Radial Menus – Comparison of Two Selection Methods

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ABSTRACT

In today's time, menus are essential when operating applications. One way to improve the operation time of menus is the usage of radial menus. These can be implemented with different selection techniques which can enhance the usability of radial menus even further. In this paper we compare a direct and a lazy selection technique for radial menus with one hierarchy level and explore whether the selection technique has a significant effect on the operation time and the error rate. Furthermore, we were interested in the subjective preferences of the participants of the study.

Our results show no significant difference between the two selection techniques in operation time and error rate. However, the lazy selection technique was preferred by the majority of the participants.

1 INTRODUCTION

Nowadays, applications grow in their complexity and provide more and more features and operations that need to be accessible for the user. Most often this is accomplished by using cascading menus. However, with this type of menu, the user often needs to navigate long paths to get to the feature they want to access.
One way to shorten menu paths is to use radial menus. Especially in context menus the use of radial menus seems like a convenient solution to provide faster access to numerous features.
On this topic, Samp and Decker found out, that the pointing speed in particular is significantly faster when using radial instead of linear menus.[1]
In this context, the different techniques to select items in radial menus have not yet been researched to its fullest content. In this study we wanted to compare two different selection techniques, the direct and the lazy selection technique. The direct technique lets the user select a menu item by directly clicking on the item, while the lazy selection technique requires the user to only point in the general direction of an item to select it.
The Goal of our study was to research whether one selection technique is more efficient than the other when using radial menus, to gain insight on how the usage of radial menus can be improved further.
To achieve this, we constructed an experiment to study which selection method is more efficient using objective and subjective measures.

2 RESEARCH QUESTION & HYPOTHESES

2.1 Research Question

Comparing the direct to the lazy selection technique, the lazy technique should be faster when operated since the user does not need to move the cursor directly to the menu item. A small movement is enough to select an element. Furthermore, overshooting is not an issue when using the lazy technique.
However, since it is no longer necessary to click directly on the item, it is also easier to select the wrong one.
Based on these considerations, our research question for this experiment was:
Is the lazy selection technique for radial menu layouts better than the direct selection technique in terms of speed and error rate?

2.2 Hypotheses

From this research question we deduced the hypotheses:
H1: The lazy selection technique allows for faster selection in radial menu layouts than the direct selection technique.
H2: The lazy selection technique has a higher error rate than the direct selection technique, when using radial menus.

3 STUDY DESIGN

The objective of our study was to research if there was a significant difference in speed and error rate when using the two different selection techniques for radial menus. In a second part, we wanted to know which selection technique was preferred by the participants.
Based on this, we developed a 2x2 study design with the independent variable, that was methodically varied, being the selection technique. Since we decided that the measure for

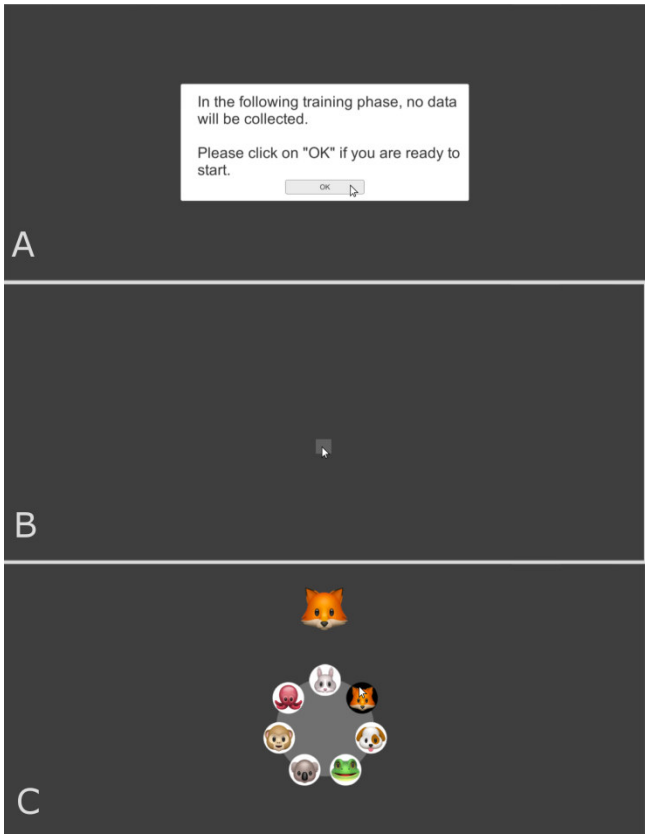

Figure 1: Visible scenes during a study phase

effectiveness of the selection techniques in this case were speed and error rate, those were our two dependent variables.

In addition, we decided to use a within-subject study design, to avoid a distortion of the results due to individual differences of the participants. To counteract an ordering effect, we changed the order in which the techniques were presented to the participants during the experiment throughout the study.

Furthermore, there were several confounding factors that we controlled in the execution of our study. For one, we chose participants from a similar age and educational background. The study environment was another factor we held constant by using a fixed location for the study with very little outside disturbances that could influence the results of our experiment.

Moreover, the setup of the experiment was the same for every participant with the only difference being the order in which the selection techniques were presented to the users.

Another confounding factor was the researcher that conducted the study. To avoid the conductor of the study influencing the participants, we minimized the interaction of participant and researcher by providing all information needed through the experiment itself.

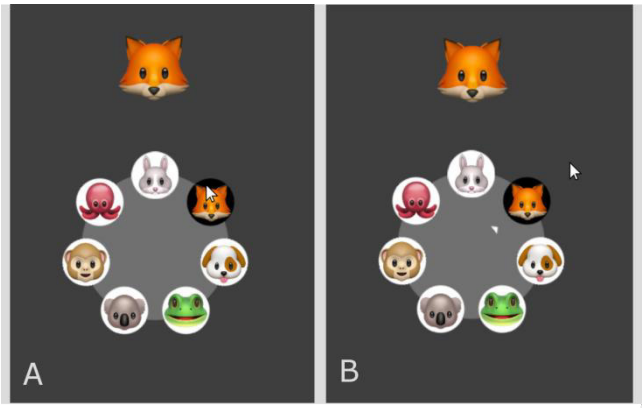

Figure 2: Menus with direct (A) and lazy (B) selection

4 STUDY SETUP

4.1 Software

4.1.1 Application

We built the application that was used in our study using the personal edition of the Unity game engine, version 2017.3.1f1 for Windows, building on the freely available Radial Menu Framework provided by Brett Gregory in the Unity asset store[1]. The scripts used for the tasks as well as the collection of the data were written in C#.

Our Application consists of four different scenes: a training and a testing scene for each menu type as well as an additional menu scene used by the researcher to switch between the different menu types.

All scenes that were seen by the participants used the same design and only differed in menu type and order and number of the tasks that were to be fulfilled.

After reading the short information text, that was displayed on the screen before each training and testing phase [Figure 1, A], and signaling that they were ready to proceed, the participants saw a grey screen with a light grey triangle that denoted the area in which a menu could be opened [Figure 1, B]. After clicking on the marked area, the participants saw a radial menu with seven different pictures of animals and a picture displayed in the screen area above the menu, showing which of the pictures to select in the menu [Figure 1, C]. During the selection process, the menu option that was currently selected was marked by changing its background color from white to black. Selecting a menu item by another left click, closed the menu as well as the picture above it, making it possible to start another iteration of the task.

For each menu type this process was repeated 7 times (once for each available menu item) in the training phase and 14 times (twice for each available menu item) in the trial phase. The order of the menu items that were to be selected was randomized for each iteration of the trial.

As can be seen in Figure 2, the menu types used during the study were very similar in design and only varying in small details concerning their look and the general input mode. As explained in

[1] https://assetstore.unity.com/packages/tools/gui/radial-menu-framework-50601

the introduction of this report, the input modes that we wanted to compare in our study were a setup that treated the different menu options like buttons, only selecting an option when the cursor of the input device was placed directly within the area covered by the menu item and a setup that always selected the menu item that lay within the sector covered by the cursor. For the second menu type an arrow was displayed in the middle of the menu to indicate the current cursor direction [Figure 2, B].

To ensure an accurate measurement of completion time and error rate during our study task, this data was collected in the application itself instead of being measured by the researcher conducting the trial. The completion time for each menu was measured only during the intervals in which the menu itself was opened and the current task was displayed for the user. We made this decision to ensure that missing the rather small area in which a menu could be opened would not influence the completion time for the different menus. The study data was only collected in the trial phases of the experiment and saved as an individual result file, containing participant number, condition, error and completion times for each task.

4.1.2 Questionnaire

In addition to the application using the different menu types, we prepared a short questionnaire using Google Surveys [A1]. The questionnaire began with a short introduction text, explaining the study procedure and informing the participants that they could terminate the experiment at any time. Additionally, there were a few qualitative questions about each menu type to be answered on five-point Likert-Scales and a set of demographic questions to end the survey. A full listing of the survey questions can be found in the appendix of this report.

4.2 Hardware

The hardware setup for our study consisted of two computers, the laptop running our application and the desktop computer and monitor on which our participants read the study instructions and filled out the questionnaires. In addition to these devices we provided a wireless mouse for the study tasks on the laptop.

All our participants used the same hardware setup, pictured in Figure 4, to eliminate technological differences as a confounding factor.

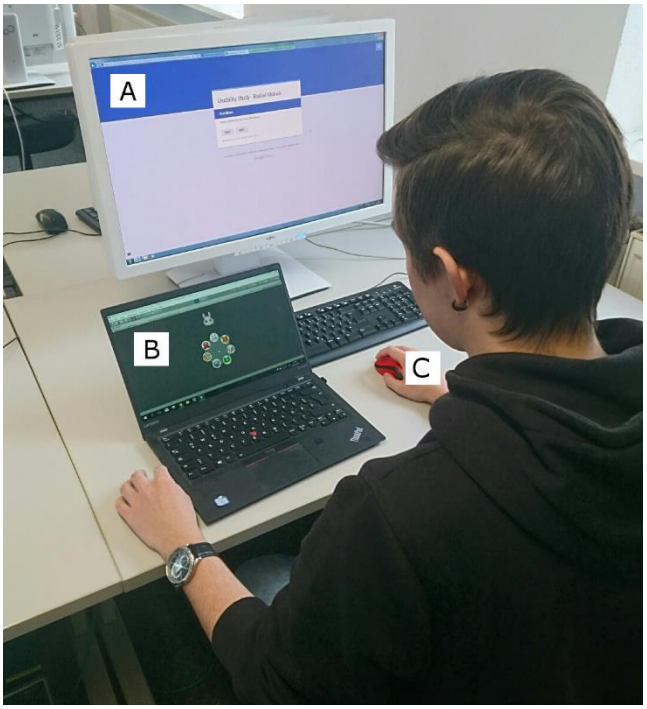

Figure 4: Hardware Setup

The Laptop used for our study is a Lenovo Thinkpad X1 Carbon with a screen size of 14''. The mouse that was used during the menu task is a wireless silent mouse by Logitech (Model Number 220).

5 STUDY PROCEDURE

The study took place in the Lint-Pool of Bauhaus-Universität Weimar over a period of two days. The setting of the experiment was held constant to avoid external influences on our test results. The experiment followed a predefined guideline. [Figure 3]

After arriving, the participants were asked to read an introductory text [A1] that informed the participants about the different phases of the study. Furthermore, the participants were informed that they could leave the study at any time and that the collected data would be anonymized and would also be deleted if the participant wished so.

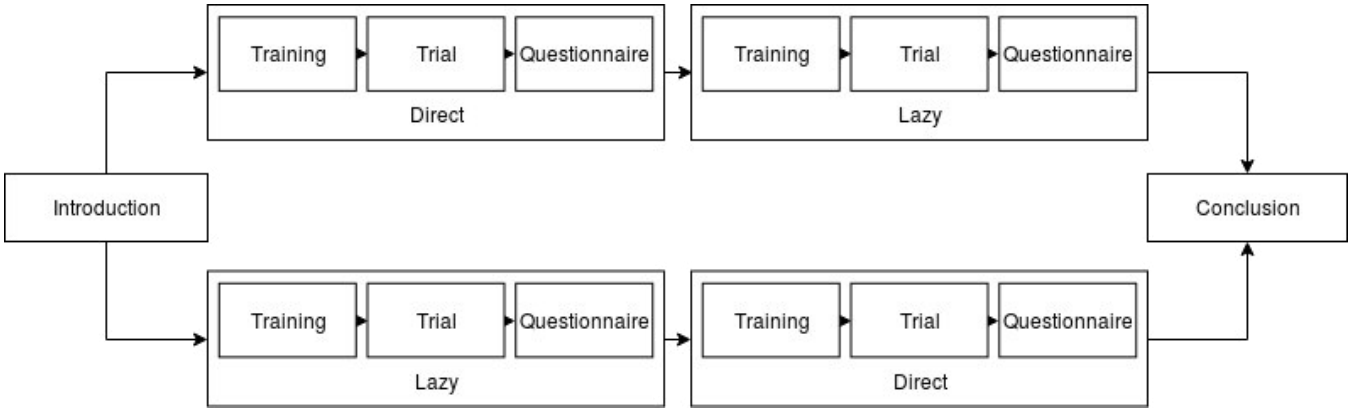

Figure 3: Study Procedure

After the introduction, the participants were presented with the first menu type. The starting menu type was alternated throughout the experiment, resulting in half of the participants starting with the direct selection and the other half starting with the lazy selection technique.
Following a short training phase consisting of 7 tasks, the participants started the trial phase with 14 tasks in total, in which the data for our experiment was collected. The first part of the experiment was concluded with a questionnaire after which the second selection type was presented to the participants. The procedure for the second selection type was exactly the same as for the first one.
The experiment ended with a short questionnaire in which the participants were asked to give information about their gender, age and field of study. Last, the participants were asked which selection type they preferred.
To avoid the experiment being affected by the researcher conducting the experiment, the interactions with the participants were limited to the researcher ensuring that the correct menu type was given to the participants at the right time.

6 PARTICIPANTS

The sample for our study consisted of 10 participants that were selected using convenience sampling [SOURCE]. All participants were students at the Bauhaus-Universität Weimar and had a background in computer science, with six participants studying in the Human-Computer Interaction Masters' program and the other four participants studying in the Computer Science for Digital Media Masters' program.

Our Participants were between 22 and 30 years old ($\widetilde{m} = 24.5$, $\sigma = 2.644$). Two of them were female and eight were male.

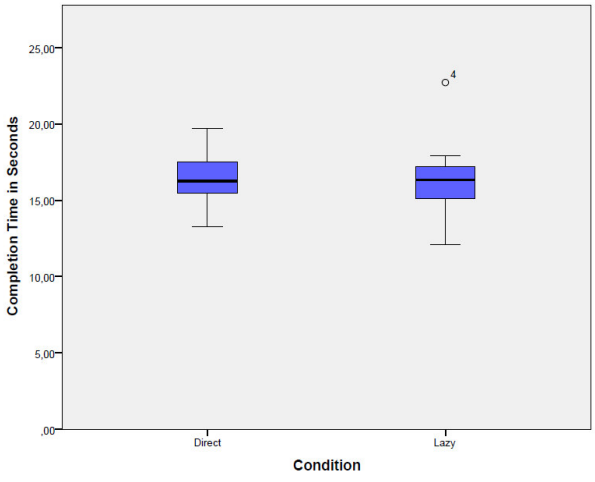

Figure 5: Box plots of completion times of the different conditions

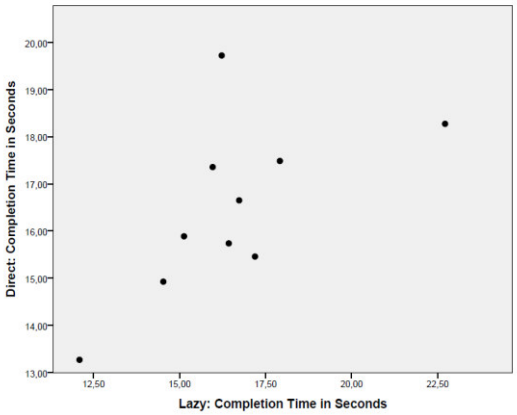

Figure 6: Scatter plot of the completion times of the two selection methods

7 RESULTS

7.1 Application Data

As none of our participants made any mistakes during the testing phase of our study, we are only able to analyse the completion times of the different conditions.

Looking at the box plots, pictured in Figure 5, it is already recognizable, that the completion times reached for both conditions were very similar to each other. This is illustrated further by the distribution of data points in the scatterplot in Figure 6, which hints at a positive correlation between the two value types.
The images also show, that there is an outlier in our data set for the completion time in the Lazy condition.
For the completion time in the direct condition, values between 13,26886s and 19,72196 were measured, resulting in an average completion time of $\emptyset = 16{,}4762590$ seconds and a standard error of 0.57928082 seconds. As the Shapiro-Wilk test for this data set does not reach a significant result (p = 0.9669) we can reject the alternative hypothesis and assume that the data comes from a normal distribution.
For the completion time in the lazy condition of our study, our results vary between a minimum of 12.0925s and a maximum of 22.71512s, resulting on an average completion time of $\emptyset = 16{,}4918590$ seconds with a standard error of 0.86103880 seconds. The higher standard error of this condition is most likely due to the outlier in our dataset. The Shapiro-Wilk test for this data set (p = 0.224) indicates that our data is normally distributed.
As we have found a normal distribution for the completion times of both conditions we can compare them using paired t-test for dependent samples. This test results in a t-value of -.023 and a two-tailed significance level of 0.982 indicating no significant change in the completion times between the two conditions

7.2 Questionnaire

As can be seen in Table 1, there were no large differences between the results of our qualitative questions concerning each menu type.

	Intuitive	Easy	Fast
Direct Selection	$\tilde{m} = 5$ $\sigma = 0.699$	$\tilde{m} = 5$ $\sigma = 0.422$	$\tilde{m} = 4$ $\sigma = 0.516$
Lazy Selection	$\tilde{m} = 5$ $\sigma = 0.966$	$\tilde{m} = 5$ $\sigma = 0.972$	$\tilde{m} = 5$ $\sigma = 0.707$

Table 1: Results of qualitative questions

This is verified further by the results of our Wilcoxon Signed Rank tests, comparing our participants ratings of the two menu types. There are no statistically significant changes to be reported between the rankings for intuitiveness ($Z = 0.378$, $p = 0.705$) easiness ($Z = -0.816$, $p = 0.414$) or speed ($Z = -0.577$, $p = 0.564$). When asked which menu type they preferred overall, seven of the participants liked the lazy selection method better, while only 3 preferred the direct selection of the menu items.

7.3 Observations & Remarks

At the end of our study the participants where given the opportunity to give individual feedback using the "Further Remarks" section of our Questionnaire. Additionally, some of the participants made some remarks during the study, which were recorded in our protocol sheet. We also made some observations concerning the use of the different menu types by our participants.

7.1.1 Observations

While there were no noticeable differences in the use of the direct menu type by our participants, we observed different strategies in the use of the lazy selection mode. As explained in the previous parts of this report, the lazy input mode gives the users the opportunity to select a menu point without having to move the cursor onto the intended target. This opportunity was used by our participants in three different ways. While some participants showed the behaviour that we expected for this menu type, moving their mouse only as much in the direction of the goal as needed to identify the intended target, others still preferred to move the cursor directly over the target before the final selection, making both menu types very similar in use. One participant used the lazy selection method to move the cursor even further away from the middle of the menu, using the selection mode to eliminate the need to stop within the given target.

7.1.1 Remarks

During the course of the study and in the section at the end of our questionnaire, our participants gave some additional remarks concerning the different menu types that they were asked to try out. One participant that started with the direct condition was dissatisfied because it was easy to overshoot the target when making fast movements and then said that the lazy condition was just was he was missing during the first trial. Two participants explained that they were confused by the lazy condition, because moving the mouse near the middle of the menu would lead to unintended changes of the selected item, which distracted them during their search for the correct menu item. One of the two participants that experienced this problem was able to adjust to the input mode during the training phase and found the lazy input type to be faster after becoming accustomed to it. The other participant stayed dissatisfied with the lazy input type after using it during trial and testing phases.

While all the other participants did notice the difference between the provided menu types right away, one participant was not able to tell what the exact difference between the two input modes had been and asked for an explanation after the trial.

8 DISCUSSION

8.1 Results

In the beginning of our study we hypothesized that the lazy selection technique would allow faster selection in radial menu layouts than the direct selection technique, while also leading to a higher error rate. As our participants did not make any mistakes during the testing phase of this study and there was no significant difference found in the time they took to complete the study task in the two different conditions, we have to reject both of our hypotheses.

Furthermore, there were no significant differences found for the subjective ratings of the different menu types by our participants. This also indicates that overall, the introduction of a lazy selection method for radial menus did not make a difference for our study task.

While a majority of our participants chose the lazy selection technique when asked which of the selection techniques they liked better, it has to be noted that we made them chose one of the two menu types by not giving them the option to say that they preferred neither of the two menu types. Further research into this topic is necessary to find out whether a preference of the lazy selection method over the direct selection method can be confirmed for a larger test sample.

Overall, the most interesting results of our study may not be the stochastic data that we gathered, but the observations we made during the study process and the input we received from our participants, as they might indicate some changes that can be made in the design of the menu types as well as in the design of a following study.

We observed that our participants used different strategies when selecting menu options using the lazy selection technique. Some participants did use the same strategy for both menu types and thus did not really utilize the possibilities given by the lazy selection method. It would be interesting to find out if further training or a direct explanation of the menu type can motivate participants to change this and if such a change makes the difference in performance for the two menu types more noticeable. It would also be interesting to find out if the lazy menu would become easier to understand for the participants if we introduced a small buffer zone around the center of the menu in which no menu option would be selected to avoid the involuntary change in selection that some of our participants found to be confusing. How big this buffer zone should be to avoid confusion while still enabling the user to select a menu option with minimal movement of the cursor is another topic for a potential follow-up study.

8.2 Threats to validity

As discussed in the Study Design section of this report, we tried to ensure the validity of our study by minimizing potential confounding factors as much as possible. Nonetheless there are multiple aspects that could threaten the internal and external validity of our study results.

8.2.1 Internal validity

As the study described in this report represents is our first try to investigate radial menus with the help of a user study, we tried to minimize the variation in our study process, to ensure a high internal Validity.

As all our participants were master students at the media department of the Bauhaus-Universität Weimar and fell within the same age group, we can assume that they all had a similar background. Furthermore, we made sure that all participants received the same information during the study process by letting them read the introduction text and following instructions and only providing them with the correct devices to minimize the influence of the researcher's behavior on the studies' results.

A threat to the internal validity of our study could be the fact, that we used the same menu for all study tasks. Although we did systematically vary the order in which our participants were presented with the two menu types, this could lead to a repeated testing bias. The small sample size of our study also means that outliers potentially had a high influence on our study-result.

8.2.2 External validity

While the lack of variation in our study design supports the internal validity of our study, it reduces the external validity. The similarity of our participants as well as the small sample size of our study implies that a similar study with a more representative sample of potential users of radial menus could lead to very different results. The high standardization of our study design and environment, as well as the simple nature of the study task also leads to the assumption that the study results may not be generalizable to other context or more complex tasks that could be fulfilled by using radial menus.

Overall, we can see our study results as a starting point for further investigation into the use of radial menus but supposing that using different input modalities for these menus in a real-life setting would not make any difference, just because we did not reach significant results would most likely be an erroneous conclusion.

9 CONCLUSION & FUTURE WORK

In conclusion, this study did not provide significant results on whether the lazy selection technique is faster than the direct selection technique. Furthermore, since there were no errors mad throughout the tasks in the experiment, there were no results regarding the error rate of the different techniques.

However, the majority of the participants preferred the lazy selection technique over the direct technique. To research this phenomenon, additional studies are needed.

In this study the menus were kept the same for the two different selection technique, which might have caused an ordering effect. To counterbalance this, different sets of menu items should be used throughout the experiment.

In addition, the training phase should be increased to give the participants more time to get comfortable in the handling of the menus.

Since there were no errors made throughout the experiment, a longer trial phase would give more insight on whether this was due to the short trial phase or the robustness against errors of the selection techniques.

This study focused on a radial menu with only one level of selectable items. The advantages of a lazy selection technique in terms of speed might only become visible in a menu with more than one level.

Furthermore, the size of the radial menu might affect the handling of the menus and should also be a topic of future research.

A APPENDICES

A.1 Questionnaire

REFERENCES

[1] K. Samp and S. Decker, "Supporting Menu Design with Radial Layouts," in *Proceedings of the International Conference on Advanced Visual Interfaces*, New York, NY, USA, 2010, pp. 155–162.

Usability Study - Radial Menus

*Required

1. ID *

2. Order *
   Mark only one oval.
   - Direct (First) -> Lazy(Second)
   - Lazy(First) -> Direct (Second)

Introduction

In the following experiment, we will test two different types of menu. For each type you will have a training phase and a trial phase. During the training phase you have time to familiarize yourself with the menu type. No data will be collected.

During each task, you will see a square in the middle of the screen. Clicking on this square will open a menu.

Your task is to select the picture in the menu that matches the one displayed above the menu.

This process will happen 7 times in the training phase and 14 times in the testing phase.
After each testing phase there will be a short questionnaire to fill out.

All data is recorded anonymously.
Please be aware that you can terminate the experiment at any point. All of the recorded data will be deleted if you wish.

Thank you for participating in our study!

First Menu

Please complete the task on the other device!

First Menu - Questionnaire

3. The menu type was intuitive. *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

4. The menu was easy to use. *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

5. The menu type was fast. *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

Second Menu

Please complete the task on the other device!

Second Menu - Questionnaire

6. The menu type was intuitive. *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

7. The menu was easy to use. *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

8. The menu type was fast. *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

Personal Data

9. Gender *
   Mark only one oval.

   - ◯ Female
   - ◯ Male
   - ◯ Other: _____

10. Age *

    _____

11. Field of Study *

    _____

12. Which menu type did you like better? *
    Mark only one oval.

    - ◯ The first menu type.
    - ◯ The second menu type.

13. Additional Remarks

    _____

Thank you for participating in our study!