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Conception, design and testing of a split menu for smartphone

Dissertation presented by
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"It is far better to adapt the technology to the user than to force the user to adapt to the technology."

Larry Marine

Acknowledgements

This Master's thesis is the accomplishment of many years of ongoing learning. It represents my contribution to this magnificent field of study which is human-computer interaction.

I would first like to thank sincerely my thesis advisor Prof. Jean Vanderdonckt. His door was always open whenever I ran into an issue or had a question about my research or experiment. He steered me in the right direction from our first meeting until the very last one. Even though he was travelling or on vacation, he was always careful about my doubts and questions.

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Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my own process of learning, studying, researching, coding and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Nathan Magrofuoco

Abstract

In 1994, Sears and Shneiderman proposed the changing concept of split menu. They have radically influenced the way we have designed menus until today. Unfortunately, their guidelines haven't evolved in 20 years and the advent of smartphones have led HCI researchers to new and different usability issues. Based on their initial study, this master thesis aims to conceive, design and test a split menu adapted to smartphone resolutions.

Along the way, the approaches from various researchers have influenced our experiment and diverse menu organizations have also been designed and tested. An experimental method has been conducted combining traditional, split, responsive, minimised and mixed-initiative menus. The objective of this method was to assess the usability of these new menu organizations on smartphones. Usability has been studied along with 3 interesting properties: (1) effectiveness, (2) efficiency and (3) user satisfaction.

The experiment proved that split menu may not be the ideal solution for smartphones. Another novative menu organization called "responsive" has shown a better usability. This dissertation aims to explain the development of the experiment and argue the analysis of its results.

Contents

Chapter 1

Introduction

Since the initial drawings of Charles Babbage and the first modern computer built by Konrad Zuse, computer technology has widely evolved and spread around the globe. Initially dedicated and used by a few IT professionals, the advent of personal computing radically changed the game and made everyone a potential computer user [1]. Computer providers faced serious usability issues with the initial command dialogs. Some still recognized brands took advantage of innovative and creative minds to overcome these problems.

Unfortunately the effectiveness of their solutions has often not been scientifically proven. In the early 1980s, some computer scientists showed a great interest into assessing the usability of the traditionally designed UI's. An area of research and practice called "*human-computer interaction*" - and commonly referred to as *HCI* - started to emerge along with these scientists. They focused on studying the quality and quantity of information transfer between humans and computers. Later they started to publish their own mathematical models and related UI solutions to enhance UX.

Last decade saw the rise of mobile technologies. Minimising computer components has always been a common interest for computer manufacturers. Smartphone in the hand, tablet in the other. People have become keen of these microtechnologies. Unfortunately they raised new issues. Among them, the complexification of UI has become an increasing problem for users, especially for novices. We come to a point where humans themselves must adapt to the technology and HCI has still a long road ahead.

Objectives

This master thesis was initially focused on the conception, the design and the testing of a split menu for smartphone. Starting with the guidelines proposed by Sears and Shneiderman [2] almost 20 years ago, the first objective was to design a *usable* split menu in the context of a small touch screen. Assessing *usability* requires to be attentive to 3 interesting properties : (1) effectiveness, (2) efficiency and (3) satisfaction. A controlled experiment has been conducted in order to evaluate these properties and compare a traditional menu organization to a split menu designed for smartphone.

The conception and the design of such a split menu also required to update the guidelines published by Sears and Shneiderman. Indeed these guidelines haven't been modified since 1994. An intense review of the field of study brang us to take into account diverse approaches. Many researchers and studies have therefore influenced the conducted experiment. The master thesis is finally more about conceiving, designing and testing new menu organizations for smartphone.

Structure of the written dissertation

The written dissertation is organized as follows:

1. **State of the Art**: the first chapter is the starting point of the study. It provides a review of the field of research and describes the knowledge base over which the entire experiment has been built.
2. **Methodology**: the second chapter describes the methodology used to conceive the experiment. First, it presents the initial hypotheses. Then, it describes the experimental method. Finally it argues the Android app used during the study.
3. **Results**: the third chapter provides an overview of the results gathered during the experiment, then it analyzes these results to confirm, reverse and update the initial hypotheses.
4. **Conclusion**: finally, a conclusion ends the written dissertation by discussing the confirmed hypotheses, the encoutered issues, the unchallenged matters and the future improvements to be made.

Chapter 2

State of the Art

The state of the art is the starting point of a study. A critical review of the research question is always a necessary prerequisite. It allows to identify the findings, nuances, authors and remaining issues of an area of study. This literature survey is illustrated as a time line (see Figure 2.1) which depicts the evolution of knowledge on the effects of menu organization on user experience. It starts with the premises, the initial researches that began almost 40 years ago. Then it describes the advent of split menu - an important change in menu organization - and tries to clarify the debate between adaptive and adaptable approaches. It also describes an interesting work about responsive menus. Finally it brings a final note about the learning outcomes of these previous researches.

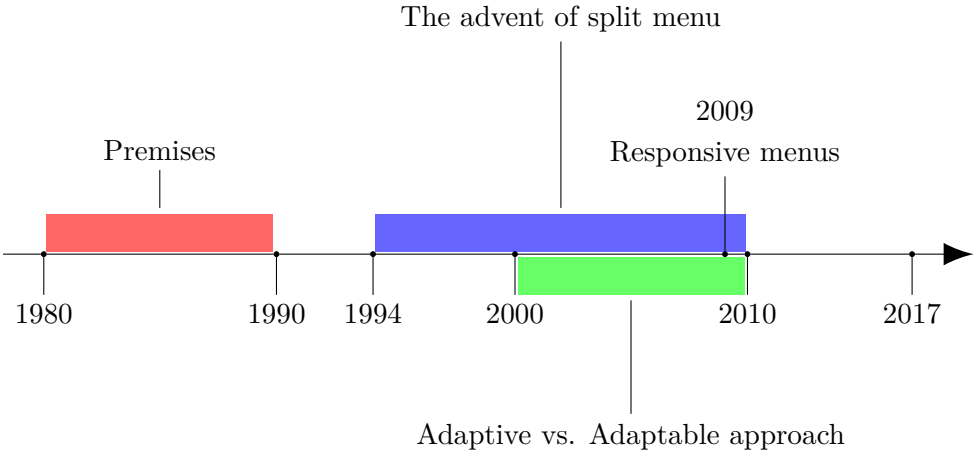


Figure 2.1: Time line of major research topics from 1980 to 2017.

Premises

Back in the early 80's, a few researchers conducted a first set of experiments to better understand the effects of menu organization on user experience and user performance. However the scope of analysis was restrained to static and dynamic menu organizations only. Most of these studies resulted to be partially useful but they set interesting premises for the next ones.

According to Sears and Shneiderman [2], Card [3] was the first researcher to show interest in assessing menu usability. In 1982 already, Card conducted an experiment based on 3 menu organizations: (1) alphabetically ordered menu, (2) categorically ordered menu and (3) randomly ordered menu. These menus are depicted by Figure 2.2. Card proved that the alphabetically ordered menu was the fastest whereas randomly ordered menu was the slowest ones. He also assumed that a *meaningful organization* - such as alphabetical or categorical ordering - could be beneficial for user experience.

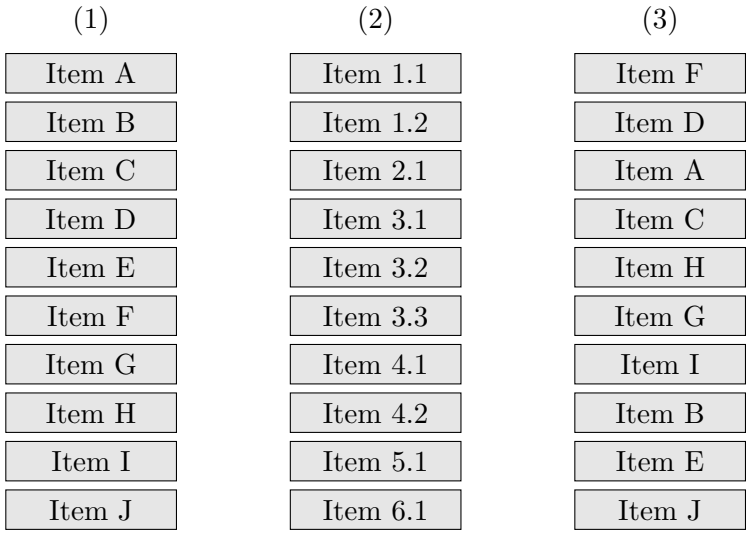


Figure 2.2: Card's menu organizations with 10 items : (1) alphabetically, (2) categorically and (3) randomly ordered menus.

In 1987, Somberg [4] also investigated the effects of menu organization on user performance. He replaced Card's categorically ordered menu with a new approach based

on probability of selection. A probability was bound to each item and was modified at each step of the test, displaying different menu organizations throughout the entire study. The alphabetical menu was also subject to changes as the first displayed letter was chosen randomly from one iteration to another. The randomly, alphabetically and probability ordered menus were then considered as dynamic menus. These designs are depicted by Figure 2.3 which highlights two potential iterations for each dynamic menu. The 4th menu organization proposed by the author was called "positionally constant" and consisted of a static alphabetically ordered menu. Somberg proved that keeping the items in *fixed locations* was more performant than allowing the items to move within the menu. Indeed the positionally constant menu was prefered and resulted in better user performance than dynamic ones.

In 1985, Greenberg and Witten [5] investigated the benefits of organizing a menu based on a-priori set of frequencies and updating these frequencies according to user's selections. Mitchell and Shneiderman [6] provided the first convincing results about such a frequency reordering in 1989. They conducted an experiment in which they compared a static menu to an automatically reorganized menu based on frequency. At first exposure, users preferred, were faster and made fewer errors with the static menu. After practice, Mitchell and Shneiderman proved that user performance was not a problem anymore with the dynamic menu. However this menu organization was still not preferred over the static one. They ended up by concluding that automatically updating menu organization to reflect the current usage patterns might be useful but could also lead to several problems.

The Advent of Split Menu

In 1994, Sears and Shneiderman [2] proposed the changing concept of *split menu*. Based on the early work of Greenberg and Witten, Smith and Mosier [7] were already suggesting in 1986 "where some data items are used more frequently than others, consider grouping those items at the top of the display". Their solution was articulated in 3 steps: (1) maintaining the standard selection mechanism, (2) eliminating the need for users to remember additional commands and (3) reorganizing menu items based on usage frequency such that the most frequently selected items are moved to the top of the menu. The founding notions of split menu were finally set.

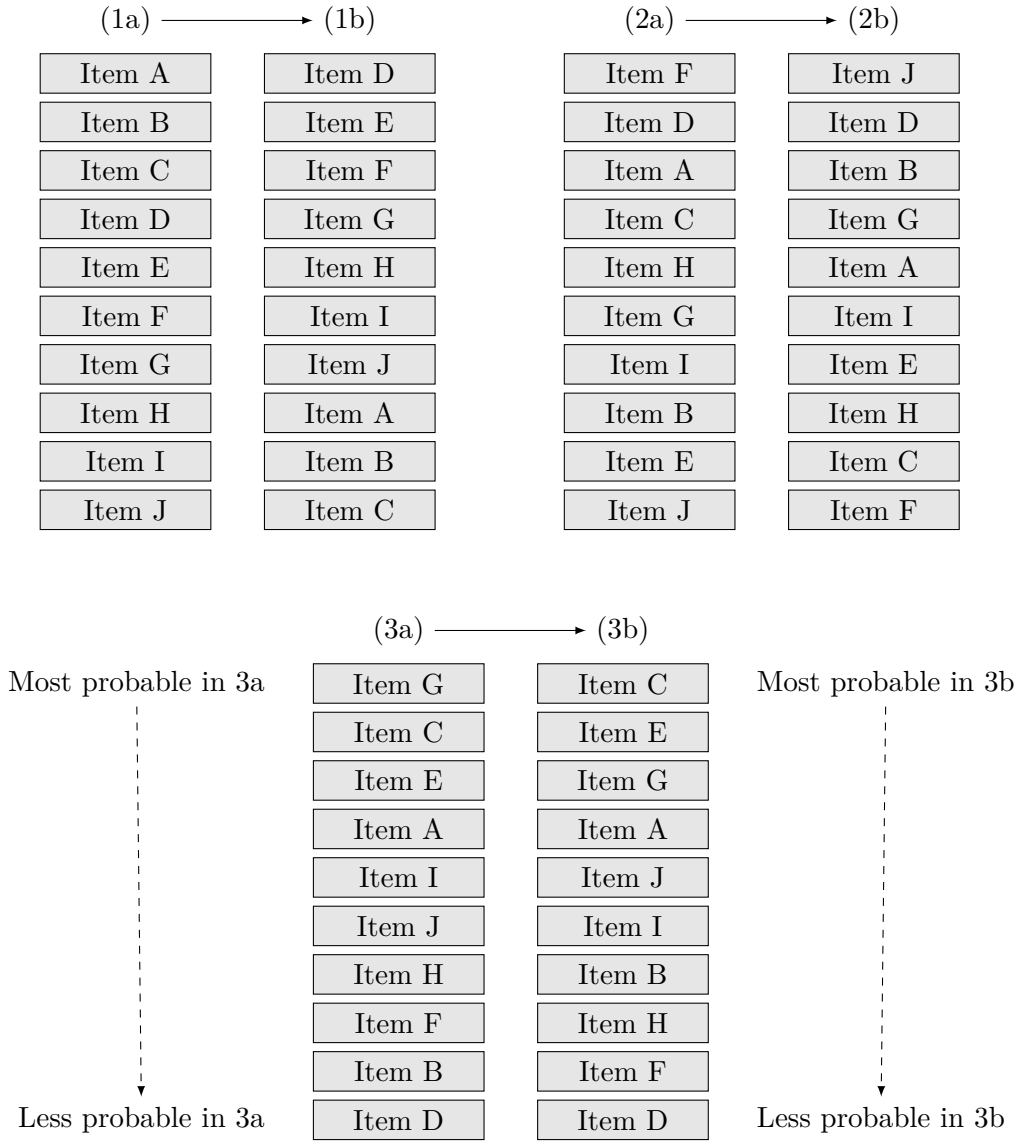


Figure 2.3: Illustrating 2 potential iterations (a) and (b) for each Somberg's dynamic menu organization with 10 items : (1) alphabetically, (2) randomly and (3) probability ordered menus. The menu (1a) can be considered as the static alphabetically ordered menu described by Somberg.

Sears and Shneiderman defined a split menu as a menu created by splitting a menu into two sections such as frequently selected items are placed in the top section and infrequently selected items are placed in the bottom section. Such a menu organiza-

tion proves useful *if and only if* a small subset of the menu items represent the majority of selections. This menu organization is illustrated by Figure 2.4 with a dark gray top section above the usual alphabetically ordered menu. Notice that most frequently selected items are moved to the top section and do not appear anymore in the remaining alphabetically ordered menu. Both authors defined a set of preliminary guidelines based on initial observations about user's selections and refined them into a cognitive model. These guidelines are still applicable nowadays and will be explained later in the report considering their importance. The cognitive model allowed both researchers to prove that (1) a linear model could be applied to the infrequently selected items and (2) a logarithmic model called *Fitts' Law* could be applied to the most frequently selected items. The linear model illustrates the fact that users spend most of their time searching an unfamiliar item in a linear fashion by scrolling down the given menu. The logarithmic approach proves that users do not scan the entire menu when searching for a familiar item but use the order of the menu instead. For example, a subject will start at the middle of the menu and will then decide if the desired item should be above or below this position.

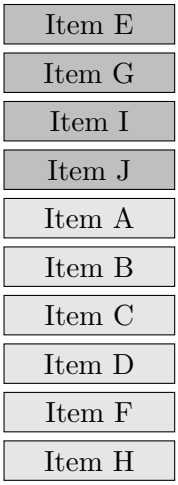


Figure 2.4: Sears' split menu organization with 10 items. The 4 most frequently selected items are moved to the top section and displayed in alphabetical order.

Split menu provided the missing concept to conciliate both user performance and user preference. Indeed Sears and Shneiderman conducted two in situ usability stud-

ies and managed to prove interesting properties: (1) split menu allows to enhance user performance only after a short period of one week adjustment, (2) split menu allows 17-58% time savings, (3) 9 out of 13 users expressed preference for split menu, (4) 3 out of 13 users expressed no preference and (4) split menu provides benefits of both frequency ordered and alphabetically ordered menus. In conclusion, SEARS and SHNEIDERMAN proved that frequency reordering was not sufficient alone. Indeed, a usable split menu must be combined with a traditionally ordered menu *and* must display the most frequently selected items as a *hot list* at the top of this traditional menu.

Split menu was widely adopted and implemented in many user interfaces. The most renowned split menu is the font menu displayed in Microsoft Word which was already used by SEARS and SHNEIDERMAN to conduct their in situ usability studies. However we must wait the early 2000's to find interesting studies about their concrete contextualized efficiency. Paula SELVIDGE [8] conducted an intensive test to assess split menu performance. It was based on 112 tasks to be performed by 73 individuals. She proved that split menu was achieving a faster completion time than static menu but she also pointed out that they both had the same error rate. Finally she identified a clear preference for split menu among participants. James R. WARREN and Patrick BOLTON [9] proved that split menu was more effective than static menu in the context of ophthalmologic diagnoses. They conducted a test with several doctors and found out that a small list of 20 diagnoses was mostly used. In this context, a split menu was indeed more efficient than a static menu. Mona TOM et al. [10] proved that split menu was also very efficient for automotive mobile multimedia applications. Mahamad SAIPUNIDZAM et al. [11] embedded a split menu into a web browser address bar for data entry purposes. They proved that (1) it was easier to access Internet and find the desired address through split menu and (2) 80% of participants agreed with the implementation of such a split menu in their web browser. In conclusion, many studies confirmed the importance and usefulness of split menu to improve both user experience and user performance.

Adaptive vs. Adaptable approach

During the 2000's, two antagonist notions - respectively called *adaptive* and *adaptable* menus - were also prone to discussions and researches. Some findings are unclear and highly nuanced but they are still worth investigating.

Khalid Al-Omar and Dimitrios Rigas [12] defined the concept of *adaptive menu* as "a system-controlled menu that dynamically changes the interface layout and content to each user's needs". These menus tend to use *graphical* or *spatial techniques* to reduce visual search time. A *spatial technique* consists of recognizing the most interesting items and copying/moving them for easier access. Split menus are based on this notion such that the most frequently selected items are moved to the top of the menu. A *graphical technique* consists of recognizing the most interesting items and then modifying their graphical representation. For example, the most frequently selected items could be bold-faced to become catchy for the eyes. Both authors defined the concept of *adaptable menu* as "a user-controlled menu that provides techniques which permit the users to adjust their layout and content to suit their needs". Some adaptable menus are said to be *coarse-grained* and allow users to move interesting items up or down the menu. Others are said to be *fine-grained* and allow users to move directly these interesting items to a specific position in the menu. Khalid Al-Omar and Dimitrios Rigas finally insisted on a third notion called *mixed-initiative* which has the ability to combine both adaptable and adaptive approaches at the same time. For example, by providing a menu that either displays the most frequent or the most recent items in the top section and such that this criteria is chosen by the user itself. This type of menu can be considered as adaptable and adaptive at the same time because it is customized by the system according to the user's choice. Adaptable, adaptive and mixed-initiative menu organizations are depicted by Figure 2.5.

Many studies were performed before the work of Khalid Al-Omar and Dimitrios Rigas. A first controlled lab study compared user performance between a static, an adaptive and an adaptable split menu. The findings were the following: (1) 55% of the 27 subjects preferred the adaptable menu over the adaptive and static ones, (2) the static and adaptable split menus were equally performant but allowed a faster selection time than the adaptive one. A second study involved the traditional Microsoft Word font menu, and an adaptable and an adaptive versions of this menu. The experiment proved that (1) 65% of the subjects preferred the adaptable menu, (2) 20% preferred the default font menu and (3) 15% preferred the adaptive menu. However it is important to put these conclusions into perspective because (1) both adaptable and adaptive interfaces

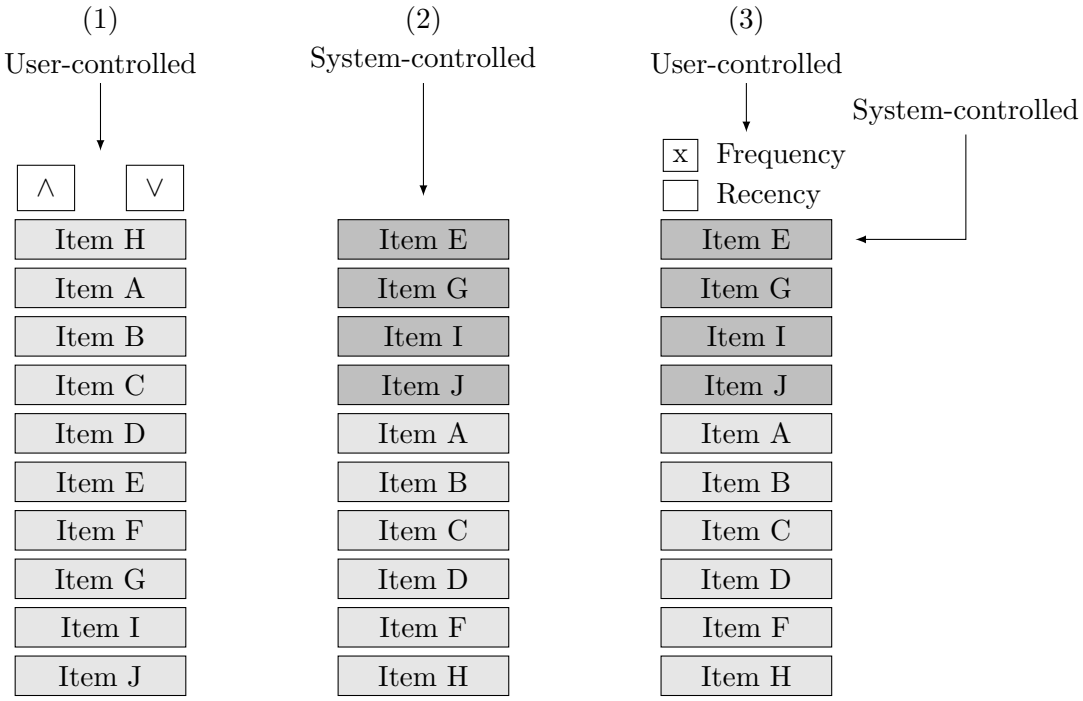


Figure 2.5: (1) Adaptable, (2) adaptive and (3) mixed-initiative menu organizations with a focus on system-controlled and user-controlled features.

were very different from the traditional font menu and (2) all participants used the adaptable interface before the adaptive approach such that they were already used to their own customization choices. A third study proved that (1) the adaptable approach was the most performant one, (2) adaptive and static split menu were equally performant, (3) 55% of subjects preferred the adaptable approach *if and only if* they received guidance to use it efficiently, (4) 30% of subjects preferred the adaptive alternative and (5) 15% preferred the traditional split menu. In conclusion, the adaptable approach seems to be the most preferred and the most performant alternative. However the results vary a lot from one study to another in terms of adaptive and static menus. Guidance also seems to be an interesting prerequisite to enhance user performance and user experience.

Another set of studies restrained their focus on adaptive and static split menus. The first study required to perform a set of telephone directory searches. The authors proved that the adaptive menu reduced the selection time by 35% and the error rate by 40% in comparison to the static menu. Moreover the adaptive menu was preferred by 69%

of the participants. A second study presented different results. Indeed, the traditional static approach provided better time performance than the adaptive alternative for the first group of tasks. It's only during the second part of the experiment that both menus were considered equally performant. In this case, it is interesting to point out that users preferred the static approach to the adaptive one. In conclusion, it seems that the adaptive approach still needs a few tweaks in order to prove a concrete usefulness. Notice that both a period of adjustment and guidance seem essential for users to become performant with new types of menu organization.

In 2005, Teophanis Tsandilas [13] managed to explain why the adaptive approach was often disliked by users. He conducted an experiment based on 2 different adaptation techniques respectively called *highlighting suggestions* and *shrinking non-suggested items*. The first technique consisted of highlighting 4 to 8 suggested items based on the user's cursor position. The second one consisted of highlighting 4 to 8 suggested items while shrinking the undesired items with a fisheye lens method. Both menu organizations are depicted by figure 2.6 which highlights items A, B, F and H as suggested items. Teophanis Tsandilas proved that the effectiveness of adaptive techniques may vary along with the accuracy of their prediction mechanism. Indeed, a low prediction accuracy leads the users to untrust the system. And, of course, user performance vary a lot according to this level of accuracy. In conclusion, Teophanis Tsandilas explained that adaptive mechanisms had to be carefully implemented and tested to prove efficient enough.

In 2010, Khalid Al-Omar and Dimitrios Rigas went even further. They conducted an experiment based on 5 distinct menu organizations: (1) adaptable menu, (2) adaptive split menu, (3) adaptive/adaptable highlighted menu, (3) adaptive/adaptable minimised menu and (4) mixed-initiative menu. These new menu organizations are depicted by Figure 2.7. It is interesting to notice that the adaptive split menu was divided into 2 top sections. They were respectively dedicated to frequency and recency ordering. Each organization was respectively tested with a large menu of 29 items and with a small menu of 17 items. Both authors found out that user satisfaction was affected by the size of the menu. In overall the adaptive/adaptable minimised menu was the most preferred approach for the small menu, followed by the adaptable and adaptive/adaptable

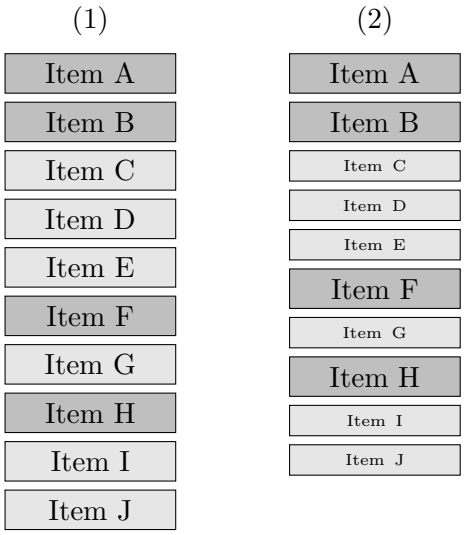


Figure 2.6: Tsandilas' menu organizations with 10 items and considering that items A, B, F and H are the suggested items : (1) highlighting suggestions and (2) shrinking non-suggested items.

highlighted menus. The worst alternatives were the mixed-initiative approach and the adaptive split menu. However the mixed-initiative approach was by far the most preferred one for the large menu, followed by the adaptive/adaptable minimised interface. Adaptive split menu, adaptable and adaptive/adaptable highlighted menus were mostly disliked by the participants for the large menu. Therefore Khalid Al-Omar and Dimitrios Rigas concluded that the *size of personalised content* was a matter of concern for user satisfaction: (1) users preferred to have less control and receive more help from the system for large menus, (2) users preferred when desired items were moved to the top section and undesired ones were hidden from the menu and (3) the concept of split menu was less efficient for small menus. In other words, users preferred the adaptable interfaces for small menus because they are more likely to customize a small menu than a large one. Indeed, a large content requires more effort to be understood and used efficiently. Users also liked the idea of minimising the menu and reducing the number of displayed items. Finally, both authors made an interesting observation: the recency criteria was not used by the test participants. Using such a criteria implies to update the menu each time a selection is performed. Therefore, the menu is constantly being modified and it becomes very confusing for users.

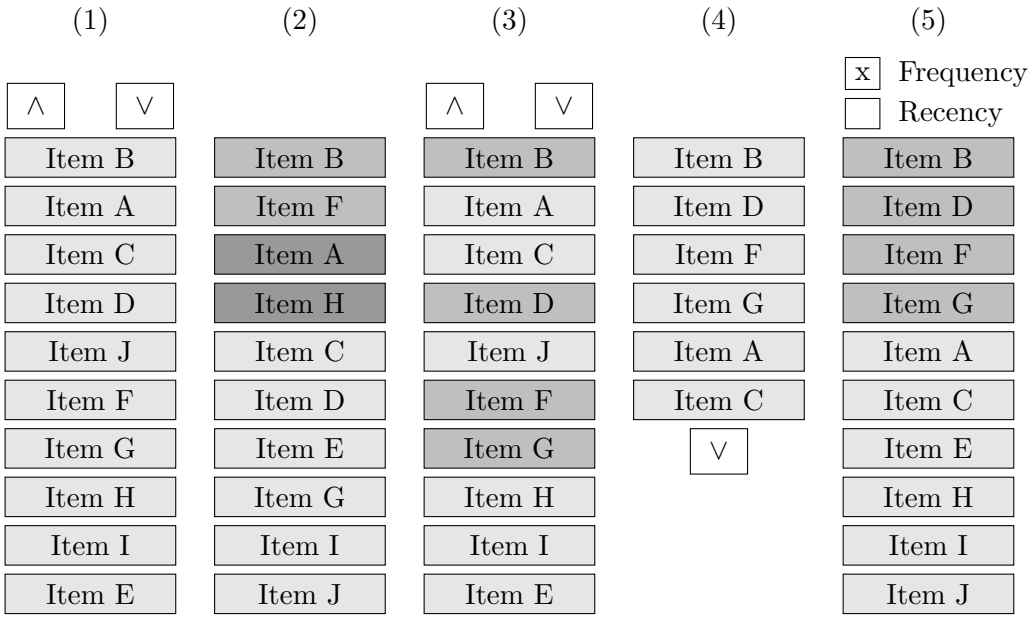


Figure 2.7: Al-Omar and Rigas' menu organizations with 10 items : (1) adaptable, (2) adaptive split, (3) adaptive/adaptable highlighted, (4) adaptive/adaptable minimised and (5) mixed-initiative menus.

Responsive menus

In 2009, Yusuke Fukazawa et al. [14] focused their researches on menus for mobile phones, observing an increasing complexity in mobile interfaces. They conducted an experiment that last 6 days with 20 participants. Each subject was given an additional Windows mobile phone configured with 3 distinct menu organizations described as *responsive*. A *responsive menu* is designed with the idea that mobile screens are smaller than desktop computers and that menus should therefore be adapted to this constraint. Fukazawa et al. developed 3 responsive menu organizations (see Figure 2.8). The first one was made of 2 columns of items and was displaying the most important items at the top. The last two menus were displaying varying item sizes: the more important the item was, the bigger it was displayed. Yusuke Fukazawa et al. observed that 70% of the participants were both satisfied by the new menu organizations and by the prediction function used to identify important items. However, they noticed that *master users*

showed higher preferences for old menus and *novice users* showed higher satisfaction for the new menu organizations.

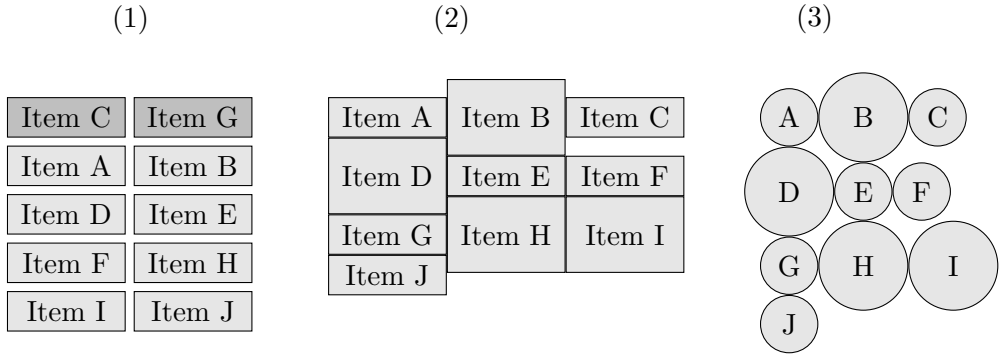


Figure 2.8: Fukazawa's menu organizations with 10 items : (1) 2-column, (2) rectangle-shaped items and (3) circle-shaped items.

Learning outcomes

Lots of interesting findings have been highlighted by these previous researches. First, Card proved that a *meaningful organization* of menu items such as alphabetical or categorical ordering was beneficial for user experience. Somberg later proved that *positionally constant* menus were preferred by users such that items should not move too much within the menu. He also identified that a *period of adjustment* was required to handle efficiently new menu organizations. Then, Sears and Shneiderman managed to find the right balance between dynamic and static menus by introducing the concept of *split menu*. It is a great example that combines almost positionally constant menu, frequency-ordering and meaningful organization. Experiments conducted before Khalid Al-Omar and Dimitrios Rigas proved that the *adaptable approach* was the most preferred alternative. They also proved that both a *period of adjustment* and *guidance* were necessary prerequisites for users to understand new menu organizations. Teophanis Tsandilas later explained that the *accuracy prediction* of the adaptive mechanism was critical for the adaptive approach to be performant. Finally, Khalid Al-Omar and Dimitrios Rigas proved that users showed preferences for their *minimised menu* because it was hiding unwanted items and therefore displaying less items at the same time. They

also proved that the split menu was less efficient for small menus and highlighted the fact that alternatives may be required for small screens. Yusuke FUKAZAWA et al. investigated this possibility and implemented *responsive* menus. They identified varying reactions between *master* and *novice users*. Indeed, master users liked to have more control and novice users preferred to be helped by the system. Master users also showed preferences for traditional menus because they were already use to them.

Chapter 3

Methodology

The methodology is mainly inspired by the previous researches described in the state of the art. A set of 11 hypotheses are described and argued based on the learning outcomes of the previous chapter. Then, the experimental method that aims to confirm or reverse these hypotheses is deeply reviewed. Finally, the related implementation is reported for computer scientists' interests.

Hypotheses

A set of 11 hypotheses have been initially formulated. Each hypothesis is based on one or several learning outcomes from one or several researchers. The objective is to study the field of research even further than the previous experiments. The hypotheses will be later confirmed or reversed by the experiment. Some new hypotheses may even be formulated afterwards with respect to the results of the experiment.

- **H1a:** the split menu reduces the selection time.
- **H1b:** the split menu is preferred by users.

Sears and Shneiderman proved that a split menu following a strict set of guidelines could be beneficial for both user experience and user performance. Therefore, a menu providing a hot list of items based on frequency reordering should indeed reduce selection time and receive a higher user preference.

- **H2a:** the minimised menu reduces the selection time.

- **H2b:** the minimised menu is preferred by users.

Khalid Al-Omar and Dimitrios Rigas identified a clear user preference for their minimised menu. Such a menu hides unwanted items and therefore reduces the number of items displayed on the screen. This is very related to the *rules of ergonomy* taught by Professor Jean Vanderdonckt in his course entitled "human-computer interaction" at Univeristé Catholique de Louvain (BE). One HCI rule called "rule of thumb" states that an interface should display a minimum of 4 items and a maximum of 8. Unfortunately, this rule is still neglected by the researchers. The idea is to implement a menu which displays a restricted number of items at the same time. It should be easier to read and manipulate for users, especially for novice ones.

- **H3a:** the responsive menu reduces the selection time.
- **H3b:** the responsive menu is preferred by users.

Yusuke Fukazawa studied the effects of menu organization with a specific focus towards small mobile screens. He proved that a responsive menu organization could be beneficial for user experience. Unfortunately, his work must still be argued by further experiments. Since this master thesis aims to conceive and design a menu organization for smartphone, it is necessary to include his findings in the experimental method. Therefore, a responsive menu should be designed and tested.

- **H4a:** novice users show a preference for the adaptive menus.
- **H4b:** master users show a preference for the traditional menu.

Yusuke Fukazawa found out that *master users* preferred to have more control over menu customization and preferred to be less guided by the system. Therefore, they showed higher preferences for traditional and adaptable menus because they are respectively use to it and user-controlled. Our experiment is mainly focused towards adaptive menus and master users should therefore show a preference for traditional menu organizations only. At the opposite, *novice users* showed higher preferences for adaptive menus which prove the system ability to handle menu customization by itself. They should show the same preferences during our experiment.

- **H5a:** guidance informations help users to understand how a menu works.

- **H5b:** guidance informations help users to handle a menu more efficiently.
- **H5c:** a period of adjustment helps users to handle a menu more efficiently.

Khalid Al-Omar and Dimitrios Rigas proved that users needed both *guidance informations* and a *period of adjustment* in order to handle and understand new menu organizations, especially for adaptable menus. The experiment should however provide the same results for adaptive menus since they still represent new menu organizations for users. Notice that Somberg, and Sears and Shneiderman also observed that a period of adjustment was beneficial for user performance during their respective experiments.

Experimental method

The experimental method aims to confirm or reverse the hypotheses. In order to achieve this objective, 8 menu organizations have been designed and implemented in an Android application developed especially for the experiment. This subsection argues the choices performed during the development of the experimental method. It also describes its overall operation.

Test protocol

Participants were first asked to answer a preliminary set of sociodemograhic questions on a survey paper. In order to prevent users from being distracted by a second computer screen, it was decided to use a paper version of the survey. It is available at the end of the dissertation, see Appendix A. The users were then asked to perform 2 kinds of sessions on the Android application. The first sessions were called *training sessions* - or *adjustment periods* in reference to Somberg' study [4]. Each training session last for 2 consecutive selections and was preceded by guidance informations. For each selection, the system randomly chose an item and displayed it on the screen. Once the menu was displayed, the participant had to press on the required item. Guidance informations were used to help users to understand the following menu organization. A second set of sessions was organized after the 8 training sessions. These new sessions were called *evaluation sessions* and last for 10 consecutive selections. An evaluation session was not preceded by guidance informations but was followed by a set of questions to answer on the survey paper. These questions were used to assess the usability of the menu

organization and gather user's feedback. During the evaluation sessions, 6 parameters were recorded for each selection: (1) the the required item, (2) its position in the menu, (3) the selected item, (4) its position in the menu, (5) the selection time and (6) the correctness of the selection.

Items

The items displayed by the Android application have been selected from a controlled experiment conducted by Findlater [15]. This experiment used 16 items divided into 4 specific categories. Notice that Khalid Al-Omar and Dimitrios Rigas considered such a menu as a *small* one during their own study [12]. Figure 3.1 depicts the categories of items described by Findlater and used during the experiment.

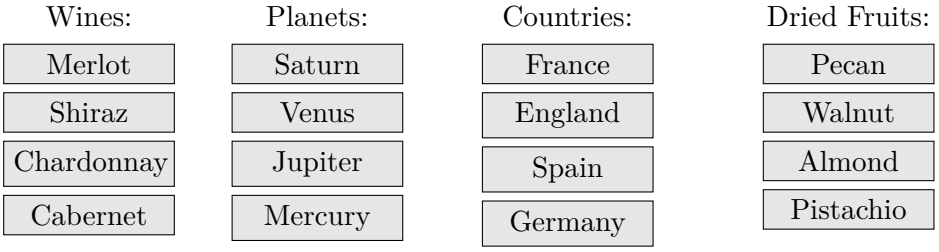


Figure 3.1: The 4 categories of 4 items described by Findlater and used during the experiment.

Control condition menu

A control condition menu stands as baseline to perform the comparison between a set of menu organizations. For this experiment, a traditional vertical menu was chosen to be the control condition menu. It consisted of a 1-column menu which displayed the items in categorical order such that wines were grouped together, followed by planets, countries and dried fruits in the order displayed by Figure 3.1.

Split menu

We followed the guidelines described by Sears and Shneiderman in order to confirm the hypotheses related to the split menu. Indeed, both authors defined a strict set of

guidelines to design efficient split menus. As explained previously, these guidelines are based on 3 preliminary observations: (1) users know the name of the item they are looking for, (2) some items are more frequently selected than others and (3) these most frequent items are ideally not already located at the top of the menu. These preliminary observations are met during the experiment because users have to select items that are chosen and displayed by the system. SEARS and SHNEIDERMAN developed 3 guidelines based on these observations: (1) both the hot list and the traditional sections should respect the traditional ordering, (2) the hot list should not display more than 4 items and (3) the hot list should only display the most frequently selected items.

For the experiment purpose, the hot list was decided to hold 3 items as FINDLATER used during his own study [15]. The hot list was also decided to be highlighted. Therefore, the background of the hot list items was displayed in a dark blue colour called *primary colour* in the initial Android theme.

Minimised menu

Traditional menus display the entire set of items at the same time. The users usually require to scroll down the menu to show the last items. Minimised menu aims to reduce the number of displayed items. Following the *rule of thumb* described in the section 1, we designed a menu divided into consecutive and distinct *pages*. Each page displays at most 8 items. Since our initial set of items is made of 16 items, each menu organization is divided into 2 pages of exactly 8 items.

Responsive menu

The main objective of a responsive menu is to adapt the menu organization to the small size of mobile screens. The idea is to reduce both the size of displayed items and the margins in between these items. Sometimes it also consists of reducing the number of displayed items but we already implemented this opportunity with minimised menus. The responsive menu implemented for the experiment is designed with 2 columns of items. The first item is displayed in the top left column, the second one is displayed in the top right column and so on for the next items.

Mixed-initiative menus

Khalid Al-Omar and Dimitrios Rigas defined a *mixed-initiative* menu as a menu that combines both adaptive and adaptable properties. During the experiment, a mixed-initiative menu was a menu organization combining split, minimised and/or responsive properties. Therefore 2x2x2 menu organizations have been designed to implement all the potential combinations of menus. These configurations are described in the following section and screenshots from the Android application are provided to better visualize the different menu organizations, see Appendix B.

Implementation

An Android application called *Menuz* has been implemented to conduct the experiment. The application was responsible for displaying the menus and providing their guidance informations. It has also been designed to act as a guide during the experiment and therefore to give relevant directives to the participants. This subsection describes the architecture and choices performed during its implementation. Screenshots of the application are provided by Appendix B.

Application architecture

The Android application has been developed with *Android Studio*. It is divided into 13 activities, 13 related XML layouts and Java classes, and one additional Java class for utility purpose. An android activity takes care of creating a window. It is first described by a XML layout in which Android components are assembled to form its UI. An additional Java class must also be implemented for each activity. This class allows to manage the activity lifecycle but also to react to user's actions through listeners. Figure 3.2 illustrates the concept of activity through the combination of an XML layout and a Java class.

The entire application architecture is depicted by Figure 3.3. The first activity is called *MainActivity*. It welcomes the user and requires him to enter a username before starting the experiment. This first window is followed by an activity called *IntroductionActivity* which introduces the course of the experiment. The user then receives the guidance informations of the first menu. Guidance informations are provided by

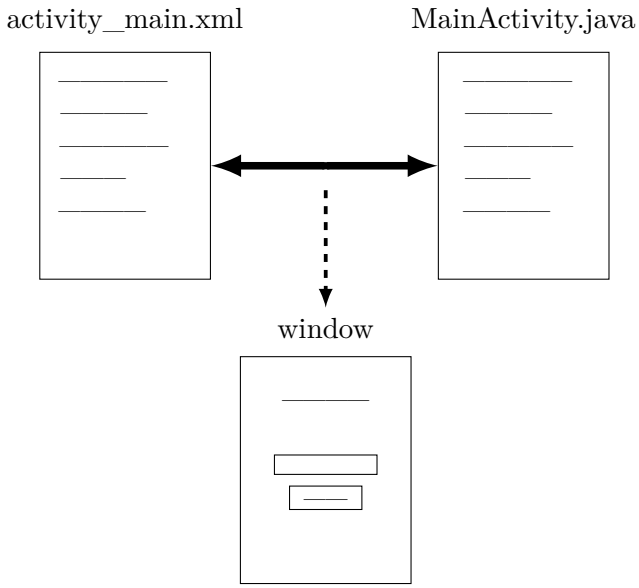


Figure 3.2: An activity takes care of creating a window by combining a XML layout which defines its UI and a Java class which handles the activity lifecycle and user's actions.

an activity called *MenuIntroductionActivity*. Its purpose is to introduce the new menu organizations to the subjects of the experiment. It leads to a fourth activity called *NextSelectionActivity* which chooses a random item to be picked by the users. It also contains a selection counter to show the progress of the experiment. A selection timer starts when the participant presses on the "ready" button and once the menu has been entirely displayed on the screen. Each menu is designed to be a distinct activity. The activity is stopped when the user has performed a selection and the *NextSelectionActivity* is called upon to display the next required item. The process is repeated until the 8 training sessions and the 8 evaluation sessions have been successfully achieved. Notice that a fifth activity called *SurveyRequestActivity* is started at the end of each evaluation session to recall the user that he must answer a set of questions on the survey paper. During these evaluation sessions, *MenuIntroductionActivity* doesn't display guidance informations anymore but acts as an intermediary window to announce the start of the next evaluation session. Finally, a class called *Utility* has been implemented to allow developers to set up the experiment from one single file.

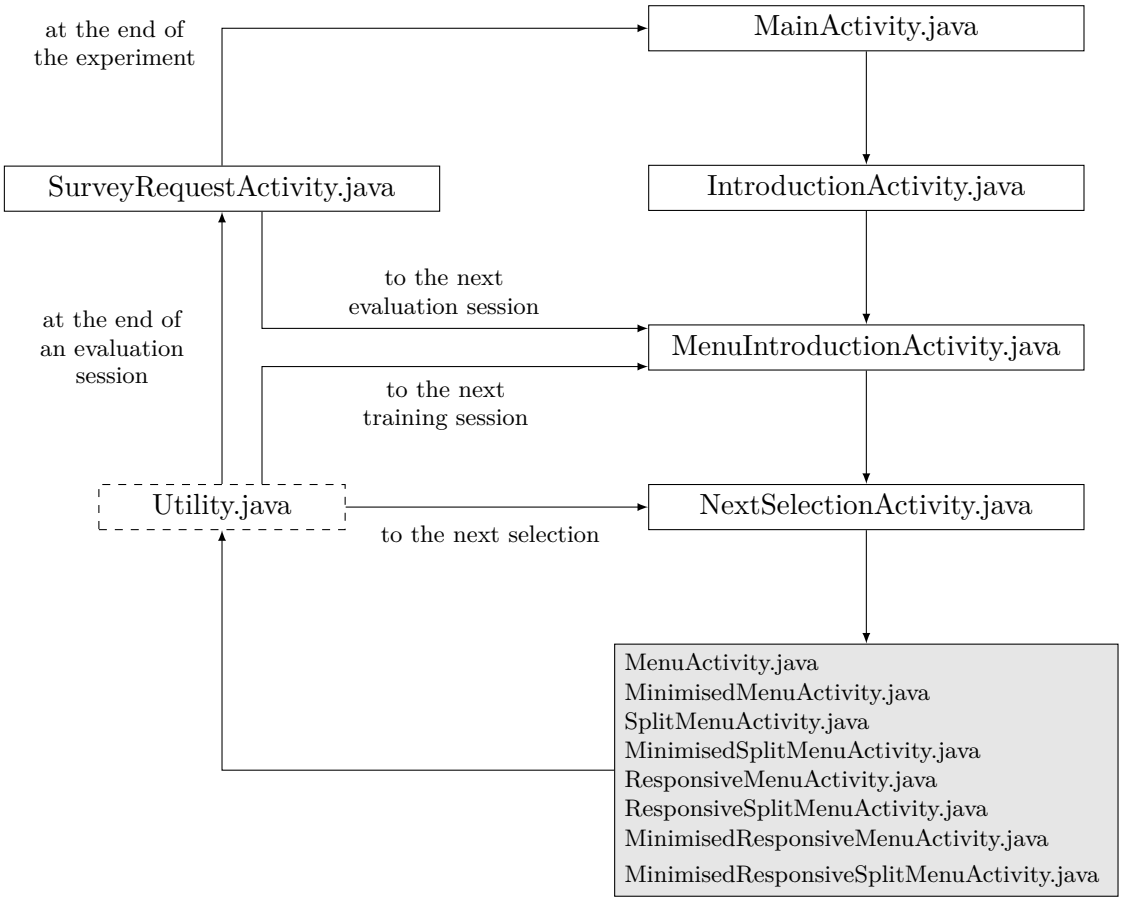


Figure 3.3: Application architecture.

Activities

This second subsection describes the overal operation and the content of each activity and the additional *Utility* class implemented in the Android application.

MainActivity

MainActivity.java is the first activity called at the start of the application. The window is made of a *TextView*, an *EditText* and a *Button*. The *TextView* is an interface element that displays text to the user [16]. In this case, it is used to welcome the user to the application. The *EditText* is a UI element for entering and modifying text [17]. It is used to enter a username that will be saved when the user presses the button. Notice that a *cheatcode* can be used to jump directly to a specific menu organization. The cheatcode

must start with the "#" character and must be followed by the id of the menu organization. In this case, the participant will be redirected to the *MenuIntroductionActivity* which announces the start of the corresponding evaluation session.

IntroductionActivity

This second activity is started by *MainActivity*. It is made of 5 *TextView* widgets and a *Button*. Each *TextView* is used as a title or as a paragraph and aims to introduce the course of the experiment and its overall operation to the user.

MenuIntroductionActivity

MenuIntroductionActivity is called at the beginning of each session. Before a training session, it provides guidance informations about the next menu organization. Before an evaluation session, it is only used as an intermediary window to announce to the subject that a new evaluation session is about to start. The XML layout is made of 3 *TextView* and 1 *Button*. The third *TextView* is hidden before an evaluation session because there is only one sentence to display.

The activity is also responsible to reset the *parameter arrays* and the *selection counter*. A *parameter array* is a Java array used to store the values recorded during the experiment. There are 6 interesting parameters to monitor for the experiment purpose: (1) the required items, (2) the positions of the required items, (3) the selected items, (4) the position of the selected items, (5) the selection time for each selected item and (6) the correctness of the selection. The 6th parameter is not recorded as an array. It is measured later by the *Utility* class. *MenuIntroductionActivity* must also reset the *selection counter* since it is called before the start of a new session. Finally, it must increment the *menu counter*.

NextSelectionActivity

NextSelectionActivity is an activity called before a selection must be performed. It is responsible for choosing the next required item, displaying this choice on the screen and starting the appropriate menu organization when the user presses the "ready" button. Items are selected by following the approach taken by FINDLATER [15] : a ZipF distribution (Zpifian $R^2 = .99$) over 8 randomly chosen items for each menu organization to

avoid the learning effect between sessions. Zipf's law is an empirical law concerning the frequency of words in a language. It was developed by the Americain linguist George Kingsley Zipf and refers to the fact that some words are more frequently used than others and such that their selection frequencies can be approximated with a Zipfian distribution.

The activity is made of 1 *Button* and 4 *TextView*. The 1st *TextView* corresponds to the title, the second one to a directive, the 3rd one is responsible for displaying the required item and the 4th one consists of a counter which represents the progress of the experiment.

Activities related to menu organizations

As explained previously, 2x2x2 menu organizations were implemented for the experiment. Each menu organization represents a control condition menu, a split menu, a minimised menu, a responsive menu or a mixed-initiative menu. A mixed-initiative menu is the result of the combination between one or several types of menu among split, minimised and/or responsive. Each menu organization was designed to be a distinct activity. Two initial methods are required for these activities. The first one, called *onCreate()*, is responsible for providing relevant directives in order to create the window. It displays the menu according to the XML layout and may eventually apply a few modifications if required. This method is the most basic function required by an Android activity. The second method, called *selectionPerformed()*, is perfomed when a user chooses an item in the menu. It is responsible for calling the *Utility* class that will save the relevant parameters and redirect the user to the next activity.

MenuActivity represents the control condition menu. It is made of one column within which all items are displayed vertically. Users require to scroll down the menu to see the last items. It comprises the most basic implementation of both methods *onCreate()* and *selectionPerformed()*.

MinimisedMenuActivity carries a self-descriptive name. It represents the minimised menu organization. It consists of a vertical menu divided into 2 pages. Each page is made of 2 categories of 4 items and no scrolling is required to see the last items of a page. A page is also accessible through "previous/next" arrows respectively located in

the bottom left and bottom right corner of the menu organization. The previous or next arrows are only displayed if respectively a previous or a next page is available. Two additional methods have been implemented to handle these buttons. They are respectively called *previousProposals()* and *nextProposals()*.

SplitMenuActivity represents a split menu organization. It is very similar to *MenuActivity*. Indeed, it corresponds to a vertical menu but it displays the 3 most frequent items at the top of it. These items are highlighted with a blue colour and highlightings are handled by the method *onCreate()*.

MinimisedSplitMenuActivity corresponds to the first mixed-initiative menu presented to a participant. It combines both minimised and split menu properties. Therefore, it consists of a menu divided into 2 pages such that each page displays 8 items and the first page displays the 3 most frequently selected items at the top of the menu. These items are also highlighted with a blue colour and no scrolling is required to see the last items of a page. It is implemented with the additional methods *previousProposals()* and *nextProposals()*. Highlightings are handled by these methods and the method *onCreate()*.

ResponsiveMenuActivity represents a responsive menu organization. It consists of a menu divided into 2 columns within which the items are displayed opposite to each others. This new menu organization allows to display all the items on the screen of the smartphone used during the experiment. Therefore, no scrolling is required to see the last items.

ResponsiveSplitMenuActivity combines responsive and split menu properties. It is very similar to *ResponsiveMenuActivity* but it displays the 3 most frequently selected items at the top of the menu. These items are highlighted with a blue colour and highlightings are handled by the method *onCreate()*.

MinimisedResponsiveMenuActivity is a mixed-initiative menu that combines minimised and responsive menu properties. It is divided into 2 pages such that each page is itself divided into 2 columns within which the items are displayed opposite to

each other. Each page is made of 2 categories of 4 items and is accessible through "previous/next" arrows. The additional methods *previousProposals()* and *nextProposals()* have been implemented to handle these buttons. Notice that a navigation arrow is only displayed if necessary.

MinimisedResponsiveSplitMenuActivity represents the combination of minimised, responsive and split menu properties. Therefore, it is very similar to *MinimisedResponsiveMenuActivity* but it displays the 3 most frequently selected items at the top of the menu for the first page only. These items are highlighted with a blue colour and the highlightings are handled by the methods *onCreate()*, *previousProposals()* and *nextProposals()*.

SurveyRequestActivity

SurveyRequestActivity is an activity called at the end of an evaluation session by the *Utility* class. It is used to recall the user that he must answer a set of questions on the survey paper, or to announce the end of the experiment and thank him for its participation. The UI is made of 3 *TextView* and 1 *Button*. At the end of all evaluation sessions, the button redirects the user to the *MainActivity*. Otherwise, it redirects the user to the next *MenuIntroductionActivity*.

Utility

As described previously, *Utility* is not an Android activity but a traditional Java class instead. It is used to set up the experiment from one single file. For example, a developer can modify the length of the sessions, update the list of items or even change the way parameters are gathered and printed. The class is essential for the application and almost all classes call one of its methods at some point of their execution.

Chapter 4

Results

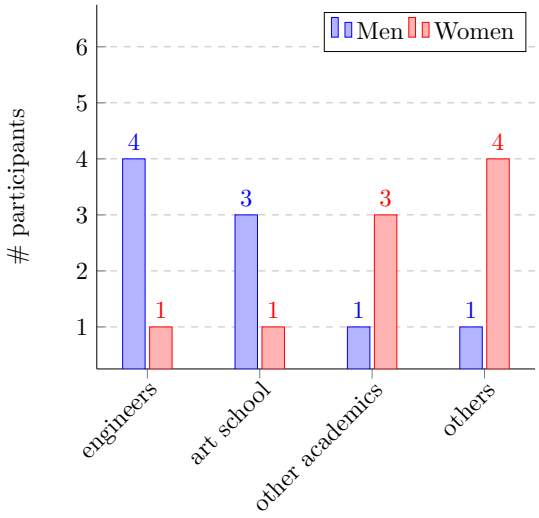
During the experiment, some interesting properties were assessed using the survey paper while other parameters were recorded by the Android application. This chapter aims to collect, classify and analyze these records to achieve 3 objectives. First, to confirm or reverse the hypotheses, then possibly to formulate new hypotheses and finally to assess the usability of new menu organizations. As explained earlier, usability is measured with 3 interesting properties: (1) effectiveness, (2) efficiency and (3) satisfaction. This section first describes the participants who took part to the experiment and then analyzes these usability-related properties one after the other. The hypotheses are finally discussed at the end of the chapter.

Participants

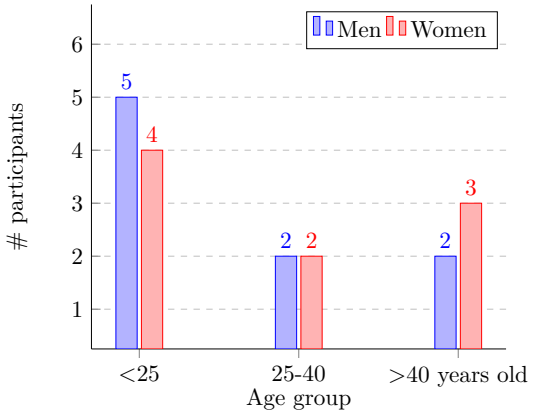
The study was conducted with 18 French speaking subjects between 17 and 61 years old. To avoid bias due to language, the application and the survey used during the experiment were translated in French. Moreover, the experiment has been conducted with the same smartphone for each participant. The smartphone was a Sony Xperia M2 with a 4.8 inches screen. Half the participants were men while the other half was women. Parity gender was therefore achieved.

The subjects come from various backgrounds that we have grouped in 4 distinct categories: (1) engineers, (2) art school students/workers, (3) other academics, and (5) others. *Engineers* and *art school students/workers* were enough to get their own rep-

resentative category. *Other academics* consisted of 1 law student, 1 foreign language student, 1 psychology student and 1 physical education student. Finally, 2 administrative employees, 1 worker, 1 saleswoman and 1 pupil were part of the last category called *others*. Figure 4.1 (a) depicts the distribution of participants according to their educational background. It also highlights the distribution of men and women among these categories. Notice that men are mainly representing engineering and artistic careers in our participant sample. Women are mostly representing other academics and other careers. Unfortunately, the parity gender is not well represented by a distribution based on the educational background.



(a) Distribution of participants according to their educational background.



(b) Distribution of participants according to their age group.

Figure 4.1

Figure 4.1 (b) depicts the distribution of participants according to their age group. It also highlights gender distribution. Most participants were between 18 and 25 but each age group was at least represented once during the experiment. We were able to form and use the 3 following groups of participants during the analysis: (1) <25, (2) 25-40 and (3) >40 years old. Parity gender is very well represented among these categories. Therefore it can be appropriate to distinguish gender and age groups during the analysis.

Participants were also asked to rate their skills with smartphones and touch screen technologies. The objective was to differentiate 2 groups of subjects: (1) novice and (2)

master users. Unfortunately, smartphone users and touch screens are becoming more common nowadays and we haven't found enough novice users for the experiment. Even subjects without smartphones considered themselves rather efficient with touch screens and smartphones. Therefore, we will not be able to prove the hypothesis based on novice users and their preference for adaptive menus. Figure 4.2 illustrates the distribution of participants' responses about their skills with smartphones and touch screens. Notice that a rating ranging from 1 (bad) to 7 (excellent) was at their disposal to assess their abilities.

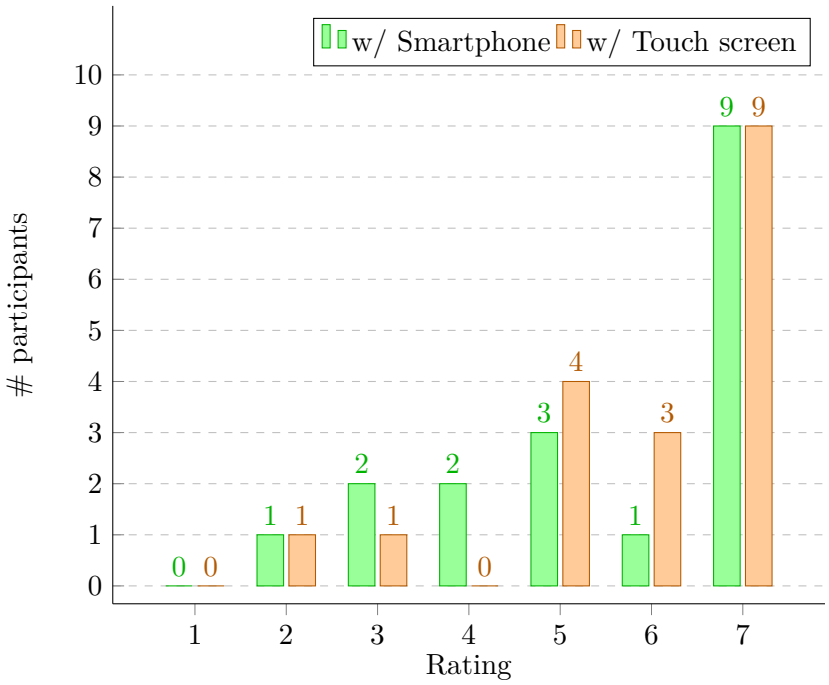


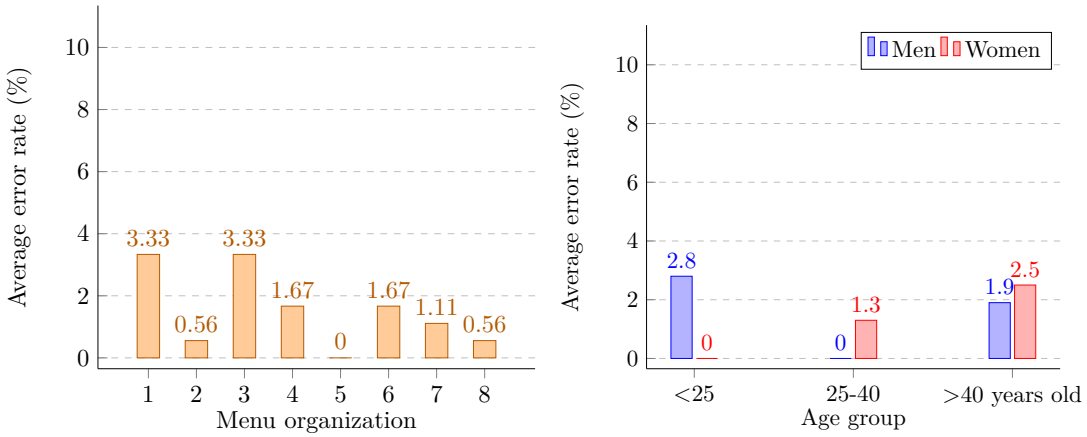
Figure 4.2: Distribution of participants according to their own estimations of their skills with smartphones and touch screens.

Effectiveness

Effectiveness is the first property to evaluate in order to assess the usability of a menu organization. According to the Oxford English Dictionary, effectiveness can be defined as "the degree to which something is successful in producing a desired result; success" [18]. In 1998, effectiveness was defined more precisely by HCI researchers in the ISO9241-11

standard which describes it as “the accuracy and completeness of users’ tasks while using a system” [19]. Indeed, when using the menu of a computer system, a user wishes to fulfill a precise action - e.g. saving a document - and must press the related menu item - e.g. the button “save” - in order to execute this action. In other words, the effectiveness of a menu organization can be assessed by observing its average error rate. A low error rate means that users have managed to produce the desired results by pressing the correct buttons during the experiment. The control condition menu displayed by *MenuActivity* can be used to benchmark the effectiveness between menu organizations. A lower error rate than *MenuActivity* means that the users have managed to produce the desired results more frequently with new menu organizations.

Figure 4.3 (a) depicts the average error rate for each menu organization. The control condition menu (1) and the split menu (3) seem to be the worst menu organizations in terms of effectiveness. The new menu organizations showed better results as users achieved lower error rates when using them. Even more interesting, the users did not commit any mistake when using the responsive menu (5). However, notice that the worst average error rate does not even exceed 3.33%. In conclusion, all the displayed menu organizations can be considered as greatly effective.



(a) Average error rate for each menu organization.

(b) Average error rate according to the age group and the gender distinction.

Figure 4.3

Figure 4.3 (b) depicts the average error rate according to the age group. It also

highlights gender distinction and shows that men are slightly less effective than women. In general, they commit more mistakes than women. However, women tend to commit more and more errors over the years. Older participants show the worst average error rate while the intermediary age group shows the best average error rate.

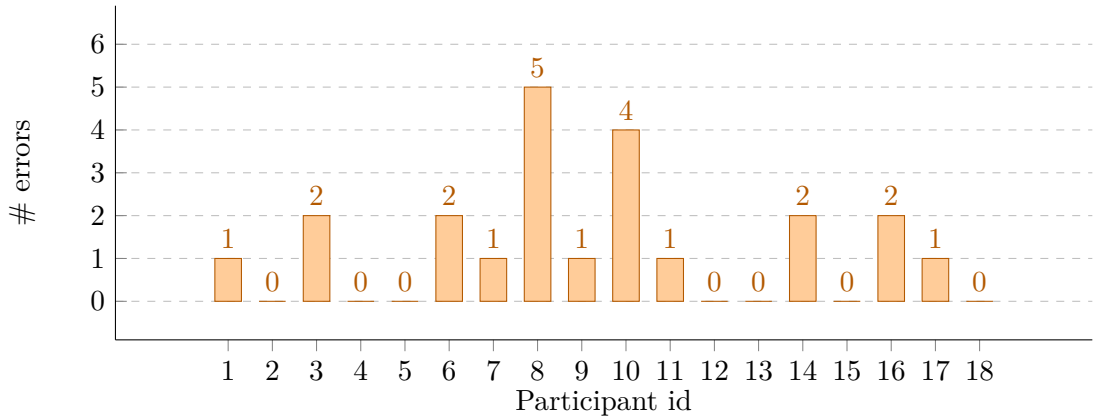


Figure 4.4: Number of errors performed by each participant after 80 selections.

It is finally interesting to observe more precisely the errors performed during the experiment. Figure 4.4 illustrates the distribution of errors among the subjects of the experiment. We can first notice that nearly half the mistakes were performed by 2 participants. These subjects made 4 and 5 errors which is respectively 4 and 5 times greater than the average number of mistakes performed by each participant. A deeper analysis of mistakes allowed us to identify 4 types of errors: (1) forgetting, (2) touch screen imprecision, (3) inattention and (4) confusion. Some participants complained about *forgetting* the required item because it disappeared once the menu was displayed. The problem occured 9 times as illustrated by Figure 4.5. It corresponds to nearly half the mistakes performed during the study. The *imprecision* mistake also occured a few times. It happened when subjects ended up pressing on a button instead of scrolling down the menu, or when they ended up pressing on a button above or below the desired item. The *inattention* error occured when the hot list of a split menu was updated and users were not attentive enough to these changes. Therefore, they ended up pressing on a wrong button. Finally, *confusion* happened a few times between the words “Germany” and “England”, and “Walnut” and “Pecan” due to the fact that these words are pretty close to each other in french (Allemagne/Angleterre and Noix/Noix de Pecan).

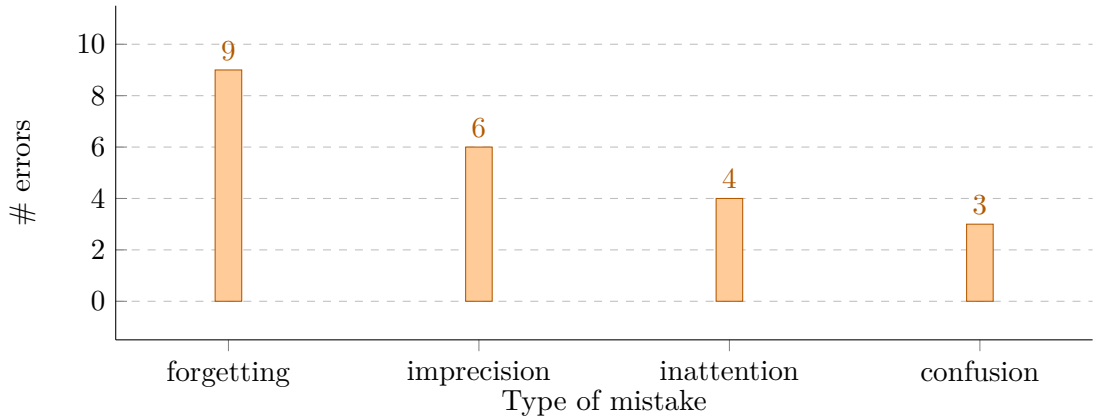
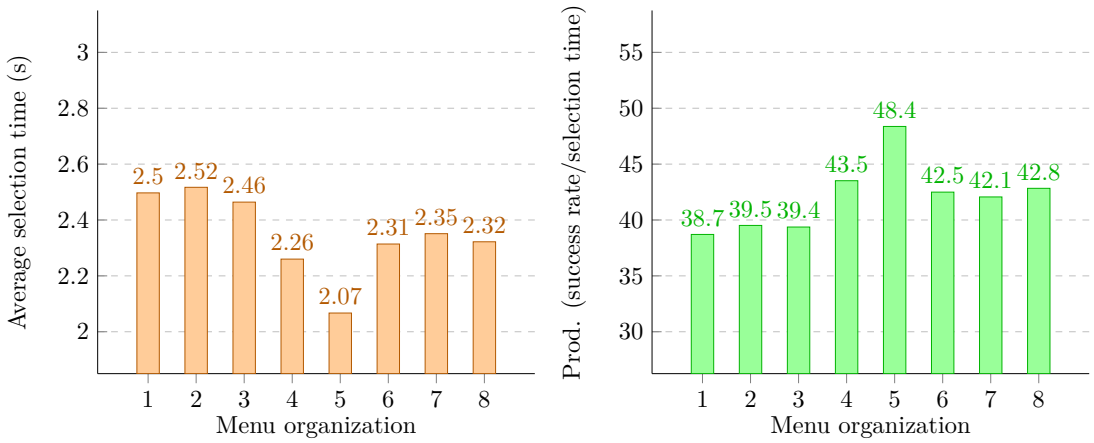


Figure 4.5: Distribution of errors among the 4 identified types of mistakes.

Efficiency

Effiency is the second interesting property to observe when assessing menu usability. According to the Oxford English Dictionary, efficiency is defined as "the ratio of the useful work performed by a machine or in a process to the total energy expended or heat taken in" [20]. In 1998, HCI researchers defined the term more rigourously with the ISO9241-11 standard. They described it as "the resources expended by the user in relation to the accuracy and completeness of goals achieved" [19]. In other words, a computer system is said to be efficient if users manage to reach their goals while expending as little resources as possible. Therefore, we should focus on observing lower selection time for new menu organizations compared to the control condition menu. It is also relevant to adopt a *productivity* approach such that we can observe the ratio of successful selection rate (useful output) to average required selection time (input). Figure 4.6 (a) depicts the average selection time for each menu organization. It shows that all menu organizations reduce the selection time in comparison to the control condition menu (1), except for the minimised menu (2) which slightly increases this value. The responsive menu (5) is once again the most performant one. Figure 4.6 (b) illustrates the productivity ratio for each menu organization. All menu organizations can be considered as more efficient than the traditional menu. The productivity approach also confirms that the responsive menu is the most performant one. Indeed, it provides the best results in terms of effectiveness (lower error rate) and efficiency (lower selection time).



(a) Average selection time for each menu organization.

(b) Productivity ratio for each menu organization.

Figure 4.6

Figure 4.7 depicts the productivity according to the age group and highlights gender distinction. It is first interesting to notice that younger participants are more productive than older ones. In average, men are also more productive than women. We observed in the previous section that women are more effective than men because they are performing less mistakes. However, men perform selection faster than women and therefore their productivity ratio is slightly better.

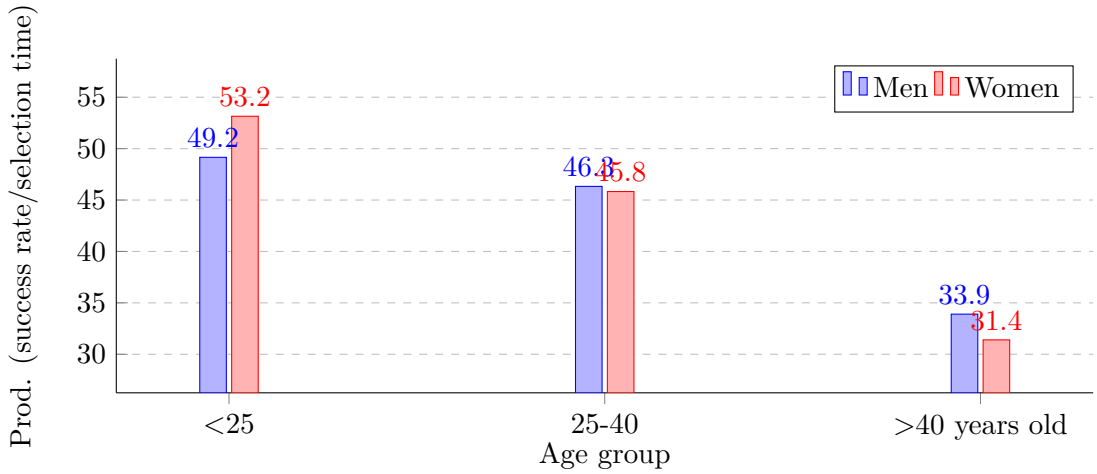


Figure 4.7: Productivity ratio according to the age group and the gender distinction.

Satisfaction

Usability is finally and mostly influenced by user satisfaction. Subjects may feel productive but uncomfortable with a given menu organization and its underlying operation. The survey paper was mainly focused on gathering users' thoughts. The idea was to evaluate how each user was personally *feeling* and *perceiving* each menu. There are 6 interesting sentences from the survey paper useful to assess user satisfaction:

1. I felt productive using this menu.
2. I found this menu easy to use.
3. I think this menu requires some improvement.
4. I found this menu well integrated into the smartphone.
5. I noticed some problems with this menu.
6. I was frustrated by the menu design.

Subjects had to rate each sentence with a value ranging from 1 (disagree) to 7 (agree). Figure 4.8 illustrates the average satisfaction ratio for each menu organization. First, a satisfaction ratio was computed for each participant and for each menu organization. This ratio comprised the values expressed by the participant for each sentence and was returned on a scale of 7. The 3rd, 5th and 6th sentence values were inversed because agreeing with the fact that a menu requires some improvement, contains problems or is frustrating to use is negative for user satisfaction. It is also interesting to notice that values from 3 participants were considered as invalid. Indeed, they responded with the value 7 for each sentence of the survey. Finally, the average satisfaction ratio was computed for each menu organization in order to gather all ratios into a single one. This final ratio proves that subjects were in general mostly satisfied by the menus designed for the experiment. The control condition menu was perceived as the most satisfying while the responsive split menu (6) and the minimised responsive split menu (8) were perceived as the less satisfying menu organizations. The responsive menu (5) which showed great effiency and great effectiveness in the previous sections also received a very good satisfaction ratio. Figure 4.9 depicts the average satisfaction ratio for each menu organization and it highlights the gender distinction. It shows that men were more

satisfied than women about new menu organizations. The traditional menu (1) received a better satisfaction from women instead.

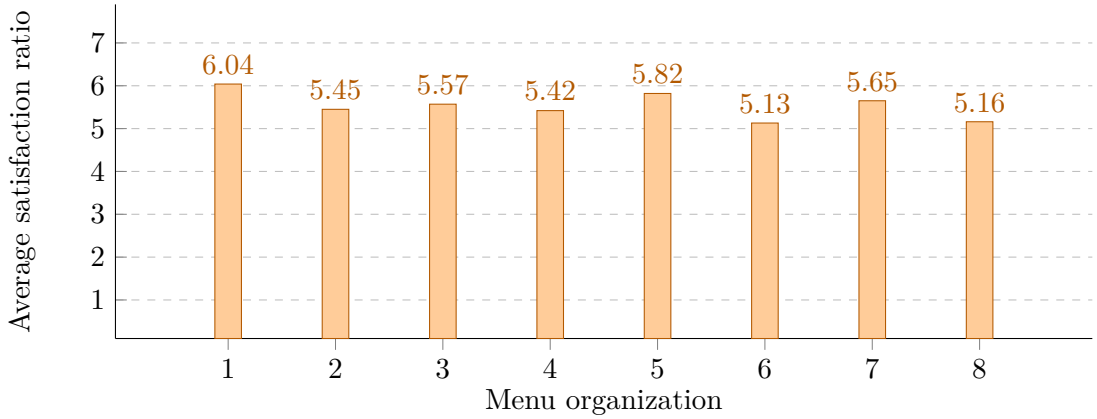


Figure 4.8: Average satisfaction ratio for each menu organization.

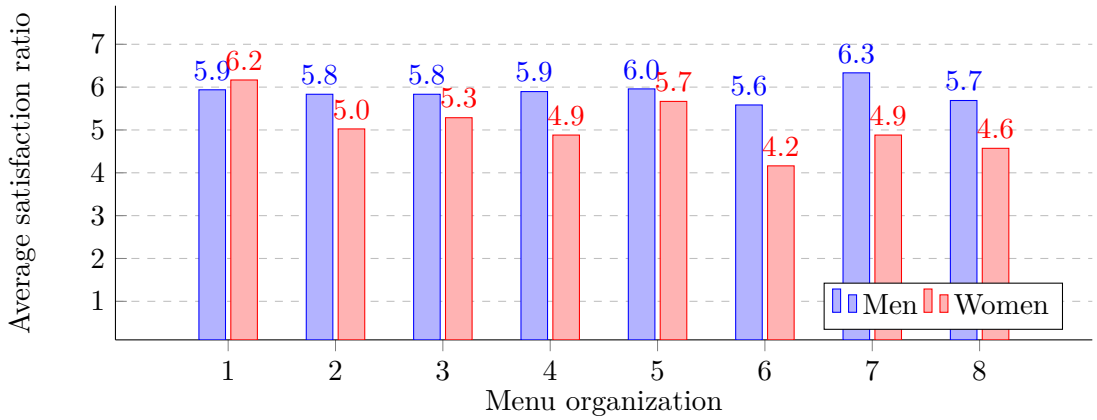


Figure 4.9: Average satisfaction ratio for each menu organization according to the gender distinction.

At the end of the experiment, participants were asked to *rank* the menu organizations in order of preference and such that a menu ranked at the first place was considered as the most preferred menu by the subject. Figure 4.10 depicts the average ranking received by each menu organization. The traditional (1) and responsive menus (5) were mostly preferred by the subjects of the experiment. The responsive minimised split menu (8) was by far the less preferred menu. It was ranked by 10 participants as the worst menu

organization.

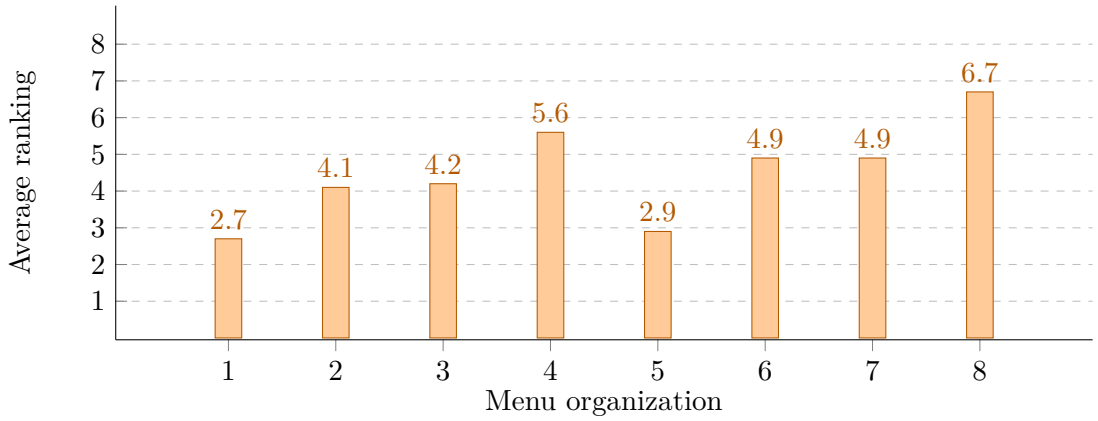


Figure 4.10: Average ranking received by each menu organization.

Confirming, reversing and updating hypotheses

The objective of the experiment was to confirm or reverse an initial set of 11 hypotheses. The results analyzed in the previous sections have led us to undertake interesting observations. This section finally aims to confirm, reverse and update the initial assumptions based on these observations in order to conclude our study.

Hypotheses and usability

In the previous sections, we performed an in-depth analysis of 3 usability-related properties: (1) effectiveness, (2) efficiency and (3) satisfaction. Effectiveness was measured by comparing the average error rate between the control condition menu and the new menu organizations. Therefore, this property will help us to confirm or reverse hypotheses based on the fact that some menu organizations may *reduce the error rate*. The efficiency analysis was based on identifying *selection time reduction* and eventually *productivity enhancement*. Finally, user satisfaction was measured for and between each menu organization. It helped us to identify *user preference* for some menu organizations.

Selection time and user preference were already mentioned by the 11 initial hypotheses. Two types of hypothesis must now be added up to each menu organization. These

assumptions are about error rate and productivity which were not taken into account at the beginning of our study. These additional hypotheses are formulated below:

- **H1c:** the split menu reduces the error rate.
- **H1d:** the split menu enhances the productivity.
- **H2c:** the minimised menu reduces the error rate.
- **H2d:** the minimised menu enhances the productivity.
- **H3c:** the responsive menu reduces the error rate.
- **H3d:** the responsive menu enhances the productivity.

Split menu

In 1994, Sears and Shneiderman proved that split menu helped to reduce the selection time and received a greater user preference for desktop computer system. Unfortunately, our experiment based on mobile systems did not show promising results. During the experiment, the split menu provided the same average error rate than a traditional menu (3.33%). It appears that it also slightly increased the average selection time (2.52s instead of 2.5s for the control condition menu). Khalid Al-Omar and Dimitrios Rigas already experienced the same results with their small menu.

In conclusion, the split menu does *not* reduce the error rate, nor the selection time in the presence of a mobile system. It was also *not* preferred over the traditional menu. Therefore, all the hypotheses based on the split menu have to be reversed.

Minimised menu

The minimised menu was meant to help users to identify the desired item quicker by reducing the number of displayed items. At first glance, the experiment showed promising results. Indeed, the minimised menu provided the second lowest average error rate with 0.56% only. Unfortunately, this menu organization did not allow to reduce the selection time. The productivity of users was slightly increased but still remains unsignificant to be recognized. Finally, users were satisfied by the minimised menu organization but did

not prefer it over the traditional menu.

In conclusion, the minimised menu help users to reduce their error rate. However, it is not sufficient to reduce their selection time, nor their productivity, and it was not recognized as a preference. Therefore, we are only able to confirm one hypothesis:

- **H2c:** the minimised menu reduces the error rate.

Responsive menu

Yusuke Fukazawa was the first researcher to publish results based on a a responsive menu organization. The idea was to adapt the menu organization to the small size of mobile screens. The responsive menu provided great results. First, the participants managed to achieve a 0% average error rate by using this new menu organization. They also achieved the lowest average selection time and therefore, the highest productivity ratio. The responsive menu received the better satisfaction ratio along with the traditional menu and was preferred over all menu organizations.

In conclusion, we managed to prove the 4 hypotheses formulated about responsive menus:

- **H3a:** the responsive menu reduces the selection time.
- **H3b:** the responsive menu is preferred by users.
- **H3c:** the responsive menu reduces the error rate.
- **H3d:** the responsive menu enhances the productivity.

Novice and master users

Yusuke Fukazawa also noticed that novice and master users usually express different preferences regarding new menu organizations. Unfortunately, the participants of the experiment were mainly master and frequent smartphone users. Therefore, we can only prove the assumptions made on the master users and we have to dismiss the assumptions about the novices. Eventhough these frequent users expressed a great satisfaction to all menu organizations, they mainly ranked the traditional and responsive menus as their

favorite ones.

In conclusion, we can only confirm and update one hypothesis:

- **H4b:** master users show a preference for the traditional and the responsive menus.

Guidance informations and period of adjustment

The survey paper was also used to gather users' thoughts about the guidance informations and the period of adjustment. There were 3 interesting sentences to analyze the impact of these notions on menu usability. Each sentence had to be rated on a scale ranging from 1 (disagree) to 7 (agree) for each menu organization. These sentences are listed below:

1. I found this menu presented as expected.
2. I needed to learn more this menu.
3. I needed more guidance informations about this menu.

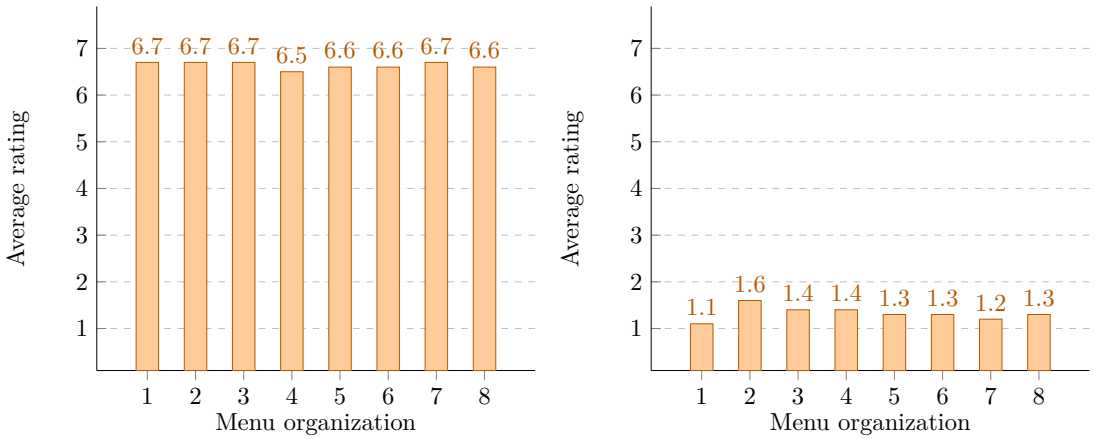
The 1st and last sentences are helpful to assess the quality of the guidance informations provided at the beginning of each training session. Figure 4.11 depicts the average rating received for these sentences for each menu organization. According to these ratings, the subjects of the experiment were very satisfied by the quality of the guidance informations. They found menus were all organized as expected and guidance informations were sufficient for them to understand new menu organizations.

During the experiment, the participants were first able to train themselves with each menu organization for 2 consecutive selections only. Then, they were asked if this period of adjustment was long enough according to them. The second sentence described above is interesting to evaluate this objective. Figure 4.12 depicts the average rating received for this sentence for each menu organization. The results are very prositive. Indeed, users have agreed to rate the period of adjustment long enough for all menu organizations.

In conclusion, the guidance informations and the period of adjustment have been widely appreciated by the participants of the experiment. However we haven't tested

the experiment without these notions. Therefore, we cannot take proper conclusions on the fact that they help users to handle a menu organization more efficiently. Since users appreciated the quantity and quality of the provided guidance informations, we can only prove the following hypothesis:

- **H5a:** guidance informations help users to understand how a menu works.



(a) Average rating gathered for the sentence "I found this menu presented as expected" for each menu organization.

(b) Average rating gathered for the sentence "I needed more guidance informations about this menu" for each menu organization.

Figure 4.11

Figure 4.12: Average rating gathered for the sentence "I needed to learn more this menu" for each menu organization.

Mixed-initiative menus

The experiment was also set up with 3 mixed-initiative menus which combined split, responsive and/or minimised properties. The idea was to implement complementary menu organizations and benefit from their respective advantages. The first results were encouraging as all these mixed-initiative menus provided a lower average error rate. The minimised responsive split menu even provided the second lowest average error rate with 0.56%. Moreover, these new menu organizations provided a lower average selection time and thus enhanced users' productivity. Unfortunately these mixed-initiative menus did not sufficiently satisfied the subjects of the experiment. The minimised responsive split menu was even ranked 10 times as the worst menu organization in terms of user preference.

In conclusion, we can add and confirm the following hypotheses to our study:

- **H6a:** the minimised split menu reduces the error rate.
- **H6b:** the minimised split menu reduces the selection time.
- **H6c:** the minimised split menu enhances the productivity.

- **H7a:** the responsive split menu reduces the error rate.
- **H7b:** the responsive split menu reduces the selection time.
- **H7c:** the responsive split menu enhances the productivity.

- **H8a:** the minimised responsive menu reduces the error rate.
- **H8b:** the minimised responsive menu reduces the selection time.
- **H8c:** the minimised responsive menu enhances the productivity.

- **H9a:** the minimised responsive split menu reduces the error rate.
- **H9b:** the minimised responsive split menu reduces the selection time.
- **H9c:** the minimised responsive split menu enhances the productivity.

Chapter 5

Conclusion

Conceiving, designing and testing new menu organizations was a long and tough task. First, it was necessary to understand and summarize previous researches. It was an essential step to extract the currently available knowledge about menu usability. Then, it was essential to formulate an initial set of hypotheses in order to guide the development of the experimental method. Based on these assumptions and this experimental method, an Android application has been implemented to conduct the experiment and results were extracted from it. After a torough analysis of these results, we were finally able to confirm, reverse and update our hypotheses.

The experimental method set up during the study helped us to confirm many assumptions. First, we observed that all new menu organizations were beneficial in reducing the average error rate, except for the split menu that provided the same error rate as the traditional menu. Then, we proved that the responsive and the 4 mixed-initiative menus helped users to reduce their average selection time and enhance their productivity. Moreover, users showed a higher preference rate for the responsive and the traditional menus. Finally, we have shown that guidance informations can help users to understand the overal operation of a menu organization.

In conclusion, the split menu organization developed by Sears and Shneiderman is not the ideal solution for smartphone resolutions. The traditional and responsive menus received the highest user preference. The responsive menu also proved to be the most performant one in terms of usability. Therefore, the responsive menu designed by

Yusuke Fukazawa with a specific focus towards small touch screens appears to be the most promising menu organization for smartphones. Further experiments should focus on this novative menu organization.

Further

Some matters remain unchallenged at the end of this study. Further improvements and additional issues remain to be accomplished, improved and set to keep enhancing our knowledge base about HCI and menu usability. This section aims to enumerate some of these matters.

- **Large menu**: according to Khalid Al-Omar and Dimitrios Rigas, our set of menu items should be considered as a "small menu". They tested new menu organizations with both a small set of 17 items and a larger set of 29 items. During their controlled experiment, they identified varying preferences between these menus. Therefore, the responsive menu may not be the ideal solution with larger menus.

- **Hot list**: according to Sears and Shneiderman, the hot list of a split menu should not exceed 4 items. During the experiment, we decided to implement a hot list made of 3 items. A split menu organization displaying a different hot list length may eventually be preferred by users and/or enhance their productivity.

- **Learning effect**: some subjects of the experiment were concerned about the learning effect between each session. Indeed, a few ones recognized to know the items better after a few evaluation sessions. Therefore, the final results may include some sort of bias.

- **Evaluation session**: some menu organizations are now acknowledged to be more usable than other ones with smartphones. We should conduct a second experiment which targets specifically these menu organizations and offers longer evaluation sessions. Indeed, a set of 10 selections for each menu seems like a short session in comparison to previous studies.

- **Keystroke menu**: during our research, we implemented another type of menu organization called "keystroke". It consists of a traditional menu overhung with

a search bar. This feature allows users to type the name of the desired item and watch the menu updated in real time. Unfortunately, the conducted experiment was already quite long and we decided to set aside this menu organization.

- **Log file**: a final improvement to the Android application would be to store each user's actions in a log file for a deeper analysis of their behaviours with new menu organizations.

Chapter 6

Abbreviations

HCI : Human-Computer Interaction.

IT : Information Technology.

LSM : Louvain School of Management.

UCL : Université Catholique de Louvain.

UI : User Interface.

UX : User Experience.

Bibliography

[1] John M. Carroll. Human computer interaction - brief intro. *The Encyclopedia of Human-Computer Interaction, 2nd Ed.*, 2013.

[2] Andrew Sears and Ben Shneiderman. Split menus: Effectively using selection frequency to organize menus. *ACM Trans. Comput.-Hum. Interact.*, 1(1):27–51, March 1994.

[3] Stuart K. Card. User perceptual mechanisms in the search of computer command menus. In *Proceedings of the 1982 Conference on Human Factors in Computing Systems*, CHI '82, pages 190–196, New York, NY, USA, 1982. ACM.

[4] Benjamin L. Somberg. A comparison of rule-based and positionally constant arrangements of computer menu items. *SIGCHI Bull.*, 18(4):255–260, May 1986.

[5] Saul Greenberg and Ian H. Witten. Adaptive personalized interfaces—a question of viability. *Behaviour & Information Technology*, 4(1):31–45, 1985.

[6] J. Mitchell and B. Shneiderman. Dynamic versus static menus: An exploratory comparison. *SIGCHI Bull.*, 20(4):33–37, April 1989.

[7] Sidney L. Smith and Jane N. Mosier. Guidelines for designing user interface software. *The MITRE Corporation*, August 1986.

[8] Selvidge Paula. Menu design : To adapt, or not to adapt? *Usability News*, 4(1), January 2002.

[9] Patrick Bolton James R. Warre. Intelligent spit menus for data entry: A stimulation study in general practice medicine. *Inform Assoc*, pages 450–454, November 1999.

[10] Mona L. Toms, Mark A. Cummings-Hill, David G. Curry, and Scott M. Cone. Using cluster analysis for deriving menu structures for automotive mobile multimedia applications. In *SAE Technical Paper*. SAE International, 03 2001.

[11] Saipunidzam MahamadSyarifah Bahiyah Rahayu Syed MansoorRajaletchume A/P Annamalai. User perception on intelligent split menu for web browser data entry. *Innovations and Advanced Techniques in Computer and Information Sciences and Engineering.*, pages 439–442, 2007.

[12] Khalid Al-Omar and Dimitrios Rigas. The effect of size of personalised menus on user satisfaction. In *Proceedings of the 11th WSEAS International Conference on Mathematical Methods and Computational Techniques in Electrical Engineering*, MMACTEE'09, pages 322–327, Stevens Point, Wisconsin, USA, 2009. World Scientific and Engineering Academy and Society (WSEAS).

[13] Theophanis Tsandilas and M. C. Schraefel. An empirical assessment of adaptation techniques. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '05, pages 2009–2012, New York, NY, USA, 2005. ACM.

[14] Yusuke Fukazawa, Mirai Hara, Masashi Onogi, and Hidetoshi Ueno. Automatic mobile menu customization based on user operation history. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services*, MobileHCI '09, pages 50:1–50:4, New York, NY, USA, 2009. ACM.

[15] Leah Findlater, Karyn Moffatt, Joanna McGrenere, and Jessica Dawson. Ephemeral adaptation: The use of gradual onset to improve menu selection performance. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, pages 1655–1664, New York, NY, USA, 2009. ACM.

[16] Google Android. Textview. `https://developer.android.com/reference/android/widget/TextView.html`, 2014. [Online; accessed 23-July-2017].

[17] Google Android. Edittext. `https://developer.android.com/reference/android/widget/EditText.html`, 2014. [Online; accessed 23-July-2017].

[18] Effectiveness. *Oxford English Dictionary*. Oxford University Press, 2017.

[19] ISO. ISO 9241-11:1998 Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability. Technical report, International Organization for Standardization, 1998.

[20] Efficiency. *Oxford English Dictionary.* Oxford University Press, 2017.

Appendix A

Survey

Survey paper to assess UX with distinct menu organizations

Experiment realized by Nathan Magrofuoco for his master thesis at the Louvain School of Management, under the supervision of Professor Jean Vanderdonckt.

Before starting the *Menuz* application and dive into the experiment, please take a few minutes to answer the first 6 questions of this survey. We ensure that anonymity will be maintained throughout the experience. No personal information will be publicly disclosed.

1. Name used during the experiment :	_____.								
2. Gender :	o Female	o Male							
3. Age range :	o <18 years	o 30-40 years							
	o 18-25 years	o 40-50 years							
	o 25-30 years	o 50-60 years							
		o > 60 years							
4. Profession or branch of study :	_____.								
		1	2	3	4	5	6	7	
5. I consider myself competent and at ease with touchscreen technologies.	disagree	o	o	o	o	o	o	o	agree
6. In general, I consider myself competent and at ease with smartphones.	disagree	o	o	o	o	o	o	o	agree

You can now launch the *Menuz* application. Start by introducing your name with the help of the touchscreen keyboard. Once ready, press the button called “Start the experiment”. Directives will now be provided by the *Menuz* application.

Menu 1/8 - Evaluation session		1	2	3	4	5	6	7	
7. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
8. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
9. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
10. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
11. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
12. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
13. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
14. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
15. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 2/8 - Evaluation session		1	2	3	4	5	6	7	
16. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
17. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
18. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
19. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
20. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
21. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
22. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
23. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
24. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 3/8 - Evaluation session		1	2	3	4	5	6	7	
25. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
26. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
27. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
28. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
29. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
30. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
31. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
32. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
33. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 4/8 - Evaluation session		1	2	3	4	5	6	7	
34. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
35. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
36. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
37. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
38. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
39. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
40. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
41. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
42. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 5/8 - Evaluation session		1	2	3	4	5	6	7	
43. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
44. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
45. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
46. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
47. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
48. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
49. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
50. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
51. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 6/8 - Evaluation session		1	2	3	4	5	6	7	
52. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
53. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
54. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
55. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
56. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
57. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
58. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
59. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
60. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 7/8 - Evaluation session		1	2	3	4	5	6	7	
61. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
62. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
63. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
64. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
65. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
66. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
67. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
68. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
69. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Menu 8/8 - Evaluation session		1	2	3	4	5	6	7	
70. I felt productive using this menu.	disagree	o	o	o	o	o	o	o	agree
71. I found this menu easy to use.	disagree	o	o	o	o	o	o	o	agree
72. I found this menu presented as expected.	disagree	o	o	o	o	o	o	o	agree
73. I think this menu requires some improvement.	disagree	o	o	o	o	o	o	o	agree
74. I found this menu well integrated into the smartphone.	disagree	o	o	o	o	o	o	o	agree
75. I needed to learn more this menu.	disagree	o	o	o	o	o	o	o	agree
76. I needed more guidance informations about this menu.	disagree	o	o	o	o	o	o	o	agree
77. I noticed some problems with this menu.	disagree	o	o	o	o	o	o	o	agree
78. I was frustrated by this menu organization.	disagree	o	o	o	o	o	o	o	agree

Rank the 8 menus in <u>decreasing order</u> by <u>preferences</u> :	1	2	3	4	5	6	7	8
Menu 1/8 - Vertical	o	o	o	o	o	o	o	o
Menu 2/8 - Vertical by pages	o	o	o	o	o	o	o	o
Menu 3/8 - Vertical with frequent items	o	o	o	o	o	o	o	o
Menu 4/8 - Vertical by pages with frequent items	o	o	o	o	o	o	o	o
Menu 5/8 - Multiples columns	o	o	o	o	o	o	o	o
Menu 6/8 - Multiple columns with frequent items	o	o	o	o	o	o	o	o
Menu 7/8 - Multiple columns by pages	o	o	o	o	o	o	o	o
Menu 8/8 - Multiple columns by pages with frequent items	o	o	o	o	o	o	o	o

If you wish so, write down a positive aspect noticed during the experiment :

If you wish so, write down a negative aspect noticed during the experiment :

Appendix B

Application UI

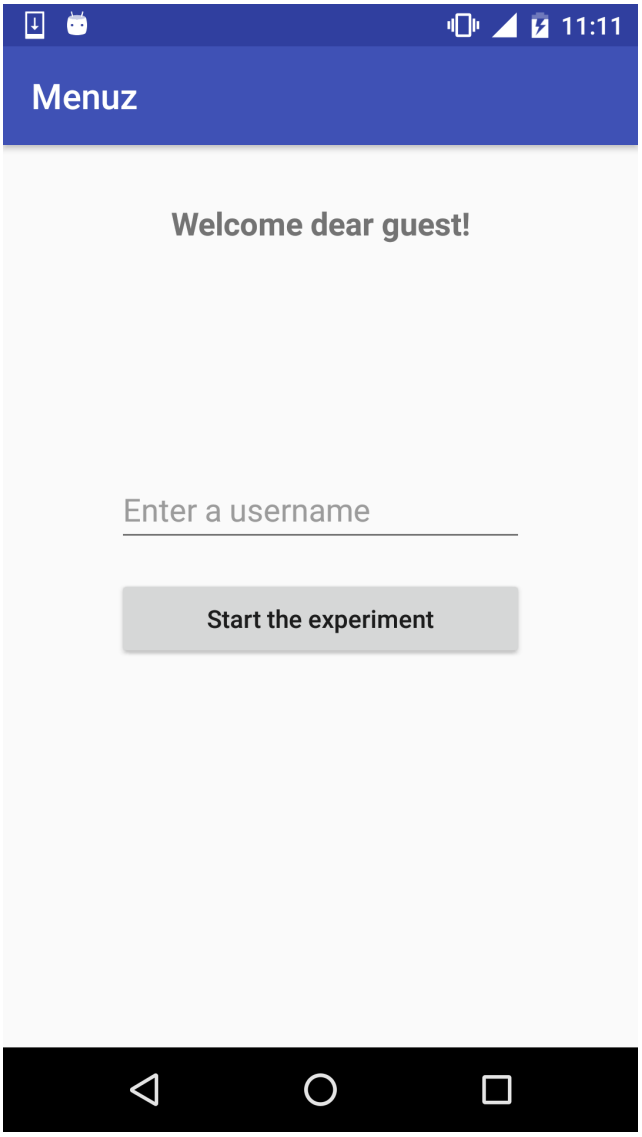


Figure B.1: MainActivity.

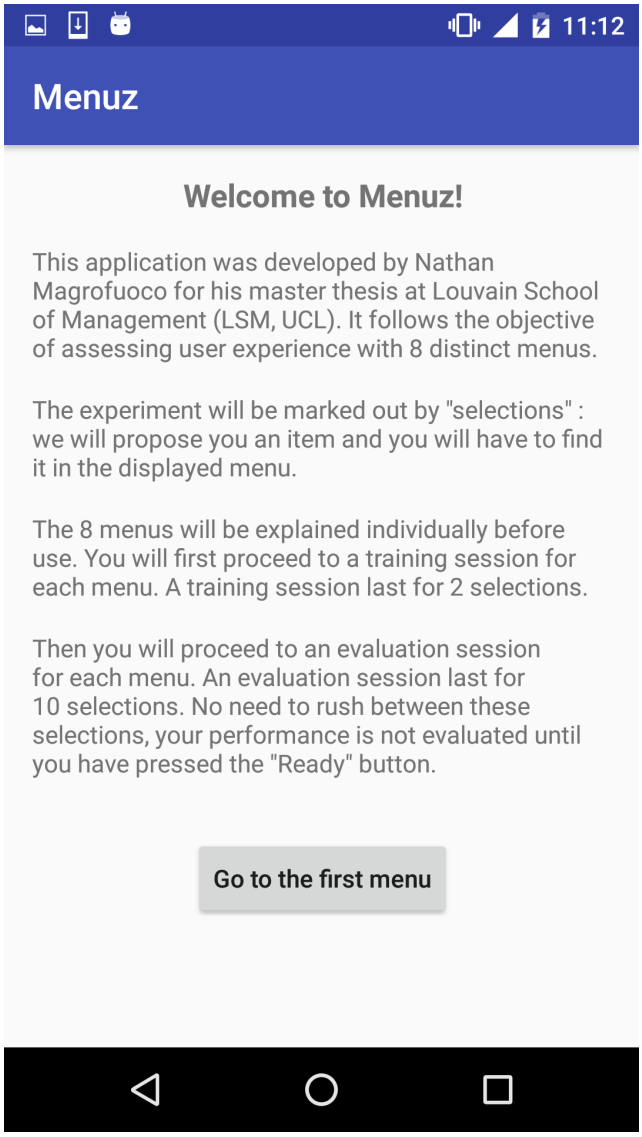


Figure B.2: IntroductionActivity.

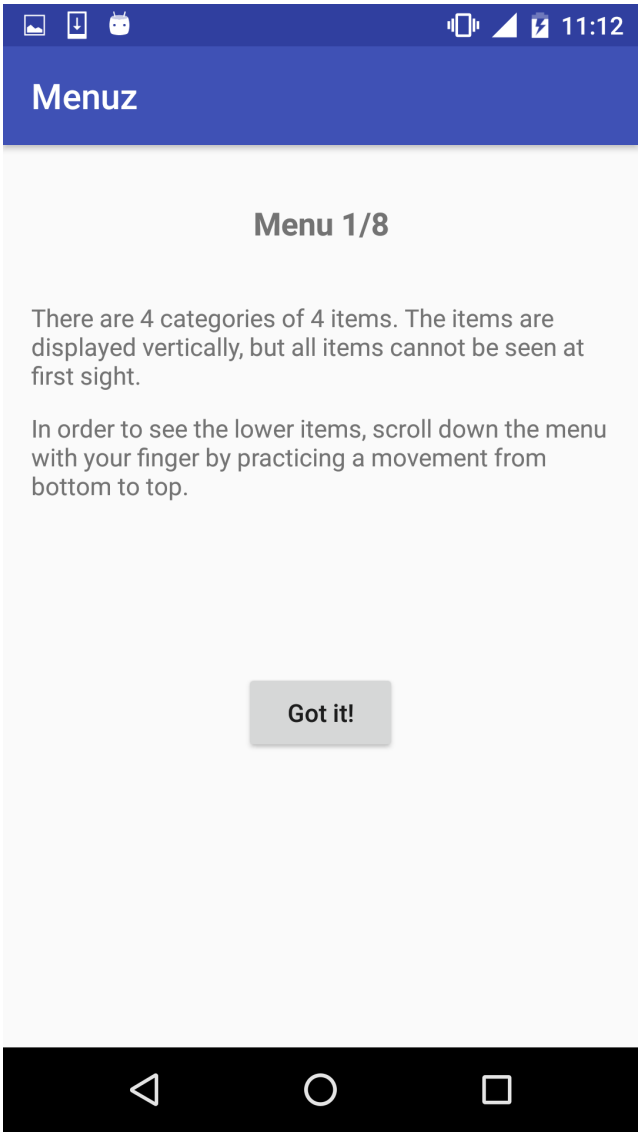


Figure B.3: MenuIntroductionActivity, before the 1st training session.

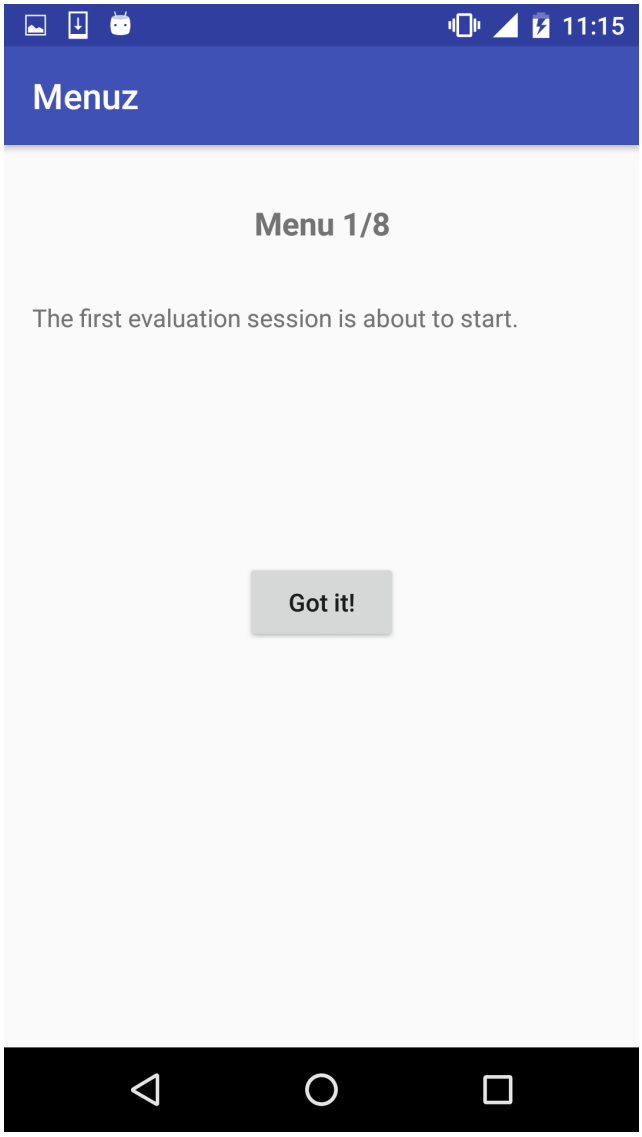


Figure B.4: MenuIntroductionActivity, before the 1st evaluation session.

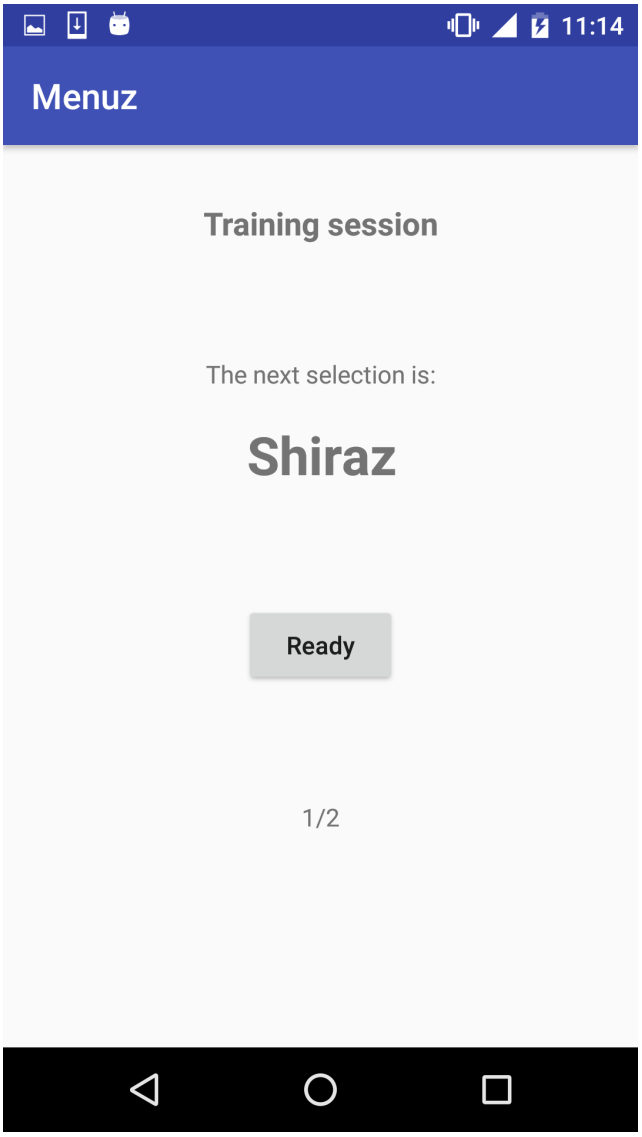


Figure B.5: NextSelectionActivity, during a training session.

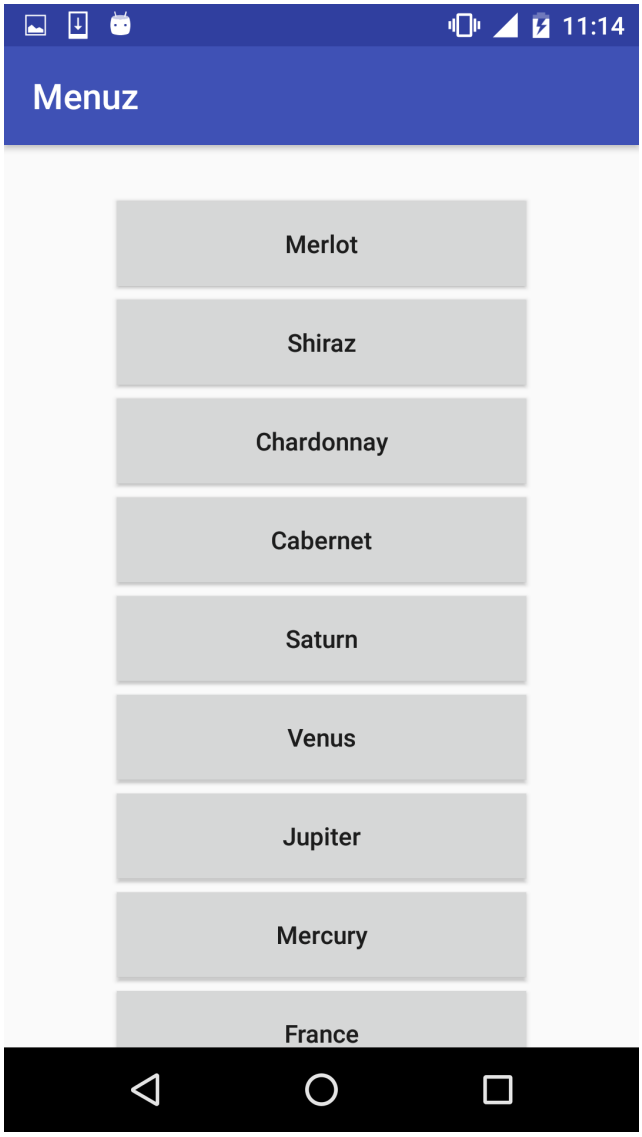


Figure B.6: MenuActivity.

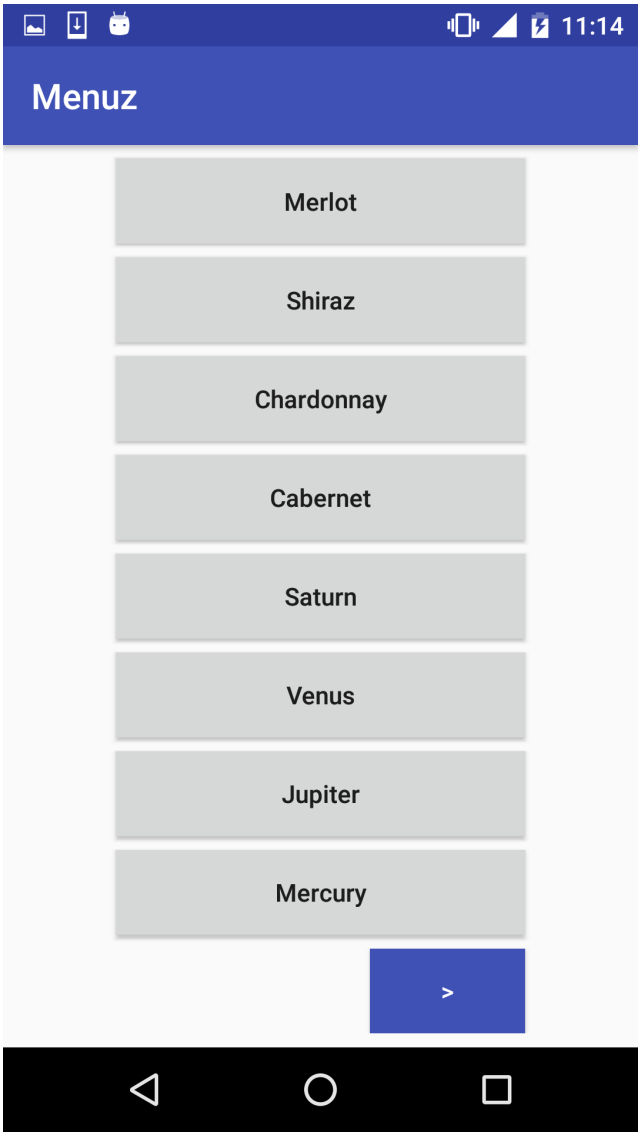


Figure B.7: MinimisedMenuActivity.

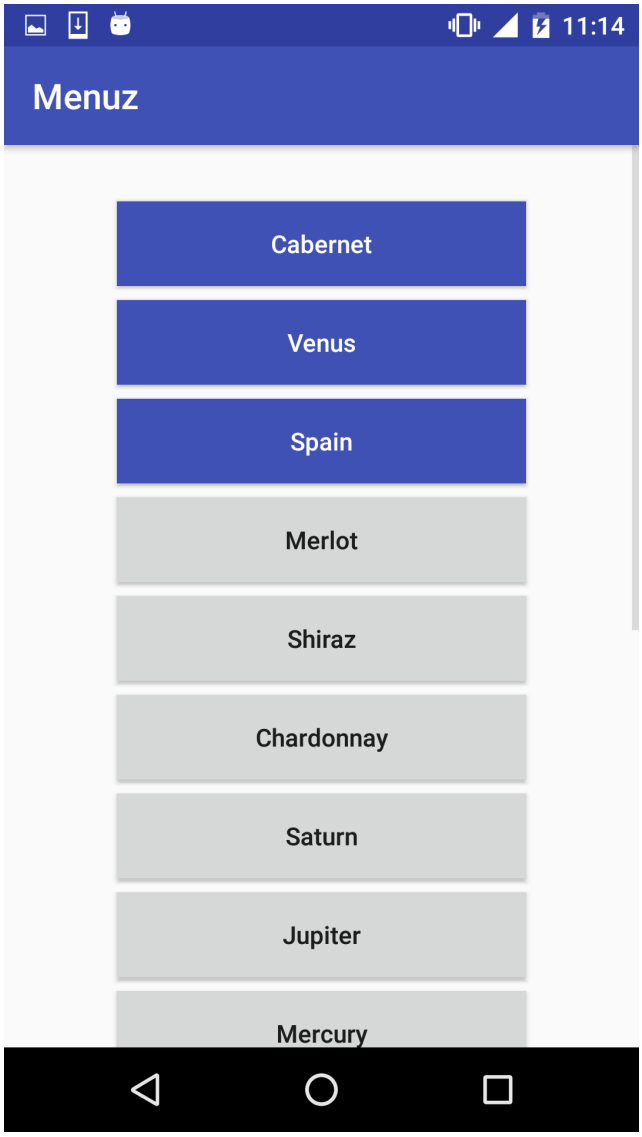


Figure B.8: SplitMenuActivity.

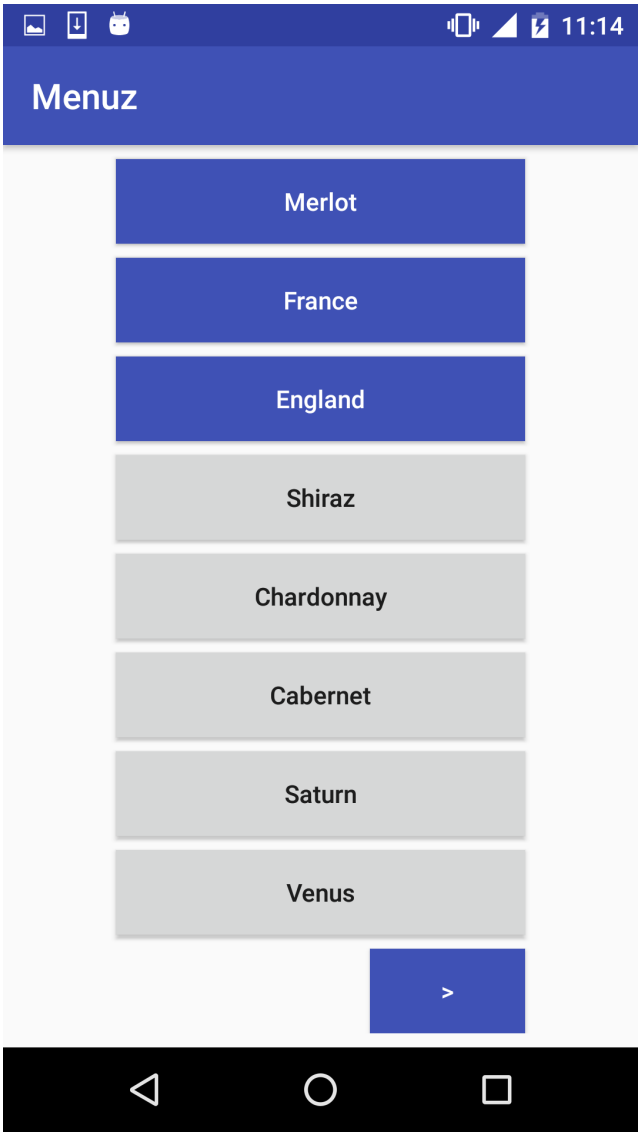


Figure B.9: MinimisedSplitMenuActivity.

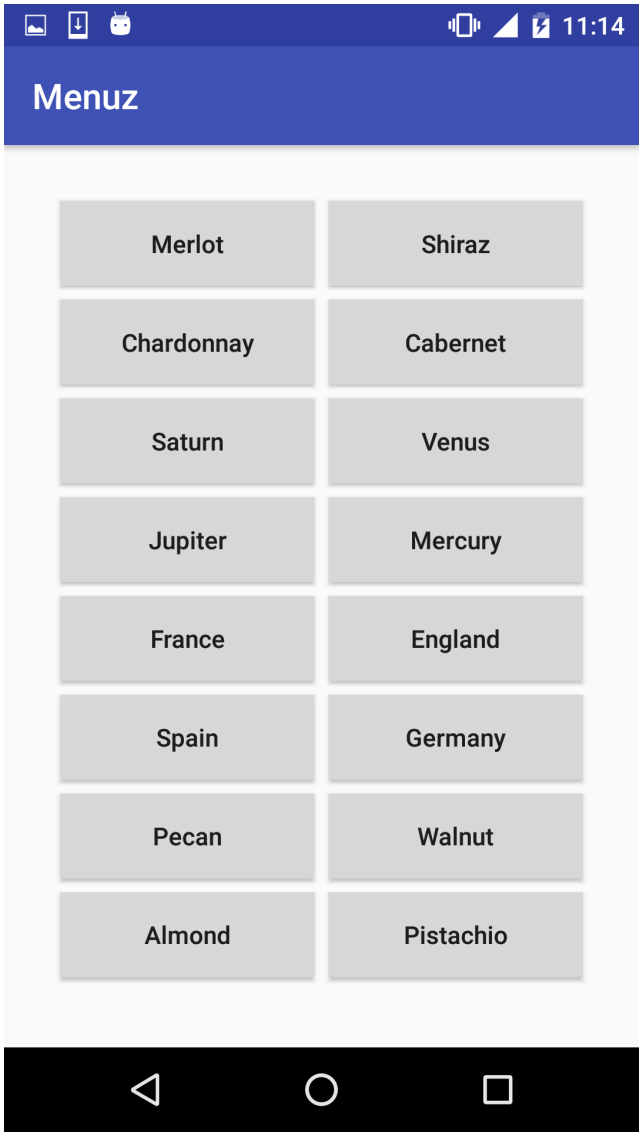


Figure B.10: ResponsiveMenuActivity.

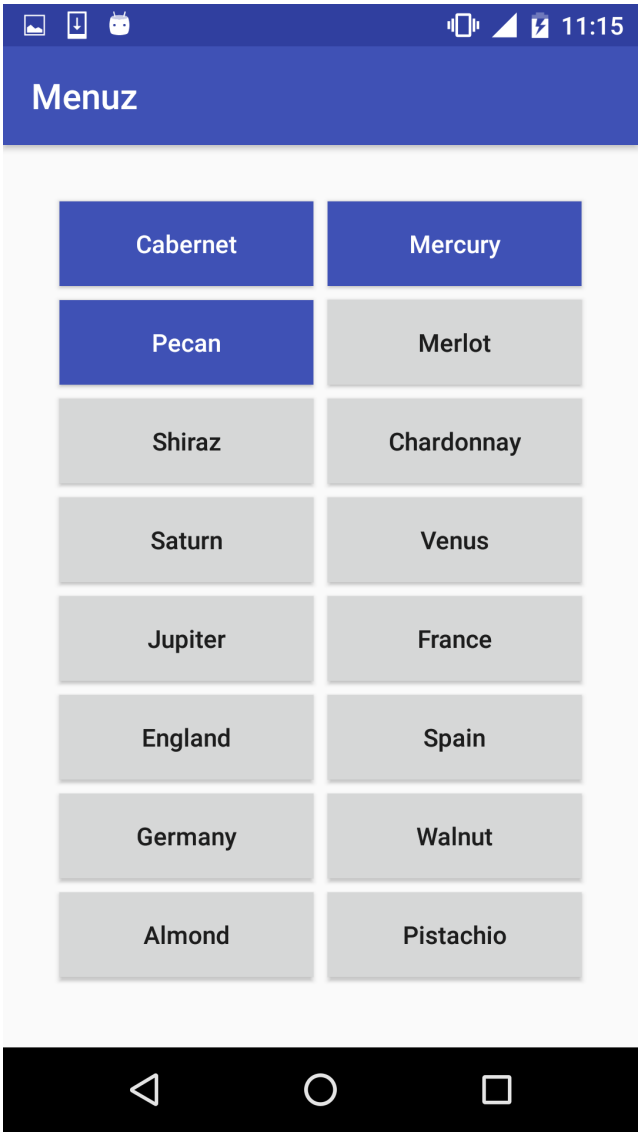


Figure B.11: ResponsiveSplitMenuActivity.

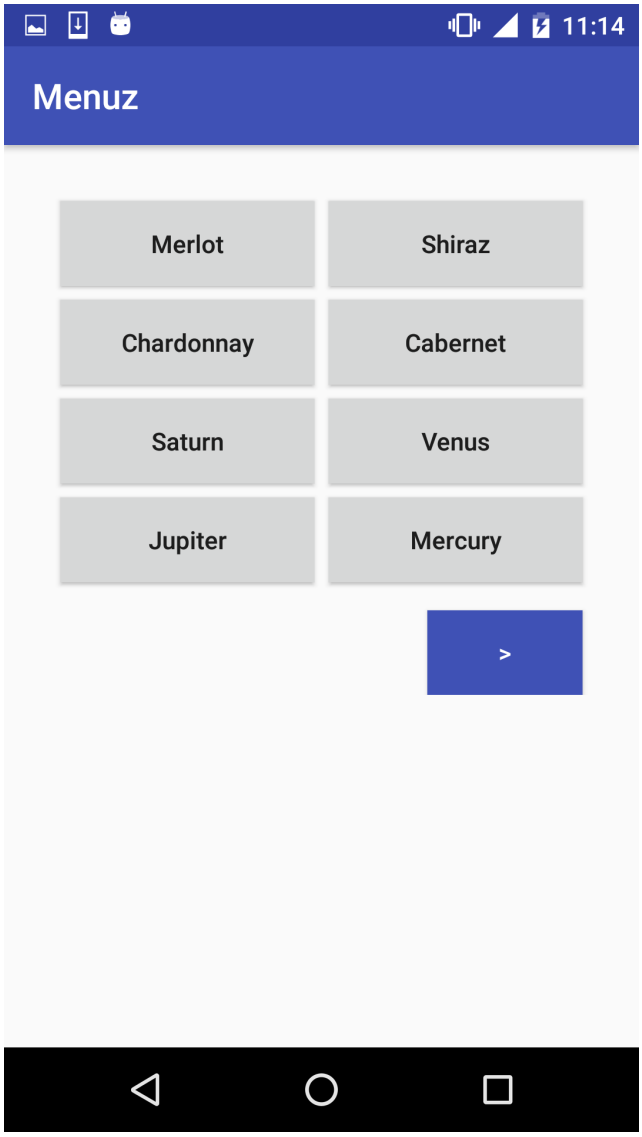


Figure B.12: MinimisedResponsiveMenuActivity.

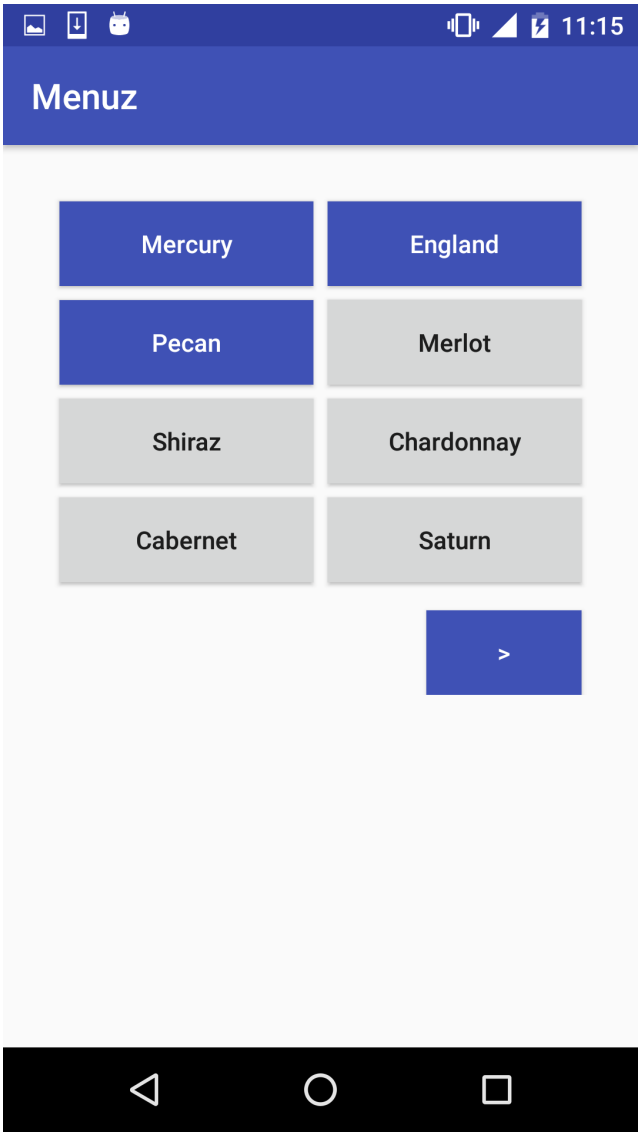


Figure B.13: MinimisedResponsiveSplitMenuActivity.

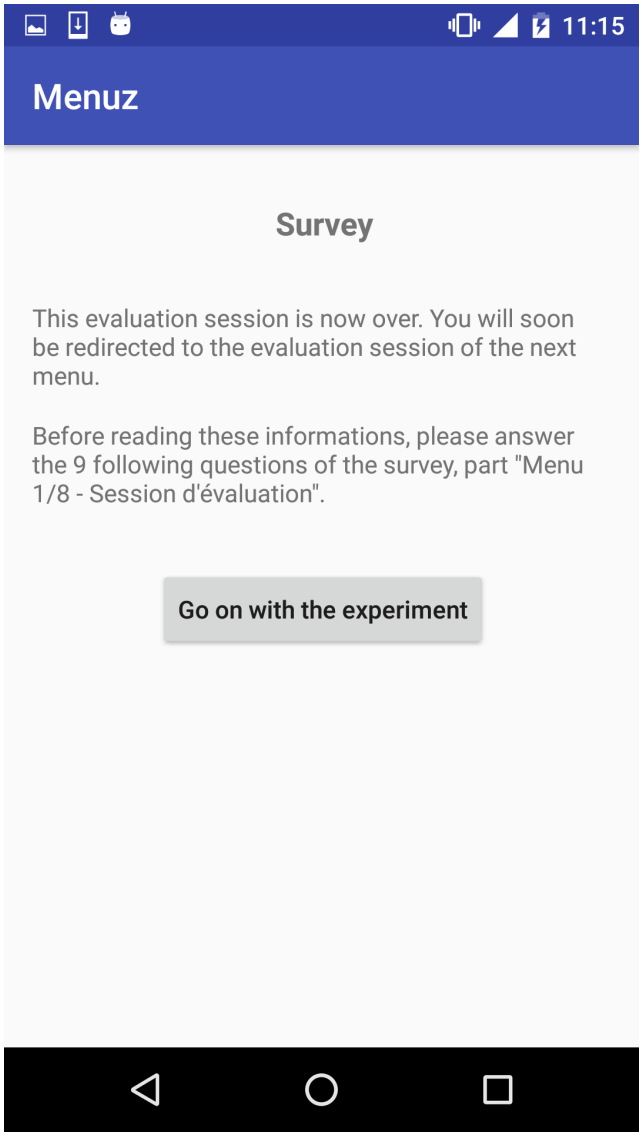


Figure B.14: SurveyActivity, at the end of the 1st evaluation session.

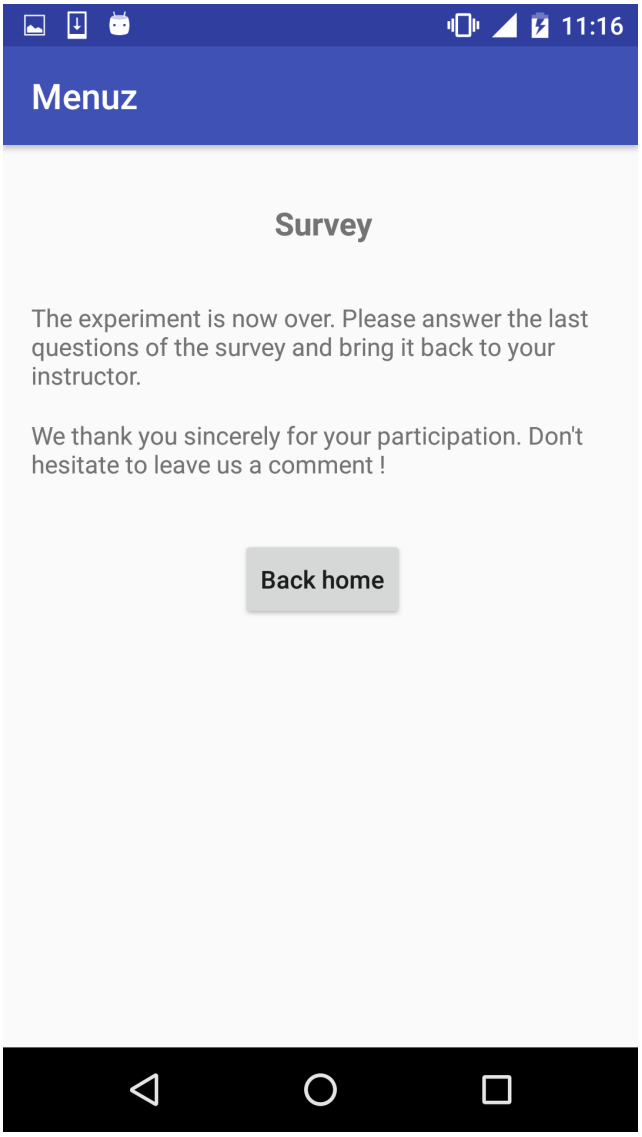


Figure B.15: SurveyActivity, at the end of the experiment.

Appendix C

Get the app (How to)

The Android application developed during the experiment is available as an open source repository on GitHub, see github.com/nmagrofuoco/menuz. The application is currently implemented in its French version. A readme file is available to switch the application to its English version. The repository also stores the sources of the dissertation.

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