How Big Data Affects User Experience

Reducing cognitive load in big data applications

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0.1 Keywords

Cognition, Designing for big data, Big data, UI design, Filtering, FMCG, Fast moving consumer goods, Structure, Promotional analytics, Cognitive load, Decreasing cognitive load, HCI, Numeric data, Economic data,.

Abstract

We have entered the age of big data. Massive data sets are common in enterprises, government, and academia. Interpreting such scales of data is still hard for the human mind. This thesis investigates how proper design can decrease the cognitive load in data-heavy applications. It focuses on numeric data describing economic growth in retail organizations. It aims to answer the questions: *What is important to keep in mind when designing an interface that holds large amounts of data?* and *How to decrease the cognitive load in complex user interfaces without reducing functionality?*.

It aims to answer these questions by comparing two user interfaces in terms of efficiency, structure, ease of use and navigation. Each interface holds the same functionality and amount of data, but one is designed to increase user experience by reducing cognitive load. The design choices in the second application are based on the theory found in the literature study in the thesis.

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Chapter 1

1 Introduction

In today's society, the amount of accessible information is incredibly large, so large that it is often perceived as intimidating and impossible to digest. 70 percent of Swedes have difficulties handling the flow of information at their workplace[21], and many have problems distinguishing what is important [7]. The need for structure and filtering of large data amounts is, therefore, increasing rapidly. This study focuses on that problem and investigates the possibilities of structuring, processing, and filtering numerical data to ease the cognitive load of users and in whole improve the user experience.

This study is conducted at a company that makes an analysis platform for online and offline promotional campaigns in retail. Their clients often have hundreds of different campaigns and promotions running every week. Keeping track of how they are performing is difficult without analytic software. Today less than 50 percent of Swedish retail promotions create any incremental sales lift, and 20-30 percent of promotions actually negatively affect the retailers' profit margin [14]. The company analyses data from receipts to help companies solve this problem. With better data analysis, their software enables users to see which promotions that are creating a true profit lift, free from economic switching & stockpiling effects.

The problem faced today is that these numbers are presented in a way that is difficult for the user to comprehend cognitively and leaves them feeling overwhelmed by complexity. This thesis will, therefore, focus on exploring ways to make the user experience as light and easy as possible without reducing the amount of information accessible in the user interface (UI). The goal of this thesis is to get a better understanding of how to best design systems that convey large amounts of information without demanding much cognitive effort from the user.

1.1 Objective

The objective of this study is to investigate how to ensure a good user experience in applications with large complexity and data amounts. It aims to answer the questions: *How to decrease the cognitive load in a complex UI without reducing functionality? What is important to keep in mind when designing an interface that holds large amounts of data?* and *What negatively affects the amount of data a user can comprehend?*

The goal of the study is to gain a better understanding of how to design systems built to display large amounts of data. As well as to contribute knowledge of how information from HCI can be applied in the analysis of big data.

Chapter 2

2 Background

This section will describe the circumstances of the project. It will describe the company the project was conducted at as well as limitations to the study. It will also include some general HCI-design principles that the foundation of the research lies on. Lastly, it describes is the starting point of the thesis. To be able to improve the user experience of a product it is important to know what state the project starts in.

2.1 The company the study was conducted on

The company was founded in 2016, it does statistical analysis of promotional campaigns. The company has created a web application with three mayor functions, this thesis will focus on one of them. That feature shows the result of previous promotional campaigns in several different metrics. The application contains large data sets where each client can see how all promoted products are doing in regards to multiple aspects. It calculates multiple metrics with regards to performance, such as volume, value and profit metrics. This gives the client a true estimate of how campaigns, in general, are affecting their profit margin. It also gives them a tool for finding the reason behind why some campaigns work and some not and shines a light on which campaigns that are underperforming or over performing.

The company's biggest clients today are retailers in FMCG (fast-moving consumer goods) and in pharmacy. They measure sales in traditional brick-and-mortar stores as well as e-commerce. These chains often have many campaigns every week, some up to a hundred different running at once. These campaigns often include several products adding to a large tree of data that is supposed to be available for the users to analyze in the app. The data should preferably be structured and visualized in the most favorable way for the user to be able to easily extract the data they are looking for. This study aims to figure out how to do so.

2.2 How the application works

When first opening the applicationthe users are met by a large data table showing all previous campaigns, this data set can be filtered to only show campaigns from a specific supplier, brand, category, time period, with a certain discount depth, or with a certain tactic. The data set contains information about the campaign such as which products it contained and what time period it ran as well as metrics that describe how well it performed. The user can choose to show more metrics about the campaign by choosing from a column menu. Each column can be sorted to show the highest or lowest result.

After choosing metrics to describe the data and filtering it to show what information they are looking for, the user can save the table in a view that they can revisit. In this way, the user is not compelled to sort the information each

time they want to access it. The users can also choose to add a visualization of the data. To do this, they need to choose between a bar chart and a scatter plot, and which variable to plot. There is no default choice on the visualization.

2.3 The Users

The company's users are made of two groups, Superusers, and Base users. The ratio of them is 1:10 where Base users are the bigger group.

Base users are often promotional mangers of a certain category of goods. They are between 35-55 years of age, half of them have an academic background the other half not, they are highly experienced in their role but limited by time. They are used to numbers and very knowledgeable of the Microsoft program Excel, but not necessarily teach savvy or curious in learning an additional computer program.

Super users are usually a bit younger, ranging between 25-40. They most often have a degree in economics and are working as analyst or controllers. They tend to be curious and often want to dig into the numbers and find the reasons behind them. They are a bit more tech-savvy and often excited about this application since it can give them further insights into how their campaigns are doing.

2.4 The Data

The company specializes in measuring sales of campaigns accurately. There data there for describes the campaigns, how much profit they made and which factors contributed or hurt the profit. The data is divided into three categories, campaign features, campaign results, and contributing factors.

An average customer using the software has around 100 000 campaign per week in their stores. Each campaign can hold several products sometimes as many as 20. Making the total of view-able data points around 8,4 million per week and customer and around 435 million per year[1]. Each campaign has 11 metrics that describe the campaigns features and 9 values that describe how the campaign performed and 10 values that show contributing factors to the results.

In UX terms the data can be viewed as 9 factors describing **What** the campaign was, 9 values showing **How** it performed and 10 factors showing **Why** it performed the way it did.

All values describing results or contributing factors are numerical and the campaign feature values are a mix of numeric values and alphabetical.

2.5 Limitations

The current UI does not agree with standard HCI design principles. Using the current UI as a starting point to evaluate the benefits of Filtering, Processing & Structuring for increased User experience is therefore sub-optimal. The results will show the benefits of not only filtering, structuring and processing the data but also show the benefits of correctly following HCI-design principles. Knowing how much the results are connected to filtering, processing, and structuring vs

[1]The value 8400000 comes from multiplying 100 000 campaigns with 3 and 28, where 3 stands for the average amount of products per campaign and 28 for the number of different values describing each campaign

correctly following design principles will be difficult to assess.

Examples of UI components not following HCI-design principles The main design principle that is not met in the current UI today is **affordance**. It is very hard for the users to predict what an action will affect since some of the action buttons have the same appearance but executes different actions.

In the current UI four buttons are displayed in the top right corner of the screen(can be seen in figure one). These buttons from left to right perform the actions of:
1. Deletes the settings the user has chosen.
2. Adds a table that visualizes data.
3. Downloads the information as a PDF.
4. Opens a menu where the user can choose to add more columns to the menu.
Clearly, these actions are not similar, yet the appearance is the same. The mapping of the buttons is not ideal either, they are both far from the objects they affect and placed in non-standard ways affecting visibility.

The application also has a lack of visual hierarchy, most items look of similar importance.

2.6 Starting point

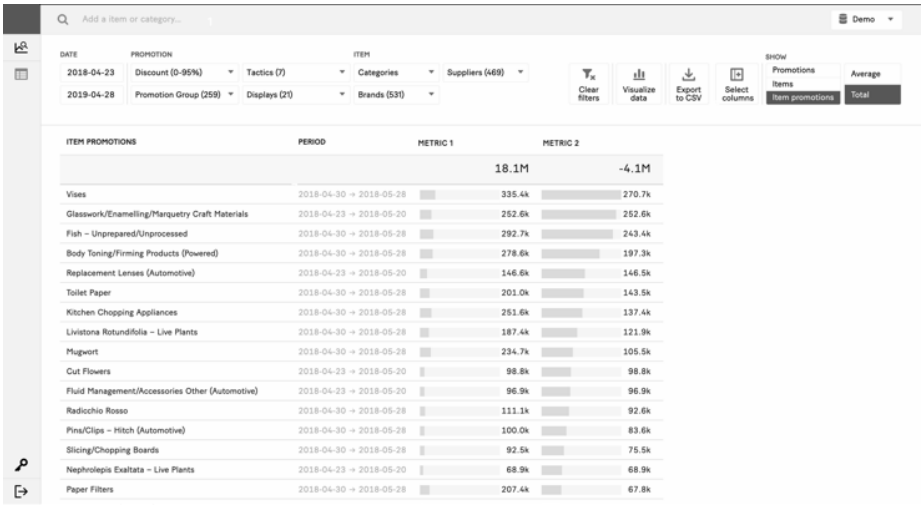

Figure 1: Starting point

Figure one shows a picture of the UI that represents the starting point of this project. It shows a design with a table of data, different buttons that manipulates the data and some save and download functionality. The goal of this project was to improve this screen without removing any of the current functionality. The general functionality fits the user's need accurately when viewed as giving them access to all past campaign's economic results and the ability to filter between them. However, it does not allow an easy or fast way of finding specific results. which makes it ideal for answering the objective of this thesis: How to decrease the cognitive load in a complex UI without reducing

functionality.

2.6.1 Problem area today

The problem with the existing design is that the information is presented in a way that is hard for the users to cognitively digest. There are no visual hierarchy or clues to where to start. There is an overload of numbers and choices, visually showing 14 sets of data containing 6 additional categories of information. The users are faced with 11 choices, excluding sorting and 4 additional action buttons. On top of that is the deviation from some standard HCI and UI-design principles.

2.7 HCI design principles

To be able to focus on the processing, structuring, and filtering of data some basic HCI principles need to be met in the UI. If the user interface does not comply with these principles the UI will be hard to use and understand even if the data itself is not. Below are two sets of principles that when applied together build a solid UX platform that enables testing and focus on the aspects this study aims to answer (i.e How to decrease the cognitive load in a complex UI without reducing functionality). These principles will be followed stringently in the final prototype but will not be addressed in the result since they are supposed to always be followed in HCI and only build the basis for this research. The design will also follow the gestalt laws[12] and try to stay as close to common UX/UI practice as possible to build on existing mental models[17].

2.7.1 The five E's

The five E's are usability requirements where each of them focuses on one dimension of user experience. They are based on research done by Michael J. Albers and Beth Mazur. [3] These five are: effective, efficient, engaging and error-tolerant and easy to learn.

Effective describes how completely and accurately the application fills the user's needs and completes their goal.

Efficient refers to how a program or service should always enable the user to finish their task in the quickest way possible.

Engaging aims to describe that user experience is not only about efficiency and functionality, it should always strive to be engaging and exciting as well. Apple is a company known for its engaging design that captures the users and excites them with each new product.

Error tolerant. The program should minimize the user's mistake. No actions should be irreversible and common mistakes should have plans for handling. Messages like *"are you sure you want to delete this"* make sure deleting a file always is made as an active decision and not mistakenly.

Easy to learn The learning curve should be easy for the users. The user should be given the tools for an easy start and be able to learn at an accessible rate. Users should always be able to do basic actions without any prior knowledge, like reading a manual or having a workshop.

2.7.2 Don Normans 6 principles of designing interaction

Don Norman's six key principles have long been used by designers to create UI design that clearly communicates. They are visibility, feedback, constraints, mapping, consistency, and affordance.

Visibility refers to the simple fact that elements and actions have to be visible. The easier they are to detect the more likely are they to be used. The opposite is true too, if something is out of sight it is hard to know about and even harder to use.

Constraints are rules that limit the possible number of outcomes. In UI-design this means that they limit the number of able actions or interactions. Giving the user constraints simplify the users track towards their goal since it guides the user to the next appropriate action and makes clear what can be done. Constraints minimize the number of choices the users have to make as well as the number of options they have to choose from.

Affordance, the affordance of an object gives clues about how it is supposed to be used. The higher the affordance is the easier it is to know what something does and how to use it. Chairs are a famous example of a high affordance.

Consistency is important for remembrance in an application. If all buttons that look the same do the same thing, they are easy to predict and use correctly. This is important within applications and between them, if your application is consistent with other applications the user has tried before they are far easier to use. Consistency in design makes the user familiar with the UI and therefore more confident in their use.

Feedback, there is full and continuous information about the results of actions and the current state of the product or service. After an action has been executed, it is easy to determine the new state.

Mapping, the relationship between controls and their actions follows the principles of good mapping, enhanced as much as possible through spatial layout and temporal contiguity.

2.8 Mental models

Mental models is a well established concepts in interaction design.

"A mental model is an explanation of someone's thought process about how something works in the real world. It is a representation of the surrounding world, the relationships between its various parts and a person's intuitive perception about his or her own acts and their consequences"- Wikipedia.[2]
Jakob Nielsen defines mental models in the world of User experiance design as *"A mental model is what the user* ***believes*** *about the system at hand."* [19] Mental models are built of experience of things users believe to be similar. They can therefore shift between users and fail to be true. However untrue they might

be they still effect how the users interacts with the interface. When the users existing mental model is not matched by the UI frustration occurs. They might expect to find an action in the right corner, and even if it clearly visible in the left, they cant find it. Good UX-design builds on pre-existing mental models in order to take advantage of the knowledge the users already have. When building with the users mental model in mind it reduces the amount of new patterns or behaviors they have to learn.

2.9 Summery

This thesis design work will be based on two sets of design principles, Don Normans 6 principles of designing interaction and The Five E's of usability. It will stay as close to the users Mental models as possible, which requires in dept information about the applications two user groups. It will be designed to show a large amount of numeric and alphabetic data in a way that is not cognitively demanding from the user.

The company the thesis was conducted at shows statistical analysis of promotional campaigns in a web application. The application has three mayor functions, this thesis will focus on one of them, a feature that shows the result of previous promotional campaigns with 19 different metrics.

The current UI of the application does not agree with standard HCI design principles, there is an overload of numbers and choices,visually showing 14 sets of data containing 6 additional categories of information. The information is presented in a way that is hard for the users to cognitively digest. There is no visual hierarchy or clues to where to start.

Figure one shows a picture of the UI that represents the starting point of this project The goal of the project is to improve that screen without removing any of the current functionality. The general functionality fits the user's need accurately when viewed as giving them access to all past campaigns economic results and the ability to filter between them. However, it does not allow an easy or fast way of finding specific results. Which makes it ideal for answering the objective of this thesis: *How to decrease the cognitive load in a complex UI without reducing functionality.*

Chapter 3

3 Method

In this section, the process of conducting the study will be presented. This study will consist of five larger parts, a literature study, a user study, an evaluation of the current state of the application, a design phase and a comparison between the new and old design. The evaluation of the current state of the application will take place together with the user study to give a good perception of where to start with the re-design. The new design will base its changes on the insight gained in the phases before it. It will root its changes in theory and apply them in places that are problem areas today. The new design will be tested before being finalized and then evaluated to see if it truly resulted in a UI that requires less cognitive load.

3.1 Literature study

A literature study will be the first step of this thesis. It will collect the available research on this subject to see if there are conclusions that can contribute to this work and push the starting point further. It will aim to answer the question *"How do large amounts of data affect User Experience"*

The goal of starting with such a broad question is to find an entrance to this specific field of UX to collect more knowledge about the subject before choosing a more narrow research question. This will increase the possibility of basing the study on the user's needs, and the specific UX-challenges this company's set of data gives. The literature study will contain three parts, Search, Selection, Information extraction.

3.1.1 Search

The search strategy for the thesis will consist of using an online search tool such as google scholar and looking for source material that discusses cognitive aspects of dealing with large sets of information and choices. The search will also include general interface and user experience (UX) guidelines. The search terms used was the following: *Large data and UX, Cognitive aspects of large data in UX, Filtering large amounts of data,* and other several combinations of the search terms and the words *Big data, User Experience, Cognition, UI-design, Challenges,Problems, Filtering, Processing, Structure, complex data, Numeric data, economic data.*

These search terms often showed reports that where semi-linked to the search-phrase but interesting for the thesis topic. Such articles were also included in the findings.

3.1.2 Selection & Information extraction

The selection and information extraction parts where simplistic. The selection of the material was based on the Author, type of text, credibility, and relevance.

The information extraction was based solely on relevance and credibility. Credibility was based on publisher, Author and the author's previous work in the field of UX and previously published articles. Articles from the Nielsen Norman group were favored, along with Medium blog posts written by established UX-journalists and Research papers from highly academically ranked schools.

Relevance is challenging to judge before having knowledge about the topic or subtopic but gets easier to judge further into the study. Relevance was therefor easy to judge in the information extraction part but very difficult while selecting what literature to read.

3.2 User study

The user study will contain three parts, user interviews, an analysis of the user's behavior in Fullstory and an analysis of questions asked in Intercom. The goal of the user study is to find out who the users are, how they behave, what needs they have and how those needs are full filled in the current UI. It will also aim investigate the users mental models, it will ask questions about which other computer programs they work with to see if there are standards this design can advantage from complying with. Together with these three parts, there will also be a review of all information the company has about its users, in previously written documentation and in meetings where their knowledge will be shared with me. The results of the User study are found in the background of the thesis.

3.2.1 Review of the company's information of their users.

In this current date, the company has two major clients with whom they have quite close relations with. There is some documentation of previous user needs, insights and interviews these documents will be reviewed. There is also a lot of acquired information about the users that have not been documented this information will be shared with me through meeting with the founders of the company. The aim of this is to prepare for the user interviews by knowing some basic information about who the users are, and if they should be separated into multiple groups. Socioeconomic facts such as age, gender, education basic work responsibilities are what will be gathered here.

3.2.2 User interviews

Quantitative user interviews will be held with each subcategory of users from both mayor client companies. They will aspire to give a deeper understanding of:

- Who the users are.
- What they want to do in the software.
- What they crucially need to be able to do in the software.
- Where they experience trouble in the UI.
- What their general attitude towards the application is.
- What frustrates them in the application.

- What level of technology they are used to and feel comfortable with.

The interviews will be held one by one and go on for 30-60 minutes depending on how much time the user has available.

3.2.3 Analysis of user behavior

There will be an analysis of the user's behavior in Fullstory. Fullstory is a user behavior tracking software, that follows the user's mouse movements and in other way captures how users behave in your application or website. The software has two categories that will be reviewed in this paper and they are User engagement and User friction. User engagement holds seven subcategories, four of them will be measured, they are:

- Total session count
- Active time on site
- Last seen date
- Suspicious activity

In the user friction category all subcategories will be examined, they are:

- Dead clicks
- Error clicks
- Rage clicks
- Thrashed cursor
- Abandoned form

3.2.4 Analysis of questions asked by users.

The application uses an add on chat feature called Intercom. Intercom enables the users to ask questions as well as give feedback about the applicationwhile using it. The dialogues the questions amount to are saved inside intercom which gives the opportunity to see some of the conversations and get insight too what the users have had trouble understanding. It also gives a historical view of how the applicationhas developed and how the user's learning curve has been.

3.3 Creating Prototype

An interactive prototype will be built in the software Sketch and Invision studio. This prototype will follow the graphic profile of the company as closely as possible, the focus will, therefore, be on the functionality of the UX.

3.3.1 Design method.

To structure the design work, a proven design process was chosen. Design Thinking 101 by Gibbons is a tool that is used to create a design with the users in focus. The method has three categories: (1) Understanding, (2) Exploration (3) materialization (see Figure). Each category has two parts that make the process tangible and easy to follow. The picture below illustrates how this is an iterative process, where many of the steps can be repeated.

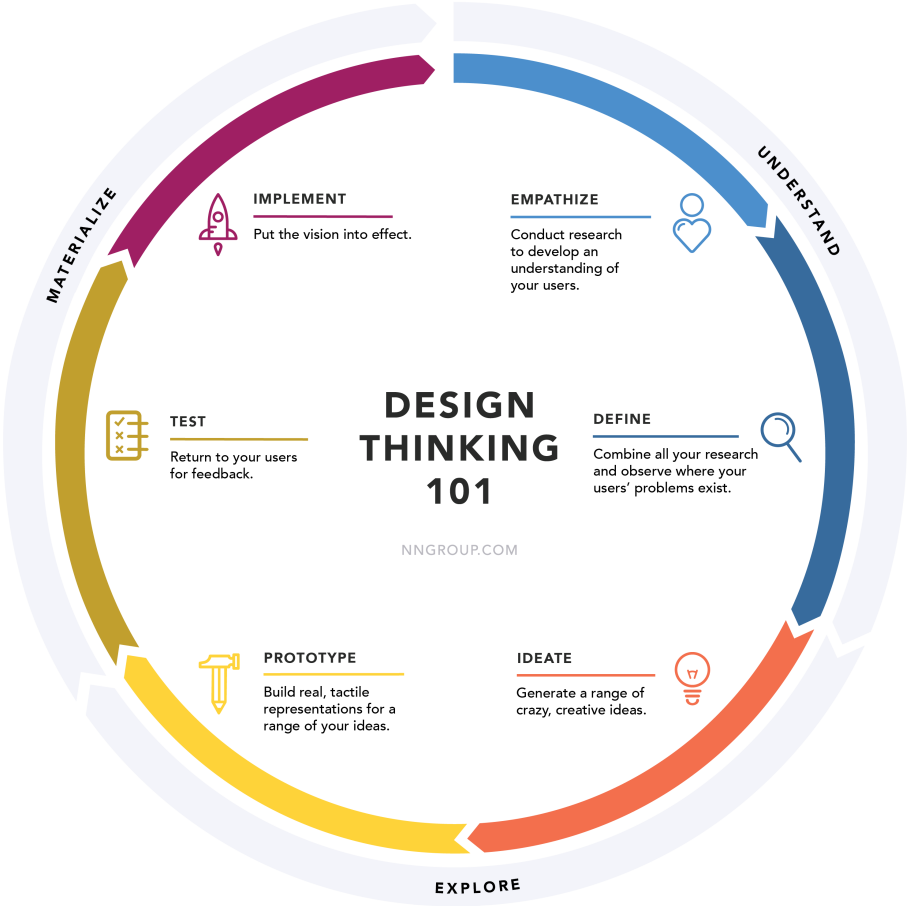

Figure 2: Design Thinking 101 by Gibbons

Empathize

Understand what your users do, say, feel think by conducting research. The research can consist of surveys, observations or interviews. Questions like *what motivates or discourages users?* or *where do they experience frustration?* should be answered here. The goal is to obtain enough information about your users to be able to empathize with them and see the product from their perspective.

Define

Combine all research to observe where the users experience problems and frustration. Pinpointing the users' needs helps to highlight where the opportunities for innovation and improvement lies. Organizing the research findings also helps with drawing conclusions and finding common pain points.

Ideate Brainstorm a large number of ideas too, later on, pick favorites from. Any idea is welcome, creativity is the most important thing. No ideas are to be viewed as crazy or far fetched, the ideas, however, should be focused on the user needs found in previous steps.

If this is done in a team setting it should be done in two steps one individual and one where team members are allowed to build on top of other members ideas.[2]

Prototype

Evaluate the ideas from the brainstorming session and sketch out prototypes of the ideas that you believe might work. The goal of this step is to understand which ideas work, and which do not. In this step, you begin to weigh in feedback on your ideas. Make changes based on the feedback and then share it with another group of people.

Test Test it out yet again on the users, does it change any perception that existed before - for the worse or the better?. If not for the better jump back to the Emphasize step and try to figure out what problems that were not solved or solved incorrectly.

Implement Implemented the provided design and make sure that the usersâ are affected as intended at the beginning.[3]

[2]This step will not be made by a team of multiple people in this thesis.

[3]The implementation will not be done by me, but from a frontend team. I will work closely with the team, answering questions to ensure that the implementation follows the intended design.

3.4 Extracting results

To confirm that the changes made to the UI truly increased the UX a series of testing will be conducted. These tests will be done both on the current UI and the final prototype. They will compare the two UI's in factors of complexity, navigation, structure, efficiency, and ease of use. The tests will be conducted in three parts. In part one the testers will be asked to complete three tasks, these tasks will be timed and after each part is finished the testers will be asked to grade their experience on a scale of 1 to 10. The first task will look at the filtering, sorting, and navigation of the application. The second and third will aim to measure visibility, affordance, and navigation.

The second part of the test will ask the users more general questions about the experience. They will be asked to answer the questions on a scale of 1 to 10, but also to explain their reasoning behind their choice. Part one and two will be done twice one on the new UI and one on the old. Half of the test group will start by doing the tasks on the old UI and half on the new. This will eliminate bias caused by the users perceiving the task easier the second time they do it and thereby favoring the second application they try.

In part three the questions asked will be of a more open nature. This part will ask the users to compare the two apps, to describe the difference between the applications in their own words. The testers will be encouraged to speak freely and explain the reasoning behind their answers. They will also be asked which application they prefer in order to measure if the new UI was truly an improvement.

During the entire tests the users were asked to think out loud, and encouraged to voice all opinions they had.

The tests where made on 12 people. 5 people is recommend for qualitative studies based on research by Jacob Nielsen [18]However this test also had a part where the users where to grade the application from 1 to 10 which most often is considered quantitative research. For quantitative studies the amount of recommended users is at least 20[16]. 20 people was hover not possible to get in touch with for this study, which left it at 12 which is more then enough for the qualitative questions but on the low side for the quantitative studies.

Chapter 4

4 Theory

To know which data and how much of it that is appropriate to present to the user we need to look at how human brains work. In what ways do we absorb information, what limits the amounts, and does structuring matter? Only when these questions are answered can we know which data to filter out, and how to best process and structure it.

It is known that the amount of information our brain can hold and work with is limited, and it is sometimes not sufficient to perform the tasks that are required to do. This section of the thesis will write about why the human brain performs the way it does, and which problems that are possible to solve with proper UI-design.

4.1 Cognitive load & overload

Cognitive load describes the amount of mental effort that is required to complete a task involving processing of information. Cognitive overload refers therefore to when the amount of mental effort required is higher than the capacity of the user. Cognitive overload makes it impossible for a user to complete a task. It leads to confusion and task abandonment.

To understand cognitive overload we first have to understand Cognitive load. Cognitive load is often described as the working memory of the brain and is similar to the processor of a computer. There is a limit to what it can do at a time, and when faced with too many tasks at the same time[5], they are completed slower and some will fail.

4.1.1 Types of cognitive load

There are three types of cognitive load [1], Intrinsic cognitive load, Germane cognitive load, and extraneous cognitive load. Intrinsic cognitive load is the effort of absorbing the intended new information and of keeping track of their own goals. Part of it is therefore impossible to eliminate and should not be aimed to be restricted. Helping the user keep track of their goal is possible and is thus a part of intrinsic cognitive load that can be reduced by thoughtful design. Extraneous cognitive load, however, should be as limited as possible, it represents the processing that takes up mental resources but doesn't actually help users understand the content (for example, different font styles that donât convey any unique meaning). Germane cognitive load is the effort it takes to move something from the working memory to the long-term memory, this is something that shouldn't be discouraged since it complies with the user's goal of finding the right information.

Dividing the user's task into subparts and helping them to keep track of there goal can minimize the intrinsic cognitive load [10]. But removing all extraneous cognitive load should be the first goal when trying to minimize the demands on cognitive load from the UI since its effect is much grander.

Extraneous cognitive load in UI are often linked to incomplete Affordance[4] Examples are:

- Wondering what the next step is (failed constraints or visibility)
- having to remember information that could be shown.
- Not knowing how to complete an action
- Interpreting colors that are used purposelessly.
- Noticing changes in fonts.
- Understanding objects that break UX design practice.
- Wondering if an action was completed or not (Failed feedback)[5]

4.1.2 Cognitive barriers.

In UX-design it is important to look for and remove cognitive barriers. Cognitive barriers are points where the user has to overcome a challenge or perform a new action to continue with their goal[22]. These challenges are often very simple but require some form of information processing.

It is important to remember in UX is that the perceived difficulty is equally as important as the actual difficulty. This makes it very important to deal with cognitive barriers because even though they might be minor when known, they represent potential abandonment points if the user perceives them as difficult. To reduce the cognitive load and potential abandonment points we look at three aspects of user experience [11]:

1. The number of steps (clicks)
2. The length of the steps
3. The difficulty of the steps (perceived and actual)

When these three steps are balanced the cognitive load is decreased. It is a common belief that the number of steps should be reduced as low as possible, but reducing the number of steps often increases the length or difficulty of the step. Finding a balance between them should instead be the goal to strive for.

[4] Affordances are clues about how an object should be used, typically provided by the object itself or its context. It is a usability principle first claimed by Don Norman[20], the concept of understanding what something represents before using it.

[5] feedback is information about the results of actions and the current state of the product or service.

4.1.3 Cognitive overload.

Sometimes the amount of information shown in a UI is too much for the brain to digest resulting in cognitive overload. This can be caused by multiple reasons such as [25]:

- Giving the user to many options to choose from.
- Expecting the users to remember more information than possible.
- Adding intrinsic cognitive load by not dividing the task into subparts.
- Extraneous cognitive load.
- More information or complexity then the user can handle.

Often when users experience cognitive overload it leads to task abandonment and gives the user a negative association to the app. This is therefore crucial to eliminate in advance to get a usable UI.

4.2 Choice overload

Making choices seems like a pretty simple thing, but when choosing is not about A or B but A-Z and each of those options come with 1-10 characterizes, the choice is not so simple anymore. There are many studies made on choice each with a different purpose in mind, this section will write about how many options an average brain can choose from, how different people react to choices and what choice overload means.

A study by the journal of consumer psychology[4] tells us that 4 key factors influence choice overload:

1. The difficulty of the decision. Which they measure by time constraints, decision accountability, number of attributes describing each option, the complexity of the presentation format.
2. The complexity of the choice set. This depends on the presence of a dominant option, the overall attractiveness of the choice options, align ability and complementary of the options. [24]
3. The consumers or users preference certainty. This refers to which level the user can evaluate the benefits of the choice options and have an articulated ideal point.
4. The consumer's decision goal. Which reflects the degree to which individuals aim to minimize the cognitive effort involved in making a choice. Are their minds set on taking a decision fast, or are they looking around to find the best options and know beforehand that no decision will be made today.

Applying this to UX/UI design we can conclude that the more certain the user is of what their goal is, the more time they have to spend on in, how fast they want to make a decision / if their decision will be questioned all impact how the likelihood of inability to make a decision. Factors like how the options are presented, how many they are and in how many ways they differ also affects the user.

To limit choice overload in UI, the most effective action is to focus on easing the difficulty of the decision the complexity of the choice set.

Factors that are already determined by the user and hard to impact include: How much time the user has to make the decision, if they will be held accountable for their choice and are expected to defend their reasoning, The user's decision goal, the users preference certainty. These factors are however are good to know of and remember to take into account when designing.

Factors that can be effected and eased by proper UX design are: The number of visible options, the complexity of the presentation format, presence of a dominant option, number of attributes describing each option & number of options.

Giving the users to many choices increases the probability of them opting for the default choice or choosing something that seems acceptable but not optimal to end the choice-making ordeal. [6] [9].

4.2.1 Happiness of choice

Within one of the company's application features, it is equally important that the users are happy and satisfied with their choice as that they are able to take one. Since this will affect the emotions connected to the application and therefore the probability of using it again, as well as the duration of intervals of use. The report previously referenced to a study about choice overload [4]that measures choice overload not only in ability of choice but also in switching likelihood, choice deferral, regret and confidence of choice.

4.2.2 Maximisers & Satisficers

Maximizers & satisficers are an established concept in Psychology, It describes two groups of decision behavior that fit most people. Maximizers are people who always strive to make the most informed, intelligent decisions. Satisficer choices are determined by more modest criteria. It is easy to believe that this would mean that maximizers make superior and more satisfying decisions, but that is far from true. Multiple studies have shown that maximizers often are less effective with decision making since they suffer from the pressure of high self-expectation [23][26]. Setting high goals when making decisions can interfere with the primary goal of making a choice that the person will be satisfied with. Maximizers ofttimes experience a sense of buyer's remorse after decision making, doubting if their decision was correct and envisioning how the outcome would have been if they had taken another decision. Whether it's a choice between jobs or the purchase of a snack, maximizers are prone to the fear that a better choice was, or is, available."

4.3 Analysis paralysis

The phenomenon of overthinking options to the point where no choice is made is called Analysis paralysis. The process of choosing an option simply overwhelms the person to such a point where they freeze and don't make a choice and thus paralysis the outcome. This phenomenon appears when the perceived cost of decision analysis exceeds the impression of potential benefits gained by enacting some decision.

There are two options of solving this:

1. Decrease the cost of analyzing the decision.
2. Increase the potential benefits or at least the impression of potential benefits gained by taking a decision.

4.4 The magic number of seven

"The magic number seven plus or minus two: Some Limits on Our Capacity for Processing Information" is a research paper by cognitive psychologist George A. Miller of Princeton University's Department of Psychology. It was first published in 1956 and is often interpreted in ways to support that the human working memory only holds 7 pieces of information (plus or minus two).

These pieces of information can hold different values, it can be words, objects or numbers the important part is that the brain views them as single pieces. For example, a word in a foreign language is often interpreted as several phonetic components and would, therefore, be viewed as multiple pieces of information. But the same exact word would be interpreted as one piece for a person familiar with the language.

Miller calls these pieces of information chunks to empathize that they can be multiple or parts of a whole.

When talking about short term memory and words other factors affect how easy they are to remember then the length of the word. How long it takes to pronouns a word affects the cognitive ability much more than the number of letters. The same thing interestingly applies to numbers as well. If a word is known or unknown to the reader also affects the difficulty of remembering.

Later studies have shown that four chunks or even two are the cognitive limit for short term memory. No study has shown that the value of chunks is higher than 7.

The Nielsen Norman group writes about the importance of interpreting this study correctly when applying its information on interaction design. Giving the user more than 7 options to choose from does not harm the user experience as long as the users don't have to recall them. For example, in navigational menus, there can be more than 7 options to choose from because they are continuously displayed and rely more on recognition than recall. The article emphasizes that the most important take away from reading Miller's study as an interaction designer should be that human short-term memory is limited and that packing the information into meaningful chunks helps the users to retain larger amounts of information. The next section will give more in-depth information about chunking.

4.5 Chunking

Chunking is a concept with roots in cognitive psychology which refers to the process where pieces of information are bound together into a meaningful whole. [13]. A chunk is defined as a familiar collection of more elementary units that have been inter-associated and stored in memory repeatedly and act as a coherent, integrated group when retrieved (Tulving Craik, 2000).

One example of chunking is the way most people remember phone numbers instead of remembering 0768479327 as ten different numbers or as one value it is often remembered as four chunks of numbers i.e 076 847 93 27.

One other example of this is grocery lists, instead of remembering: Apples, Onions, Sour cream, Bananas, Potatoes, Carrots, Milk, Oranges, Yogurt, in such a random order. We tend to group them into chucks with similar characteristics, for example, apples, bananas Oranges would be one group, potatoes, onions, carrots a second one and Sour cream, milk yogurt a third. These chunks (or groups) are even easier to remember if given headings such as fruit, dairy, and vegetables. Instead of remembering nine objects, most people find it easier to remember 3 chunks each containing three values. this coincides with the famous 7 plus minus 2 rule.

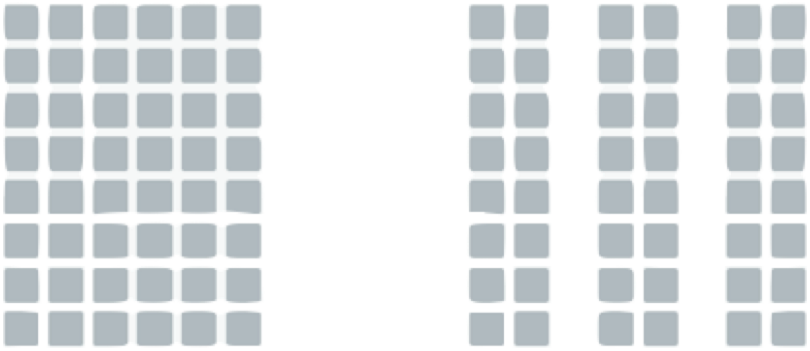

Figure 3: Example of chunking

Having clear visual hierarchies with related items grouped, prechunks the information for the user and therefore eases remembering.

While chunking content in user interfaces the Nilsen Norman group recommends stringent following the Law of proximity (form Gestalt psychology), together with using background colors, horizontal rules, and white space to help users visually distinguish between what's related and not.

4.6 Variability in User Performance

When looking at users it is easy to presume that they perform their tasks at quite the same rate and that their rate is similar to your own and the people around your office. This is far from true and the reality is that user performance rates vary largely between users. When looking at website tasks the slowest 25 percent of users take more than twice (2,4 times)[8] the time as the fastest 25 percent to finish. These differences would likely decrease significantly if the websites were perfectly designed to guide users between steps.

Type of Use	**Q3/Q1**
Text editing	1,8
Personal computing	1,9
Information search	2,2
Web use	2,4
Programming	3,0

Figure 2

4.7 Change blindness

When a large amount of information is being displayed, noticing changes can be extra difficult. Many changes can be perceived as minor even though they have important implications. When changing numeric information in a data table change blindness can easily occur. Animating changes can solve those problems which improve user experience. Giving proper feedback is another way of helping this situation since it tells the users that their occasion was valid and that they should expect change.

4.8 Browsing vs reading online

Studies have shown that people rarely read word by word online, instead, users scan websites picking out separate words or sentences. The Nielsen Norman [15]group made a study that showed that as much as 79 percent of the test people scanned new pages and only 16 percent read word by word. When scanning websites users can be looking for other matters then text, scanning through a website to find certain information or functionality is naturally just as common. When scanning through a page it is well known that the eye follows certain patterns. Three of the most proven patterns are the F-pattern, the Z-pattern, and the Gutenberg diagram. Each of these patterns map where the users look and are therefore a guide for designers to where they should place the most important information. The Gutenberg diagram describes a general pattern the eyes move through when looking at evenly distributed, homogeneous information. This makes the pattern non-applicable when designing many websites since they often have a visual hierarchy or mixed information. The study that first found the F-pattern was also done on larger pieces of text. This patter, however, is more compatible with other content types since it relates closely to people's ordinary reading style, top to button and left to right. Since this is such a deeply learned skill for most people it feels very natural.

The most important take away is that all three studies agree that the most important information should be placed on top of the page and that attention fades the further down you go.

4.9 Summary

The most important cognitive aspects to keep in mind when designing a complex UI with large amounts of data are:

- To keep the cognitive load as low as possible.
- Removing all possible cognitive barriers.
- Giving the users a way of making choices easily.
- Chunking content into smaller pieces.
- Not giving the user more information or complexity then the user can handle.

All these concepts could potentially lead to task abandoning and are therefore crucial to tackle.

4.9.1 Reducing cognitive load

To keep the cognitive load as low as possible there are multiple things to consider. Balancing the number of steps, the length of each step and the difficulty for each task is a good way to reduce cognitive load. Another important aspect is to remove all extraneous cognitive load. Extraneous cognitive load represents the processing that takes up mental resources but doesnât help users to understand the content. Extraneous cognitive load in UI is often linked to incomplete Affordance. Examples of extraneous cognitive load are noticing differences that do not convey any meaning such as changes in font or colors, wondering if an action was completed or not, wondering what the next step is or having to remember information that could be shown. Removing extraneous load gives the user more mental ability to finish the task but it is important to remember that there is a limit to the amount of information or complexity a user can handle.

User performance varies, and it is safe to say that the complexity your users can handle is not the same as you personally. It is therefore very important to user test your application to see how much complexity is manageable for your group of users.

4.9.2 Chunking information

Chunking information into pieces makes them easier for the human mind to digest. Remembering 4 chunks each containing 3 values is easier than 12 items at once. Chunking can be used as a way of grouping information or functions in an application to ease navigation and to reduce cognitive load. If the content of a website is grouped into three sections the user only has to interpret three sections, instead of each item by itself. When grouping items it beneficial to have less than 7 groups and less then 7 items in each. If one group contains more then 7 items then they can often be split into two. This is based on research saying that the human working memory only holds 7 pieces of information (plus or minus two).

4.9.3 Cognitive Barriers

Cognitive barriers are points where the user has to overcome a challenge or perform a new action to continue with their goal. It is important to look for and remove cognitive barriers to get a user-friendly UI. One common cognitive barrier is language, if a user isn't familiar with the terms used in an application they first have to learn them to be able to navigate and use the application. Some users will simply opt-out of learning the terms and try to find an application with a more familiar language. Other examples off cognitive barriers are filling out forms, If the users do not remember the required information there is a big chance that they will quite the task with the notion of finishing it later.

4.9.4 Choice in an easy way

One other important way to reduce complexity is to simplify choice. The phenomenon of overthinking options to the point where no choice is made is called Analysis paralysis, this is the most important state to avoid. This phenomenon appears when the perceived cost of decision analysis exceeds the impression of potential benefits gained by taking a decision. There are two options of solving this: 1. Decrease the cost of analyzing the decision. 2. Increase the potential benefits or at least the impression of potential benefits gained by taking a decision. One way of decreasing the cost of analyzing the decision is simply to reduce the number of options. Other factors that affect decision making are: the complexity of the presentation format, the presence of a dominant option, number of attributes describing each option number of options. Giving the users to many choices increases the probability of them opting for the default choice or choosing something that seems acceptable but not optimal to end the choice-making ordeal. This is very difficult for people described as maximizers who always strive to make the most informed, intelligent decisions. For maximizers, a situation like this causes a high switching likelihood and risk of choice deferral, regret and low confidence of choice. All these factors decrease the user experience.

Chapter 5

5 Findings

This section of the paper describes the insights found form the user interviews. The knowledge gained from the Review of the company's information of their users can be found in the background of the paper under the section: The Users.

5.1 Insights from user interviews

The biggest insights from the user interviews were the need for simplicity, the user's lack of time and their vast knowledge about Microsoft excel.

5.2 Complexity

There was a consensus between the base-users that they much rather would like to see a quick summarized version of how their campaigns had gone then the ability to search and dig deep into the data. They wanted something quick and easy that did not require a lot of effort or time. The users complained about the number of choices they had to make and about features they thought where overly complicated. The feature that was mentioned most repeatably in this way was the date picker (see picture below).It had a lot of options but was mainly operated by a drag and drop timeline that the user found hard to be precise with.

Figure 4: UI-element: Date picker

Many users expressed that the application was complicated and difficult to use in general. It was clear that the learning curve was too steep and that many users felt overwhelmed by the impression of the app. It was also clear the users only wanted to see the results of the campaigns they were responsible for and no others[6].

Many users expressed that they wanted a version of the application where they instantly could see the data they were interested in. That they *"didn't have time to make all those decisions"*, revealing the fact they viewed each of the settings as part of a complected whole.

[6]The division of responsibility of campaigns is by category. Each user is typically responsible for planning all campaigns in one or several categories of products. The users where interested in seeing the results of the campaigns they where responsible for and the ones that could affect their categories.

5.2.1 Language

One other big finding was how strongly the users wanted the applicationto be translated from English into Swedish. They where not familiar with the economic terms in English and had to translate them one by one them self to understand the results. This caused frustration that contributed to negative feelings associated with the app. Many of the users had requested this change before and commonly asked for a translation of economic terms in the applications chatbot feature (Intercom). These questions where so common that the company made a translation list of terms on their blog page where the users could find the term they where looking for.

5.3 Mental models

The users expected to see the data over the last week and the last four weeks, since that was the way the normally evaluated the results of their promotions. They were uninterested in seeing results that they where not responsible for and most of all they wanted everything to work as in the Microsoft software program Excel. These users all spend a lot of their work time in excel and had been for many years, which gave a big insight to their mental model. This insight was later on used when designing the new UI. It was considered when placing functionality and also in processing of the numbers.

Chapter 6

6 Changes made to the UI

This chapter describes the changes made to the new UI. All changes are based on information found in the theory of the thesis and the knowledge gained about the users. Each change was made with the goal of increasing the user experience by reducing the user's cognitive load, without reducing any functionality. The changes are divided into four parts, the first section is an overview of the changes, the following parts describe changes made that are connected to filtering, reducing extraneous cognitive load and Ease of use. Each section states which improvements were made to the UI in regards to that specific factor.

6.1 Overview

Knowing where to start is a common problem for users in complex applications. User interviews clearly showed that this case was no exception. The users had described the application as overwhelming and difficult. To solve this, the applicationwas given a more well defined visual hierarchy and an easier learning curve.
To reduce the cognitive load and give a more welcoming impression, the number of choices that are immediately visible for the users where reduced. This was an important step in reducing the chances of analysis paralysis caused by choice overload.
The filters together with the data table were made the visual focal point of the application. Only five of the filters are shown by default, the rest is hidden behind a fold, based on George A. Miller's research paper "The magic number seven plus minus two". This division also chunked the filters into two groups instead of one, which decreases the cognitive barriers and perceived difficulty.

Figure five and six show the starting page of the application, it has orange numbered marks that visualizes the changes made. Each number represents a function in the application. By comparing the numbers it's possible to see how features were changed and moved in the new UI. These pictures show the more general changes that were made. Below you read about what changes each numeric label in the pictures aims to highlight.

6.1.1 Numeric labels in figure 5 and 6

1. The big Search field has been moved into the data table. It is only available on a subset of columns that are non-numeric and nontrivial. Numeric columns show their total in the same place as non-numerical columns have a search function. This decision was made by two causing factors, one being that I wanted the action to be closer to the item it changes. The other one was that I wanted the filter to be a clear visual focal point and that this was a competing element.

2. The filters now take up the whole width of the screen and are designed to be a natural visual focal point of the screen. Only five of ten are visible

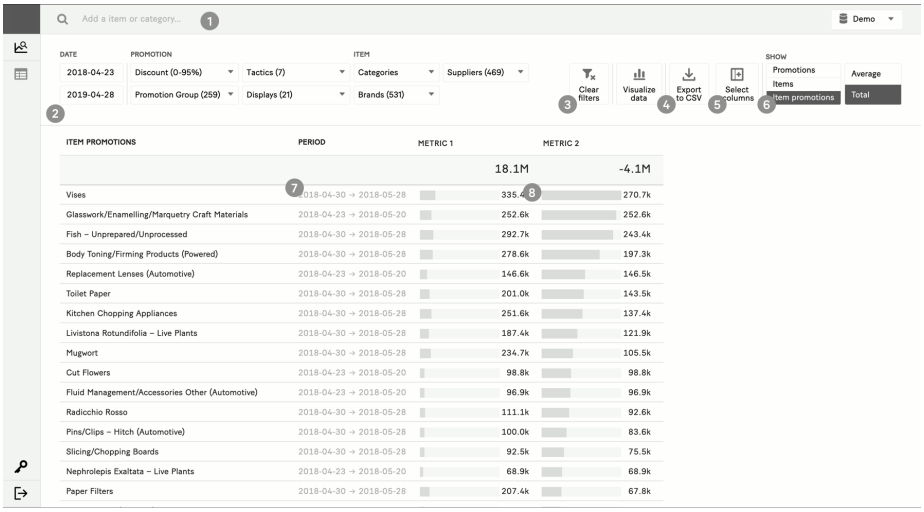

Figure 5: Old UI

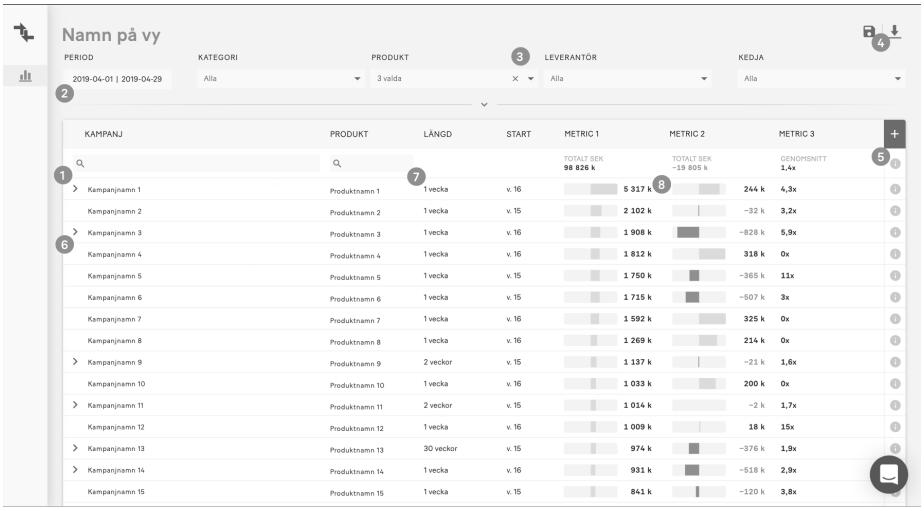

Figure 6: New UI

all the time, the others that are not used as often are hidden behind a fold. But accessible with only one button click. The filters where logically chunked into two groups, the first group describing what, where and when the campaigns took place. The other one describing what the actual offer was. I found it important to keep them in that natural logic. This decision was also motivated by the "rules of the magic number of seven" as well as reducing chances of analysis paralysis.

3. The clear filter functionality is now placed inside each filter, simply to enhance mapping and visibility.

4. The download button has been moved to a more standardized position

(top right corner).

5. The add new columns button is now inside the data table, also to increase mapping, visibility, and affordance when adding a column of data.

6. The choice of having the data table shows, items, promotion or item promotion has been changed into the non-choice of always showing the promotion with the option of expanding it to see each item in that campaign. Reducing the number of choices was one of the key goals with the general UI changes. This was previously 3 three choices with very similar non-descriptive names but is now invariably a combination of two of the options.

7. Instead of repeatedly showing the period the campaign was active as yyyy-mm-dd - yyyy-mm-dd, the UI now shows which week it started and how many weeks it was active for. This reduces cognitive load but also gives the user the ability to sort on both the starting date and length of the campaign which is an important factor in campaign analysis. Having them in the format yyyy-mm-dd allows a big risk of change blindness since most campaigns usually only differ one or two weeks in starting date meaning only two of eight numbers would change.

8. The inline charts have changed appearance so that zero is in the middle and that negative values are shown to the left and positive to the right. All numeric numbers are now in a heavier font and all negative numbers are red. These changes were made to increase the users browsing visibility.

The changes made in figure seven were made with three major goals in mind. Those three goals were to 1.) Follow UX/UI design principle 2.) Reduce cognitive load 3.)Ease the users' learning curve. To reduce the cognitive load I aimed to reduce the number of choices, hide complexity, reduce visual noise. To ease the learning curve I aspired to give the applicationa clear visual hierarchy and to hide complexity.

One other way I reduced the learning curve was by adding an info button available on all campaigns. This info button opened a details view where the users could see explanatory information as to why a campaign performed the way it did and a histogram that helped them understand if the performance should be interpreted as good or bad in comparison to others. This details view allowed the user to get some insights into the campaigns without having to search for it them self.

In figure seven you can see that the user now is only met by 5 initial choices which are a reduction from 15. These choices also already have a default setting that was made in the user on boarding. The choices are the filters marked with number 2 in figure 7 and the numbers 2,3,4,5 6 in Figure 6. The functions marked with 3,4,5, 6 in figure 5 are far less important than the filters that are marked as number 2. I, therefore, chose to give them less visual impact to give a more telling visual hierarchy to the user.

Numbers 3,4, 5 are buttons that look very similar in fig 5 but perform very different actions. They have all been moved and changed appearance in figure 6. Having similar actions looking differently or similar-looking buttons performing very different actions increases visual noise and extraneous cognitive

load. They are now placed much closer to the object they are changing, to better the mapping of the UI.

One other major general change that has been made is that the application-has been translated from English into Swedish. Many of the users had requested this change before and commonly asked for a translation of economic terms in the applications chatbot feature (Intercom). Language can be a very hard cognitive barrier to cross, expecting users to operate in a different language then their native is a sure way to increase cognitive load. This was, therefore, an important change and one of the most appreciated changes to the UI from the users.

6.2 Visual hierarchy

To reduce the overwhelming impression expressed in the user interview the application was given a more clear visual hierarchy. The applicationnow has two prominent features, the filters, and the data table. To make them the visual focus point they were given a lighter background then the area surrounding them. All filters look the same and are grouped which gives a chunking effect where the filters can be viewed as one component. The data table has the lightest background (pure white) and the filters the second lightest (FDFEFF) this was chosen to indicate significance. Pure white is the color that differentiates itself the most from the color-scheme which makes it the color the eye is drawn the most too. Giving this color to the data table makes it the first object a user notice when entering the application.

The sidebar where views[7] are navigated between has the third lightest color but this one is very similar to the background since it is also distinguished with a shadow.

All icons have one of two colors, either a light grey or dark grey. The dark grey is used for more important features most often action buttons. Where the lighter grey is used for less important often informative purposes. All positive numbers are written with black font color and all negative with red. Since black is a natural part of the grey color scheme and red is not, the numbers stand out and grabs the users attention more. This is beneficial since negative results are very interesting for the users. If the design would have had green and red numbers instead it would not have had this effect.

[7]Filter-settings, column-setting, time periods and sorting options can be saved into views. These views are accessible for the users to return to at any point. They will be referred to as reports or reviews in this thesis.

6.3 Filtering

6.3.1 Choosing default data

In many data-heavy applications, the option of showing all data simply does not exist. Choosing which data to show on default is therefor an important decision. The amount of data shown is equally important to choose carefully. In this application, seven columns of information were originally chosen to be shown by default in the data table. Four of them are descriptive metrics that help the user to identify the campaign. One of the descriptive metrics were later split into two. Showing the period the campaign ran for as the start week and length instead of the exact period it started and ended. This enables the user to compare the periods of campaigns in an easier way. When comparing the profit of campaigns it is important to know how long period they were available for. Having the period displayed as ***start:*** *w42*, ***length:*** *2 weeks* instead of *2019-10-14 - 2019-10-27* makes it easier to digest and compare.
The three other default columns showed results of the campaigns. These columns were chosen by the company and users together. One of them where chosen solely by the user, it is a comparative metric that shows the promotions sales in comparison to the non-promoted sales. This metric was considered less important by the company than many other metrics but since user interviews clearly showed that it was one that the users were most interested in seeing it was added as one of the default columns. This was a metric the users where custom to looking at, although it was consider alot less value adding then most, it was kept. Removing it would have interfered with the users mental modal and probably reduced their entrustment in the app.

Below you can see a picture of the default choices of columns for both apps.

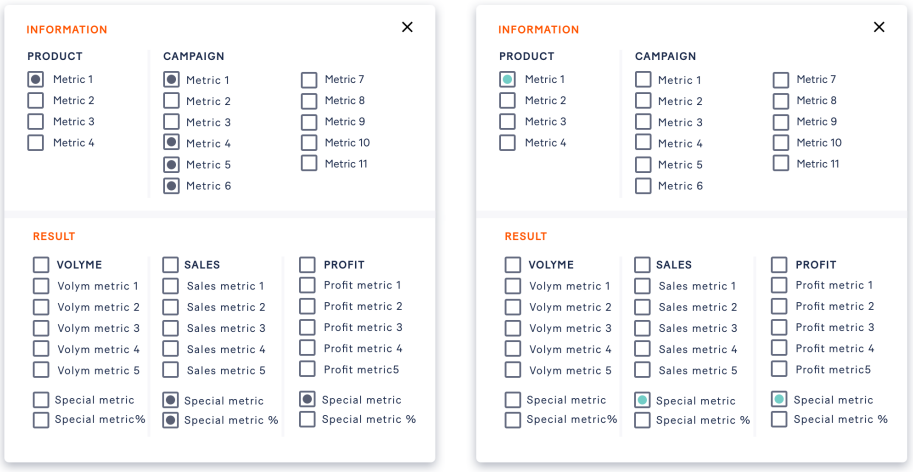

Figure 7: Column meny
Black dots (left picture) represents default columns in the new UI, green dots (right picture) represents default columns of old UI.

6.3.2 Deciding the order of the columns

Displaying the data in a logical order allows for better scanning abilities. In this application the data has been divided into two subsets one called descriptive data and one called result data. The descriptive data describes the campaign, it says which products that were in it, what period it ran, in which stores, etc. The result data are different metrics describing how successfully the campaign was economically. The descriptive data is placed to the left in the data table and results columns are to the right. This is simply because the users read left to right and it's more valuable to know which campaign it is before knowing how it performed. The columns that users find most interesting are placed to the left in their field. When a new column is added they are placed to the far right in that division. Dividing the data into two sections places all result related values closer together which makes them easier to compare.

6.3.3 Reworking the data into smaller subsets

One way to reduce the data is to see if there are ways of reworking it so that it is possible to show smaller subsets of the data at a time. One way that this was applied in the application was adding a new feature that approximates the result of future campaigns. Adding this feature made the need of analyzing previous campaigns smaller. Instead of the user having to look trough past data to see what type of campaign has worked in the past, they could now with this feature try out a hypothesis and see how such campaigns would perform in the future. This reduces the users' interaction with the data set in its complete form.

Another way of showing a smaller subset of the data that has been used in the application is by choosing parts to visualize in charts. Scatter plots that show the distribution of four different metrics has been added. The four metrics each slice the data into sections in a unique way allowing the user to get different insights from each plot.

6.4 Reducing extraneous cognitive load

The goal of the changes made to the UI were in large part to reduce the user's cognitive load without reducing the amount of data accessible or any functionality. Extraneous cognitive load represents the processing that takes up mental resources but doesn't help users understand to the content, this was therefore the type of cognitive load it aimed to reduce.

6.4.1 Changing language

One of the decisions that had the most impact on reducing cognitive load was the choice to change the language of the app. Translating it from English to Swedish made the terms easier to recognize and digest since they were displayed in their the users' native language and the language they use at work. The users were simply not familiar with the economic terms in English and translating them by them self took cognitive effort and time. Many of the users had requested this change before and commonly asked for a translation of economic terms in the applications chatbot feature (Intercom). These questions where so common that the company made a translation list of terms on their blog page where the users could find the word they where looking for. Language can be a very

hard cognitive barrier to cross, expecting users to operate in a different language then their native is a sure way to increase cognitive load. This was therefore an important change and one of the most appreciated changes to the UI from the users.

6.4.2 Affordance & Visibility

Having to search for functionality or not understanding what actions mean, takes unnecessary cognitive load. Confusion and frustration in common when an application has poor visibility or affordance. Giving the application a good basis of clear visibility and affordance thus reduces cognitive load by eliminating confusion. In Figures five and six some of the changes made to the UI are pictured. The dots inside of the pictures represent changes made and dot number 1, 3 and 6 symbolizes changes made to improve affordance. Dot numbers 7 and 8 are done to improve visibility and 4 and 5 for better mapping. They key to getting good visibility and affordance is in the details. Complying to design standards and building on existing mental modals is very important. All actions in this UI where placed as closely to the object they where changing as possible and all features where kept as standardized as possible.

6.4.3 Chunking

Chunking the information into smaller pieces has been done throughout the whole UI. The filters have chunked into two fields where only one part is visible at all times. The visible fields have uneven distances between them creating an illusion of three chunks. The data in the table has been chunked into two parts, one of the descriptive data and one with data describing the results. The column menu has clear chunks with three rows that have partitions inside of them, so it is easy to locate the column the users are looking for. (see figure number 6) The design of the application is made for the user to perceive the UI is as two mayor chunks when first entering the application. These chunks would be the data table and one the filters.

6.5 Ease of use

Making the learning curve less steep has been one goal towards increasing the user experience. This section writes about changes made to UI in order to make the application easier to use.

6.5.1 Processing

The data have been processed to look similar too other numeric data programs, especially Microsoft excel which is a program that we know that our users have a lot of experience with. All the numeric columns are right-aligned and all text columns are left-aligned. All numbers are monospaced which increases visibility and the ability to compare numbers. When numbers are right-aligned and monospaced the values that are of the same magnitude will always be placed underneath each other (see picture below).

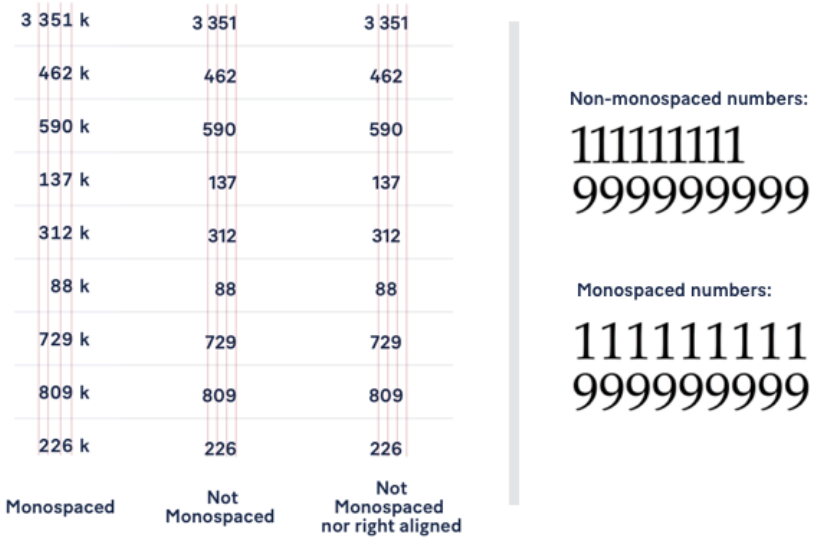

Figure 8: Numbers with different alignment and spacing

This makes a larger number easy to detect. Negative numbers are red to draw more attention to the underperforming campaigns.

6.5.2 Structure

The structure of the information in the data table has changed. Now each line in the table represents one campaign and shows the summarized result for all the products included in that campaign. All campaigns that have multiple products are expandable and when expanded the user can see the individual result of each product. This makes the number of rows decrease highly while providing the information just one click away. Removing the choice the user

had in the original applicationof showing only products, only campaigns or as in this case both were a very active choice aiming to reducing the number of choices and by that reducing cognitive load and complexity.

The Column menu has a clear visual structure that is chunked into smaller more processable pieces instead of being a list of 24 items. (See picture below)

6.5.3 Removing cognitive barriers and repetitive work

An onboarding feature was designed for the application to make it possible to auto-generate views for the users. The goal of this was to give them a pre-filtered data sets that fit their specific need of information. Again this was done to reduce the learning curve of the applicationbut also to give the users a quicker way to access the specific data that they are interested in. Many users expressed that their time available for evaluating promotions is greatly limited. Auto-generated views make it possible for the users to spend more time looking at the data since they did not have to spend time finding it. Part of the intent with autogenerating views was also to show the users a structured way of work with the information, saving it in a way that would reduce the amount of recurrent work needed each time they open the app. This would decrease the learning curve immensely, which would remove any cognitive barrier when reopening the application.

6.5.4 More user-friendly filtering functions

Even though the application supplies the users with auto-generated pre-filtered views the users need the ability to filter by them self to make new views or to find specific data. It was very important that these filters where user-friendly since each filter held a vast amount of options and scrolling through them all would be time-consuming and potentially annoying for the user. The users had also mentioned in user interviews that the date-filter was very hard to use and ineffective.

Instead of just having a long list of options in each filter two different "smart"-filters were implemented into the design. One was for the product categories which has a tree structure and the other was used for all other filters. It was important that the category filter easily showed subcategories and which subcategories that had "children" and "grandchildren" chosen. It, therefore, shows a checkmark if all categories in that branch are chosen and a line in the checkbox if only some of them are. It also shows a grey background on the branch that is being viewed so that it is easy to see which subcategory that is on display. When reopening the category filter after it has been closed it shows it just like the last time you closed it. Meaning it is scrolled to the latest clicked category and as many subcategory levels are open as the last time it was viewed. This can be viewed in figure nine below.

Both filter types have a search field on top, too make the user find what they are looking for easier. They also have a clear button to remove all choices. All filters except for the category filter shows checked options as a list floating on top, the purpose of this is letting the users remove options or see what they have chosen without having to search for them in the long list. The product filter holds over 50 000 alternatives which make scrolling through them to find something specific very time-consuming.

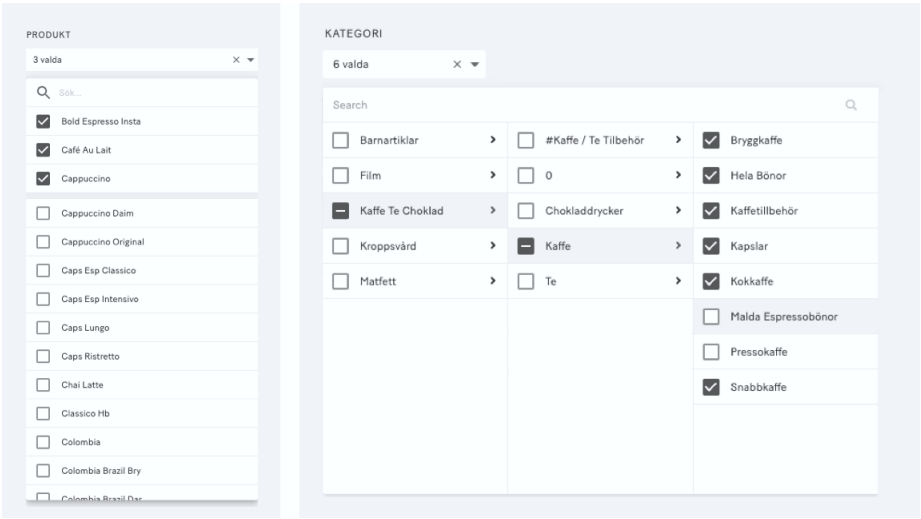

Figure 9: Filter functionality.

All filters are cross-filtered which means that if a user starts by choosing suppliers, for example, the category and product filter will only show options that have that specific supplier. This reduces the amount of choice immensely but also the cognitive load, since it only shows available options, often reducing alternatives from thousands to single-digit numbers.

Negative opinions about the date picker och period filter where reoccurring during the initial user interviews. It had a lot of options but was mainly operated by a drag and drop timeline that the user found hard to be precise with. It is now changed to one that is very standardized and simple where the user can choose by clicking the number of the week, start and end dates or writing in the input field over it. The input field on top is time-efficient in when changing year. But it lacks the option of "latest X weeks/month/year" which is convenient when the users saves a view with a particular setting.

An optimal date picker would be the one pictured on the button in the figure. It is simplistic but still gives them the option of choosing previous and coming periods of time that are static. Meaning whenever a user opens a report it would show the result of the previous 4 weeks. This date picker was however not implemented at the time the tests were made and is therefore not included in the results.

The two filters that could reduce the amount of data the most where the category filter and the supplier filter. If a user chooses a category or supplier it reduces the number of alternatives in the product filter. The product filter holds over 50 000 alternatives when no supplier or category is selected but choosing one of them often reduces the number of products to a two-digit number.

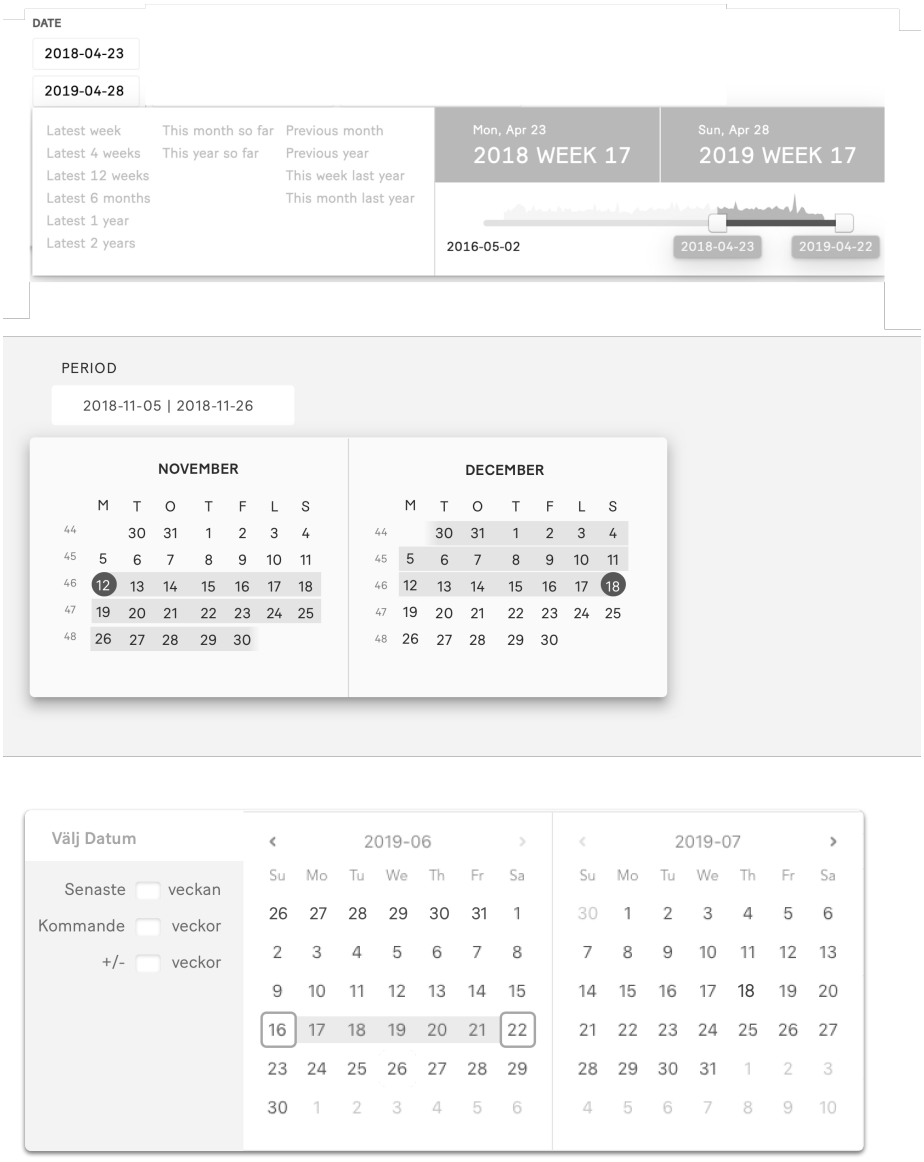

Figure 10: Datepicker
Over: Old date picker. **Middle:** New date picker **Botton:** Optimal datepicker

6.5.5 Individualizing the data set

To reduce the amount of data further an onboarding feature was designed where the users could choose which part of the data they were interested in looking at. User interviews showed that all users evaluated campaigns on a weekly basis and that each product category of the store had a designated campaign manager. It was also found that the results of some suppliers' campaigns were

considered more important than others. This lead to the design of an onboarding feature that asked all users two questions before entering the app. These two questions where: "Which are your top 3 Supplier?" and "What categories are you responsible for?". From those answers 5-7 views where autogenerated: One for each of the top suppliers, one view for each category they were responsible for and one view for all campaigns that the user is responsible for. All of these views showed the result of the campaigns that ran the previous week. This reduced the number of rows in the data table from an average of over a thousand to less than 50. Reducing the number of rows like this gives the user a stronger sense of control and lowers the overwhelming impression.

Figure 11: Individualizing the data set

Chapter 7

7 Result

To see if the changes made to the UI truly increased the UX, a test was made. The test looked at user performance and user experience. The testers were asked to finish different tasks and then rate their experience on a scale of 1-10 in terms of the required effort needed to finish. After the users finished the test they were asked to rate the applicationin terms of efficacy, structure, navigation, ease of use and complexity. They were asked how fast they perceived it took to complete a task, how structured they found the data and how complex the perceived the application. Beyond that, they were also asked to rate the applicationon a scale of 1-10 in regards to different factors and to describe their initial impression of the app. These questions where made to measure how they experienced the application and the tasks aimed to measure user performance.
The test was made of three parts, parts one and two were done twice by all participants, once on the old UI and once on the new. Part three was done after the users had tested both apps and purposed to ask questions that let the users compare the applications.

In the first part they were asked to complete some tasks and rate how they perceived the experience, each task was timed to check the efficiency of the app. Part two consisted of more general questions about the experience and part three asked the users to compare the apps. The question asked in part three where of a more open nature, where the testers could speak freely and explain the reasoning behind their answers. In that section, the users were not asked to rate anything. During the entire tests, the users were asked to think out loud and encouraged to voice all opinions they had.

7.1 Grade

	New UI Mean grade	Old UI Mean grade	Difference
Ease of use	6,57	3	3,57
Navigation	6,57	2,14	4,43
Structure	8,14	4,14	4
Efficiency	7,43	3,6	3,83
Complexity (10 = most complex)	3,6	7,4	3,83
Overall grade	8,29	4	4,29

Figure 12: General grade

As seen in figure 12, The new user interface got a higher score in all categories. Structure was the category that got the highest mean grade at 8,14. Navigation was the category that had the biggest grade difference between the old and the new (4,43 points difference). Ease of use was the category where the difference was the lowest, still, the new UI got a score 3,57 points higher than the old UI.

7.2 Tasks

The users were given three tasks to complete. All tasks were timed and after each task, the user graded the experience from 1 to 10. The grade symbolized the required effort needed to finish the task. The higher the grade the less effort needed.

	New UI	Old UI	Difference between old and new UI	Differance betweene first and second test
Task 1 Grade (mean on scale 1-10)	5,4	5,3	0,1	2,4
Task 1 Time (mean time to finish task)	2 min 15 sec	1 min 20 sec	1 min 5 seconds	
Task 2 Grade (mean on scale 1-10)	7,3	4	3,3	0,4
Task 2 Time (mean time to finish task)	2 min 58 sec	4 min 58 sec	2 min	
Task 3 Grade (mean on scale 1-10)	7,7	1,4	6,3	0,6
Task 3 Time (mean time to finish task)	56 sec	5 min 3 sec	4 min 7 seconds	

Figure 13: Task grade and time taken to complete

7.2.1 Task 1

The first task tests the applications filtering, sorting and navigation. It asked the user to find the campaign with the highest value of metric 1 that was from a specific supplier. In order to find this information, they needed to add a new column, filter to see a specific supplier and tactic and sort the right column. Both versions of the UI got very similar grades 5,4(New UI) and 5,3(Old UI). The average time spent on the tasks was one minute longer on the new UI. The result varied quite a lot between the first application the users tested and the second. The second application tested was on average given a 2,4 point higher than the first one. This was the only task where there was a significant difference between the grades where given the first and second application tested.

7.2.2 Task 2

This task focused on visibility, affordance, and navigation. It asked the user to download a file that included some specific metrics for a certain subcategory

during a specific time period. The new UI got a higher score (3,3 point difference) and a lower meantime (-2 minutes) to finish the task. The first application tested got an average a 0,4 point lower grade than the second.

7.2.3 Task 3

This task also focused on affordance and navigation. It tested a particularly critical part of the users' workflow, being able to save the information viewed as reports inside the program. The mean time spent to complete the task on the new UI was less than a minute, on the old UI it took over 5 minutes. The experience was rated on average 7,7 for the new UI and 1,4 for the old. Which order the users tested the two applications did not have a big impact in this case. The application that was tested secondly got 0,6 points higher grade on average.

7.3 User Comparison of the two apps

All users were asked which applicationthey found easiest to use, which had the best structure, if they were to use one in the future which one they would pick and why they felt that way. They were also asked to describe what the differences were between the two applications in their own words.

All testers said that the found the new UI easier to use and better structured. Every single one also picked the new one to work with in the future.

They said that the new UI was more "straight forward", easier to understand and more similar to the program Excel which many users spend a lot of time working in. That the new UI is in Swedish was mentioned as a reason for choosing it by 80 percent of the users. Some users mentioned that the new UI was more effective and that it takes fewer clicks to finish an action. Visibility was commonly voiced in different ways as an advantage of the new application. Some users also said that they found the navigation easier in the new UI.

7.4 Summary

The result clearly shows that the changes made in the interface improved the UI's efficiency, constraints, Affordance, and usability. It also shows that the application scored a higher grade in those factors and has an overall grade which is more than doubled its opponent. This indicates that UI design has a large effect on user experience in big data applications. It shows that the changes made to the new UI successfully increased the User experience which shows that adapting a UI to reduce cognitive load is a successful strategy in improving user experience in data heavy UI's.

Chapter 8

8 Conclusion

The changes made in the UI successfully improved the User experience without reducing the amount of information accessible or available actions. The changes improved the ease of use and reduced the complexity of the application. Factors that increase cognitive load such as bad navigation, bad structure and low efficiency were improved. All were given a grade more than two times high the grade of the old UI. The application was graded as easier to use and less complex and the overall grade went from a 4 to a 8,29.

This chapter will talk about which steps were made in the prototype to reach these results. It talks about them in a more general way, making them applicable to more cases than promotional-analytic software. It answers the questions *"What is important to keep in mind when designing interfaces that hold large amounts of data?"*, *"What negatively affects the amount of data a user can comprehend?"* and *"How to decrease cognitive load without decreasing functionality?"*.

8.1 Important to keep in mind when designing interfaces that holds large amounts of data

This section of the thesis will conclude the information gathered about what to keep in mind while designing an interface that holds large amounts of data. It will summaries information gathered from the thesis comparative testing but also its literature study about the cognitive effects of large data.

8.1.1 Increase visibility and reduce cognitive load.

Improving visibility in applications that hold big data is also very important. Visibility enables better navigation and less user frustration but also decreases the amount of effort it takes to cognitively digest the data. This means that it is important to fallow gestalt law, keep action-triggers close to what they are changing visually, having a clear visual hierarchy and chunking the information.

Always provide the service in the users' native language and the language they use at work. Translating the UI from English into Swedish was one of the most appreciated changes made in this application, which shouldn't be a surprise. Having the UI in an other language than the one the users are most comfortable with increases the required cognitive load in every single interaction. It is therefor very important to provide it the users native language to keep down the cognitive load.

8.1.2 Reduce number of choices

The number of choices a user has can easily become overwhelming in application with large amounts of data. It is crucial to minimize the number of mandatory decisions that the user has to make to be able to access the application. Hiding

and dividing complexity is important to make the learning curve of an application smooth, this is extra important in big data applications since they often have a more complex UI which means a longer learning period. Making the users take multiple decisions before accessing the applications information can make the users perceive the applicationas overwhelming and in the worst case cause a cognitive barrier resulting in the user exiting the program. In this application, the user does not have to take any decisions to access the default data. The default data has carefully been chosen to fit the users' needs in a general sense. By filtering the data or adding columns the users can choose what data to examine. But these are not required decisions. Only half of the filters are shown at all times, the other half is hidden behind a fold. The ability to add columns is not pushed on the users but neatly displayed in the top right corner of the data table. This keeps the choices of adapting the data avalible at the same time as the required number of choices is zero. Having the required number of choices at zero also minimizes the chance of the user getting analysis paralysis.

8.1.3 Filter away as much data as possible

Not all data points are important for each user. Filtering away as much of the unnecessary data as possible makes the application more effective for the user. This allows the users to find the information they are looking for in a faster and easier manner. Which makes the application perform well without having to take into account user performance levels. It also removes pressure from the UI's design. If the user is not obligated to interact as much with UI to find what they are looking for it reduces the pressure on having the interactions go perfectly.

8.1.4 Make sure to find out what data is important for what user

Making sure to find out what data is important for what user is the key to filtering away a large percent of the data. Investigating what makes a user interested in which sub-part of the data is an important part of the process. In this case, it boiled down to how the responsibilities were split at the companies our users work. The application used in this thesis described the economic profit of promotion in fast-moving consumer goods. Which meant that each user most often were responsible and usually only interested in the results from one or multiple categories of goods. On top of this, suppliers, time frames, location, etc also limited the amount of data they were interested in. Knowing this made it possible to provide them with helpful filters and sorting options. It also makes it possible to individualize the data shown on default, which removes a lot of the required effort of the user and increases the user experience.

8.2 Decreasing cognitive load without reducing functionality

To decrease cognitive load without reducing any functionality there are multiple things to take into consideration. Underneath there is a list of the actions that have been applied in this thesis that was based on research and shown to work by the result.

- Have a clear visual hierarchy.
- Reduce the number of required and visible choices.
- Hide and divide complexity.
- Always provide the service in the users' native language and the language they use at work.
- Filter away as much data as possible.
- Make sure you have the right default settings that fit the users' immediate needs.
- Chunk the information into smaller groups of similar information.
- Never show more than seven items that are supposed to be cognitively digested and remembered in comparison to each other.

In chapter number 5 *Changes made to the UI* you can read more specifically how these steps were implemented into the design.

8.3 Negative affects on the amount of data a user can comprehend

The biggest negative effect there is on user comprehension of data is trying to get them to comprehend multiple things simultaneously. User performance is highly varied between users [8] but getting their full attention is the most crucial aspect in order to increase the amount of data a user can comprehend at a time. If a hundred percent of their cognitive load is built of Germane[8] and Intrinsic cognitive load [9] the comprehension is maximized. To archive this it is required to minimize confusion and extraneous cognitive load.

Extraneous cognitive load in UI is often linked to incomplete Affordance. Examples of extraneous cognitive load are: noticing differences that do not convey any meaning such as changes in font or colors, wondering if an action was completed or not, wondering what the next step is or having to remember information that could be shown. If proper design principles are withheld extraneous cognitive load is thus very low.

Intrinsic cognitive load can be reduced by chunking the information into smaller pieces but also by processing it fittingly. Visual hierarchy and chunking are in other words key to reducing Intristic cognitive load.
In the setting of numeric economic results negative effect on cognitive load are given when:

[8]Germane cognitive load is the effort it takes to move something from the working memory to the long-term memory

[9]Intrinstic cognitive load is the effort of absorbing the intended new information and of keeping track of their own goals.

- There is no clear visual hierarchy
- All numbers look the same (Same font, size, color).
- Numbers are not typed in a mono-spaced font.
- There is the same spacing between all numbers. (Not chunking the information)
- Numbers that should be compared are not next to each other.
- The UI does not show the right default data.
- Different numbers of decimals are used in vertical columns (making the values dis-align and harder to compare)

8.4 Conclusion

Having a clear visual hierarchy together with well-researched default data and good affordance has been the tactic in this thesis which has shown to successfully increase the user experience by the result of comparative user testing. Removing extraneous cognitive load should be the first task to look at to better the user experience in a big data application. Getting the basics right in terms of chunking and affordance is a good way of doing it which has proven positive effects on user experience in big data applications.

Chapter 9

9 Discussion

This section of the thesis will talk about what to keep in mind while interpreting the results of the study, how the process of writing the thesis has gone and what parts have been excluded and could be a good starting point for future work.

9.1 To keep in mind when interpreting the result

To exclude bias from having the same test group on both applications, half of the group started by testing the old interface and the other half by testing the new. It was clear that the users found the second test easier, and benefited from having done the tasks once before. However, the amount of impact differed between tasks. Task one had a difference in grades of 2,4 points between the first and second applications while tasks 2 and 3 had a difference of 0,4 and 0,6. It seems natural that the first task the users tried would be the most difficult since some of the steps reoccur in the second and third tasks.

The test did not investigate effectiveness or engagement which are cornerstones of User experience. The tests aimed to examine how filtering, structuring, and processing data affects user experience and while that is impossible to do while excluding results given as a consequence of more strictly following UI-design principles, that was not the intent of the test.

Two users decided to give up on a task after seven to eight minutes of trying. Those instances were given the maximum time anyone had taken to finish the task. The maximum amount of time was 9 and 10 minutes on the two different tasks. Allowing the testers to give up affects the mean-time, in this case, it most likely dragged it down. However, the grade of that task is very much affected by users giving up. The instances where users gave up on a task were the ones that got the worst score when asked to grade the required effort.

9.2 Processing, structuring & filtering VS Proper UI design

In the beginning of the thesis it is stated that: *To be able to focus on the processing, structuring, and filtering of data some basic HCI principles need to be met in the UI. If the user interface does not comply with these principles the UI will be hard to use and understand even if the data itself is not. These principles will be followed stringently in the final prototype but will not be addressed in the result since they are supposed to always be followed in HCI and only build the basis for this research.* Building a UI based on those HCI principles has taken a vast portion of this thesis time frame. Viewing them as only the base of the result might be misleading. The results show the benefits of not only filtering, structuring and processing the data but also show the benefits of correctly following HCI-design principles. Knowing how much the results are connected to

filtering, processing, and structuring vs correctly following design principles is not only difficult but impossible to assess.

9.3 Future work

Visualization of data is something that this thesis has excluded due to time constraints but it has a heavy influence on user experience. Visualizations often increase user engagement which is one part of user experience that this study does not include. Examining how this UI would benefit from an addition of visualization would have been valuable to the study. User engagement can be affected by many other factors than visualizations and investigating it as a whole should be considered as an addition in future work.

This thesis focus on how data should be presented. It does not look deeply into what quantities of data best suit the comprehension of the human mind or explore the potential benefits of presenting it in partitions.

9.4 Workflow

While working with this thesis a number of obstacles have been met. Time has been one limitation that has fallowed me throughout the project both in quantity and in timing. This thesis tested the UI of one older application that was all ready developed and a new version that was in development in the brief window of time where both were available online. Many parts of the design were not added before the old application was taken off the web. Those parts could of course not be included in the thesis since they could not be tested in an equal setting. This has limited the thesis to only one of the applications' three features. Which made it exclude all visualizations of the data. Creating charts and visualizations has taken up a lot of the design time and accepting that they would not be included in the thesis was unfortunate.

Following the method has at times not run smoothly. I wish I had added more time to do the design before the tests as well as more time for both the first and second steps of the literature study. Had I done it again I would have added more time for scheduling and planning the workflow. Some of the tasks in the test investigates multiple aspects of user experience, having them test only one would have made the interpretation less complex.

Chapter 10

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