The Efficiency of Item Selection in Cascading Menus: An Empirical Evaluation of Three Interaction Modalities

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***Abstract*—On most menus actions of moving and selecting are executed with moving the mouse and clicking the left mouse button. This research paper examines is that really the most efficient and fastest way in compare with keyboard and scroll-wheel. In addition, we wanted to show how the speed and effectiveness of a particular modality depends on the complexity of the menu and examine does the certain complexity can be easier used with keyboard or mouse-wheel selecting. The study included 12 students who needed to perform tasks of selecting an item when given full item path. Mouse modality indeed turned to be the fastest as well as the most learnable. But, unlike with mouse, no mistakes were made while testing Keyboard. Scroll modality did not prove to be the worthy alternative to keyboard and mouse.**

***Keywords*—Pull-down menu, Menu Complexity, Modality, Mouse Input, Keyboard Input, Scroll wheel Input, Usability Attributes, Selection efficiency, Selection speed;**

I. Introduction

Selecting an item in a typical pull-down menu using a mouse as a pointing device requires user to move a mouse cursor in order to navigate the menu and to click left mouse button in order to select the desired choice. The advantage of cursor is the ease of learning and comfort, and disadvantage is that it is slow for menus with many items [1]. Some pull-down menus thus also support keyboard navigation (using arrow keys and return key for selection).

In addition to these two interaction modalities a not-typical modality is introduced- navigation using solely scroll wheel. Moving up or down the menu item list is performed by rotating the wheel in desired direction and selection is performed by clicking the wheel.

This research tests the assumption that navigation using a mouse is the fastest and most efficient (in terms of not choosing unintended choice) in comparison to the keyboard modality and the scroll wheel modality. There is a need to test the idea (assumption) in an empirical evaluation.

User performance also depends on complexity of the menu. In a complex menu system (as is cascading pull-down menu) with many choices and many levels in the hierarchy it is difficult to find the desired item [1]. Also, for inexperienced user using a mouse for navigating cascading menus it can be very hard to get to next level as the "gate" are quite tight Figure1. Therefore, user performance on three mentioned modalities should be tested on simple (not cascading), medium-complex and highly-complex menu (both cascading). This makes total of nine conditions. Menu complexity was defined considering number of choices (menu items) and number of levels. (The details are under subsection Design-Menu Complexity).

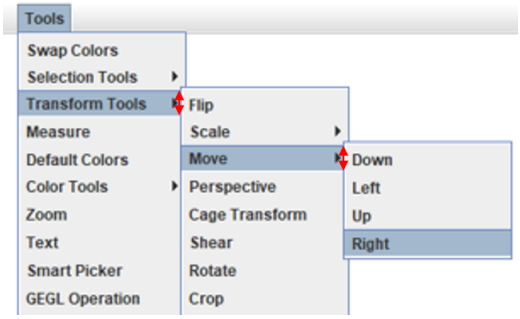

Fig. 1. For inexperienced user using a mouse for navigating cascading menus it can be very hard to get to next level as the "gate" (red arrows) are quite tight

II. Method

A. Participants

The study included 12 Participants, all of which were university students. Age range was 20-27. 50% were female and 50% were male.

B. Apparatus

1) Hardware: Participants interacted with the experiment application on Hp Laptop 15-bs0xx with a 1536 x 864 screen resolution ruining Windows 10 and JVM 9. Wireless Bluetooth Logitech mouse - model M185 was used. Default values in Windows 10 Mouse properties (speed = 6 notches, Enhanced Pointer precision checked).

2) Software: Experiment used application with custom interface developed in Java programming language, using Swing library. Eclipse IDE was used. The code was written in a way that should make it easy for future developer to change or add menus, redefine or define new complexities, increase number of tasks (task paths per condition), change item texts, all without interfering with test procedure.

Application takes two arguments, first is modality group (0-5) and menu group (1 or 2), which refer to counterbalancing groups explained lower in report under Counterbalancing subsection. (Disclaimer: Counterbalancing groups inside program were defined considering 3 levels of complexity and modality. If one wishes to add more or exclude complexity levels mentioned arguments no longer apply and counterbalancing has to be redefined).

C. Procedure

Participants volunteered without pay. At the start participants were given a demonstration of the interaction. They were then asked to practice the interaction minimum 5 trials each modality (more if they felt the need). The researcher moderating the session observed the participants during the practice period and advised them to only use the assigned modality.

Questionnaire before testing - regarding previous experience

Before testing participants were asked which modality they prefer using in everyday interaction: Mouse, Keyboard, Mouse Touchpad or other. 9 stated they prefer using Mouse, 2 stated they prefer using keyboard and 1 preferred using Laptop touchpad. They were also asked to answer questions on experience in using "click on the scroll wheel". Only 4 participants stated that in common use (Browser, IDE, games..) they use "click on scroll wheel" very often or always, while the rest 8 use it seldom or never. Nevertheless, when asked to rate how much they think they are used to clicking on scroll wheel on 5-point Likert scale majority of 7 chose 4 or 5. Average accustomedness to clicking the scroll wheel was 3,417. (See Figure 2). (Participants also completed one more questionnaire after testing).

1) Task: The task was: Read the path in the frame title. When ready click "Start" to position cursor (and start measuring time). Using given modality navigate the given path in given menu and select correct option. The goal was to select correct option as fast as possible. In case a participant failed to choose the correct option, task had to be performed again while time continued to be measured until the right choice was made. Each participant performed 5 such tasks in each of 9 condition. Average time was taken in account when conducting tests over data. Total of 45 tasks. The total time for testing each participant was 10 to 15 minutes.

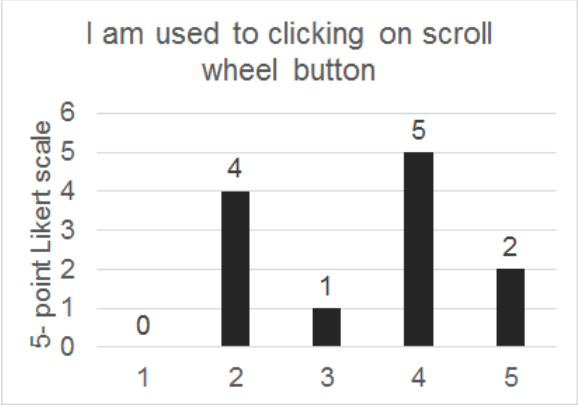

Fig. 2. 8/12 participants claimed they use click on scroll wheel "rarely" or "never". Nevertheless, 7/12 participants rated their accustomedness to clicking a scroll button 4 or 5

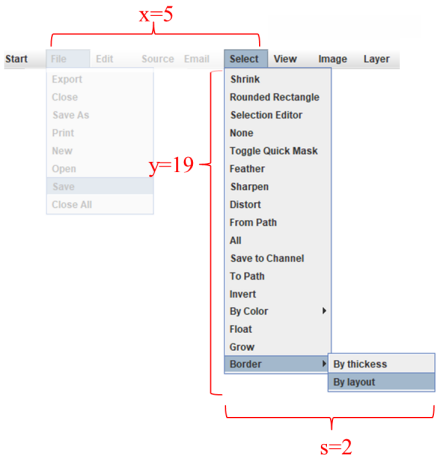

Fig. 3. Example of path properties - x, y and s

2) Path definition: Each path is defined by its properties- x - index number of first-level-menu in menu ribbon, y sum of items on the way to final choice, s number of levels. See figure 3 for example.

For each of 3 simple pull-down menus (one for each modality), from all possible paths, 5 random paths are chosen as tasks. For each of 3 medium-complex pull-down menus (one for each modality), from all possible paths, 5 random paths with property $y >= 15$ are chosen as tasks. For each of 3 highly-complex pull-down menus (one for each modality), from all possible paths, 3 random paths with property s = 3 and 2 random paths with property $y >= 15$ and $x > 45$ are chosen as tasks.

Defining paths using this properties could perhapse be of good use in developing predictive KML model for keyboard modality or predicting time using The Fitts Law for mouse modality[5].

Questionnaire after testing regarding personal ranking and Usability Attributes

Except questions regarding experience in using "click on scroll wheel" as mentioned in Participants subsection participants completed questionnaire after taking test.

They were ask to rank modalities based on preference and evaluate usability attributes (Ease of Use, Learnability and Satisfaction) of each modality.

D. Design

The experiment was 3 x 3 within-subject design. Independent Variables are Menu Complexity and Modality. Each has 3 levels. Dependent variables are Time and Error.

E. Modality

1) Mouse: As one hovers a menu in ribbon or menu list it opens. To select item one hovers over item and clicks the right mouse button.

2) Keyboard: This research does not cover Keyboard Shortcuts. Navigation is done only using arrow keys, opening next level is performed by clicking right arrow key, final selection is performed using return key. As one travels the menus in ribbon or menu list current menu opens.

3) Scroll Wheel: Moving right or left in the ribbon is performed by rotating the wheel up or down. As one travels the menus in ribbon current menu opens. Moving up or down the menu item list is performed by rotating the wheel in desired direction, opening next level and final selection is performed by clicking the wheel.

F. Menu Complexity

We defined a *simple menu* as a menu consisting of 5 first-level-menus in menu ribbon, and 2 to 8 items in each first-level-menu, *medium-complex menu* as a menu with 5 first-level-menus in the ribbon, each with 10 to 17 choices, some of which open second-level-menus with 2 to 13 choices. Finally, the *highly-complex menu* we defined as a menu consisting of 9 first-level-menus in ribbon, with 10 to 17 choices each, some of which lead to second and then third-level-menus respectively. Figure 14 and Figure 13

G. Counterbalancing using Latin Square

Participants were divided in 6 groups in order to avoid order effect in modality results. Each group was than split into two more, to avoid order effect in menu complexity results.

M- Mouse, K- Keyboard, S- Scroll Wheel

1- Easy, 2- Medium, 3- Hard

1. MKS 123 321 231, MKS 312 213 132
2. SMK 123 321 231, SMK 312 213 132
3. KSM 123 321 231, KSM 312 213 132
4. MSK 123 321 231, MSK 312 213 132
5. KMS 123 321 231, KMS 312 213 132
6. SKM 123 321 231, SKM 312 213 132

Total number of trials administered in the experiment is 12*9*5= 540 (calculation that includes the number of participants (12) and the variables (3*3) and repetitions(5)).

III. Results and Discussion

Two-way ANOVA between-subjects (also known as repeated measurements) test was conducted using IBM's SPSS software.

A. Inferential Statistics

On figure 4 is Mauchly's Test of Sphericity, which showed that sphericity is disturbed for modality of interection.

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
mode	.448	8.022	2	.018	.644	.693	.500
menu	.649	4.319	2	.115	.740	.828	.500
mode * menu	.228	13.941	9	.130	.639	.850	.250

Fig. 4. Mauchly's Test of Sphericity

After conducted Two-way ANOVA and Greenhouse-Gaisser correction ($\varepsilon = 0.644$) we can conclude there is significant difference in the speed of selection depending on modality of interaction (figure 5). F (1.289, 14.178) = 12.366, $p < 0.05$.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
mode	Sphericity Assumed	411.679	2	205.839	12.366	.000	.529
	Greenhouse-Geisser	411.679	1.289	319.394	12.366	.002	.529
	Huynh-Feldt	411.679	1.387	296.857	12.366	.002	.529
	Lower-bound	411.679	1.000	411.679	12.366	.005	.529
Error(mode)	Sphericity Assumed	366.207	22	16.646			
	Greenhouse-Geisser	366.207	14.178	25.829			
	Huynh-Feldt	366.207	15.255	24.006			
	Lower-bound	366.207	11.000	33.292			

Fig. 5. Tests of Within-Subjects Effects

In order to know between which modalities of interaction there is a significant difference, we conduced post hoc analysis with Bonfferoni correction which showed there is significant difference of interaction between first modality - mouse (6.293 ± 0.479) and second modality - keyboard (8.254 ± 0.620), [6.293 ± 0.479 vs 8.254 ± 0.620; $p < 0.05$].

Post hoc analysis with Bonfferoni correction showed second significant difference between first - mouse (6.293 ± 0.479) and third modality of interaction (11.051 ± 1.488). [6.293 ± 0.479 vs 11.051 ± 1.488; $p < 0.05$]

However, there is no significant difference between keyboard (8.254 ± 0.620) and scroll wheel (11.051 ± 1.488), where p is 0.078.

Estimates and Pairwise Comparisons are showed in figures 6 and 7.

Mauchly's Test of Sphericity, which was on figure 4 showed that sphericity is not disturbed for complexity of menu nor for interaction between modalities. On figure 8 we see Tests of Within-Subjects Effects for menu complexity for which is F(2,22) = 39.694; $p < 0.001$

In order to know between which menu complexities there is a significant difference, we conduced post hoc analysis with Bonfferoni correction which showed there

Estimates

Measure: MEASURE_1

mode	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	6.293	.479	5.239	7.347
2	8.254	.620	6.890	9.618
3	11.051	1.488	7.776	14.326

Fig. 6. Estimates

Pairwise Comparisons

Measure: MEASURE_1

(I) mode	(J) mode	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-1.961*	.495	.007	-3.356	-.566
	3	-4.758*	1.161	.005	-8.032	-1.484
2	1	1.961*	.495	.007	.566	3.356
	3	-2.797	1.087	.078	-5.863	.269
3	1	4.758*	1.161	.005	1.484	8.032
	2	2.797	1.087	.078	-.269	5.863

Fig. 7. Pairwise Comparisons

Pairwise Comparisons

Measure: MEASURE_1

(I) mode	(J) mode	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-1.961*	.495	.007	-3.356	-.566
	3	-4.758*	1.161	.005	-8.032	-1.484
2	1	1.961*	.495	.007	.566	3.356
	3	-2.797	1.087	.078	-5.863	.269
3	1	4.758*	1.161	.005	1.484	8.032
	2	2.797	1.087	.078	-.269	5.863

Fig. 8. Tests of Within-Subjects Effects

is significant difference between simple menu (4.393 $\pm$ 0.416) and medium-complexity menu (9.818 $\pm$ 0.416.), [4.393 $\pm$ 0.416 vs 9.818 $\pm$ 0.416; $p < 0.001$].

Post hoc analysis with Bonfferoni correction showed second significant difference between simple menu (4.393 $\pm$ 0.416) and hard-complexity menu (11.387 $\pm$ 1.213), [4.393 $\pm$ 0.416 vs 11.387 $\pm$ 1.213; $p < 0.001$].

However, there is no significant difference between keyboard (8.254 $\pm$ 0.620) and scroll wheel (11.051 $\pm$ 1.488), where p is 0.078.

B. Errors

No tests were conducted on collected data on errors due to small amount of errors in general. Figure 9 shows Sum of Errors made during testing for Each condition. Participants majority of errors were made while using Scroll-Wheel modality. The most interesting fact is that there were no Errors made using Keyboard! It is arguable that the mouse used in this experiment influenced the results. Also, returning to previous level in case of choosing incorrect menu was not possible while using Scroll Wheel. Researchers truly regard not implementing this option.

Fig. 9. Sum of Errors

C. Personal ranking

Participants were asked to rank modalities based on preference. The means and standard errors on Figure 10 show that participants preferred Mouse over Keyboard and possibly Scroll Wheel, and preferred Keyboard and Scroll Wheel equally. Further tests were conducted to test significance. Significant differences were proven using Friedman and Wilcoxon Signed-Rank Test with Bonfferoni adjustment of significance level 0.05 / 3 = 0.017. Mentioned tests were conducted using IBM's SPSS software following [3] [4].

Friedman test showed that there was statistically significant difference in perceived ranking of modalities with $\chi^2(2) = 6.453$, p = 0.040.

Wilcoxon Signed-Rank Test showed that there was a statistically significant difference found in perceived ranking of modalities Mouse and Keyboard, Z = -2.495, p = 0.013 (< 0.017). Users preferred Mouse over Keyboard. There was NO statistically significant difference found in perceived ranking of modalities Mouse and Scroll Wheel, Z = -1.815, p = 0.070 nor Keyboard and Scroll Wheel, Z = -0.247, p = 0.805.

D. Usability Attributes

Participants were asked to rate 3 usability Attributes - usability, learnability and satisfaction of each modality on 5-point Likert scale. The Means and standard errors are shown on Figure 11 and Median, quartiles, minimum and maximum values on Figure 12. Further tests were conducted to test significant difference. Significant differences were proven using Friedman and Wilcoxon Signed-Rank Test with Bonferroni adjustment of significance level 0.05 / 3 = 0.017. Mentioned tests were conducted using IBM's SPSS software following [3] [4].

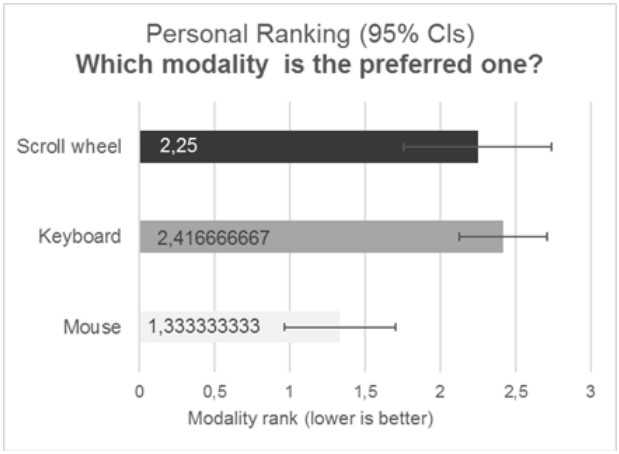

Fig. 10. Personal ranking

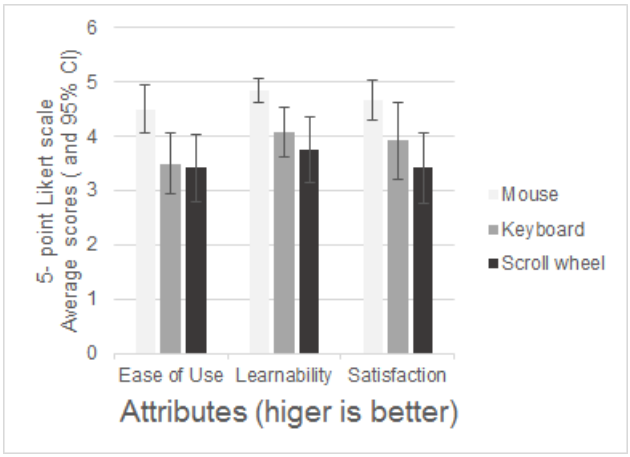

Fig. 11. Attributes

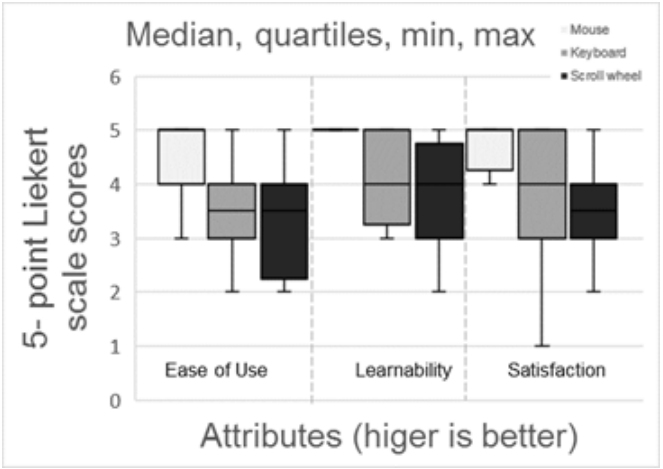

Fig. 12. Attributes Box Plot

1) Ease of Use: Friedman test showed that there was statistically significant difference in perceived Ease of use with $\chi^2(2) = 9.135$, p = 0.010.*Wilcoxon Signed-Rank Test* showed that there was a statistically significant difference found in perceived Ease of use depending on which modality, Scroll Wheel or Mouse, was used: Z = -2.360, p = 0.010. There was NO statistically significant difference found in perceived Ease of Use depending on which modality, Keyboard or Mouse, was used: Z = -2.565, p = 0.018 nor Scroll Wheel or Keyboard, Z = -1.22, p = 0.903.

2) Learnability: Friedman test showed that there was statistically significant difference in perceived Learnability with $\chi^2(2) = 10{,}364$, p = 0.0006.*Wilcoxon Signed-Rank Test* showed that there was a statistically significant difference found in Learnability depending on which modality, Keyboard or Mouse, was used: Z = -2.460, p = 0.014, as well as Scroll-Wheel or Mouse: Z = -2.565, p = 0.010. There was NO statistically significant difference found in perceived Learnability depending on which modality, Scroll Wheel or Keyboard, was used : Z = -0.857, p = 0.391.

3) Satisfaction: Friedman test showed that there was statistically significant difference in perceived Satisfaction with $\chi^2(2) = 8{,}581$, p = 0.014.*Wilcoxon Signed-Rank Test* showed that there was a statistically significant difference found in perceived Satisfaction depending on which modality, Scroll Wheel or Mouse, was used: Z = -2.565, p = 0.010. Users preferred Mouse over Scroll wheel. There was NO statistically significant difference found in perceived Satisfaction depending on which modality, Keyboard or Mouse, was used: Z = -1,543, p = 0.123 nor Scroll Wheel or Keyboard, Z = -1.196, p = 0.232.

IV. Conclusion

In this experiment we tested the efficiency of item selection in cascading menus conducting an empirical evaluation of three interaction modalities- Mouse, Keyboard and Scroll Wheel. The study included 12 Participants, all of which were university students. Each of them was tested on all 9 conditions by preforming tasks of selecting an item when given full item path. Two-way ANOVA within-subjects (also known as repeated measurements) test was conducted using IBM's SPSS software. They were asked to answer questions regarding previous experience in using the mouse wheel, perceived usability attributes (ease of use, learnability, satisfaction) and personal ranking of interaction modalities.

Mouse modality indeed turned out to be the fastest, as well as the most learnable. But, unlike with mouse, no mistakes were made while testing Keyboard! Scroll modality did not prove to be the worthy alternative to keyboard and mouse but we assume many mistakes were made because ability to get back to previous level in cascading menu was or the ribbon was not well thought nor implemented at the end. Still, through observation of participants researchers concluded that action of clicking

the mouse wheel was hard for them, so mistakes were not due to lack of concentration but rather accidentally preforming scroll while clicking the wheel. It would be interesting to conduct the experiment on participants who have less or no experience in using a mouse.

ACKNOWLEDGMENT

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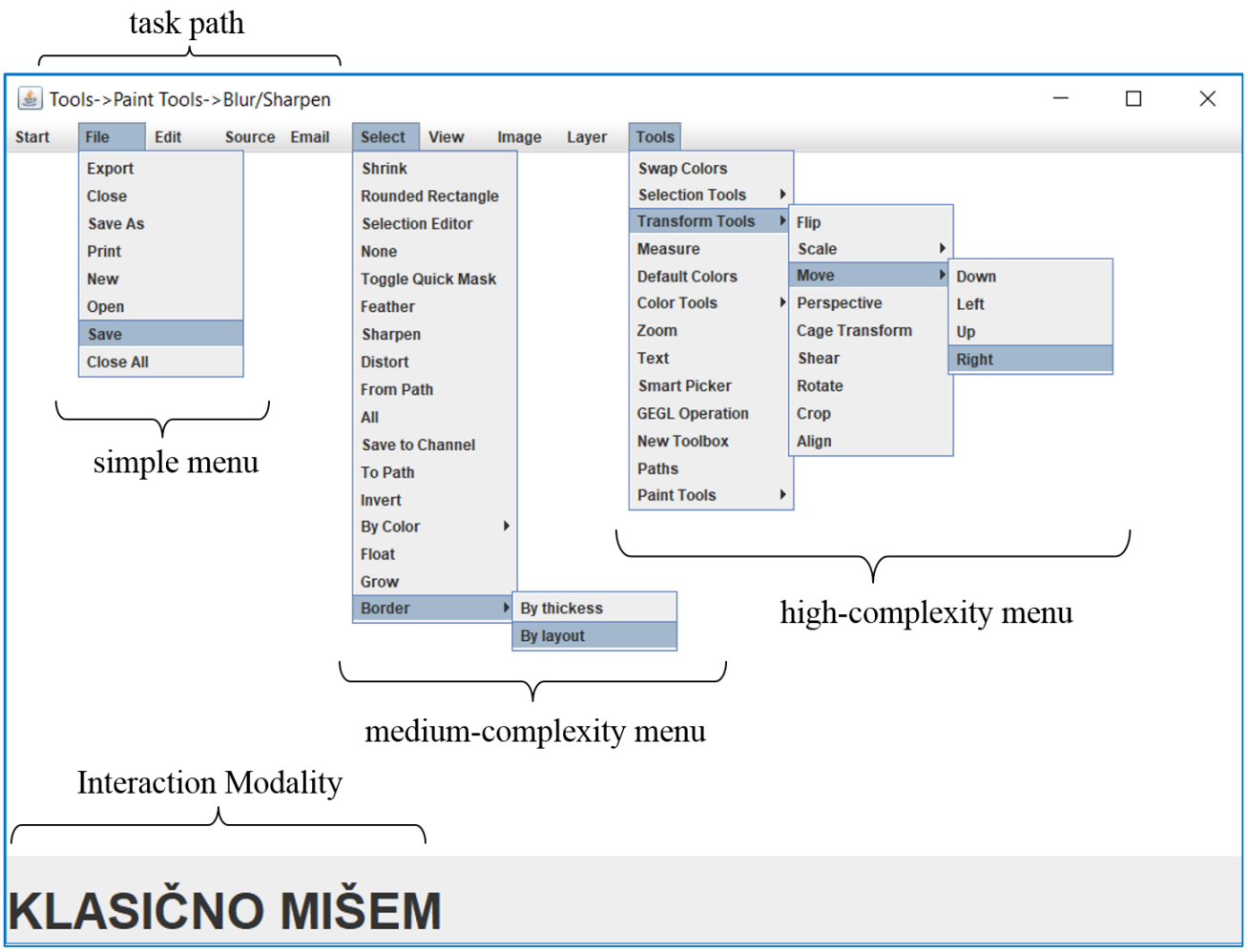

Fig. 13. Application GUI : Task path is displayed in frame title, current interaction modality at the bottom of frame. This pull down menu participants used for trails before actual testing to accommodate to interaction. See actual ribbons on the Figure below.

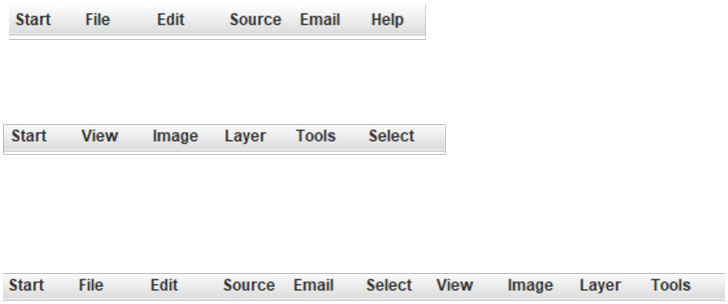

Fig. 14. Actual ribbons: from top: simple pull-down menu, medium-complexity pull-down menu, high-complexity pull-down menu