Linnéuniversitetet
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Master Thesis

Visualizing complex data

A use case evaluating an interactive visualization about food purchases

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Abstract

Complex data are being stored daily in databases in an unstructured way. Visualizations techniques can be used to present complex data in a user friendly and understandable way. This thesis presents the implementation of a visualization interactive tool called Eco Donuts. It is part of a set of tools created to visualize complex food data called Ekopanelen. The feature Eco Donuts presents time-dependent food data which are ordered in categories. It gives the opportunity to users to explore their data over time by performing simple interactions. This thesis documents an exploratory study on how this visualization tool can be used to enhance the user experience and provide insights of complex data. The visualization feature was implemented and evaluated with ten participants. The participants were asked to evaluate the visualization tool by accomplishing nine different tasks. The sessions were recorded using a log system as well as video recording. This study shows that the proposed tool can be used to visualize complex information in a user friendly and presentable way.

Keywords: Information visualization, food-visual analysis, ecological awareness, user experience, interactive techniques.

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1 Introduction

Nowadays, there are many and different ways to produce data such as social networks, sensors, images, videos and many other unstructured sources (McAfee and Brynjolfsson (2012)). For instance, with the current evolution of technology, now people are using computers daily. Information computing technology (ICT) is embedded in many devices according to Ebert et al. (2012). A direct result of this is the production of big amounts of data. This data is stored in huge databases. Companies, organizations, governmental authorities and etc., even if when having access the data, have trouble interpreting the meaning of the information which is hidden in these unstructured datasets. For that reason, this data has to be translated into useful and meaningful information in order to be user friendly and presentable.

Shaw (2014) discusses the presentation of huge datasets in a user friendly, easy and understandable way. He recommends to use the most powerful tools for these cases, the visualization techniques. Visualization techniques are used in order to to enhance the user experience. A lot of applications offer the visualization of complex data sets in order to deliver valuable and useful information about the habits and preferences of the end users. Nevertheless, there are cases where visualizations misrepresent the real information or confuse the end user because of the vast amount of information that is included. For that reason, as Shaw (2014) said visualizations should not contain unnecessary information rather only the ones that are important and are comprehensible for the user.

This thesis is an exploratory study about, the extent of complex data visualization, how it can increase the understanding of the information that is delivered and how it can enhance the overall user experience. This examines a specific use case scenario where participants interact with a graphic user interface (GUI) that contains an interactive navigation visualization pattern (Heer and Agrawala (2006)). In particular the prototype focuses on visualizing the amount of food products, ecological or otherwise, which have been consumed per month by users. We also, evaluate the user experience through a usability study. The study attempts to discover if the tool is delivering successful insights to the end users (i.e. data that is not confusing and is visualized in a user friendly way).

1.1 Background

This master thesis is based on a research project called *From data to sustainable practices*, based at the Centre for Sustainable Communications at KTH Royal Institute of Technology, in Stockholm, Sweden. *From data to*

sustainable practices, has several goals. It aims to create methods and tools that will be used for creating sustainable data, helps existing users to live more sustainably, helps the users learn more about the connection between data sets and helps with the creation of sustainable practices. The main goal of *From data to sustainable practices* was to design and create prototypes that can be used in real life to collect data for further analysis. The main use case is called Ekopanelen. It is a web application focusing on organic food. Ekopanelen explores how presenting detailed and real-time data to the consumers. Specifically data about their own food consumption. This can help the users to gain insight about the impact of their purchases regarding organic food. Ekopanelen visualizes the following: The total amount of user's food consumption per year, a timeline presenting the food consumption for the last twelve last months and a interactive navigation tool that details data from each month.

This thesis presents an implementation of a visualized monthly overview, which offers insights about the complex information (regarding their food consumption). The name of this feature is *Eco Donuts*. This feature is an information visualisation and makes up one part of the prototype developed in this thesis. *Eco Donuts* is based on the design provided by the team of the parent project (*From data to sustainable practices*). Furthermore, the purpose of this thesis is to evaluate the user experience and the extent of the navigation tool ability to offer successful insights about the data. The overall goal is to have *Eco Donuts* reach a validated stage and be ready for consumer use.

1.2 Motivation

The main focus of this work is on the enhancement of the user experience when using the proposed feature (*Eco Donuts*) and then evaluate how successful it is at providing insights. Specifically, the proposed visualization tool refers to the consumption of products that are either ecological or not. The thesis will attempt to explore concepts like, how to offer an advanced and delicate experience to the end user and to trigger the awareness of ecological thinking a.k.a. green thinking. Green thinking is an important principle that helps humans understand that we have to care about our planet. It is important to remember in the future our planet will still be a place where the next generations should be able to live decently (Bashkite and Karaulova (2012)). Also, the current study can be used as a guideline for evaluating user experiences within the domain of information visualization systems.

At this point we would like to talk about the main motivation of this thesis, which is the importance of organic food and why it is worth it to

pay attention on the products that we are consuming every day. We will try to explain why organic food is important in our lives and the life of our environment. First of all, we will give a definition of organic food and present terms that can be used similar to organic. Organic farmers rely on biological diversity in the field to naturally reduce habitat for pest organisms instead of synthetic pesticides or fertilizers. Based on Schifferstein and Ophuis (1998) there are a lot of terms that can be used to refer to organic food, such as biological, ecological, natural, alternative, unsprayed, free of pesticides and environmental friendly products. All these are terms, which can be used on the current thesis to refer to organic food. Moreover, they mention that organic food is good because during the production the farmers are not using synthetic chemicals like pesticides or fertilizers. That has as a result that organic products do not contain chemicals but this is not the only reason that make organic food healthier than the conventional food.

Williams (2002), made a research to compare the organic versus conventional methods. Based on his research, there are evidence that prove agricultural methods affect on the nutritional quality of the food. The aim of these evidence was to throw spotlight on the differences between organic and non organic methods On his results he presents that organically-grown foods have higher nutritional quality than the conventional ones. Additionally, there are higher nitrate rates on vegetables that have been grown under conventional farming methods. Foremost, in the same research it has been shown that organic vegetables have more vitamins than the conventional. During his research, experiments had been conducted on animals by feeding them organic and conventional food in an effort to pinpoint the differences. The research came up with the result that organic food is better for plenty of reasons such as diet reasons, reproductive performance, long-time fertility and higher chance of survival of the newborn. Furthermore, there are studies on human beings, from organic farming areas and non-organic farming areas. The results of these studies have shown that the sperm quality is better for the organic farmers rather than the non-organic.

Moreover, there are a lot of studies, which provide reasons why is good and necessary the transition from conventional to organic food consumption habits. For instance, Hughner et al. (2007) in their study pinpoint that healthiness is a very important factor for people to eat organic food. In addition, they mention that organic food taste better, increase the environmental concern, the concern of food safety, the concern over animal welfare, supports local economy and help to sustain traditional cooking, is wholesome reminiscent of the past and fashionable.

Another study which provides benefits of ecological consumption is conducted by Davies et al. (1995). In their study they explain why people

in Northern Ireland are purchasing organic food. Some of the reasons are health concern, environmental reasons, taste, concerns about the future of their children, future of planet, animal welfare, freshness of products and flavours.

One more example is the study of Makatouni (2002) who did a research in England on parents with respect on organic food. Due to the fact that parents in UK feel responsible for welfare, the animals and the environment they prefer ecological food. Other motivations for organic food consumption are include the fact that it taste better, being like home-grown, being free from BSE (Bovine Spongiform Encephalopathy), genetic modifications and food additives. All these are reasons that turn consumers to organic food. As a direct result of that, is the fact that organic food consumption habits expands rapidly.

From all the aforementioned reasons we can understand the value of the organic food and why is so important. However, individuals do not know exactly what is their ecological behaviour if no information is provided to them. The big chains of supermarkets have all these information stored in their databases. But what if these information could be accessed and presented to users in an easy and comprehensible way.

1.3 Structure of Thesis

This research work consists of 6 main sections. The first section introduces the research problem of this study and relates it with an information visualization feature called *Eco Donuts*. Second, there is a general description and technical details of the proposed system. In the third section, we reference previous research studies that support our work. In the following section, there is an extensive description of methodology. In the fifth section, the experiment results are provided. Finally, the findings are discussed in order to conclude the study.

2 Research Problem

This thesis conducts research in the field of HCI (human-computer interaction) and the IV (information visualization) of complex data (Ware (2012)). Both the project *From data to sustainable practices* and this thesis aims to use new visualization techniques. The aim of both projects was to implement an interactive navigation visualization feature called *Eco Donuts* that provides insights on complex data concerning food consumption. In addition this thesis, and what sets it apart from *From data to sustainable practices*, is the evaluation of the UX (user experience). Therefore, the main research questions are:

- How successful is the proposed interactive navigation visualization feature (*Eco Donuts*) at providing insights?
- What is the learning curve of the feature (*Eco Donuts*)?
- How successful is the ease of use in the proposed interactive navigation visualization feature (*Eco Donuts*)?
- How can the proposed visualization feature be developed to have further improvements of usability?

To answer these questions we ran a series of studies. In the next section is presented a detailed description of the system.

3 System Description

3.1 General

The system description section provides a brief summary of the software parts that have been used in the Ekopanelen prototype. In addition, it will give a more detailed description of how the software parts are linked and what kind of processes have to be followed thus the system serve its goals. The main purpose of Ekopanelen prototype is to visualise complex food data, providing a comprehensive and easy overview to the end user.

3.2 Overview and Technical Details

The system consists of two main parts/processes. The first part is the processing of the incoming data and the second part is the visualization of the data of each authenticated user see Figure 3.1. For the first part of the system, the incoming data is in a machine-readable format, in the case of this prototype the data is in JSON format. The system can receive POST requests, which contain data in a specific JSON format provided from a third party and in our case the cooperating supermarket. However, this process is not an important part of the current study, so for that reason we will not provide more information about the specific functionality and it will be taken for granted that the system can receive data. For the purposes of this study we created dummy data which imported into the system manually. In the next step the system has to process, analyse and store them in order to be ready to be used by the second part, which is the visualization of the processed data.

The prototype of Ekopanelen is a web-based application and it is implemented using web technologies. The client side is implemented using CSS and Handlebars.js, a semantic web template system. On the top of that, a Javascript library called D3.js (Bostock (2012)) has been used to produce the dynamic and interactive visualization features of Ekopanelen's GUI (Graphical User Interface). To build the backend of Ekopanelen it has been used an open source Javascript runtime environment for easily building server-side and networking applications called Node.js. Node.js, also runs locally on different operating systems such as OS X, which was the case for us. On the top of that, a Node.js web application framework called Express.js used to organize Ekopanelen into an MVC architecture. Moreover, the system supports user authentication using Passport.js, which is an authentication middleware for Node.js, and is compatible with Express.js. The last part of the system is the MongoDB, which is a NoSQL database and contains all

the data of the system. The data of the system are stored in models using Mongoose a Node.js ODM (Object Data Mapper).

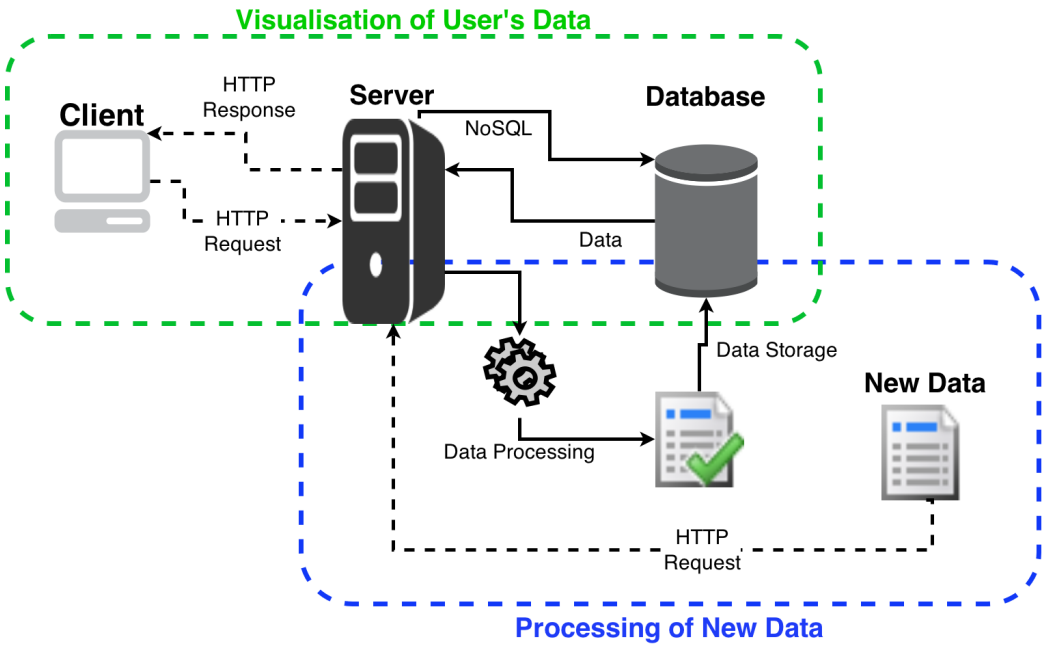

Figure 3.1: System Overview

3.3 Vizualization

After the processing and the storing of the incoming data, the system is ready to be used by the users. Hence, when a user visits Ekopanelen to check his data he has to authenticate his identity. When the user is authenticated, he has access to a GUI (Graphical User Interface) with the offered visualizations. In the proposed prototype system the user has the ability to check his data through the visualizations and interact with them. However, as we have mentioned before the participants of this study they did not view their own data but dummy data which created for the purposes of this study. The proposed GUI consists of three main visualizations. A sample of Ekopanelen's GUI (Graphical User Interface) can be seen in the Figure 3.2.

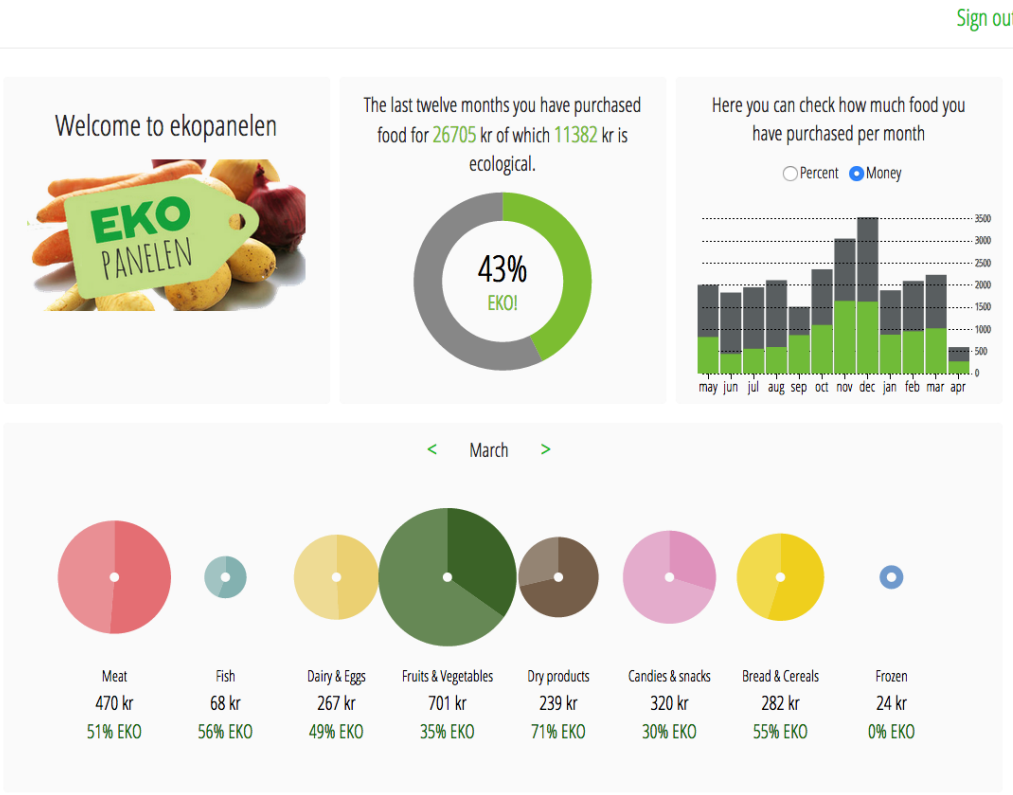

Figure 3.2: Graphical User Interface of Ekopanelen. In the top-center visualization is illustrated the total amount of money for ecological and not ecological food purchases for the last twelve months for a specific user. In the top-left visualization is presented the amount of money and the ecological percentage spent for purchases per month, in two different views. In the bottom visualization, is displayed the amount of money and ecological percentage for each food category in the last twelve months.

The first visualization (top-center) illustrates the total amount of money, which a user spent for his ecological and not ecological food purchases for the last twelve months. In the text the first number indicates the total amount of money purchased, when the second number indicates the amount of money for the ecological products purchased for the last twelve months see Figure 3.3. In the donut visualization the green arc shows the ecological percentage of the purchases and the grey arc is always hundred percent and represents the total amount of purchases.

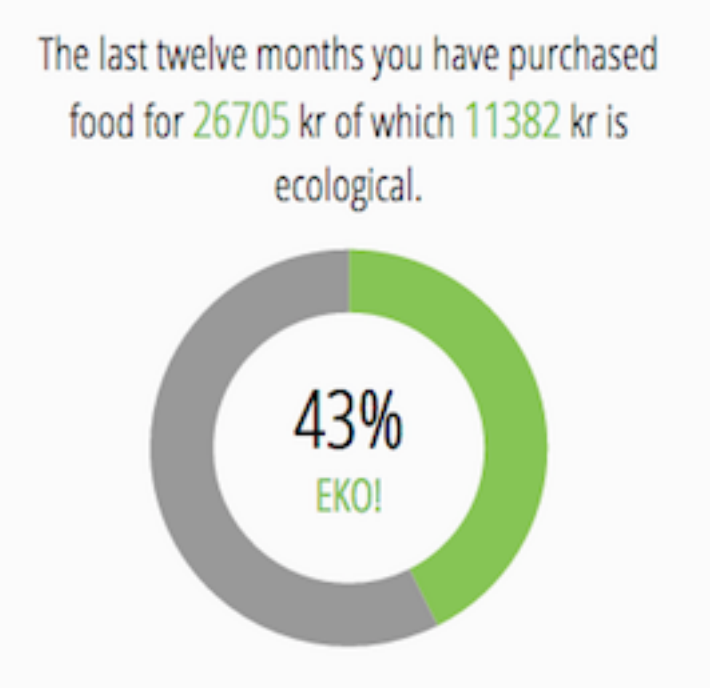

Figure 3.3: Total amount of purchases and ecological percentage

In the second visualization (top-right), there are two different views the amount of money and the ecological percentage of his purchases per month for the last twelve months. The user can switch between these two views using the radio button on the top of the visualization. On the first view the horizontal axis shows the last twelve months and the vertical axis shows the percentage of ecological purchases see Figure 3.4. For instance, on May we can understand that the user purchased approximately forty five percent of his total purchases for ecological products.

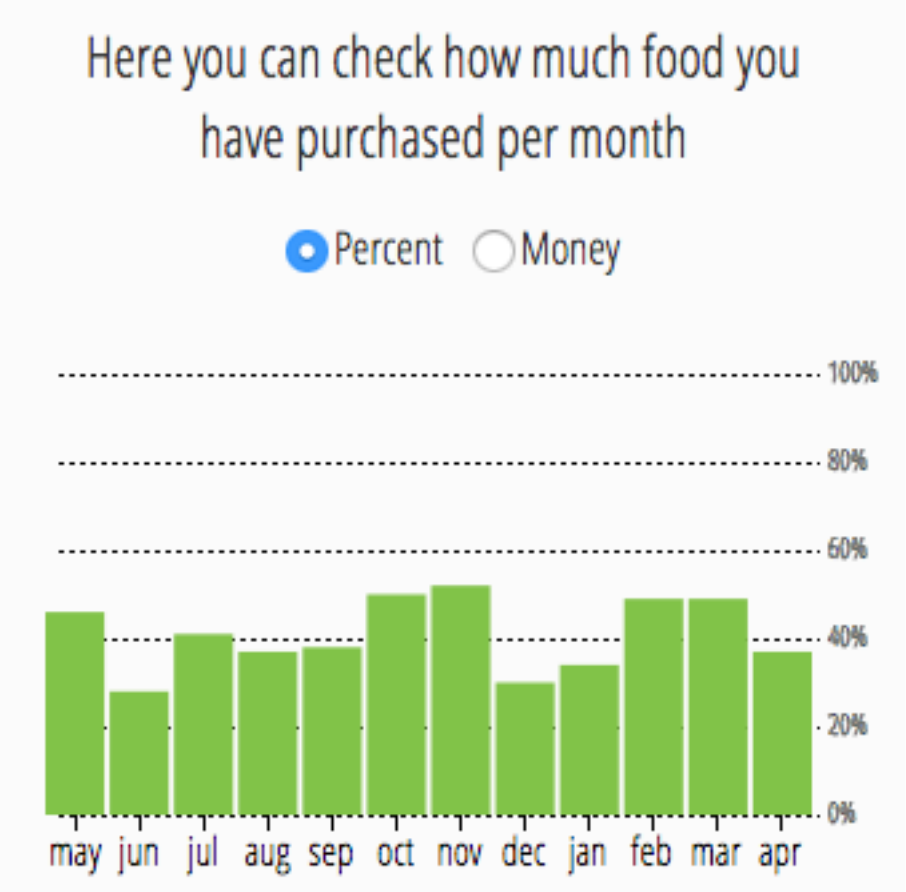

Figure 3.4: Ecological percent per month view

On the second view the horizontal axis shows the last twelve months and the vertical axis shows the amount of money. The currency displayed on this view is Swedish Kronas. The grey color represents the total amount of money spent for the month and the green color represents the amount of money spent for ecological products. For example, on March it is easy to understand that the user spent approximately 2200 Swedish Kronas for all of his purchases and approximately 1000 Swedish Kronas for purchases of ecological products, see Figure 3.5.

Figure 3.5: Total amount of purchases and ecological percentage per month view

The last visualization layout (bottom), is the food purchases per category for the last twelve months and it is called *Eco Donuts*. The *Eco Donuts* is visualizing the data from the food categories that the consumers have purchased. In this visualization is also presented the percentage of ecological products that has been purchased for each category. Each category is presented with different colour that is relevant with the category that represents. For instance, the *Meat* category is represented with red color and the *Bread and Cereals* category is represented with yellow color and so on. Moreover, the donuts have different size depending on the amount of money that have been spent on the specific category see Figure 3.6. On the top of this layout there is an interactive navigation controller which can be used from the user to navigate among the twelve months. When the user clicks on the left or right arrow of the navigation controller the month will change accordingly. In addition the donuts and the respective numbers of each category will change also. The names and the colors of the categories will remain the same see Figure 3.7.

The main color of each category is the brighter color and the percentage of ecological consumption is represented in a darker shade of the same category's

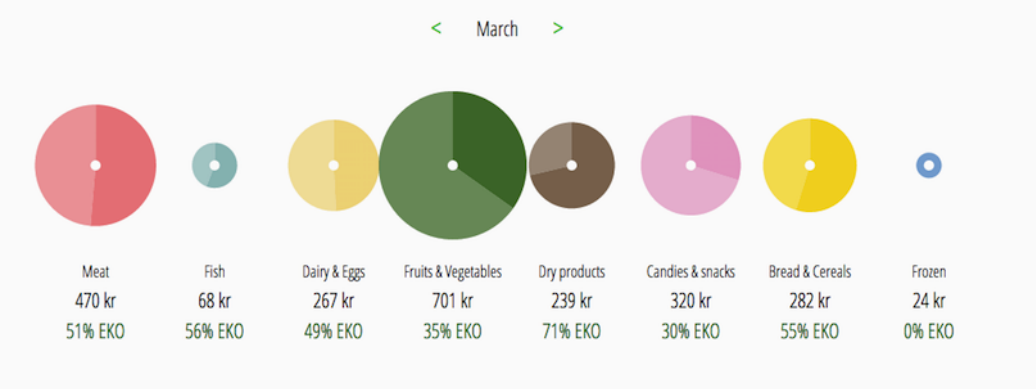

Figure 3.6: Eko Donuts view for March

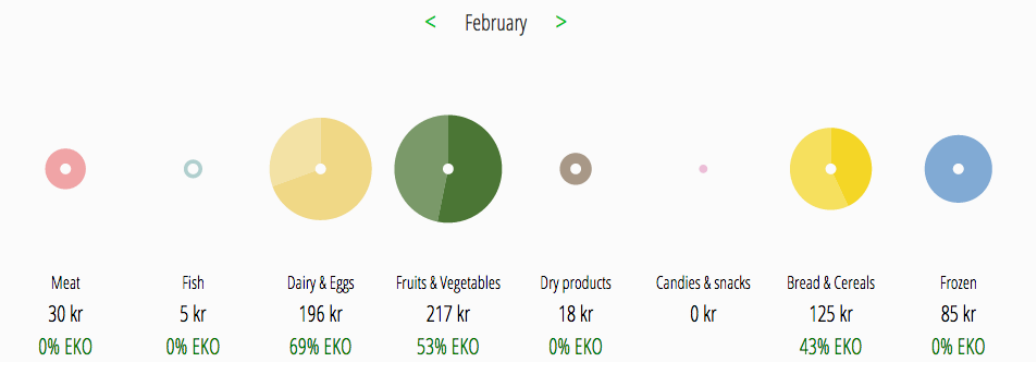

Figure 3.7: *Eco Donuts* view for February

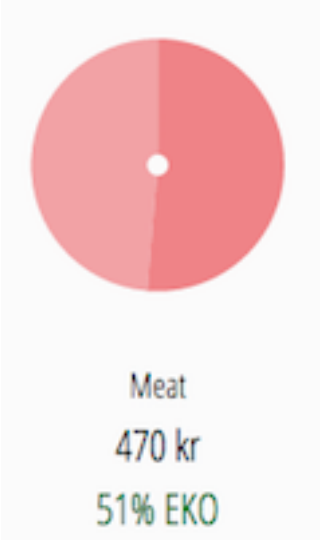

Figure 3.8: Donut for the category of meat in state 1

color. In order to complement the visualization of the donuts, text have been added showing the ecological percentage and the total amount of money per category. The size of the donut represents the total amount of money which spent on products, ecological or not, for the specific category see Figure 3.8. In the case where there are no purchases of ecological products for a specific category the text which shows the ecological percentage and the arc with darker shade are not present any more on the visualization see Figure 3.9. Last but not least, in the case where there are no purchases at all on a specific category then the donut is being converted into a bubble while the ecological percentage text and the darker shade are hided as before in the previous case see Figure 3.10.

The reason of the implementation of the current prototype and especially of the *Eco Donuts* is to enhance the user experience. In addition, the current prototype has been implemented to raise the awareness of the end users related with their ecological behaviour. However, in order to do that the system should usable and easy to understand. In the next section we present a brief review of the related work.

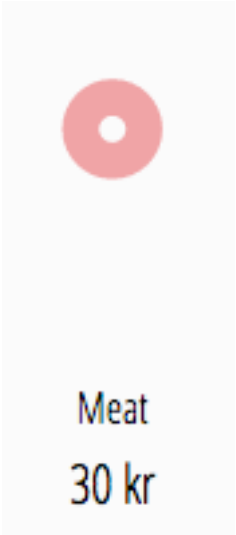

Figure 3.9: Donut for the category of meat in state 2

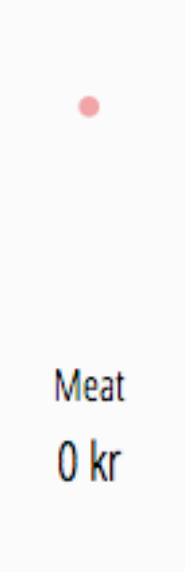

Figure 3.10: Donut for the category of meat in state 3

4 Related Work

This section is structured in two parts. In the first part of this section it will be presented the importance of visualization techniques in the research domain of HCI (Human Computer Interaction) and how they can deliver valuable information. Moreover, we will talk about the current web visualizations techniques and the evaluation studies in information visualization. In the last part, it is provided a description of Infographics (Graphical representation of information designed in a way to be easily understandable) and the relation with this thesis.

4.1 Visualization

HCI (Human Computer Interaction), is an interdisciplinary research area related with many other research fields such as sociology, computer science, graphical design, business etc. As Ebert et al. (2012) have mentioned, the main goal of HCI research is to improve, enhance and develop the interaction between the human beings and the machines. Moreover, they mention that when HCI is combined with visualization techniques, it can offer meaningful insights of the datasets that are illustrated in a GUI (Graphical User Interface). The visualization techniques have this advantage because of the way the human visual system is structured, which can process well visual representations of data.

Data visualizations are explained by Few (2013) in one of his studies, as a way to interpret valuable information in a graphical way. He adds that the main goals of the data visualizations are to offer sense-making and communication between the users and the visualization system. Furthemore, he points that in the big datasets there are a lot of hidden valuable information, which can be utilized with the usage of visualizations techniques. Thus, the data visualizations can offer, in a simplified way for the human visual system, insights and understanding of big complex data. Hence, data can be easier to understand for users by seeing a picture displaying a clear message, rather than information in rows and columns.

Information related with athletic performance, medical issues, demographics etc can be visualised using visualization techniques. In this thesis we present the implementation of a prototype which visualises food consumption in different food categories with web technologies. There are a lot of visualization techniques, which can be used to create many graphical representations of data for different purposes. At this point we will present some of the most well known web visualization techniques and the purposes they serve.

Exhibit is a framework that allows developers to create web pages with advanced text search and filtering functionalities, with interactive maps, timelines, and other visualizations. CartoDB is a web tool to create interactive maps. It helps users with no coding skills to create interactive maps, while programming-savvy users can use its API and Javascript library to create more advanced maps based on de la Torre (2013). The googleVis package is another visualization technology that offers the ability to the users to create interfaces such as Motion Charts, Annotated Timeline, Maps, Geo Maps, Tables and Tree Maps. The offered interactive charts by googleVis are based on the R frames and can be easily integrated in the websites Gesmann and de Castillo (2011). Last but not least, D3 stands for Data-Driven Documents and is a free JavaScript library that can create a wide variety of creative charts, maps and diagrams which can then be embedded into web pages Bostock et al. (2011).

In addition, D3 can be used to produce information visualizations which can be supported by animated transitions. Some examples of other projects which have used the D3 library for their GUIs (Graphical User Interface) and offer interactivity are the Superconductor of Meyerovich et al. (2013) and the Fuseviz by Ghidini et al. (2012). Because of the reason that D3 provides the ability to create your own and initiative visualizations, compared to the rest of the frameworks, and we wanted to implement a custom interactive navigation visualization tool, it seemed that D3 is the proper way to follow. Plus the fact that the developers of this project have extended knowledge of D3.

4.2 Infographics

Infographics is a way to illustrate a combination of data and ideas in a visual and informative way that can say a story to the final viewer. Krauss (2012) explains that infographics are not just a simple illustration of data such as the traditional charts, tables, graphs etc. but a combination of ordered complex datasets. The aim of these ordered complex datasets is to rise up questions but also to say a story to the end viewer. The infographics let the end-viewers to interpret the message, they want to send, in their own way.

Based on Mol (2011), the history of infographics started when the publication stores wanted to add illustrations in the newspapers and magazines. Some great examples of infographics are the IKEA manuals, the safety instruction cards on airplanes etc. In the latest years there has been a popularization of infographics thanks to internet. With the evolution of web 2.0 and the rise of the web technologies, infographics have expanded a lot. This is a direct result of the fact of high accessibility to open source and freeware

programs that can be used to produce infographics. These technologies can be taught quite easy and be used to design beautiful infographics.

In Ekopanelen, we used a combination of numbers and visualizations where the users have the ability to explore the proposed GUI (Graphical User Interface), in their own way and figure out patterns, associations, trends etc. In Ekopanelen, you can say that static snapshots of the visualizations are very close to the idea of Infographics. In the next section it is provided a detailed description of the methodology.

5 Methodology

In this section we will describe the methods and techniques, which we used to assess our prototype. The methods and the techniques that have been used were chosen based on the literature survey. Based on the literature survey we decided to conduct a usability test in order to collect feedback from the participants about the UX (User Experience) of the proposed information visualization feature called *Eco Donuts*. In the subsection, Data Collection and Sampling we describe in detail the methods and instruments that we used to collect the data. In the last subsection we talk about the data analysis techniques that we used to analyze the data. These techniques are the IDA (Instant Data Analysis) in combination with VDA (Video Data Analysis).

The primary purpose of this study is to collect feedback about the user experience of the participants. From the varied methods that could be followed for evaluating the user experience as presented by Lam et al. (2012), we chose to run a usability test. In order to run a usability test in a proper way, we followed the guidelines described by Rubin and Chisnell (2008). Following these guidelines we prepared carefully all the elements of our usability test such as the metrics, tasks, participants etc. All of these elements will be explained extensively later in the data collection and sampling subsection.

The moderation technique which have been used for this usability test is the Retrospective Think Aloud (RTA) method (Kjeldskov et al. (2004)). During the session the moderator was taking notes of the comments or actions of the participants. Furthermore, the moderator was asking questions in order to gain a better understanding of the thoughts and actions of the participants. This specific technique have been chosen because it works better with IDA (Instant Data Analysis), as it is proven by Kjeldskov et al. (2004)

The first and most important step of the usability study are the participants, who should be highly related with the use case that is getting examined. In particular, the participants of the usability study should be aware about green thinking (Bashkite and Karaulova (2012)). For that reason, a survey have been conducted in advance of the usability study with questions related with the green thinking awareness of the candidates in order to assist us choose carefully the suitable participants. Therefore, the participants who have been chosen had high ecological awareness based on the results of the aforementioned survey.

Furthermore, about the number of the participants of the usability study, we decided to keep the sample small but highly related with the research problem since we have limited time and access to human resources. Hence, in the usability study participated ten participants. A similar case to Wong-

suphasawat and Shneiderman (2009) where they had a small sample also.

Regarding the analysis of the collected data it has been used the IDA (Instant Data Analysis), which is a light-weight analysis technique in combination with the VDA (Video Data Analysis) technique. Due to the time limitations the IDA technique is an ideal technique in our case and in the most complicated scenarios can be supported by the VDA technique as it has been proven by Følstad et al. (2012).

5.1 Data Collection and Sampling

In this subsection we present the different steps which have been used to collect the data during the usability test. To begin with, we would like to remind the scope and the purpose of this study. The scope of this usability test is to test the user experience and how successful insights can provide the *Eco Donuts* feature, which visualization classified data into food categories. The data presented to the participants are dummy data, which have been constructed for the purposes of this study. The target group of Ekopanelen is consumers who are environmentally aware and interested about organic food, to help them gain insight about their consumption and to increase their percentage of organic purchases. To check and choose the most suitable participants for the usability test we conducted a survey with questions about ecological issues. The survey distributed to the public using two different channels, Facebook and personal emails. In this survey for each participant a total score calculated, which is representing the level of awareness of the participants. The ten participants with the highest score asked to participate in the usability study. In case someone of them could not participate there was a list with the rest of the candidates. The candidates who agreed to participate to the usability test booked their session using Doodle a free online poll maker.

The tests took place in Linnaeus University, Vaxjo, Sweden in the Interactive Lab of Media Technology department. Each session last for one hour and there was a fifteen minutes break in between of two sessions to finalize the notes from the running session and reorganize the testing environment for the next one. An Apple laptop, MacBook Pro (13-inch, Late 2011) have been used for this usability test, with screen resolution 1280x800 which was connected with an HP monitor screen (17-inch) with screen resolution 2560x1440. The HP monitor screen was used to present the user interface to the participants through Google Chrome browser. The same time on laptop's screen we could monitor the progress during the usability study. The running operating system is the OS X Yosemite (Version 10.10.1). In addition, a Logitech computer camera have been used to record the par-

ticipants during the sessions. Furthermore, a software tool called Lookback used to record the reflections of the participants, the monitor screen and their activity on the screen.

An important step beforehand the usability study was the pilot technical validation, which has been conducted one week earlier. The purpose of this pilot technical validation was to check for the flaws, gaps and any other technical issues in the usability testing tasks. After the pilot study some final adjustments have been made on the monitor configurations and everything was ready to run the usability test. Since it is a usability test for a thesis and there is no budget for hiring extra staff to run it, the researcher had to take multiple roles during the usability study such as the role of the test moderator and the facilitator.

Before the beginning of each session the test moderator asked the participants to complete a survey with demographics and background questions about how familiar are they with the information visualization systems and an approval form of using their data for the purpose of this research. After the completion of the profile survey the participants introduced to the *Eco Donuts* feature of the prototype, which is an interactive navigation visualization tool and can provide navigation between the last twelve months. The feature is visualizing the ecological and not ecological food consumption per month for eight food categories. A category is each of the donuts on the *Eco Donuts* feature and each donut identify one category such as Meat, Fish, Dairy and Eggs etc. as we have mentioned in the System Description section. Thus, the purpose of this study is to collect feedback from the users about the navigation tool *Eco Donuts* and figure out in which level is understandable and easy to use. For this reason in the next section we describe the design decisions and define the metrics which assisted us to identify trends of the collected data.

5.2 Usability Design

During the usability test the participant asked to accomplish the following task list:

- **Task 1:** In which category the user spent the most money in a predefined month?
- **Task 2:** During the whole year, in which month/s the user spent the most money for a predefined category?
- **Task 3:** In which categories the user spent money in ecological products in a predefined month?

- **Task 4:** In which category, the user spent the most money for ecological products between two predefined categories in a predefined month?
- **Task 5:** During the whole year, in which month/s, the user did not spent any money for a predefined category?
- **Task 6:** For a period of two months, how would you describe the evolution of the ecological behaviour of the user for a predefined category?
- **Task 7:** During the whole year, would you say that the user is consuming frequently ecological products for a predefined category?
- **Task 8:** During the whole year, in which category/ies do you think that the user spent the most money?
- **Task 9:** During the whole year, in which category/ies do you think that the user spent the least money?

At this point we will describe the quantitative and qualitative data which have been collected during the usability study. While the participants were solving the tasks, the moderator was observing and was ready to take notes in case they were mentioning or doing something relevant with the IV (Information Visualization) feature. At that time, the moderator was asking follow up questions to the participants about their thoughts and actions in order to understand the reasons of the flaws, difficulties or possible misinterpretations of the system. In addition, an activity logger was recording all the actions of the participants keeping logs of time measurements and measurements about the number of interactions for each task. In order to log these data special software have been implemented for the purposes of the usability study. Moreover, Google forms were used to record metrics such as successful task completion, critical errors, non-critical errors, error free rate for each task (O'Connell and Choong (2008)). To sum up, the metrics which used during the usability study are:

Successful Task Completion

- **STC** = Number of participant's correct answers / Number of expected answers
- **Average STC** = SUM(STC1 + STC + ... + STCn) / Number of participants per group

Critical Errors

- **CE** = Number of participant's wrong answers / Number of expected answers

- **Average CE** = SUM(CE1 + CE2 + ... + CEn) / Number of participants per Group

Time on Task

- **TOT** = Time spent per task in seconds
- **Average TOT** = SUM(TOT1 + TOT2 + ... + TOTn) / Number of participants per Group

Number of Interactions on Task

- **NIT** = Number of clicks per task
- **Average NIT** = SUM(NIT1 + NIT2 + ... + NITn) / Number of participants per Group

Error-Free Rate

- **EFR** = Number of participant's wrong answers / Number of expected answers

After the completion of the aforementioned tasks the participants asked to fill out one more survey for evaluating the user experience of the proposed visualization feature *Eco Donuts* and in what extent the tool provides successful insights. During this survey the analysts were asked to answer a series of questions about the system related with the:

- Ease of use
- Subjective Satisfaction
- Liked elements
- Disliked elements

For some of the questions, in the evaluation survey used a five point Likert scale for quantifying the participants'opinions created by Likert (1932). The rest of the questions of the survey were open-ended questions in order to help us identify patterns in the replies and pinpoint the most common issues.

5.3 Data Analysis Methods

After collecting quantitative and qualitative data from our studies we used some methods to make the analysis of the collected responses. For the data analysis of the usability study we used the IDA (Instant Data Analysis) technique supported by VDA (Video Data Analysis) technique. For the evaluation study it was used a Likert scale data analysis and a qualitative analysis of the open-end questions.

After running the intended sessions for each day, there was an one hour debriefing session. During the debriefing session the researcher was trying to identify the usability problems based on the replies and the comments of the participants in each task. In their study, Kjeldskov et al. (2004) proved that short time analysis IDA technique could be used instead of the time consuming VDA technique. Nevertheless, during our usability test we were recording the sessions with the use of a webcam. Thus, in the cases where the IDA technique could not show us clear conclusions, the VDA analysis was used to support our analysis.

The quantitative five point Likert scale data analysis was used to understand the subjective opinions of the participants about the IV (Information Visualization) feature. Their opinions about how well the feature solves the intended jobs, how efficient they perceive the feature to be, satisfaction etc. Additionally, it took place a qualitative analysis of participants'comments for the metrics which mentioned before. The qualitative analysis used to support the findings from the Likert data analysis. The methods and the techniques were applied during the analysis and in the next section are presented the results of this analysis.

6 Experimental Results

This section consists of three parts. The first part is a presentation of the results gained from the background user study. It was conducted in order to categorize the participants based on their experience with IV (Information visualization). The second part is a presentation of the experiment results gained during the usability study. In the third and last part we show the results from an evaluation study of feedback acquired from the participants.

Ten individuals have participated, each between the age of 18 and 40 years old, and from seven different nationalities. Eight out of ten participants are students and the other two work in professional sectors. One half of the participants are females and the other half are males.

6.1 Background User study

During the first user study the participants were asked to fill out a short survey about how familiar they are with the data visualizations. Before the questions were presented the participants were introduced to the term data visualizations. After the introduction they moved on to relevant questions about data visualizations. They were asked to answer questions about their familiarity with the specific term. In the cases, where the participant answered that they were familiar with the term, they would be asked to answer some further questions related to data visualizations. The further questions were asked to help us validate their previous answers about their experience in data visualizations. After the analysis, the results show us that four of the participants are familiar with data visualizations and the rest are not. For the rest of this paper we will refer to the participants with previous experience concerning data visualizations as Group A and the others, without previous experience, as Group B.

The same ten participants participated in both of the following studies, usability tests and the prototype assessment. The results of each study were then analyzed and illustrated in the following subsections respectively.

6.2 Usability Testing

In this subsection we will present the results gathered from the participants of the usability study. As previously mentioned in the methodology section the participants were asked to complete nine tasks and, give their answers for each, based on their perceptions. In Figure 6.1 you can see the participants and the setup of the usability study environment.

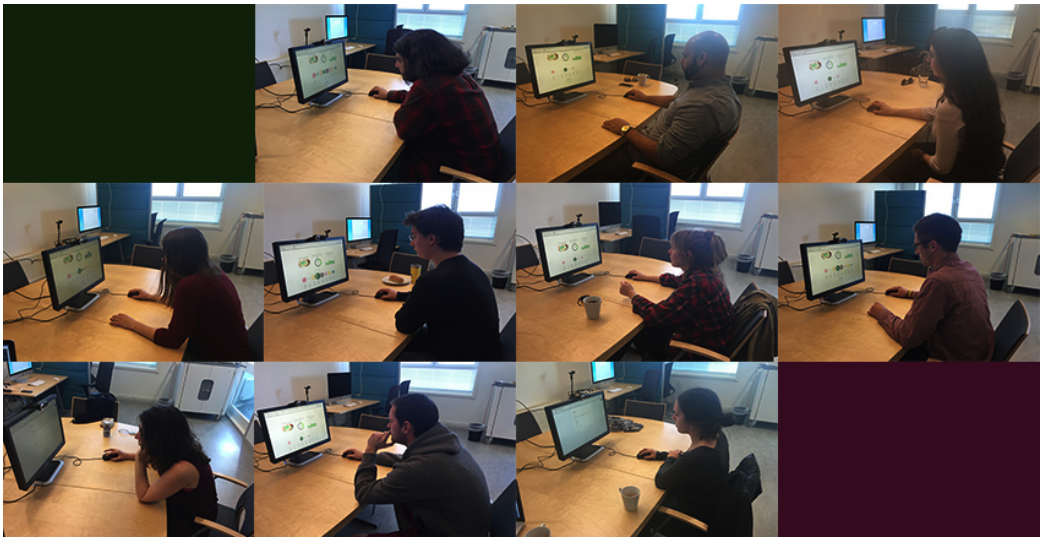

Figure 6.1: Participants during the Usability Study

For each of the nine tasks we measured the STC (Successful Task Completion), the CR (Critical Errors), the TOT (Time on Task) and the NIT (Number of Interactions on Task). In addition we measured the EFR (Error-Free Rate). First, we present the metrics average STC, the average CR and the EFR (Figure 6.2, Figure 6.3 and Figure 6.4). In order to gain a better understanding of the results we had to, also, explore each metrics in further detail. All the calculations made are based on formulas which described in previous subsection 5.1 Usability Design.

The first four metrics were calculated for each user and task separately. A sample of a single participant's metrics is provided in Table 1 and for the rest of participants can be found in appendix A. An analysis was done for each group based on the data gathered from the usability study. This was done in order to provide an average performance overview of all groups and all tasks.

Participant 1	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Task 7**	**Task 8**	**Task 9**
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
TOT	9.50	55.76	17.48	17.23	29.51	21.01	29.59	29.47	34.12
NIT	5	32	3	11	13	8	14	13	13

Table 1: Sample of the STC (Successful Task Completion), CE (Critical Errors), TOT (Time on Task) and NIT (Number of Interactions on Task) metrics.

As we can see in the Figure 6.2, Group A completed all the tasks suc-

Figure 6.2: Average STC (Successful Task Completion) metrics.

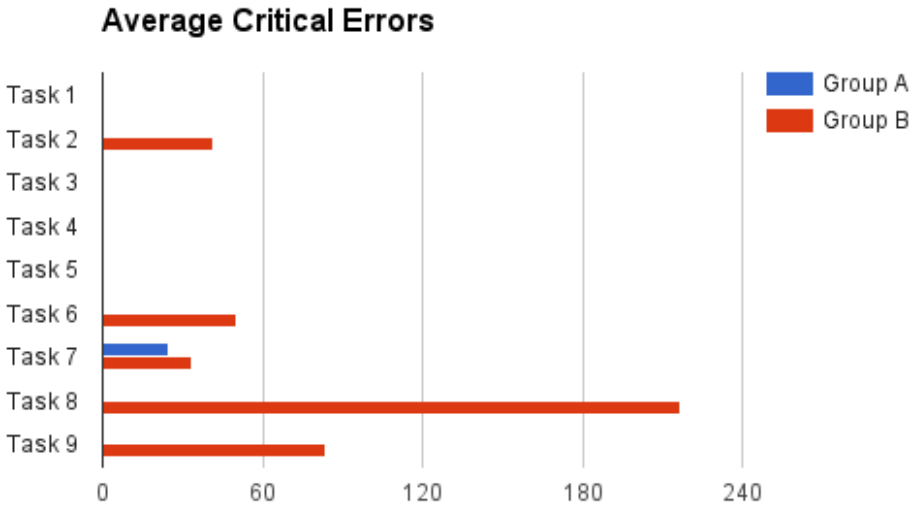

Figure 6.3: Average CE (Critical Errors) metrics.

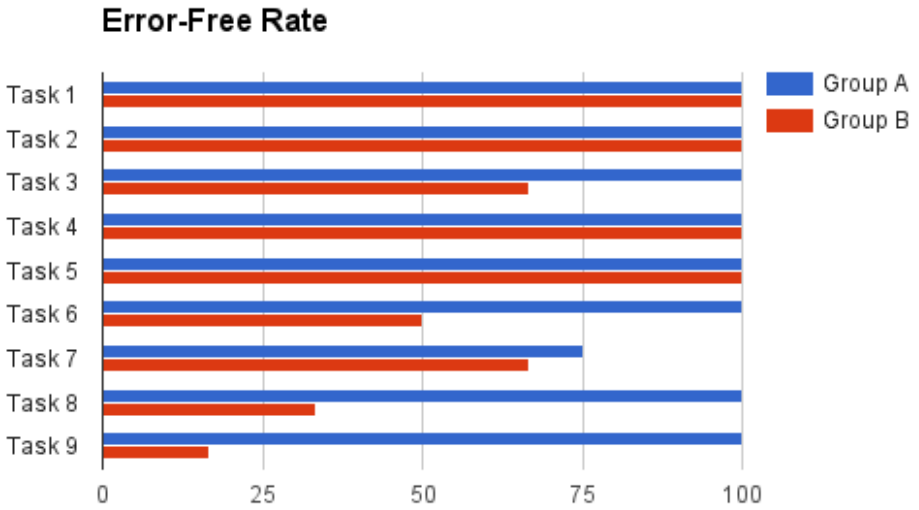

Figure 6.4: EFR (Error-Free Rate) metrics.

cessfully, except for the seventh task. The experienced users of Group A did not fall into any critical errors during the majority of the tasks see Figure 6.3. Group A completed the eight out of the nine tasks with an EFR (Error-Free Rate) of 100% see Figure 6.4. The novice participants of Group B did not have as much success with the performance as Group A. Some of the participants of Group B were not able to complete nearly as many tasks. In particular some of Group B's participants only completed 6 of the 9 tasks. In addition, the participants of Group B fell into critical errors for more than half of the tasks. Group B completed just four out of nine tasks with an EFR (Error-Free Rate) of 100%. The first five tasks had results with very little deviation between the two groups. It is easy to understand that most of the participants performed very well during these tasks. Group A continued to do well on the last four tasks. However, Group B's performance started to decrease during these tasks. In order to gain a better understanding of the reasons why that happened we explored the last four tasks individually and in further detail.

We present in detail the reflections the participants had on the last four tasks. Below you can see the sixth and seventh task and the responses the participants presented (see Table 2 and Table 3).

During the sixth and the seventh task the participants asked to indicate:

	Increasing	Stable	Decreasing	Not Clear
Group A	0%	100%	0%	0%
Group B	0%	50%	33.33%	33.33%

Table 2: Participants'reflections for Task 6

	Yes	No	Not Clear
Group A	75%	25%	0%
Group B	67%	17%	17%

Table 3: Participants'reflections for Task 7

- **Task 6:** The ecological behaviour of the user for a specific category, during a period of two months.
- **Task 7:** If the user is a frequent consumer of a specific category, during the last twelve months.

In Tables 2 and 3 we show that the answers of Group A are more precise than the answers of the Group B. It seems Group A thought the sixth task was clear and each participant replied that ecological behaviour for the period of the two months is stable. On the contrary, more than half of the participants, in Group B, said the ecological behaviour was different for the period of two months. Looking back at the video recordings and the comments given by the participants it became clear that these answers occurred because the participants were confused by the visualizations and the text references see Figure 6.5. In some particular cases they misinterpreted the content of the text references shown below the donut visualizations. It was evident that they misinterpreted the total amount of money spent on a category with the amount of money spent on the ecological purchases of the relevant category.

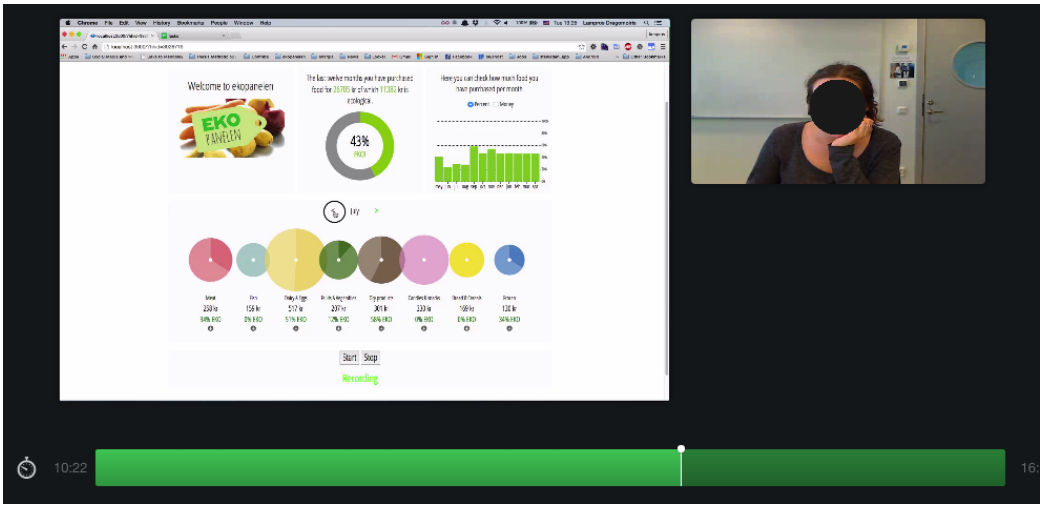

Figure 6.5: Screenshot from the video recordings during the usability study.

In the seventh task, we can see that most of the participants understood that a user is consuming products from a specific category frequently. However, there is a small percentage of participants from both Group A and Group B who did not agree with this or it was not clear for them that the user was purchasing products from a specific category.

After the participants were asked to accomplish two more tasks. For tasks 8 and 9 the participants were asked to indicate:

- **Task 8:** The category/ies, in which the user spent the most money.
- **Task 9:** The category/ies, in which the user spent the least money.

The use case scenario for Task 8 is that the primary actor, who is the participant, has to indicate in which category/ies they have been spent the most money during the twelve last months. There are two preconditions for this use case scenario. The first is that the size of the Eco Donuts reflects the amount of money and the second one is the text reference below the Eco Donuts which is the exact amount money spent per category see Figure 6.6. The basic flow to solve this scenario is that the participant is watching the changes in size of donuts while he is navigating through the months and he is trying to memorize which of the categories has the biggest size each month but in total also. For instance in Figure 6.6 the category Fruits and Vegetables has the biggest size of all donuts for April. After the participant interacts with the system by clicking the left arrow on the navigation bar to see the donuts on March see Figure 6.7. On March, the donut of Fruits and Vegetables'category has the biggest size once again, so we can say that for

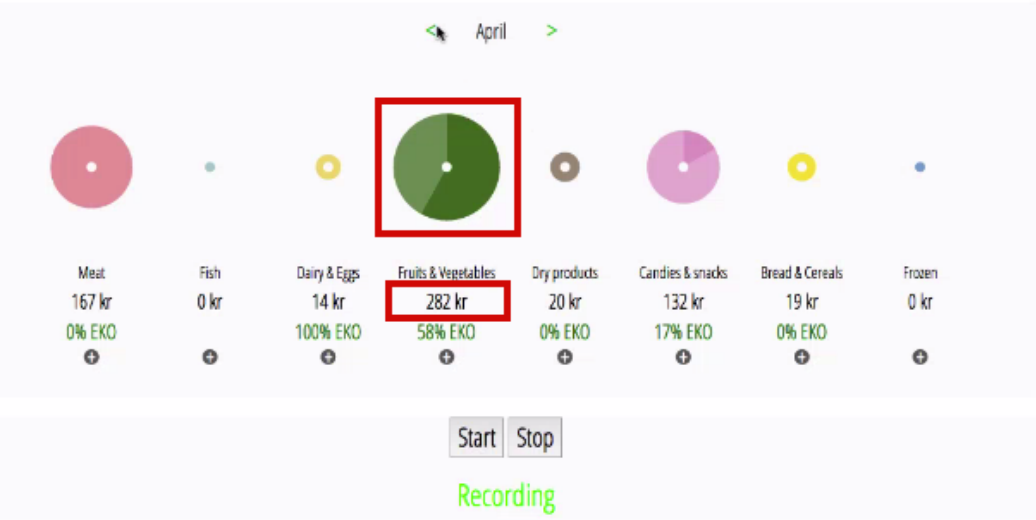

Figure 6.6: Participant's Instance of Eco Donuts for April

these two months (March and April) the most of the money have been spent for the category Fruits and Vegetables. Following this way the participant can figure out for which category have been spent the most money during the last twelve months. When it is not clear or easy to memorize the change in size of donuts, the participants can follow an alternative flow. In the alternative flow, the participant can sum the amount of money spent per category, which can be found as text reference below the visual illustration of each donut.

Tasks 8 and 9 gave the participants the option to answer multiple choice questions. These questions showed a large inconsistency between the variation of both groups. Once again, the answers of the Group A are more precise than the answers of Group B. A summary of the reflections from the two groups can can be seen in Table 4.

In Table 4 the responses of Group A, for eight of the nine task, were just one unambiguous category. However, Group B correctly answered task 8 and 9 but they also incorrectly checked more categories and thus answered incorrectly. Looking back at the comments provided it became clear that some participants from Group B felt like checking just one option could not be correct. The comments indicated that they checked more options because they felt like they would be more likely to complete the task correctly.

At this point we would like to show another two measurements that have been logged during the usability study sessions. These measurements are the NIT (Number of Interactions on Task) and the TOT (Time on Task).

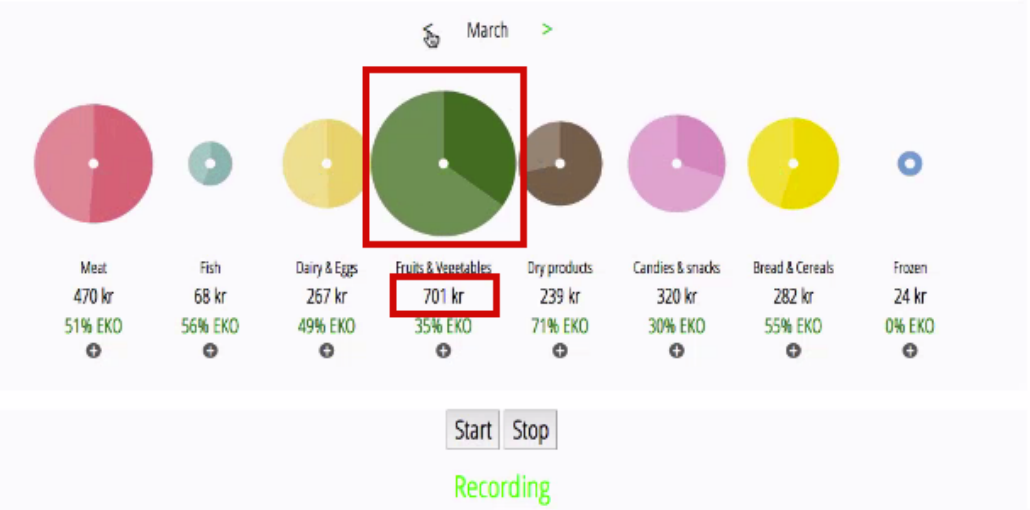

Figure 6.7: Participant's Instance of Eco Donuts for March

		Meat	Fish	Dairy & Eggs	Fruits & Vegetables	Dry Products	Candies & Snacks	Bread & Cereals	Frozen
Task 8	*Group A*	0%	0%	0%	100%	0%	0%	0%	0%
	Group B	0%	0%	50%	100%	33%	50%	33%	0%
Task 9	*Group A*	0%	100%	0%	0%	0%	0%	0%	0%
	Group B	0%	100%	0%	0%	0%	0%	0%	83%

Table 4: Participants'reflections for Task 8 and Task 9

We present a diagram showing an average click per activity and a diagram showing time spent on each task (see Figure 6.8 and Figure 6.9).

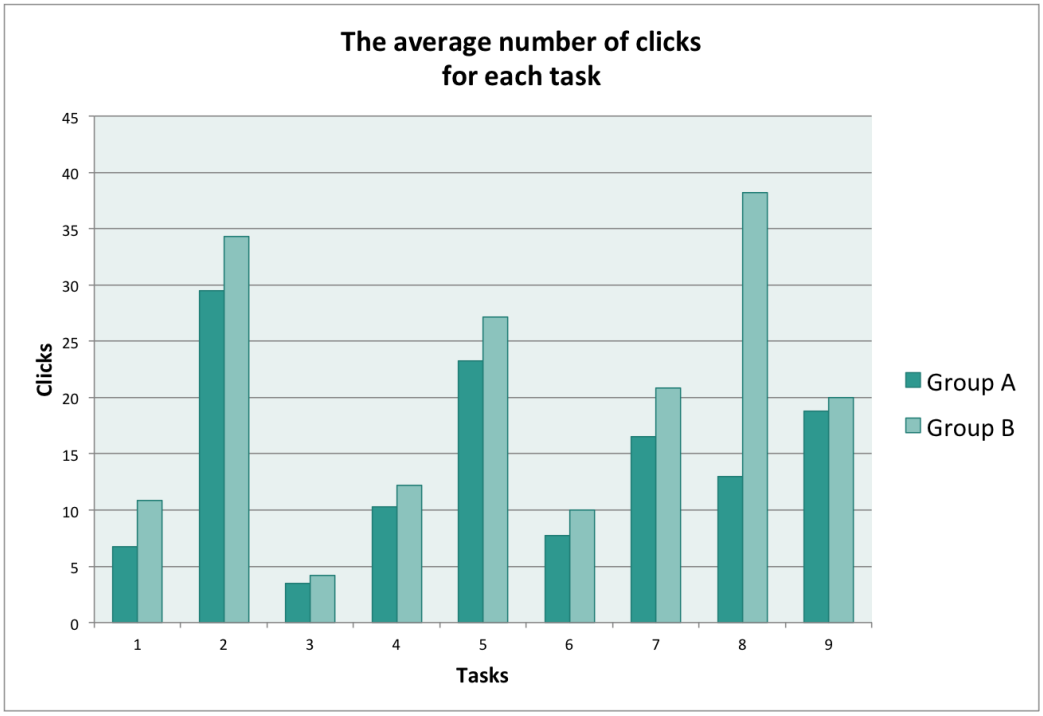

Figure 6.8: The average NIT (Number of Interaction on Task) for Group A and B

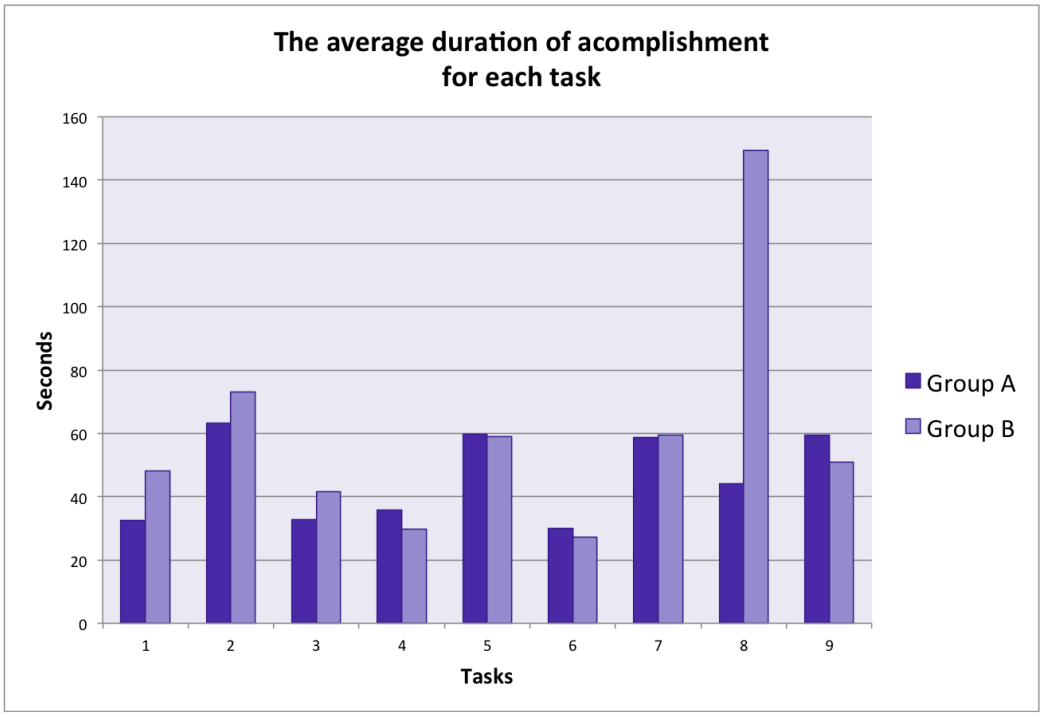

Figure 6.9: The average TOT (Time on Task) for Group A and B

By analysing Figure 6.8 and Figure 6.9, it becomes obvious that, Group A needed less interactions and time than Group B did in order to accomplish each task. However, the variation, of interactions and time, between the two groups is not dramatically huge. Nevertheless, in the eighth task there is a tremendous amount of variation between the two groups. Group A had far less clicks and the participants completed the task in less time than Group B.

6.3 Prototype Assessment

In the last part of our study we asked the participants to evaluate the *Eco Donuts* feature by rating it in a five point Likert scale and give their reflections by answering in open-end questions. In this subsection we will present participants'evaluations after testing the prototype. The subjective measures which evaluated are:

- **Ease of use**
- **Satisfaction**
- **Liked elements**

- **Disliked elements**

The Information Visualization (IV) feature called *Eco Donuts* consisted of different elements which can be used to accomplish tasks. The participants asked to evaluate how easy is to use the main four elements of the feature *Eco Donuts* to accomplish the given task list. The four elements which evaluated by the participants are the donut's size, donut's eco arc (visual representation of the ecological percentage in each donut), empty donut (categories with no purchases at all) and the navigation bar. See Figure 6.10.

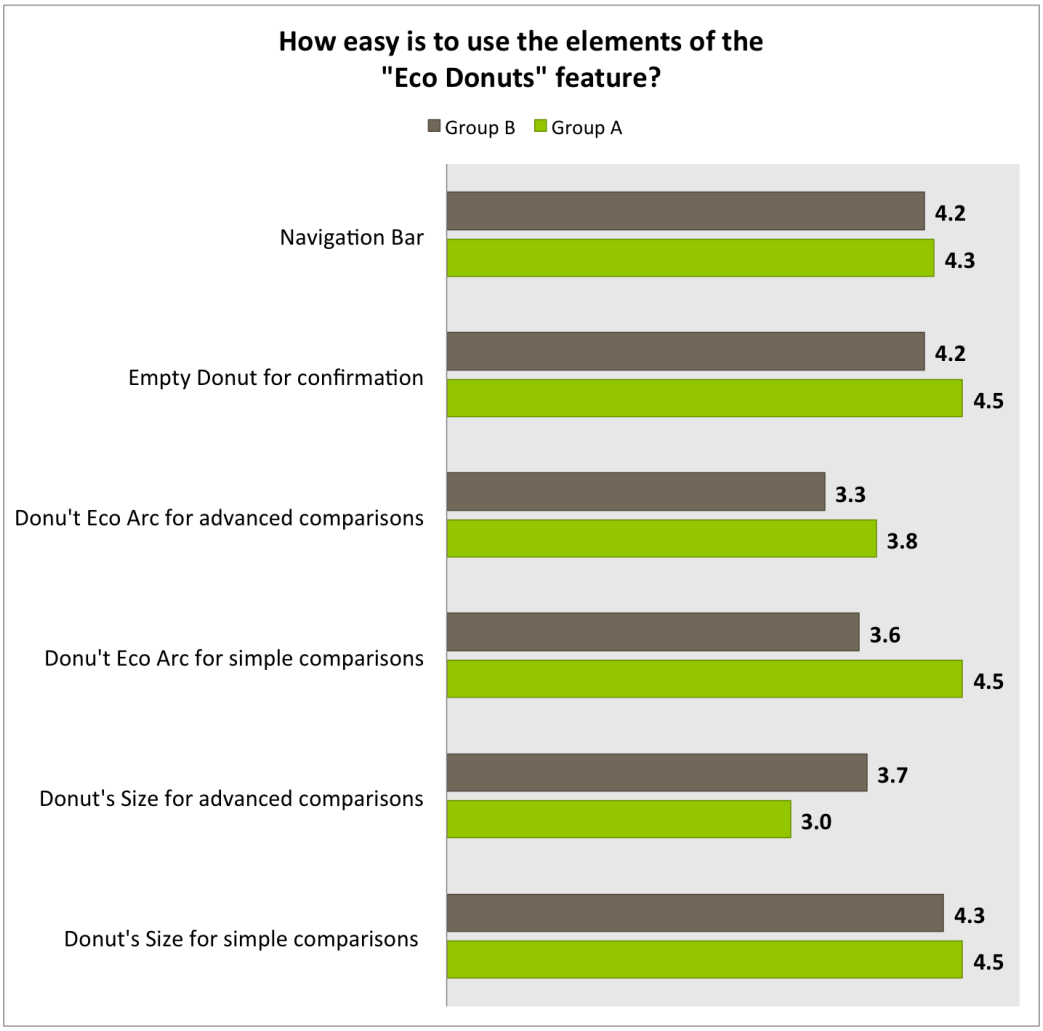

Figure 6.10: Participants ratings for how is easy of use for the donut's size, donut's eco arc, empty donut and navigation bar to accomplish tasks.

In general, both of the groups of the experienced and the novice participants rated the elements with a minimum rating of 3.5 and a maximum rating of 4.5. In addition, in Figure 6.9 we can see that Group A rated higher the elements of the *Eco Donuts* feature than Group B, in the most of the cases. Group A evaluated with the lowest score the easy of use of the donut's size element when it has to be used to accomplish advanced and complicated comparisons. On the other hand, Group B appraised the prototype with the lowest rate the use of donut's ecological percentage for advanced comparisons. Moreover, we have to pinpoint that both groups rated with the lowest score the use of the donut's size and ecological percentage when they had to use these elements to make advanced comparisons to accomplish the tasks. Regarding the use of the navigation bar, the empty donut visualization and the donut's size for simple comparisons was straight forward for the participants.

During the prototype assessment, it was measured also the subjective satisfaction of the information visualization, *Eco Donuts*. There was a group of cross questions where the participants asked to give feedback about their satisfaction with the information visualization feature of providing information and their overall experience. The satisfaction of the participants measured in a five Likert scale for these questions as we did for the easy of use analysis. Based on their answers we calculated the overall satisfaction of all the groups, regardless the group they belong. The direct result of this analysis is that the participants rated their satisfaction with a 4.2 total score. Furthemore, another set of 3 questions which helped us to examine the satisfaction of the participants with specific parts of the visualization such as the colors of the donuts for each food category, the visualization format of the charts and the color of the ecological percentage in the donut charts.

In the first question, the participants were asked to give their satisfaction rate about the colors of the donuts and their representativity for each category. The participants were asked also to share their opinions and recommend other colors for the categories. Based on their answers, it seems that for the most participants the colors of the categories where representative. Nevertheless, there was a suggestion from few of them to enlighten the color of *Eco Donuts* a bit more.

In the second question, the participants were asked if they were satisfied about the donuts charts or they would prefer the data to be presented in another chart format. After the analysis of the answers, we noticed that most of the participants were satisfied with current visualization format of the donuts charts. However, there was three of the participants who proposed to change the format to bar charts, pie charts and area charts. The participant who proposed to change the format to bar charts reasoned his

answer saying that most of the people are familiar with this format. The other two participants did not justified their answers.

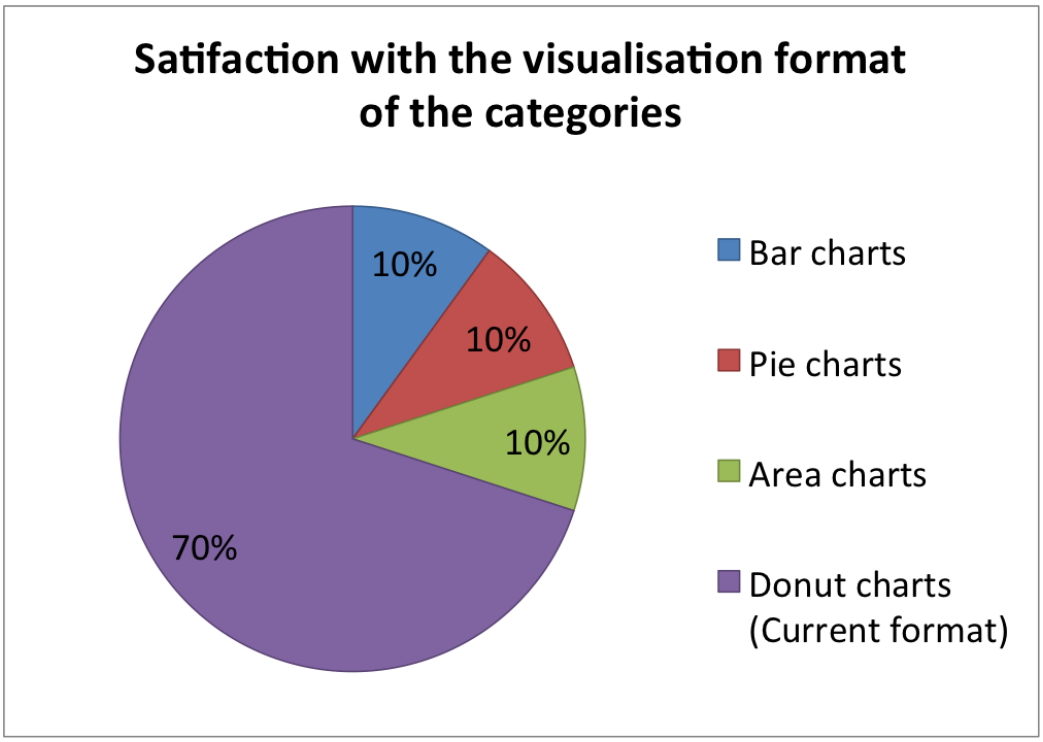

Figure 6.11: Participants'satisfaction with visualization format

In the third and last question, the participants were asked about their satisfaction with the way that the ecological percentage is presented in the donuts charts. Based on their replies most of the participants were satisfied with the current format, where the ecological percentage was presented as a darker shade of category's color. However, there was one participant who proposed to change the color to green. The argument of the participant was that if the color change to green for all the categories the future users will understand faster the meaning of the arc in the donut because of the correlation of green with ecological.

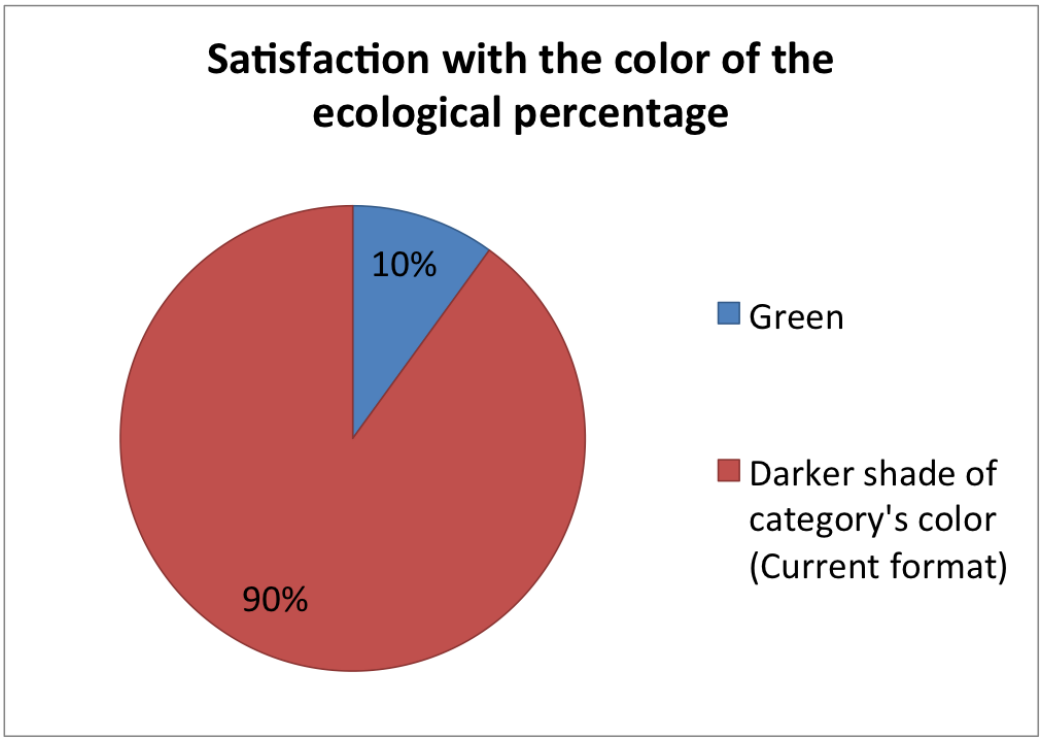

Figure 6.12: Participants'satisfaction with the ecological percentage color

Based on the open end answers of the participants, we tried to identify patterns and after the analysis of them we present to you the liked and the disliked parts of the *Eco Donuts* feature. Initially, we will start by presenting the most liked parts depending on the feedback which we collected from the participants. The most of the participants mentioned that the *Eco Donuts* feature is a quick and enjoyable way of checking the food consumption per category. They mentioned also that it is an easy way to compare data in two following months. Regarding the animated transitions, they said that they give a good feeling of progress and change while navigating among the months. Additionally, they added that the parts of the feature were well organised and structured providing to the end user a clean and minimalistic design. Last but not least, they referred to the fact that the *Eco Donuts* feature leave a pleasant impression.

On the other hand, there was some parts that the participants did not like in the current version of the proposed visualization navigation tool. To begin with, most of the participants highlighted the fact that is difficult to make comparisons of the visualised data which are not in two following months. In specific cases where donuts were referring to the end or the start of the visualised year, the participants faced problems with the navigation arrows.

The navigation arrows were confusing them when there was no data to see to the left or to the right but the navigation arrows were still available to use. Another important difficulty that worths to mention is that the *Eco Donuts* feature do not provide any information about the calendar year. Making it difficult for the participants to understand in which direction they have to move, forwards or backwards. The last common comment from most of participants is that there was no option that they could jump over the months in order to find the one which they were seeking for, rather than moving one by one.

7 Discussion and Conclusions

During this study there were three main challenges for the information visualization tool called *Eco Donuts*. The first challenge was the examining how successful the prototype can provide insights to the end users. The second challenge was exploring the learning curve. The final challenge was testing the *Eco Donuts*'s ease of use. The first two challenges were answered based on the results of the usability study. The third challenge was answered based on the subjective quantitative data delivered by the participants during the prototype assessment study. In addition, we had to explore and find ways to improve the current version of *Eco Donuts* in order to enhance the usability.

In the usability study the results show that the system provided the participants with fundamental insights in most of the cases. In particular, the results of the metrics, completeness rate, critical errors and error-free, were used to rate and justify how successful the system can be at providing insights. The metrics can be found in Experiment Results 6.2 Usability Testing. Based on the results of these metrics it is easy to understand that the interactive tool *Eco Donuts* provided successful insights to the participants of both groups. Group A consisted of more experienced participants than Group B. The rate of completeness (STC), critical errors (CE) and error free rate (EFR) were higher for Group A than Group B. This was expected based on previous research and has been proven in similar studies conducted by other researchers as was described in the related work section. The results made it clear that when identify ecological evolution for short periods of time our system would occasionally confuse participants. This happened particularly with those who have no experience with visualizations (Group B). In fact, the participants with previous experience in visualizations (Group A) were able to interpret such information easily.

Regarding the learning curve of the system we gathered the number of interactions and the time spent on each task. We presented diagrams with average values of these metrics (Figure 6.8 and Figure 6.9). Based on this data it is obvious that both groups required more time and interactions to complete the first tasks. However, in the later tasks the amount of clicks and duration needed to complete a task decreased or became stable. The learning curve of the participants showed normal progression. This happened mainly because they gained experience from each previous task they were required to do. In the most demanding tasks the values of the two metrics were increased. Based on the data from the metrics one of the tasks had a huge discrepancy between Group A and Group B. However, it became clear that the learning curve was effective because in the following task, which was

similar to the first, the discrepancy decreased. Particularly, they were asked to answer which category or categories the user spent most of their money and the least amount of their money. This fact shows that, even if the novice participants faced some issues to accomplish task 8 effectively and efficiently compared to the group with the experienced individuals, they were able to complete task 9 with more ease. The *Eco Donuts* feature provided them with the needed experience to improve significantly. Similar issues could potentially be resolved by offering a small introductory tutorial.

In the prototype assessment study the participants were asked to rate the ease of use, satisfaction, liked elements and disliked elements of the proposed information visualization tool *Eco Donuts*. As regards, the ease of use of the proposed information visualization tool, the subjective five Likert point scale ratings of the participants used to evaluate the tool. In general the participants did not face a lot of issues regarding using the elements of the feature to accomplish tasks and it was straight forward for them the use of the navigation bar, empty donut (representing an a empty category) and the donut's size for accomplishing tasks. However, the participants could not use in the same effective and efficient way some other elements of the feature. For example, the use of the donut's size and the eco arc (representing the ecological percentage of each category) in order to accomplish advanced tasks, was challenging for both groups. That means that these elements should be improved in a way that will be able to tackle tasks which are more advanced and demanding.

In addition, part of this study was to find the main issues with the design and the usability of the information visualization and the main goal was to find potential ways to rework and improve the efficiency and effectiveness of the system. Based on the comments of the participants, a remarkable point is that the usability for making comparisons between two following months was satisfactory but it was slightly hard when these comparisons were between months which are not following each other. A proposed solution by the participants of the study was that it could be an extra timeline feature on the navigation bar that could offer jumps among the months. Future improvements and modifications in these specific parts of the *Eco Donuts* feature could address the issues which we described before. Last but not least, is the confusion caused by the arrows for moving forwards and backwards between months and the not displayed calendar year in the navigation bar, could be easily addressed by removing the arrows from the interface when they are not needed and adding the year in the navigation respectively.

In general, the participants were satisfied with the overall user experience of the system and as they have mentioned the main reason was that the current version of the navigation visualization feature is well structured.

In addition, as we have discussed above the *Eco Donuts* offers a good user experience and in a comprehensible way insights for the ecological food consumption of a user.

The purpose of this thesis was to implement an information visualization tool, which enables users to make comparisons of complex data and offers them an enhanced user experience. There was an evaluation of to what extent the proposed visualization system provides successful and accurate insights for the categories of the data. The system has been implemented and tested. The implemented system visualize the data in donut charts and offers animated transitions. The data has been used to populate this studies database are dummy data and are following the structure of real data provided by the co-operating supermarket. The system performed pretty well in most of the cases, delivering successful insights to the participants. Regarding the user experience the results show that the participants had a pleasant experience while they were interacting with the interactive navigation visualization tool (*Eco Donuts*). During the usability study the elements of the system operated efficiently for the basic tasks but it became slightly challenging when participants were faced with the advanced tasks. This was especially true for the novice participants (Group B). Based on our findings, the elements *Eco Donuts* that need improvement are mainly the navigation bar and adjustments in the donut charts. Our visualization approach supports a simple, easy and structured way of providing an overview and making comparisons of complex data. The current approach is novel and can be potentially used for similar purposes in many fields by providing insights and a great user experience.

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8 Appendix A Paricipants' Ratings

8.1 Group A

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOT	42.51	83.84	38.89	29.57	40.68	44.50	25.21	41.92	26.47
NIT	11	29	3	12	13	7	13	13	14

Table 5: Usability study ratings by Participant 1

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOT	21.23	62.86	18.33	74.33	47.95	28.84	57.45	63.34	91.88
NIT	5	37	4	9	30	7	14	13	24

Table 6: Usability study ratings by Participant 2

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
TOT	9.50	55.76	17.48	17.23	29.51	21.01	29.59	29.47	34.12
NIT	5	32	3	11	13	8	14	13	13

Table 7: Usability study ratings by Participant 3

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOT	56.45	50.37	56.64	21.93	37.00	25.37	122.75	42.09	85.55
NIT	6	20	4	9	10	9	25	13	24

Table 8: Usability study ratings by Participant 4

8.2 Group B

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOT	16.55	69.27	61.80	26.01	21.57	18.11	80.14	226.41	63.14
NIT	6	39	5	14	11	7	31	82	36

Table 9: Usability study ratings by Participant 5

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	1.00
TOT	24.47	71.60	40.26	16.05	69.28	17.60	86.09	277.65	52.92
NIT	6	42	3	11	21	5	20	45	23

Table 10: Usability study ratings by Participant 6

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	0.17	1.00	1.00	0.00	1.00	1.00	1.00
CE	0.00	0.00	0.83	0.00	0.00	1.00	0.00	0.00	1.00
TOT	45.95	70.53	29.53	29.79	89.82	41.89	29.78	59.39	52.29
NIT	27	34	3	11	47	26	14	13	13

Table 11: Usability study ratings by Participant 7

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
CE	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
TOT	83.68	88.73	45.94	21.83	29.53	26.44	27.92	47.32	19.15
NIT	7	45	6	11	16	20	10	29	12

Table 12: Usability study ratings by Participant 8

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	0.17	1.00	1.00	0.00	1.00	1.00	1.00
CE	0.00	0.00	0.83	0.00	0.00	1.00	0.00	4.00	1.00
TOT	33.45	91.41	10.39	15.41	44.30	14.57	76.74	229.64	39.01
NIT	5	33	3	9	31	6	27	47	11

Table 13: Usability study ratings by Participant 9

Participant 1	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
STC	1.00	1.00	0.17	1.00	1.00	1.00	0.00	1.00	1.00
CE	0.00	0.00	0.83	0.00	0.00	0.00	1.00	0.00	1.00
TOT	84.29	46.24	61.65	68.78	108.93	64.30	56.94	55.70	71.94
NIT	14	13	5	18	38	8	13	13	25

Table 14: Usability study ratings by Participant 10

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