	C2	962
3	4	BURBLE	B1	C1	896	3	4	POINT	B1	C3	1185	3	4	AREA	B3	C2	831
3	4	BURBLE	B1	C1	934	3	4	POINT	B1	C3	1185	3	4	AREA	B3	C2	831
3	0	BURBLE	B2	C2	1077	3	0	POINT	B2	C2	953	3	0	AREA	B3	C3	94
3	1	BURBLE	B2	C2	1149	3	1	POINT	B2	C2	847	3	1	AREA	B3	C3	754
3	2	BURBLE	B2	C2	823	3	2	POINT	B2	C2	1176	3	2	AREA	B3	C3	754
3	3	BURBLE	B2	C2	969	3	3	POINT	B2	C2	998	3	3	AREA	B3	C3	807
3	4	BURBLE	B2	C2	969	3	4	POINT	B2	C2	720	3	4	AREA	B3	C3	952
3	4	BURBLE	B2	C2	914	3	4	POINT	B2	C2	720	3	4	AREA	B3	C3	952
3	0	BURBLE	B1	C2	1124	3	0	POINT	B2	C3	962	3	0	AREA	B1	C1	7722
3	1	BURBLE	B1	C2	1003	3	1	POINT	B2	C3	749	3	1	AREA	B1	C1	732
3	2	BURBLE	B1	C2	965	3	2	POINT	B2	C3	873	3	2	AREA	B1	C1	747
3	3	BURBLE	B1	C2	1259	3	3	POINT	B2	C3	668	3	3	AREA	B1	C1	1318
3	4	BURBLE	B1	C2	1259	3	4	POINT	B2	C3	927	3	4	AREA	B1	C1	784
3	4	BURBLE	B1	C2	1259	3	4	POINT	B2	C3	927	3	4	AREA	B1	C1	784
3	0	BURBLE	B1	C3	1132	3	0	POINT	B3	C2	1029	3	0	AREA	B3	C1	859
3	1	BURBLE	B1	C3	1048	3	1	POINT	B3	C2	1312	3	1	AREA	B3	C1	825
3	2	BURBLE	B1	C3	798	3	2	POINT	B3	C2	986	3	2	AREA	B3	C1	728
3	3	BURBLE	B1	C3	1012	3	3	POINT	B3	C2	786	3	3	AREA	B3	C1	700
3	4	BURBLE	B1	C3	741	3	4	POINT	B3	C2	709	3	4	AREA	B3	C1	599
3	4	BURBLE	B1	C3	741	3	4	POINT	B3	C2	709	3	4	AREA	B3	C1	599
3	0	BURBLE	B3	C1	755	3	0	POINT	B3	C3	757	3	0	AREA	B2	C1	889
3	1	BURBLE	B3	C1	1368	3	1	POINT	B3	C3	1091	3	1	AREA	B2	C1	700
3	2	BURBLE	B3	C1	1278	3	2	POINT	B3	C3	788	3	2	AREA	B2	C1	738
3	3	BURBLE	B3	C1	1810	3	3	POINT	B3	C3	827	3	3	AREA	B2	C1	679
3	4	BURBLE	B3	C1	1362	3	4	POINT	B3	C3	732	3	4	AREA	B2	C1	722
3	4	BURBLE	B3	C1	1362	3	4	POINT	B3	C3	732	3	4	AREA	B2	C1	722
3	0	BURBLE	B2	C3	1251	3	0	AREA	B2	C1	3849	3	0	AREA	B2	C2	949
3	1	BURBLE	B2	C3	979	3	1	AREA	B2	C1	965	3	1	AREA	B2	C2	683
3	2	BURBLE	B2	C3	719	3	2	AREA	B2	C1	976	3	2	AREA	B2	C2	855
3	3	BURBLE	B2	C3	1149	3	3	AREA	B2	C1	869	3	3	AREA	B2	C2	943
3	4	BURBLE	B2	C3	1270	3	4	AREA	B2	C1	1004	3	4	AREA	B2	C2	900
3	4	BURBLE	B2	C3	1270	3	4	AREA	B2	C1	1004	3	4	AREA	B2	C2	900
3	0	BURBLE	B3	C2	815	3	0	AREA	B2	C2	1509	3	0	AREA	B3	C2	756
3	1	BURBLE	B3	C2	935	3	1	AREA	B2	C2	1379	3	1	AREA	B3	C2	724
3	2	BURBLE	B3	C2	716	3	2	AREA	B2	C2	767	3	2	AREA	B3	C2	622
3	3	BURBLE	B3	C2	1007	3	3	AREA	B2	C2	1909	3	3	AREA	B3	C2	732
3	4	BURBLE	B3	C2	808	3	4	AREA	B2	C2	750	3	4	AREA	B3	C2	1209
3	4	BURBLE	B3	C2	808	3	4	AREA	B2	C2	750	3	4	AREA	B3	C2	1209
3	0	BURBLE	B3	C3	847	3	0	AREA	B1	C1	936	3	0	AREA	B3	C4	946
3	1	BURBLE	B3	C3	887	3	1	AREA	B1	C1	763	3	1	AREA	B3	C4	871
3	2	BURBLE	B3	C3	827	3	2	AREA	B1	C1	729	3	2	AREA	B3	C4	947
3	3	BURBLE	B3	C3	824	3	3	AREA	B1	C1	684	3	3	AREA	B3	C4	757
3	4	BURBLE	B3	C3	849	3	4	AREA	B1	C1	866	3	4	AREA	B3	C4	720
3	4	BURBLE	B3	C3	849	3	4	AREA	B1	C1	866	3	4	AREA	B3	C4	720
3	0	POINT	B1	C1	3574	3	0	AREA	B2	C3	1524	3	0	AREA	B1	C2	1189
3	1	POINT	B1	C1	648	3	1	AREA	B2	C3	808	3	1	AREA	B1	C2	827
3	2	POINT	B1	C1	941	3	2	AREA	B2	C3	708	3	2	AREA	B1	C2	875
3	3	POINT	B1	C1	1048	3	3	AREA	B2	C3	750	3	3	AREA	B1	C2	774
3	4	POINT	B1	C1	851	3	4	AREA	B2	C3	861	3	4	AREA	B1	C2	871
3	4	POINT	B1	C1	851	3	4	AREA	B2	C3	861	3	4	AREA	B1	C2	871
3	0	POINT	B3	C1	765	3	0	AREA	B1	C2	999	3	0	AREA	B1	C3	181
3	1	POINT	B3	C1	969	3	1	AREA	B1	C2	917	3	1	AREA	B1	C3	1203
3	2	POINT	B3	C1	1043	3	2	AREA	B1	C2	838	3	2	AREA	B1	C3	921
3	3	POINT	B3	C1	7155	3	3	AREA	B1	C2	855	3	3	AREA	B1	C3	944
3	4	POINT	B3	C1	933	3	4	AREA	B1	C2	891	3	4	AREA	B1	C3	1275
3	4	POINT	B3	C1	933	3	4	AREA	B1	C2	891	3	4	AREA	B1	C3	1275
3	0	POINT	B1	C2	1047	3	0	AREA	B1	C3	1594	3	0	AREA	B2	C4	842
3	1	POINT	B1	C2	716	3	1	AREA	B1	C3	960	3	1	AREA	B2	C4	746
3	2	POINT	B1	C2	664	3	2	AREA	B1	C3	722	3	2	AREA	B2	C4	703
3	3	POINT	B1	C2	737	3	3	AREA	B1	C3	798	3	3	AREA	B2	C4	716
3	4	POINT	B1	C2	772	3	4	AREA	B1	C3	1133	3	4	AREA	B2	C4	776

- Appendix 7. Consent form for participant #3

- The research study you are participating in may be reviewed for quality assurance to make sure that the required laws and guidelines are followed. If chosen, (a) representative(s) of the Human Research Ethics Program (HREP) may access study-related data and/or consent materials as part of the review. All information accessed by the HREP will be upheld to the same level of confidentiality that has been stated by the research team.

Participant's Printed Name Mingxian Chen
Participant's Signature [Signature]
Date Nov 2 Participant # 3 Experimenter's Initials YY



Course Instructor: Tovi Grossman (tovi@dgp.toronto.edu)
Student Investigator: Yufei Ye (yufei.ye@mail.utoronto.ca)

You are invited to participate in a controlled experiment to test an interactive system, as part of a course assignment for CSC428/2514. Your decision to participate is voluntary and you are free to withdraw at any time. You are not required to answer any questions you do not feel comfortable answering. You are not required to complete any task you do not feel comfortable completing. There will be no negative consequences for withdrawing or not completing any tasks or questions. There are no conditions for the withdrawal of your data if you do choose to withdraw.

- The purpose of this study is to understand the performance an interactive system in supporting various tasks.
- I will be asked to participate in a controlled experiment requiring me to provide input to a typical computer system, such as a laptop, computer or mobile device.
- I have been asked to participate as someone who would exhibit typical behaviors with interactive technologies.
- I will be participating in a study lasting approximately 30 minutes.
- The study can take place either in person or remotely, a convenient location of my choosing. The study can only occur in person if the university is allowing in-person human research. More information on the current state of Human Research at University of Toronto can be found here: <https://research.utoronto.ca/ethics/12>
- The researchers do not foresee any risks or stresses beyond what one might experience in day-to-day living and interacting with typical computer systems.
- By participating in this study you will be helping me with my university education. No other direct benefits are associated with the study.
- I will not be compensated for participating in the study.
- All data collected about me will be kept secure. In all data files, my name and identifying features will be removed and replaced with a code in order to preserve my confidentiality. Only myself, the course instructor, and TAS, will have access to the information I provide. The data collected will be destroyed after the end of the current course semester.
- Video and audio recordings or frame grabs of the session may be used in my course assignments which will be submitted to the course and seen by the course instructor and teaching assistants. I am free to consent or not consent to their usage without any negative consequences, as per the options provided below (check one option below):
 - ☐ Yes: Video and audio recordings or frame grabs of the session may be used
 - ☐ No: Video and audio recordings or frame grabs of the session may not be used