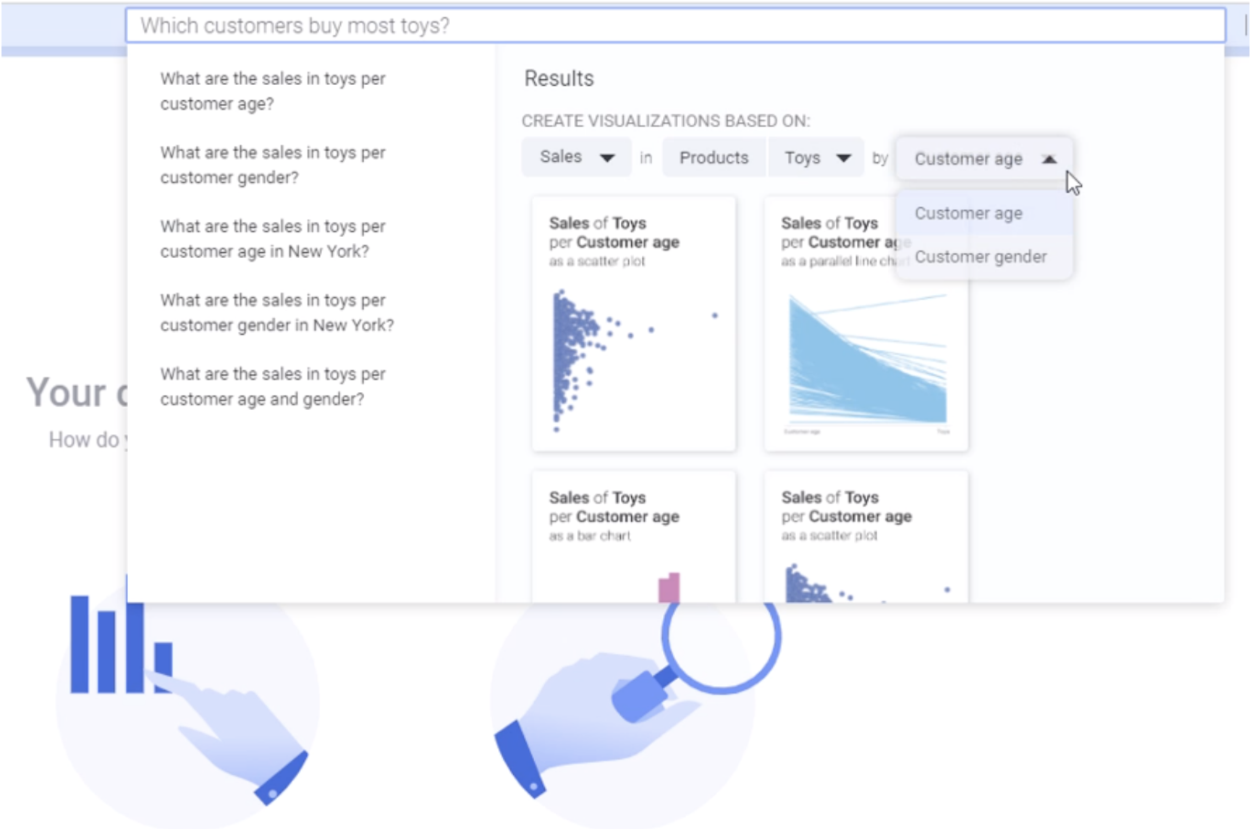

The Future of Search in Analytics

Facilitating Data Exploration Through Natural Language Interaction

Master's Thesis in Interaction Design and Technologies

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: Zoomed in view of the search tool in the final design concept.

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Abstract

Data analytics software creates a possibility to analyze data through the help of visual representations, aiming to help users gain insights from the data that can support decision making. With search functions becoming increasingly powerful, the ability to use search as a tool for exploring data in analytics software can be seen as promising. Further, interfaces for analyzing data through the use of natural language interaction has been explored in the analytics industry, striving to make sometimes complex software more accessible to novice users. This master's thesis explores how search functionality can be applied as a tool in analytic software to effectively support the exploration and analysis of data, with a specific focus on how such functionality can benefit inexperienced users. To investigate the topic, the thesis work included building upon previous knowledge within the subject of search in general and its application in data analysis, as well as prototyping design solutions and analyzing the design with target users. The design was developed during three design iterations, resulting in a concept for a search system in analytics that aims to support users in analyzing data by enabling the use of natural language. Based on previous research on the topic, tentative design guidelines were formulated, which were iterated during the project based on insights gathered from designing and testing the concept. This resulted in a set of 13 design guidelines for search in analytics, aiming to inform decisions in future design work.

Keywords: Search, visualization, analytics, natural language interaction, data exploration, interaction design

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Nils Arvidsson and Johanna Stenson, Gothenburg, September 2019.

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1

Introduction

Searching is today one of the deeply integrated and most common activities when interacting with digital tools. Many times, the use of search tools is one of the first interactions for users of digital products, making it a defining factor for shaping users' experiences. As technology has become increasingly complex with the ability to anticipate the behaviour of its users, search as a concept has matured and moved beyond matching queries with keywords to a dialogue between the user and an intelligent agent that understands the intentions and returns personalized suggestions. Morville & Callender (2010) describes the use of a search field as not only a means of finding information but as a universal remote control that allows power and flexibility by letting the user access tools and perform actions as part of searching. Hence, the borders of what constitutes search are being blurred. Further, the activities of searching, browsing and filtering are becoming seamlessly integrated into the workflow of users (Morville & Callender, 2010).

The power of search should consequently be possible to exploit as a beneficial tool for professionals in various industries, such as in the field of data analytics. Data analytics is defined as "*[...]the process of examining data sets in order to draw conclusions about the information they contain, increasingly with the aid of specialized systems and software*" (Margaret Rouse, 2019). The sometimes overwhelming amount of information should be made comprehensible in order to gain insights and facilitate decision making, while at the same time requiring as little time and cognitive effort to analyze as possible. In analytics software, the ability to single out the right information to the user, finding patterns and identifying divergence is therefore of the highest importance. Further, it should be done in a way that considers the workflow of users, understands users' needs and anticipates users' intentions and interests. Hence, integrating the right search functionality into data analytics is a way to enhance the possibilities of how to interact with data and finding valuable insights.

This thesis will explore how search functionality can be used to leverage the possibilities inherent in data analysis. More specifically, it will explore how to design the interactions and experience of a search tool in data analysis software, to give its users a powerful advantage in the analytic process. Part of this work will be to investigate ways to help users understand when search can be used as a tool, what users can search for, how users can express their intent and how results can be presented and used in an analytic workflow, in order to speed up the time to insight. In addition, an analysis will be made on how to create a pervasive and coherent search experience across a system. Based on the findings of these explorations, guidelines will be formulated that will direct interaction designers when integrating search in data analysis. To have guidance during the thesis work the following research question were formulated:

What should be considered when designing a search function in order to give its users a powerful advantage in their analytic process?

The thesis work will be conducted at Chalmers University of Technology within the Department of Computer Science and Engineering. The foundation of the thesis was initiated by the employees at an analytics software company, further referred to as the Company, situated in Gothenburg. During the thesis work, the Company will provide both guidance and tools needed for the project. A supervisor is also provided by Chalmers to support the project duo with advice within the domain of interaction design as well as in the construction of the thesis. As the thesis comes to an end, the Company will get access to the designed solution.

1.1 Goals and Deliverables

The goal of this thesis is to identify which characteristics are of importance when designing a search tool in analytics. This will be achieved by research through design, described by Gaver (2012), by investigating important factors and user needs, designing a solution and evaluating the solution with users of analytics software. This process will help to inform about what considerations are appropriate. A set of guidelines will be delivered on how to integrate future solutions for search in an analytic process. The guidelines will be grounded in previous research within the field of search, general design principles, contemporary state-of-the-art work, as well as the findings from the study.

1.2 Delimitations

There are several types of users of the Product, differentiated through their different goals, roles and experience. The target users will mainly be analysts with varying levels of knowledge in the domain but with limited experience with the Product.
The solutions designed that will help to inform about considerations regarding search tools in analytics will be grounded in the specific requirements, characteristics and users of the Product. Although the aim is to construct general guidelines for search tools in analytics, the work will not include applying and evaluating these guidelines in another context than within the Product.

The work will not include developing the envisioned design solutions but prototypes will be used to communicate and simulate its intended functionality. Although this is left out of the scope, factors pertaining to the development and the technical viability of the solutions will still have to be considered, something that will be communicated with developers within the Company.

2
Theory

The Theory chapter will present theories related to design research and search.

2.1 Wicked Problems

Wicked problems are described by Churchman (1967) as a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision-makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing." This description points towards issues regarding design thinking and the relationship between *determinacy* and *indeterminacy*. The design thinking model is grounded in the designer calculating a solution based on a determined problem with specific conditions. On the other hand, Buchanan (1992) states that from the wicked problems approach, it is suggested that there is an essential indeterminacy, except for the most trivial design problems. Buchanan (1992) also highlight the importance of recognizing the difference between *undetermined* and indeterminacy. Indeterminacy, compared to something being undetermined, implies that design problems has no limits or stated conditions.

According to Churchman (1967), a wicked problem is a symptom of higher-level problems that have no stopping rules. A wicked problem also lacks a definitive formulation in itself. Instead, each formulation corresponds to a solution. In addition, a formulation or solution of a wicked problem does not have a definitive test. Neither can wicked problems be true nor false, only good or bad. When solving wicked problems, there is no complete list of suggested operations. It is a one-shot operation without room for trial and error and wicked problem solver is always responsible for their actions. Each wicked problem is also unique and is always followed by more than one possible explanation, where the explanation depends on the designer's perspective.

2.2 Design Frameworks

Within the field of design, there are numerous frameworks to adopt that have been introduced over the years. One of the earliest and most popular design frameworks is *User-Centered Design* (UCD). The framework is mentioned by Norman & Draper (1986) in their book *User Centered System Design: New Perspectives on Human-Computer Interaction*, but was however introduced earlier by the Xerox's Palo Alto

Research Center (PARC) who played a big part in the development of establishing UCD as a design framework in the 1970s. In 1974, a project called *Applied Information-Processing Psychology Project* was formed, with the aim to create applied psychology within human-computer interaction using contextual research (**?**). As the name UCD implies, the user is a central part of the design decisions by the conduction of user research. Gathering information about the users' behaviours, needs and preferences, designers build up a knowledge base for when making decisions regarding the design. The UCD framework thence works as a collaboration between the user and the designer (Williams, 2009). According to Williams (2009), UCD derives from Usability Engineering and Human-Computer Interaction (HCI), with a focus on the user's goals and user interfaces. HCI itself was originally developed to, together with cognitive psychology, understand the use of computers and system design, and is today still used with a similar purpose.

There are three phases within UCD: *design research*, *design* and *design evaluation*. As mentioned above, the research phase focuses on figuring out whom the users are and what needs they have by i.e. carry out literature studies, interviews and research for examples of existing systems. In the design phase, these findings then lay the foundation for the development of the design which often includes some type of brainstorming, sketching and conceptualization. The design is later evaluated with usability methods and modified, based on the results from the evaluation, during the evaluation phase (Williams, 2009).

Human-Centered Design (HCD) is an alternative framework, derived from UCD, as a way of addressing the aspects that have been left out from the UCD framework. For instance, it is suggested that the narrow role of a human as a user is technocentric and that this perception risks leaving out important considerations about the human that is beyond being the end-user of a system or product (Steen, 2011). According to Giacomin (2014), a product or system designed for a user, often means the characteristics of the product or system is optimized for a specific usage pattern. As Gasson (2003) states, "user-centred system development methods fail to promote human interests because of a goal-directed focus on the closure of predetermined, technical problems." Further, Redström (2006) suggests, there can be no users of a product before the product itself. The intended use of a product may constrain the user into over-determined designs that leave little space for preferred, actual use and improvisation. In addition, all relationships and issues surrounding a product cannot be contained in the actual use, but will still have importance as contextual conditions to the ultimate use (Kelly & Matthews, 2014).

Additional to UCD and HCD, a third alternative is *Activity-Centered Design* (ACD), a framework developed from *Activity Theory* and introduced by Gay & Hembrooke (2004). Described by Williams (2009), ACD is a framework that does not ask for the users to *perform* a task or an activity, but focuses on what task or activity is *enabled* by the system or product. Rather than having an understanding of the users as people, ACD refers to the users as participants of the given activity. Additionally, Norman (2005) dismiss earlier statements about tools adapting to the people – people adapt to the tools. Further Norman (2005) states, by understanding the activity itself, the system or product will be understandable as well. As long as the product successfully follows the underlying requirements of activity, the product will be understood by the people using it. However, Williams (2009) sees the ACD framework as still being mainly theoretical. Translating a theoretical framework into practice is challenging and more work is still needed before defining what the ACD process should look like in practice.

2.3 Search

Morville & Callender (2010) describes search as a wicked problem that can have huge consequences for its users, since the framing of a question determines how people understand, answer and act. Below, some of the theories will be presented that pertains search including recommendations, best practices, use patterns and behaviours.

2.3.1 Search Models

To understand the fundamentals of search, it is beneficial to have an understanding of some of the strategies used within information seeking processes. Different models and perspectives on searching have been developed over time, of which some are described below.

The standard model of information seeking, described by Hearst (2009), is a rather static model where the user is alleged to refine a query until only relevant results have been retrieved. Roughly, it is described as a cycle with four main activities, namely *problem identification*, *query formulation*, *evaluation of results* and if needed *query reformulation*. The cycle is then repeated until the requested results are found. The standard model has been elaborated and tweaked during the years but is still fundamentally following the same steps (Hearst, 2009).

The berry-picking model, also described by Hearst (2009), is more dynamic in comparison with the standard model. From observational studies, it has been evident that the information need changes as the searcher learn more about the topic along with the process of information seeking. New subquestions are formed as former subquestions are answered, and the extent of relevant information grows correspondingly (Hearst, 2009).

Morville & Callender (2010) describe searching similarly to the berry-picking model, as preferably being a conversation where the search iterates between finding, learning and asking. An answer will change the question and the goal will hence be a moving target throughout the search process (Morville & Callender, 2010).

A term that is used to describe learning-oriented or investigative search is *exploratory search* (Kules et al., 2009) and is often suited for searchers with indistinct information needs aiming at acquiring knowledge about and explore a broader topic. The presentation of the result is a critical part of exploratory search where ranking algorithms are expected to present results that support further exploration. This support can in some cases take the form of related search queries or query suggestions (Krestel et al., 2011).

Information seeking can also be seen as a *strategic process*, partly including *sequences of search tactics*. Bates (1979) implies tactics to be an instant action or choice made in a given state of the search process. By combining them in sequences, the tactics help to achieve a subgoal of the searcher's main goal of finding information. Bates has grouped these tactics into the following four categories.

- *Term tactics*, used within the current query for adjusting words or phrases, either by suggested terms from the search system or by using synonyms.
- *Information structure tactics*, a technique used for traversing through structures of information to find additional sources or information within that source.
- *Query reformulation tactics*, refining and narrowing down the query by the use of more specific terms.
- *Monitoring tactics* is about keeping track of the search progress by constantly comparing the original goal with the current state to be able to see how it evolves. This also makes it possible to return to an unexplored or unfinished search path.

When monitoring tactics are being used, it is key to know when to change strategy. Thus, O'Day & Jeffries (1993) has additionally defined the following triggers:

- the activity of completing one step in a plan before starting with the next,
- finding a new angle to the problem which provides a new mindset,
- discover a change in former expectations that leads to a need for further investigation,
- discover gaps in previous knowledge or inconsistency in the understanding, leading to a need for further investigation.

Additionally O'Day & Jeffries (1993) also identified the following stop conditions: lack of compelling triggers, a suitable amount of gathered results or other inhibiting factors, i.e. discovering the field was too small to be worth researching.

2.3.2 Unifying Modes of Discovery

Depending on the context, users are often in different modes as they are searching, such as alternating between asking, browsing and filtering, which all should be considered when designing for findability (Morville & Callender, 2010).

Browsing refers to providing the searcher with available information, structured and presented by the search system. When navigating through the structure, searchers need to make the right decisions when selecting paths towards useful information (Hearst, 2009). Pirolli & Card (2005) discusses this difficulty in one of their other theories and proposes *information scent* as a notion of information cues to provide the searchers with information about content not immediately within reach. With the information scent, the searcher can be provided with clues of which information path is worth exploring.

Morville & Callender (2010) highlights the need for *faceted navigation* which includes filtering information and having flexible search scopes that supports narrowing down on a specific facet, such as topic, format, category or other facets that are relevant to the context. Faceted navigation can be contrasted with *federated search*, which allows the user to access all content globally (Morville & Callender, 2010).

Morville & Callender (2010) also describes the concept of *unified discovery*, where the designer should take the notion of users' tendencies to move fluidly across the borders of different modes and make them work well together, or even merge them. Morville & Callender (2010) states that searching must be placed in the centre of the digital architecture if a lot of content is available, allowing the user to utilize a combination of searching and browsing to navigate.

2.3.3 Understanding Intent

According to White (2018), today's search systems mainly focus on supporting query building and result selection, but as the expectations are growing, search systems must evolve to support search activities with complex and technologically driven capabilities. White (2018) anticipates a new revolution within search, powered by the availability of data and motivated by an enhanced interest to record, analyze and understand data from users. The application of data mining and ML models within search has improved query suggestions, as much as it has generated a better understanding of the searchers' activities including preferences, satisfaction and success.

The possibility to acquire data has led to the opportunity to understand the intent of users as they are searching. This understanding can be derived from both data acquired during the session, so-called session data, and longitudinal data that can be both from the individual user – leading to personalization – as well as aggregated data across users of the system (White, 2018). If the system has an understanding of the searchers' intentions it can respond correspondingly to the situation as well as provide a higher accuracy, which brings the user closer to task completion and end goal (White, 2018).

2.3.4 Provide Search Results

As search is leveraged by user data and accuracy is increased, there is an increased ability to provide direct *best answers* to the user when searching, as explained by White (2018). The importance of sorting the answers *best first* is highlighted by Morville & Callender (2010), stating that the search is only as good as its first results and that the top three results likely will receive at least 80 per cent of the attention from users. High-quality algorithms that are transparent and provides flexible result-ranking are hence imperative for success (Morville & Callender, 2010).

The way in which results are presented to the user is also of great importance. Morville & Callender (2010) highlights various ways that Google presents different types of data, depending on its format. Examples go beyond the familiar blue links with snippets that reveal site content, to customized views that handles the specific characteristics of maps, images, stock charts, etc. Further, the borders are being blurred as to what defines a search when it is automatically used as a calculator or a dictionary (Morville & Callender, 2010). This importance of focusing on users' goals and task completion in the design of future search tools is further stressed by White (2018). On this topic, Morville & Callender (2010) defines *actionable results*; a way of looking beyond the search itself and focusing on the goal the user wants to achieve. Examples of this include the ability to directly play videos from the search results of a video streaming service, or make a call directly from the spotlight search results on the iPhone.

2.3.5 Design Principles for Search

Morville & Callender (2010) lists a number of principles of design for search interfaces, namely:

- **Incremental construction:** The search should be possible to construct by starting small and supporting exploration, by building upon the query, modifying it, undoing or starting over. The barriers of entering search should be reduced, for instance by providing hints and having auto-completion and suggestions. This helps a user that is uncertain of what is sought after, does not remember or cannot construct the right search terms to get a start.
- **Progressive disclosure:** Uncovering features and information over time prevents users from being overwhelmed and requires the least amount of mental effort. Through search being contextually intelligent and having faceted navigation, the user can ignore paths that are undesired and dig deeper into what is relevant.
- **Immediate response:** Speed and feedback is important in order to keep the user in flow. Animations can also be used to indicate progress and transitions.
- **Alternate views:** Different views are optimal for different tasks and the right view can sometimes be suggested to the user if the user's intent can be interpreted.
- **Predictability:** The user should be able to predict what will happen next. This can be achieved by for instance providing consistency in the behaviour, results and placement of functions and interaction throughout the system. Letting the user get an idea of the results and its consequences before taking action is also important.
- **Recognition over recall:** Users of a system often forget what they can do and thus, valuable options should be visible. The use of progressive disclosure can also be powerful when trying to show the important options visually, while still not overwhelming the user.
- **Minimal disruption:** Try to stay on the same page instead of shifting the frame when moving between different activities and content.

- **Direct manipulation:** Even though this might not seem relevant for search at first glance, it might come in handy when for instance acting upon results or adding filters, where metaphors can be used such as drag and drop.
- **Context of use:** Think about how the interactions handle constraints and possibilities that arise in different contexts. For instance, what should go into designing search that is used on a small phone screen while riding a bus? Typing long queries is likely problematic in this case.

2.4 Data Exploration Using Natural Language

While there has been a growth in tools for visual data analysis that lets users get answers on data-oriented questions through interacting with visualizations, especially inexperienced users can have trouble transforming these questions into appropriate tool operations (Setlur et al., 2016). As data analysis is often time-consuming and analysis tools in many cases require training and experience, natural language interaction has seen to be promising in that it allows users to ask questions directly to a system without requiring knowledge in what tools to use (Gao et al., 2015). With a growth in the interest of these systems, following research on the topic, some considerations have been identified in regards to allowing for natural language interaction in data exploration.

2.4.1 Designing a Conversation

Dhamdhere et al. (2017) describes the process of data exploration as a repeated cycle of activities that is iterative by nature, and advocates for a conversation between the system and the user to support this. This idea is further supported by Setlur et al. (2016), highlighting the need for an interactive query dialogue between system and user while moving forward in the analysis. When communicating in natural language with the system, a novice user is unknowing of what vocabulary and grammar that is supported by the system, and consequently how a query will be interpreted (Dhamdhere et al., 2017). In their construction of a natural language interface, Dhamdhere et al. (2017) therefore take inspiration from concepts in communication to make a user learn the systems language, such as *recast*, which implicates echoing back what has been said, and *noticing*, as in giving feedback and correcting the input. Further, to simulate a human-to-human conversation, they also discuss the potential of asking followup questions and being able to leave out details in a query that have previously been stated, such as asking "What about Germany?" after having gotten the answer to "What is the trend for revenue in France in q1?".

2.4.2 Managing Ambiguity

A challenge inherent in processing natural language are the ambiguities that may exist in written queries. This ambiguity can arise on different levels when using natural language for the purpose of creating data visualizations, with two levels being elaborated in more detail by Gao et al. (2015). The first level concerns that of underspecified queries, such as having typed "products", when the data set contains both the column "product category" and the column "product name". The second level is described as queries having multiple answers that differ in meaning. The given example takes the query "show revenue for New York City and Washington DC in 2012", and the possibility to return both the total NYC revenue overall years versus Washington DC in 2012 or a comparison of both cities in 2012. In addition, there are several possible ways to visualize the answer through different chart types, as highlighted by Gao et al. (2015). Setlur et al. (2016) also refer to the challenge of ambiguity and describes the terms *syntactic ambiguity* and *semantic ambiguity*. Similarly to the first level of ambiguity described by Gao et al. (2015), syntactic ambiguity deals with the syntactic differences between query and data columns or values, such as spelling and underspecification. Semantic ambiguity, however, deals with synonyms and vagueness in the alignment between input and data. Examples brought up by Setlur et al. (2016) include vague inputs like "large" or "near", or typing abbreviations like "NYC" with the intention of finding New York City in a dataset.

When attempting to disambiguate the input queries, there are various approaches. One is to use autocomplete in order to steer the user into choosing predefined alternatives. Gao et al. (2015) however highlights the consideration that it might constrain the user when typing. The approach explored by the authors is instead to allow the user to type a query freely and to use a combination of disambiguation through ranking algorithms and user interaction. If the ambiguity is high enough, the system will present so-called *ambiguity widgets*, where the user can interact to resolve the ambiguity. A similar approach is also explored by Setlur et al. (2016), letting the user interact manually to clarify intent.

2.5 Design Materials for Search

Following the discussion around wicked problems, see section 2.1, it is argued that the formulation of a wicked design problem, and hence its possible explanations and solutions, is a matter of the perspective of the designer. Schön (1992) argues that a so-called problem space is not given with the design task, but that the designer constructs and sets the dimensions of this. This is later followed by the designers' means of finding the solutions, within what makes up their design world, where the material for design is one important constituent. Even though a material can be seen as having a fixed set of properties, different designers will see objects and materials in different ways, appreciating different meanings, features, elements, relationships and groupings (Schön, 1992).

Much like design using tangible materials will be envisaged through the materials' inherent capabilities and constraints, software can be considered through its unique material characteristics that designers have to consider in the making of design solutions. As a part of this, technologies such as machine learning (ML) also present possibilities for innovation as a material for designers (Dove et al., 2017). However, ML as a material is complex and difficult to work with, which puts a challenge for UX designers in the forthcoming years. Dove et al. (2017) highlight a few challenges in particular. One is the difficulty to understand the capabilities, limitations and potentials of ML, which creates a challenge when ideating and innovating. Specifically, UX designers might consider ML as magic, rather than understanding the relationship ML has with data and how interactions work through the perspective of statistical inference. Secondly, this complexity creates a need for close collaboration with ML experts, and thirdly, the technology also challenges traditional prototyping techniques. As for prototyping, challenging factors include the uncertainty of the output of the algorithm and the need for data is to create functional prototypes. One challenge is highlighted by Noessel (2017), pointing out that as many interactions and processes play out over time, traditional usability tests and experimental settings might be ill-suited for the purpose.

As predicted by White (2018), search systems are facing a new revolution where data from individuals and across users will be used to understand intent and ultimately bring users closer to their end goal. Following this, the technologies required will form the basis on which designers will innovate, where designers of search need to understand the capabilities and constraints of the materials at hand, being ML or other types of technologies.

2.6 Search as Agentive Technology

With the increasingly powerful capabilities of Artificial Intelligence (AI), examples are appearing around us where we see so-called *agents* doing work on behalf of its user. Noessel (2017) explains *agentive technology* as being in the middle ground between what can be considered to be *only* assistive while not being *fully* automatic. Hence, if you can delegate a task to an agent and the agent does not require the user to trigger or initiate the execution, the technology can be considered more than just assistive. However, agents do not remove the human from the system. Agentive behaviour can be found in technology such as semi-autonomous vehicles, but examples also include more subtle agents, such as the intelligent and personalized recommendation system in a music player, the spam filters in your email client, or a search tool that suggests corrections of poor search terms and provides personalized suggestions (Noessel, 2017).

2.6.1 A Change in Interaction Model

When agentive technology is being conceived, designers need to rethink the model of traditional computer programs, where the *Input-Processing-Output*-loop is combined with the simplified human model of *Seeing-Thinking-Doing*, to adopt a model where the *Seeing-Thinking-Doing* is also part of the work of the agent (Noessel, 2017). Noessel (2017) lists various ways that an agent can see, think and do. As for seeing, the various means for which a computer can sense range from object, face and voice recognition, to processing of natural language, user activities and personality insights. The agent's thinking is powered by the algorithms used in the system, such as predictive and machine learning algorithms. The means of doing can include both that of communicating between humans and machines, such as through screens, sounds or haptics, but also between APIs.

When initiating agentive activity, the amount of conscious attention required by the user heavily depends on the domain. Noessel (2017) goes through a number of considerations that are relevant. Conveying the capabilities of the system is one, such as providing affordances or trial runs. Another is conveying limitations and making the user have the right level of expectations of the system. For instance, anthropomorphising an agent too much is one mistake that designers can do to make users expect to move out of a system than what is possible. The agent also needs to acquire goals, preferences and permissions. This can both be predefined with smart defaults, working well enough from the outset, through picking up information implicitly from the user by paying attention to user actions and personal data, or through explicit specifications from the user.

While running, the agent can communicate activity, but might also give suggestions, such as options that best suit the user's goals and will be interesting and valuable (Noessel, 2017). The user might also want to tune what triggers a behaviour in the agent. Noessel (2017) explains that this might be done by learning from a user's implicit feedback, like skipping a song in a music player, or explicitly, like adding suggestions to a "blacklist", have an "ignore forever"-command, or having the possibility to share problems to developers. These all include giving feedback due to false positives, while Noessel (2017) states that the false negatives might be harder to catch, such as the agent not playing a song that you would have liked to get recommended for you. One way to circumvent this problem is to let the user declare explicitly if something should be included or to tweak the algorithms so that it lets through more positives initially and adapt the behaviour over time. In addition, a general consideration pertaining to the behaviour of an agent is that getting the trust from the agent is imperative and that the failure of one part might affect the whole system. Additionally, it might take a long time to build up trust from the user once it has been lost (Noessel, 2017).

3

Background

This chapter aims to give the reader an understanding of search within the domain of data analytics. It will focus on presenting some of the existing solutions for search that are available in analytics today as well as a background of the Product.

3.1 Existing Solutions

This section presents a few existing solutions for search that have been applied in analytics software. Their designs have then been analyzed against theories on search. For each example, only a few strategies have been highlighted, despite some of the strategies being found in several of the examples.

3.1.1 ThoughtSpot

ThoughtSpot is an analytics platform that strives to deliver an accessible solution through search and Artificial Intelligence (AI) (ThoughtSpot, n.d.). The search engine in the platform relies on Natural Language Processing (NLP), enabling the user to express oneself using less technical language when constructing visualizations. When a search is performed, a visualization is constructed automatically, based on what type is assumed to be most relevant. Once a search has been made, the platform uses *query reformulation tactics*, see Section 2.3.1, where the user can narrow down on a result or diverge by being able to swap, add or remove columns, relationships and attributes in the search query. This supports *incremental construction*(see Section 2.3.5) of a query and its corresponding visualization, by letting the user start small, build upon or modify a query. This will regenerate the new visualization based on the new properties. ThoughtSpot also allows for *faceted navigation*, see Section 2.3.2, which makes it possible to search within specific subsets when drilling down in the data.

3.1.2 Tableau Ask

Tableau is a software company with products for presenting data visualizations. By using Machine Learning (ML) and NLP, Tableau asserts that they make data analytics approachable for users of all skill levels (Tableau, n.d.). As a form of *term tactics*, see Section 2.3.1, Tableau's search function gives direct feedback in the form of *auto complete* and *auto suggestions*, see Section 2.3.5, based on what the program apprehend from the query written with natural language. Through this feedback, an understanding is acquired by the user of how the program interprets the natural language query in the search as well as the possible results that can be collected from the data set.

3.1.3 Qlik

Qlik claims to help their users develop, extend and embed visualizations of analytical data through their Qlik Analytics Platform, Qlik Sense (Qlik, n.d.). Their solution, called Associative Difference, allows for data exploration in any direction. The user selects and filters the data with instant feedback highlighting related data points while fading out unrelated ones. At further exploration within the filtered dataset, by selecting another data point, the filtering changes and highlights the new corresponding data points in light grey (Qlik, 2017). Such a data structure can allow a user to progressively disclose information on a topic using faceted navigation, as described in Section 2.3.5, when searching and exploring data. When typing in the search field, the user is also presented with *auto suggestions* based on columns and values found in the database.

3.1.4 Microsoft Power BI

Power BI is a business analytics solution that provides the opportunity to create and share visualizations (Microsoft, n.d.-a). One feature that is present for the search in the product is the dynamic update of results when typing. The user gets *immediate response* (see Section 2.3.5) through feedback on one's intentions, without the need of confirming the search term before reviewing the outcome. This allows for *incremental construction*, described in Section 2.3.5, as the user can quickly review and update the results. Microsoft Research has also developed SandDance as a new genre of visualizations, where all data elements are always represented on the screen (Microsoft, n.d.-b). One of the distinctive features in SandDance is the ability to search using voice interaction to dig deeper into data (Microsoft Research, 2013).

3.2 The Product

The Product is a business intelligence analytics. Recently the Company has launched a new version of the Product, which among other updates, contains an updated search function compatible with the use of natural language when forming queries. The user can search for existing content within the dataset and give recommendations on new visualizations based on the written query. With the help of a recommendations engine, the software can analyze the query input and provide the appropriate visualizations to the user according to the principle of *best first*, as explained in Section 2.3.4. In addition, by providing previewable results with *immediate response*, as described in Section 2.3.5, the user can quickly evaluate their relevance. The recommended visualizations can then be inserted into the analysis. In addition, the user can also search for actions, library items and data values in the analysis.

Figure 3.1: Asad - the accidental analyst.

3.3 Persona: Asad

A persona, developed by the Company, have been used during the thesis and have in mind during design decisions. Since the target user for the thesis mainly is inexperienced users within data analytics, the persona in focus is Asad - *the accidental analyst*. The following description is a summary of the Company's describing of Asad.

Asad is working at an insurance company where his main responsibility is to handle different claims and he uses existing data to follow up on each activity. His team strives to improve their processes and find new ways of working more efficiently. He would not call himself an analyst but from time to time, questions arise where he needs to delve deeper into the data. Earlier he has examined the data by using Excel, but was noticed about new software that is focusing on analyzing data by visualizing it and he hopes to get a better understanding of the data by using the software. Since analytics is not his main task, he only has about 10 hours a week to spend on analyzing the data. Data analytics is not only new to Asad, but to the whole company, and he thereof does not have anyone to ask when he struggles. He has also noticed that most of his questions are recurring and he would save a lot of time if he did not have to start from scratch each time.

4
Methodology

This section presents methodology relevant for this thesis. The methods presented are categorized based on the design model developed by Hartson & Pyla (2012) with the following activities: *analysis*, *design* (here described as *ideation*), *prototyping* and *evaluation*. Each activity has its own suitable methods, which are described.

4.1 Research Through Design

Research through design bridge theory and knowledge together by using models and theories from earlier design research in combination with up-front exploratory research, which also includes technical knowledge within the subject (Hannington & Martin, 2012). Even though this approach is meant to legitimize *Research through design* as a research activity, it is suggested that the expectations of creating extensible and verifiable theories are moderated (Gaver, 2012). In comparison to when conducting strictly scientific studies, design studies have a softer and more indistinct content, which partly comes from *Research through design* and design itself being generative. *Research through design* includes the design process and involves everything from research and development work to prototyping, analyzing and iteration etc. (Hannington & Martin, 2012). By creating statements about *what might be*, instead of *what is*, designers will have a better starting-point when using design as a research method. With creative and critically reflective practice, designers can experiment with and question their ideas while testing hypotheses and generating new questions, which by documenting can communicate their findings and results and enrich the inventory of design resources (Hannington & Martin, 2012).

There are three valuable methods, namely exploratory, generative and evaluative research, to consider when conducting research through design. With exploratory research, the goal is to examine problems that have not yet been studied clearly. Exploratory research can help establish and improve the final research design. Generative and evaluative research, however, is often used to generate new ideas or products, or validate already existing ones. As generative research typically provides user insights through user research, it has a higher probability to result in valid outcomes within new ideas and insights into the product or user (Klein, 2016). Evaluative research, however, implies that validation is made by testing or evaluating already existing design concepts, prototypes, hypothesis or products. Depending on which type of research is used, the methods can differ between them.

4.2 Iterative Design

Software development has given rise to several models for designing and implementing digital products over the years, with a few examples being the waterfall model, the spiral model and the RAD model (Preece et al., 2015). Today, the philosophy of an iterative approach has become the norm in the field of interaction design. For instance, Cooper et al. (2014) advocate for an iterative approach not only between the different phases of a design process but also within the individual stages and activities that are carried out.

Hartson & Pyla (2012) describes the rationale behind following an iterative design approach by arguing that, even though iterative design by itself will not alone produce a good design, it is essentially impossible to reach a good enough solution on the first try. Being an expert designer will certainly increase the chances of getting to an advantageous starting point, but trial end error will always be needed to get a solution right.

The process is often modelled as a few core stages that are iterated cyclically in order to achieve a design that is user-centred. One of these models is described by Preece et al. (2015), containing four categories of activities, namely establishing requirements, designing alternatives for meeting these requirements, prototyping and evaluating the design. Similar models are outlined elsewhere in the literature, such as by Hartson & Pyla (2012), where these activities are categorized into analyzing, designing, prototyping and evaluating and are described in more detail below. However, for the thesis work the model has been slightly modified – by structuring the activities as ideation, prototyping, evaluation and analysis – to undertake a personalized and more suitable approach regarding answering the stated research question.

4.3 Analysis

During the analysis phase, the aim is to get an understanding of the business domain, user work and user needs (Hartson & Pyla, 2012). To do so, Hartson & Pyla (2012) mentions some of the main activities that can be of use. They are as follows: eliciting and analyzing data from previous work and user inputs, extracting design requirements and finally, constructing design informing models such as personas and scenarios. The extracted requirements are further on used as a checklist within the design process and will determine the features and behaviours of the design (Hartson & Pyla, 2012).

4.3.1 Literature Review

Literature reviews are intended to gather information from different sources, such as previous research, published reports and books, similar projects etc., within a specific topic. With the review of the gathered information, connections can be drawn between the references and further help to gain underlying knowledge about the topic without losing focus on the current project (Hannington & Martin, 2012). Literature reviews are especially critical and of high priority when conducting design projects, both within research and practice. In design projects, literature reviews often include references from books, journals, academic websites, blogs and earlier documented design projects (Hannington & Martin, 2012).

4.3.2 Interviews

Interviews are used in various forms and at different moments in a design process depending on their intended purposes and what questions the design team needs to get answered. For instance, interviews can be a way of delving into existing situations of people, capture existing practices and attitudes, or as a way of informing a future design, something that can be combined with observation to get a deeper understanding of a context (Hartson & Pyla, 2012). Situated in a different phase of a design project, the interview can be a way of gathering impressions and feedback about ideas and design solutions from potential users (Preece et al., 2015). The preferable interview subject also varies depending on the goal, being potential or actual users, developers, stakeholders, and experts of the technology or the subject matter (Cooper et al., 2014). Typically, the different types of interviews can be categorized depending on how much control the interviewer has over the guided conversation, ranging from unstructured to structured interviews, with group interviews being an additional type outside this categorization (Preece et al., 2015). The unstructured interview contains questions that are open for the interviewee to elaborate and diverge on, generating rich data for a deep understanding of a subject, whereas the structured interview is standardized between subjects and with predetermined questions that can produce quantifiable results (Preece et al., 2015). A possible middle ground between the two extremes is the semi-structured interview, having characteristics of both the structured interview, as in containing preplanned questions and the unstructured interview, by allowing probing the interviewee with follow-up questions that may deepen the understanding of a subject (Preece et al., 2015). Additionally, a group interview, such as a focus group, can be valuable in order to study opinions, feelings and attitudes about products, services, brands or campaigns that might be elicited with the desired group dynamic (Hannington & Martin, 2012). Through focus groups, interesting insights might be derived from studying the discussions that precede conclusions within the group, as well as stories, experiences, perceptions and other valuable input that is shared (Hannington & Martin, 2012).

4.3.3 Personas

According to Cooper et al. (2014), it is better to aim for a design where a small percentage of users are completely satisfied rather than have a design where the larger population is moderately satisfied. A persona is not an actual user, but a representation created from contextual data, of a specific user in a specific context. The persona has a name, a life and specific characteristics which builds a personality (Hartson & Pyla, 2012). Personas are used to maintain a personalized design focus, test user scenarios and help communicate the design (Hannington & Martin, 2012). According to Hannington & Martin (2012), a project should not extend three to five personas to maintain focus on the target user. Since the persona is created for a specific user, it is essential when struggling with conflicting needs. As an example, several users from different user classes have the same work role. A persona can, in this case, help the designers to focus on that specific role and avoid conflicting details (Hartson & Pyla, 2012).

4.3.4 Scenarios

Scenarios are stories told from a user's point of view, about situations that might occur during the usage of a product. With scenarios, the design team highlights goals and possible user behaviour of a product that helps designers concretize their ideas and concepts (Hannington & Martin, 2012). Scenarios unavoidably evoke reflection during the design phase (Carrol, 1999) and can be seen as a sketch of the product usage. As much as a paper sketch captures the essence of a physical design, a scenario captures the essence of the interaction design (Rosson & Carroll, 2009). Scenarios always consist of at least one persona with at least one goal (Carrol, 1999), within a narrative constructed by a series of actions and events leading the persona towards achieving her goal (Rosson & Carroll, 2009). Additionally, Carrol (1999) also mentions that the goal should answer the question, *why did this story happen?* while the persona's purpose is to answer, *who is this story about?*.

4.4 Ideation

Ideation is the creative phase where a group of people forms the ideas for design (Hartson & Pyla, 2012). According to Hartson Pyla, this should be an iterative and fast-paced activity, that creates the opportunity to early and often involve users and customers.

4.4.1 Sketching

Benyon (2013) describes sketching as a tool for envisionment that is used in an early phase to generate and express ideas. It is also a skill that designers use to visualize thoughts, for oneself or for others, and help them to further explore these thoughts (Benyon, 2013). Similarly, Hartson & Pyla (2012) sees sketching as a way of enhancing creativity by using a visual language. In addition to a way of documenting what is in a designers head, according to Hartson & Pyla (2012), it is also a way of thinking through pen and paper, facilitating a conversation between the designer and the material, as well as between team members. To elaborate, sketching can be seen as a process of reflection through seeing, acting and seeing again, where the designer involves not only the mind but the body and senses, in order to incrementally approach a solution (Schön, 1992). This process is what differentiates sketching from prototyping, with prototyping being a way of representation that is used to refine ideas, communicate ideas or used as preparation for answering questions through testing (Hartson & Pyla, 2012). In contrast to this, sketching is the actual designing, the generation of ideas and the raising of questions and possibilities, according to Hartson & Pyla (2012).

4.4.2 Brainstorming and Related Techniques

Brainstorming, with its rules proposed by Osborn (1953), has its foundation in generating a large number of ideas, not criticizing ideas and building upon previous ideas. As criticism has arisen pertaining to the effectiveness of traditional brainstorming (Putman & Paulus, 2009), various techniques have been developed over the years, with different techniques being suitable for different contexts and design challenges. Among the many methods available, one is the design charette, building upon the concept of cross-pollination of ideas, where an optimized solution is said to emerge from the evolution of ideas as they are being modified between a number of small groups in rounds (Hannington & Martin, 2012). Similar to design charette, brainsketching (Vidyarthi, 2014) is also used for cross-pollination of ideas. During a limited time period, around 3-5 minutes, three ideas are sketched down around a topic and then passed to the left for further development by the next person. Another technique proposed is cheatstorming, which suggests that an ideation session does not need to revolve around creating new ideas, but that provocation through a set of – for a different purpose – already generated ideas can be an appropriate way of finding novel solutions (Faste et al., 2013). Hence, the possible directions for design teams to take when ideating are many and should be selected based on the preconditions at hand.

4.5 Prototyping

Prototyping as an activity is a way for designers to explore and express a design at different stages in the process as it evolves (Houde & Hill, 1997). The nature of the prototype can vary greatly, and different representations can work as means of envisionment depending on which aspect the designer wants to highlight in the design and at which time in the project it is made (Benyon, 2013). Among the different reasons that exist for creating prototypes, some can be for testing the feasibility of an idea, for clarifying requirements that are unclear or to use it as an instrument for testing on users (Preece et al., 2015). With these vast variations in how a prototype can serve a purpose and what aspects they can represent, choosing the right prototype is a complex task and critical task for designers (Houde & Hill, 1997). Further Houde & Hill (1997) states that the complexity of interactive systems makes it difficult to prototype the entire design, where important choices must be taken by designers on what a focused prototype with limited purposes should communicate. Hence, Benyon (2013) describes that choosing the right means of prototyping is an important skill itself for designers, juggling aspects and constraints such as available resources, development style and type of project.

4.5.1 Low-fidelity Prototyping

A low-fidelity prototype does not need to look or perform like the final product in terms of functionality and material but can be a simple, quick and cheap way of to support the exploration of ideas, especially early on in a project (Preece et al., 2015). A popular method that falls within low-fidelity prototyping is paper prototyping. This is a useful means of envisioning a conceptual design that utilizes paper sketches and can be tested with users in a quick and efficient way (Hartson & Pyla, 2012). Another way of communicating an envisioned design can be to use storyboarding, a method taken from filmmaking that pictures key moments of an interaction which gives a feel for the flow of an experience (Benyon, 2013). Using scenarios like done in storyboarding can be powerful for interaction designers, and is “intended to vividly capture the essence of an interaction design, much as a two-dimensional, paper-and-pencil sketch captures the essence of a physical design” (Rosson & Carroll, 2009, p. 1). The Wizard of Oz (Hannington & Martin, 2012) is another prototyping technique that can be used or combined with other prototypes, where responses from a non-functional prototype are simulated by a human from behind the scenes, which makes participants perceive it as real.

4.5.2 High-fidelity Prototyping

A high-fidelity prototype provides more functionality, such as allow for interactivity combined with design assets and components for greater visual similarities to the final product compared to a low-fidelity prototype (Preece et al., 2015). This makes it possible to test for technical aspects, usability issues or selling the idea of the product, according to Preece et al. (2015). In the field of interaction design, it is common to use design software, such as InVision (InVision, n.d.), Sketch (Sketch, n.d.), Axure RP (Axure, n.d.), etc. developed for creating interactivity in the design to achieve a higher fidelity.

4.6 Evaluation

Evaluation is one of the essential parts of the design process, where users’ experiences with interacting with a prototype are collected in order to improve its design (Preece et al., 2015). The type of evaluation where qualitative data is collected to identify and fix problems in the design to make it better is called formative evaluation (Hartson & Pyla, 2012). Conversely, summative evaluation is meant to sum up the qualities of a design, as indicated by its name, either to study an existing system that is intended to undergo a redesign or to assess the improvements made on a resulting design (Hartson & Pyla, 2012). The appropriate methods used for an evaluation, as well as its setting, varies depending on the goal of the evaluation, ranging from testing for usability in a laboratory setting to collecting experiential perceptions from users in the field (Preece et al., 2015).

4.6.1 Think-Aloud During Usability Testing

Usability testing is one of the primary evaluative methods used in the later stages of the design phase. The method ensures consistency and structure within a system, but also evaluates how the system responds to the user (Preece et al., 2015). With usability testing, designers can locate and identify parts within the system or interface that confuses the user and have them prioritized to be fixed (Hannington & Martin, 2012). A usability test is conducted in a closed environment controlled by an evaluator (Preece et al., 2015), where the user is given specific and concrete tasks to complete. Since usability tests seek empirical evidence, with help from user observations, of how an interface or system can be improved, the tests often follow the format of the *Think-aloud technique* (Hannington & Martin, 2012).

The *Think-aloud technique* is a method which requires the user to verbalize their thoughts, feelings and actions while completing specific tasks. This technique not only helps the evaluator to identify which parts within the system the user experiences as confusing or frustrating, but also allows the evaluator to grasp and understand the task completion process itself (Hannington & Martin, 2012). According to Hannington & Martin (2012) there are two different procedures of the think-aloud technique, *concurrent* and *retrospective* think-aloud. With *concurrent think-aloud* the test participant is verbalizing his or her thoughts as completing the tasks. Focus lays on *what* is happening, as opposed to *why*. In *retrospective think-aloud*, the activity is recorded while the participant completes the tasks in silence. When reached completion, the participant is asked to comment on their process while watching a replay of their activity. This retrospective think-aloud technique can then provide with additional insights and reasoning between the participant and the evaluator.

4.6.2 Expert Reviews

Usability experts can be used, playing the role of users of the product, in the inspection of an interface for usability problems as a less costly or more rapid alternative to involving users in usability testing (Preece et al., 2015). One method that can be used for this purpose is the heuristic evaluation, where the experts are guided by design principles – so-called heuristics – to measure the usability qualities of an interface and its various interaction elements (Preece et al., 2015). Different heuristics can be used for this purpose but common practice is to measure the interface against Nielsen's 10 heuristics, listed below (Nielsen, 1995):

- Visibility of system status
- Match between system and the real world
- User control and freedom
- Consistency and standards
- Error prevention
- Recognition rather than recall
- Flexibility and efficiency of use
- Aesthetic and minimalist design
- Help users recognize, diagnose, and recover from errors
- Help and documentation

Another expert evaluation is the cognitive walkthrough, a method specifically suited for the evaluation of the first-time usage of a system, according to Hannington & Martin (2012). By analyzing each step in an interaction sequence through asking a number of questions, the expert can get an indication as to whether the system provides the right step at the right time in relation to a user's goal (Hannington & Martin, 2012).

4.7 Tools

During the thesis work, the following tools have been used to ease the development of prototypes, as well as help during the evaluation of the Product. The tools are shortly described below.

4.7.1 Axure RP

Axure RP (referred to as Axure) is a tool used for creating interactive prototypes for digital interfaces. With Axure it is possible to prototype and test functionality without the need for programming (Axure, n.d.).

4.7.2 Balsamiq Wireframes

Balsamiq Wireframes (referred to as Balsamiq) is an online graphical tool used to sketch user interfaces with a focus on low-fidelity wireframes. With pre-created building blocks, such as icons, buttons, text fields etc., Balsamiq aims to let the user focus on structure rather than colours. It is possible to add easier interactivity in the wireframes which allow them to be used as a test friendly prototype (Balsamiq, n.d.).

4.7.3 UserTesting

UserTesting is an online platform used for testing the user experience on digital prototypes, websites, mobile apps etc. and receive customer feedback rapidly. The feedback is accessed through audio and video recordings from real target users (UserTesting, n.d.).

5

Execution and Process

This chapter describes chronologically the process that was followed during this Master's thesis project. To answer the posed research question and to deliver guidelines that can inform future designers of search in analytics, the project followed a research through design approach, as described in Section 4.1. Hence, by building upon previous knowledge within the subject, prototyping design solutions and analyzing the design with target users, the thesis aims to contribute with theoretical knowledge and insights gained through design practice.

The practical design work during the thesis followed an iterative approach, as described in Section 4.2, containing the four main activities in each iteration, namely ideation, prototyping, evaluation and analysis. In total, three design iterations were carried out, with an extensive preparatory phase in order to delve into literature, existing solutions, as well as research on the product and the user. In parallel to this, guidelines were constructed and revised incrementally based on knowledge and insights from the design work, with a final set of guidelines being formed at the end of the project. A full graphical representation of the thesis work can be seen in Figure 5.1.

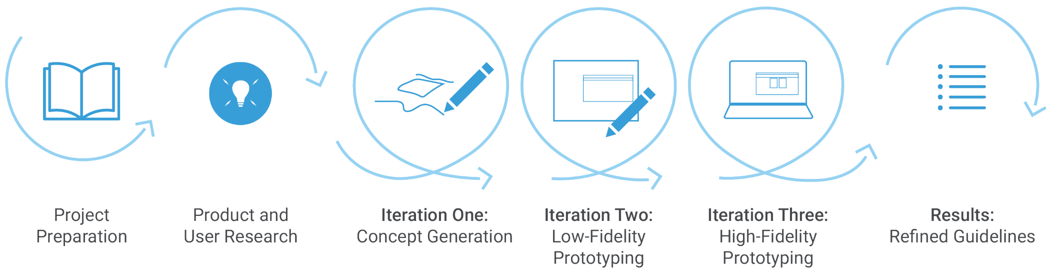


Figure 5.1: Graphical representation of the process.

5.1 Project Preparation

As a first stage in the thesis work, project preparation was done to lay a theoretical foundation for upcoming design work as well as planning out which phases and activities to undertake in regards to time and resources. The activities in this phase included planning, a literature review as well as an exploration of existing solutions on search.

5.1.1 Planning

The thesis work was to be carried out in the spring of 2019 during a total of 20 weeks. During this time, supervisions were planned to be kept weekly, both through the supervisor at Chalmers University of Technology and the supervisor at the Company, if requested by the students. The thesis work was planned as consisting of five main activities, namely project preparation, product and user research, practical design work, construction of design guidelines and report writing. Further, the practical design work, on which a substantial part of the time would be spent, was broken down into several design activities that could be grouped into three design iterations.

To get a solid understanding of the domains of search, analytics and of the Product, project preparation, including a literature review and exploration of existing solutions, as well as product and user research, was to be carried out before the start of the design work. Subsequently, the iterative design work was planned to be executed during the upcoming eleven weeks. During this time, the guidelines were planned to be iterated and updated several times as new knowledge was gained. The final report was also to be worked on continuously, with the larger part of the work being carried out in the last weeks of the thesis work. A detailed description of the thesis work can be seen in Figure 5.2.

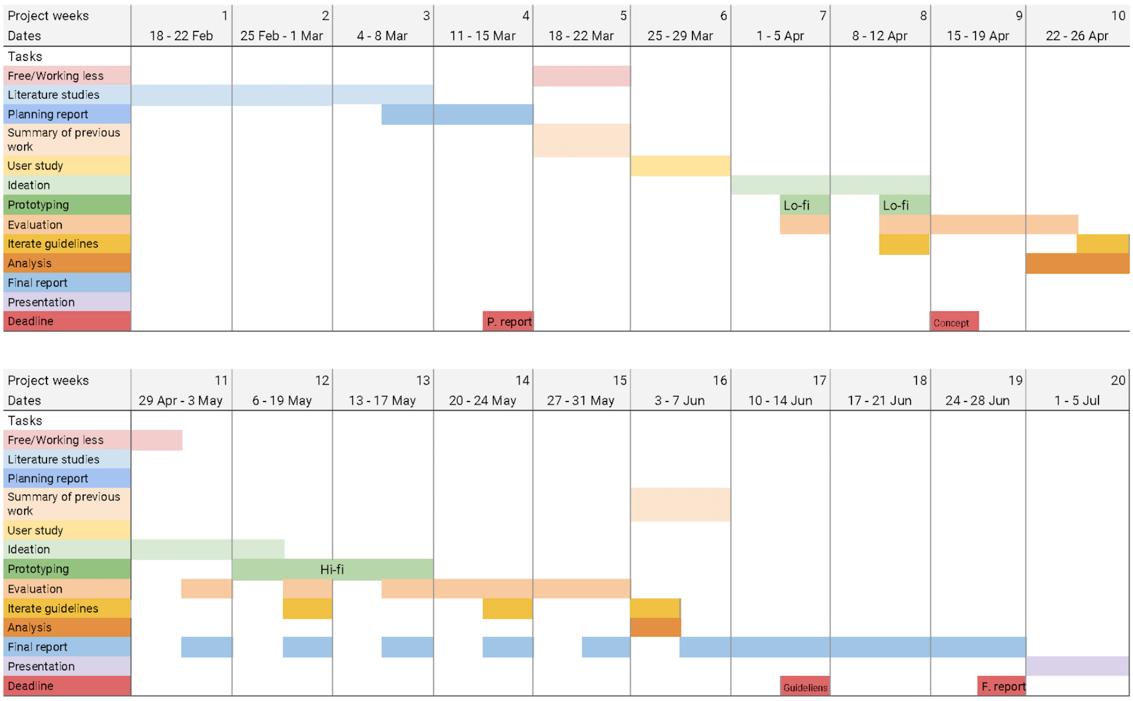


Figure 5.2: Gantt-chart showing the planned execution of the thesis work.

5.1.2 Literature Review

To get an understanding of the topic at hand, a literature study was conducted that could serve as a basis for future design decisions and the formation of guidelines. Initially, the focus was to look into literature that provided a more general view on search systems, such as books, scientific papers and blogs on best practices and the predicted future of search systems. Subsequently, and as more knowledge was gained in regards to the various facets of search systems, a more narrow focus was given on literature pertaining to search using natural language interaction, and its application in analytics software. In addition, the study also comprised of finding and studying literature related to design methodology and methods that could serve as useful during the thesis work.

To get access to the scientific articles and literature on design methodology, search engines were used such as ACM Digital Library (ACM, n.d.), Google Scholar (Google, n.d.-b), IEEE Xplore Digital Library (IEEE, n.d.) and Chalmers Library (Chalmers, n.d.). Google search (Google, n.d.-a) was also used to find relevant blogs and websites. During this process, some of the keywords used included, but were not limited to: *search*, *information retrieval*, *exploratory search*, *natural language interaction*, *search analytics*, etc. Further, the Company also provided access to books that were studied during this phase.

The search for literature followed a work process that started in searching using a specific keyword and singling out the literature that was deemed potentially relevant, by quickly surveying titles, abstracts or summaries. This emerging list of literature was later studied in more detail, whereupon a summary was written on the literature that was considered useful for the project to make the content more easy to survey. As a final step, an attempt was made to derive what was considered the most important takeaways for search systems in analytics and summarize what could be relevant to include in design guidelines.

5.1.3 Exploration of Existing Solutions

An exploration of existing solutions was made on what was done subsequently to the literature study, with the purpose of finding good examples and inspiration for the design. This was in order to be able to analyze the different search systems that were studied in light of the knowledge gathered in the literature study, such as principles and concepts for search, and hence get a more nuanced view of the different designs. It gave an indication on how well the different systems applied the different principles, showing positive aspects as well as drawbacks in the different designs. The exploration included both looking into best practices on search in some of the existing software for data analysis, as well as other design solutions for search outside the analytics industry. Looking at solutions within data analysis also highlighted the challenges inherent in search for data analysis and gave inspiration on how these could potentially be handled. Since a large part of the literature study looked into general concepts and principles, the exploration emphasized which aspects, concepts and principles that could be especially important to consider when applying search as a tool in analytics.

The exploration was done by first identifying the different analytic software programs to be looked into, where the Company provided guidance. Primarily, different tutorials and demos that were available on Youtube were then analyzed in order to see the different search systems in action. For each example, notes and screenshots were then taken on specific features that were interesting or on how well the search systems supported some specific concept or principle found in the literature. All notes were then summarized into a document. An analysis of the various analytics software and how certain concepts have been applied can be found in section 3.1.

5.1.4 Takeaways

The takeaways from the project preparation phase was a summary of the literature and existing design solutions that were thought to be of interest for the thesis work, as well as a time plan for the thesis and its various activities.

As for the literature, the relevant content that was found in the review can be categorized into two main groups. The first group of content relates to design methodology and methods that were considered relevant for the thesis work, which has been summarized in the Methodology chapter, see chapter 4. The second group concerns what was considered relevant for the topic of study, namely search in analytics. From summarizing the studied literature on search in analytics, a few subtopics could be identified. The first subtopic handled search systems and searching as an activity in large and the knowledge that has been acquired from studying various types of search systems in different contexts. The second subtopic concerned the predicted future of search systems, delving into topics such as agentive search systems that understand intent and can act on behalf of its user based upon available knowledge. The third subtopic related to using natural language interaction and how it has been applied as a tool in software for data analysis. Summarized, a number of concepts or knowledge areas were identified that were considered to be of relevance for the first set of guidelines, described below. This was elaborated in more detail in the Theory chapter, see chapter 2.

- **Exploratory search:** From the study of various models to describe searching as an activity, the concept of exploratory search seemed to be of high relevance. Kules et al. (2009) describes the concept as being an appropriate model for describing searching with indistinct information needs, aiming at acquiring knowledge about and explore a broader topic, which fits into the purpose of data analysis.
- **Data discovery:** Dhamdhere et al. (2017) highlights the problem of sorting out what is relevant from the increasing amounts of data that are gathered by organizations, where the user needs to find out what data exists and what analysis can be performed with it. It was deemed interesting to potentially address this problem through search.
- **Unifying modes of discovery:** The concepts of unifying modes of discovery is described by Morville & Callender (2010), and was considered interesting to take into account in order to make search work well with other activities in data analysis, where searching can be seen as one way among others to advance in the analytic process.

- **Flexible search scope:** The concept of flexible search scopes is elaborated by Morville & Callender (2010) as a way of allowing for search on a subset of the available information, for instance filtered down to a category. For data analysis, the idea of allowing a user to search on a subset of the data that is relevant to explore further was deemed interesting to explore.
- **Incremental construction:** Morville & Callender (2010) describes incremental construction as being able to start small, build upon a query, modify it, undo or start over in order to reduce the barriers of entering search. This was considered relevant for the context of analytics as users should be able to get answers to subquestions and move forward in a given direction as insights are gained. Search should preferably support such exploratory behaviour in analytics.
- **Understanding intent:** Inspiration was taken from White (2018) in that data can be used to understand user activity and preferences, ultimately to provide higher accuracy and bring the user closer to the end goal. This could also include giving suggestions and results that are relevant for the user but not necessarily expected. This idea providing results and suggestions that are not initially sought after relates to the concept of serendipity, described by Morville & Callender (2010). Finding ways to achieve this was considered relevant to explore in the design of search in analytics.
- **Agentive search:** Related to the idea of creating search systems that understand user intent through studying user activity, the concept of agentive technology, described by Noessel (2017), was deemed relevant by highlighting considerations for designers of such systems. By looking at an intelligent search system as an agent that can potentially handle natural language interaction and give tailored suggestions and recommendations, some considerations could be seen as especially relevant. These included conveying the right expectations of the system based on potentials and limitations, ways to pick up on user intent, providing transparency of the system and how to design the interaction of a system that acts on behalf of its user.
- **Conversational interaction:** The potential to use natural language interaction to help inexperienced users of analytics was highlighted in the literature, as described in Section 2.4, such as providing support to create visualizations and access appropriate tools. The studied literature on the topic provided knowledge and inspiration on how to design an interface that supports a conversation between the user and the system in order to move forward in the analytic process. For instance, Dhamdhere et al. (2017) describes how to allow for followup questions in natural language and how to create an understanding of the system by providing feedback to the user's input.
- **Other design principles:** Morville & Callender (2010) describes some general design principles for search, found in 2.3.5.

From the exploration of existing solutions, it could be seen that various of the principles and concepts identified in the literature were applied in the search tool in different analytics products. While every existing solution was not studied in detail in regards to all concepts found in the literature, a number of concepts were highlighted when reviewing the various solutions. The existing solutions and the identified concepts can be found in the Existing Solutions section, see 3.1.

5.2 Product and User Research

The general information about search and analytics gathered in the preparatory phase aimed to serve as a basis for the first set of guidelines. However, there was still a gap in the knowledge regarding The Product and its users and it was required to look deeper into the interaction between the target users and the search system currently available in the Product, technical aspects of the current solution, as well as what needs and potentials that had been identified for search in the future.

5.2.1 Interviews with Internal Stakeholders

Five interviews with internal stakeholders were held to gain a deeper understanding of the technical aspects of the product, the design choices made for the current search system, as well as getting information about the considerations for search in the future. The interviews were held with two product owners, two developers and one interaction designer, with the questions being of different nature depending on the role of the interviewee. The interviews followed a semi-structured approach, having a number of preconstructed questions but also allowing for followup question to be asked if needed.

From studying the persona that had been created by the Company, a general view was given as for the type of tasks and purposes supported by the Product and considerations that were relevant for the user type. However, deeper knowledge was needed in regards to their specific needs and demands for search. As the product owners had gathered substantial knowledge from studying use cases and getting feedback from users, reaching these considerations was deemed valuable. In addition, it was considered important to collect ideas and visions for search that were grounded in identified user needs and directions in the analytics industry. Questions that were asked to product owners included:

- How would you describe the main purpose of having search in the Product?
- What was the reason for adding a search tool?
- What is the feedback from clients on the current search system?
- What is important to consider when designing search?
- What potential do you see for search in the future?
- Do you see ways of making use of user data to create a better experience for search?

Interviews were also conducted with two developers to better grasp the technical aspects of search. Even if a design solution was not supposed to be implemented during the thesis work, acquiring knowledge would create an understanding of potential constraints and possibilities for the context of data analysis and the Product. This aimed to inspire ideas on how to make use of available technology, how to make it better or how to make feasible alternatives for the future. The interviews included questions such as:

- How does the search tool work today from a technical perspective?
- How does the tool process natural language?
- Did you have ideas that had to be left out? If so, why?
- How does the recommendations engine work that provide results?
- How may the recommendations engine be improved to provide better results?

One additional interview was also made with one of the UX designers at the Company. This was in order to get further background on the user needs that search aims to meet, as well as why certain decisions had been made. The questions asked were the following:

- How did you think about designing search in the Product?
- What are the main user needs that search aims to fulfil?
- What are the reasons for how search is designed today?
- What results can currently be searched for?
- What needs do you see that search can address in the future?
- What do you think should be considered when designing search for the future?

5.2.2 Usability Tests of Current Search System

To get a grasp on how the interaction with the current search system in the Product was experienced by the target users, usability tests were conducted remotely using usertesting.com (see Section 4.7.3). The main purpose of the usability tests was to get an indication of how new users perceived the interaction with a search tool in analytics, as well as to get an understanding of the positives and negatives of the current solution for search in The Product.

The usability test was constructed together with an employee from the Company and was targeted towards inexperienced users of analytics. In total, the test was conducted with ten participants. During the test, the participants were asked to perform a number of tasks which required interacting with the Product in order to create visualizations, as well as to answer questions pertaining to their experience. The test was divided into two groups, with five participants for each test, using data from two different data sets.

Usability Test 1

- Use the find tool to compare how men and women buy electronics. Create a visualization to answer the question
- The data set contains information about stores in different cities. Use the Find tool to see which store has the least amount of sales. Create a visualization to answer your question.
- Use the find tool to explore what age group buys the most toys. Create a visualization to answer the question.

Usability Test 2

- Use the find tool to create a visualization to compare salaries in different regions.
- Use the Find tool to create a visualization that shows how much people get paid in different industries.
- Use the find tool to explore what level of education the people that got the most bonus had.

During the test, the participants were asked to think-aloud as they answered the given questions by using the current search system. Their comments and actions were both audio and screen recorded. The results from the usability tests were compiled and analyzed by the Company and later shared in order to be able to extract insights from the tests for the thesis.

5.2.3 Takeaways

From interviewing internal stakeholders at the Company, a number of considerations were brought forward, about technical aspects, design choices for the current solution, needs from users, as well as expressed opportunities for search in the Product in the future. As for the technical aspects, an understanding was gained on how the search and recommendations systems worked in the Product, how it might be used or improved and which technologies might have potential for future solutions. Additionally, the interviews helped to delineate some of the requirements for the search tool, as in what functionality ought to be included. As for now, one main feature in current search tool is for creating visualizations through searching columns in a dataset and getting results based on output from the recommendations engine. In addition to this, the search tool can be used for finding actions that are available in the toolbar, analysis files in the library, so-called pages in an analysis and values in the data in an open analysis. Further, the envisioned role of search in the Product was discussed. Rather than the Product being search-driven, as in using search as the only type of interaction for a user to analyze data, search is meant to support and work well with other types of interactions. The basic rationale behind this is that search is thought suited for certain tasks, whereas direct manipulation might be more apt for others. These were considerations worth bringing forward in the design process.

As for the areas of improvement and potentials for the future, some of the ideas brought forward included:

- A major requirement that was highlighted concerned allowing for more advanced and specific expressions by the user in general and being able to read more intention from a written query using natural language. In more detail, some of the suggestions to this included:
  - Being able to specify relationships between columns.
  - Being able to specify configurations of a visualization, such as chart type.
  - Allowing the user to specify aggregations such as sum or average.

  - Filter out a subset of data that is considered relevant, such as being able to ask for the "top 10 salesmen"
  - Allowing for a more "loose" vocabulary by being able to interpret synonyms and misspellings.
- Helping the user more while typing through enabling autocomplete features.
- Being able to configure existing visualizations, by knowing which one is active.
- Enabling search to remember what has previously been asked, to make a conversation with follow-up questions possible.
- Being able to use search for data discovery, to surface what data might be important to perform an analysis on, or find insights that have previously been gained.
- Enabling the use of statistical functions through search.

From conducting usability tests, knowledge was gained based on studying the interaction with the Product and the current search system.

5.2.4 Guidelines: First Set

The first set of guidelines was based on findings from the literature, stakeholder interviews and usability tests in the current search system in the Product. While some of the studied literature pertained to search in analytics specifically, a large part of the existing theory covered general recommendations for search systems, which could potentially be applied to search in analytics more specifically. During the preparatory phase of the project, an attempt was therefore made to use or reformulate concepts and considerations on search that were deemed especially relevant for analytic software, based on takeaways from the various activities. These were then summarized into an initial set of guidelines, described below.

1. **Allow for an exploratory approach.** Design search to support the exploration of data by allowing for new questions as the information need changes throughout the analytic process.
2. **Search for data discovery.** Expand the use of search beyond searching in data loaded into an analysis to cover the discovery of new, relevant data.
3. **Unify modes of discovery.** The search system should allow the user to move fluidly between the different modes when exploring data, such as searching, browsing results and interacting with visualizations.
4. **Allow for flexible search scopes.** The search system should support filtering of information and drill down on specific subsets of data relevant to the context.
5. **Allow for an incremental construction.** Let the user construct questions and requests incrementally, by building upon previous ones, modifying them, undoing or starting over.
6. **Understand the user's intent.** Use information from session activity and the search scope to read intention and provide accurate results. Additionally, consider using personal data or data gathered across users to read intent and provide higher accuracy in results.

7. **Create possibilities for serendipity.** Use available knowledge about a user and her activities to provide best guesses on desired results while searching, to make the user find results that were not initially sought after.
8. **Convey the right expectations.** Indicate the search system's capabilities and constraints, such as how a query should be formulated in order to be correctly interpreted by the system.
9. **Allow expressions in natural language.** Allow the user to construct queries in natural language using a vocabulary that is familiar to the new user.
10. **Design for a two-way conversation.** Use a two-way conversation between the user and the system that includes confirmation and corrections of the user's input in order to create an understanding of the system's interpretation. Additionally, allow the user to be able to resolve ambiguities in the query through interaction when the system cannot.
11. **Allow for follow-up questions.** Allow for iterative data exploration by letting the user express follow-up queries in a conversational way.
12. **Support analytical functions through search.** Allow users to perform analytical functions through natural language interaction, such as filtering, performing aggregations, viewing trends etc.
13. **Have transparency in given results.** Be transparent as to how and why specific results are provided.
14. **Provide hierarchical search results.** If the results can be interpreted as hierarchical, they should be presented according to the principle of best first.
15. **Provide actionable search results.** The search system should if possible provide actionable results, to bring the user closer to the end goal.
16. **Provide alternating views.** The results should be presented in their most optimal format.
17. **Support learning.** The search system should help the user become a better analyst.

The first set of guidelines were supposed to represent a theoretical foundation that would inform future design decisions. Further, these were also to be examined and built upon by evaluating and exposing the upcoming designed prototype to users. At the end of each phase, findings and takeaways were compiled in order to support the guidelines, as well as to improve the initial set in order to be able to develop a final set of guidelines at the end of the process.

5.3 Iteration One: Concept Generation

The purpose of the first iteration was to get a large variety of ideas that would explore the conceptual image of how a search system could be used in analytics in the future. The ideas were gathered during design workshops and further explored in various concepts. The concepts were then evaluated in relation to the guidelines and during a design critique session.

5.3.1 Ideation

As an ideation method, two design workshops were held at the Company with the purpose of creating a conceptual image of what search could be, before delving deeper into the details of the user interface design. Besides from being provided with a large number of ideas, input was given by the employees from an expert point of view. For each of the two workshops, four members from the UX team and one developer attended. The purpose of inviting both designers and developers was to get a mix of futuristic and conceptual ideas while maintaining the developers' viewpoint of implementable solutions and potentially relevant technologies. Besides the five participants, the project duo also participated in contributing with ideas.

The workshops were scenario-based with a fictional persona, described in 3.3 on page 15, symbolizing the target user. The participants were, however, given directions that the scenario was not supposed to constrain them, but rather work as food for thought. Each workshop was planned to take an hour and a half and during that time four questions were discussed. The questions differed slightly between the two workshops with the hopes of covering a larger span of ideas. In order to explore the conceptual image of search, the questions were mainly developed from the first set of guidelines, covering a number of areas that were of interest to explore. Since it was conceptual solutions that were aimed for, the questions had a rather open formulation. The questions used were the following:

Workshop 1

- How can we make the user understand what can be done with a search tool?
- How can we help the user formulate a question and understand what can be asked?
- How can we let the user delve deeper into an analysis using search?
- If we knew everything about the user and her/his activities, how could this be used to help the user in the analytic process? How might we anticipate and act upon the users intent? (both as a new user and continuously over time)

Workshop 2

- How can we make the user understand what can be done with a search tool?
- In what ways can the user learn how to communicate through search?
- How can we let the user delve deeper into an analysis using search?
- How can we help the user become a better analyst through using search?

After a short warm-up to bring forth creativity, the scenario and persona were presented followed by the first question. To get ideas on the posed question, an ideation technique with inspiration from *Brain sketching* and *Brain writing* was used (see Section 4.4.2). The session was divided into two rounds per question. Before a question is presented, the attendees are given one A4 paper each. The paper is then used to sketch or write down at least three ideas for three minutes. When the time runs out, each attendee gets one minute to present their ideas. The first round ends when everyone has presented his or her ideas. The A4 is sent in a circle to the left and the timer is set to another three minutes. For the second round, the attendees can choose to either continue working on the previous ideas or add new ones. After three minutes have passed the attendees are once again asked to present their ideas during one minute. The choice of ideation technique was deemed suitable for the situation at hand because it allowed attendees to be inspired by each others' ideas, build upon them further or develop previously conceived ideas in a new direction.

The design workshop yielded in a large number of ideas, often incomplete ones or features that could be used for search. Some were written down in text, whereas others were sketches. As a first step of analyzing the ideas, they were categorized in the following groups to allow for a better overview:

- Analyzing input data and giving recommendations
- Construct queries
- Having flexible search scopes
- Using data gathered across users
- Suggestions for next step
- Demo
- Personalization
- Different modes in the search tool
- Supporting work flow
- Getting external help
- Conversational UI
- Complex analytical questions
- Gamification
- Uncategorized

5.3.2 Concept Sketching

With the list of ideas categorized by focus areas, it was possible to analyze them further in order to understand the value of each idea and transform them into six design concepts. The concepts were sketched upon whiteboards to allow for collaboration and easy modification during the development. To help the development further, a scenario was used based on a fictional data set. Each concept followed the same scenario but had slightly different approaches, such as different starting points for search. The different concepts were explored far enough to be able to clearly communicate the differences between them and to be able to review their strengths and weaknesses in an evaluation.

5.3.3 Concepts

5.3.3.1 Query as Widgets

The first concept was based on having a search system that is initiated by entering the search tool on a global level, and taking the complete analysis with previously created plots into account when recommending and giving results on new actions and visualizations, see Figure 5.3. When the user adds a new visualization from the search results, the headline of that plot transforms into what can be considered a query in a local search field, which compared to the global one is specific to the visualization at hand. The query consists of a number of so-called widgets, representing what can be seen in the visualization, which can be manipulated by the user. For instance, one widget might represent a column in the dataset or an attribute of interest. Clicking on the widgets might reveal options like switching to alternative columns, changing values in a filter, etc. As the query represents what is seen in the visualization, it is dynamically updated as the plot is manipulated. The user can hence enter the local search field to build upon or modify an existing visualization. If the user wants to create an additional visualization, the global search can once again be accessed.

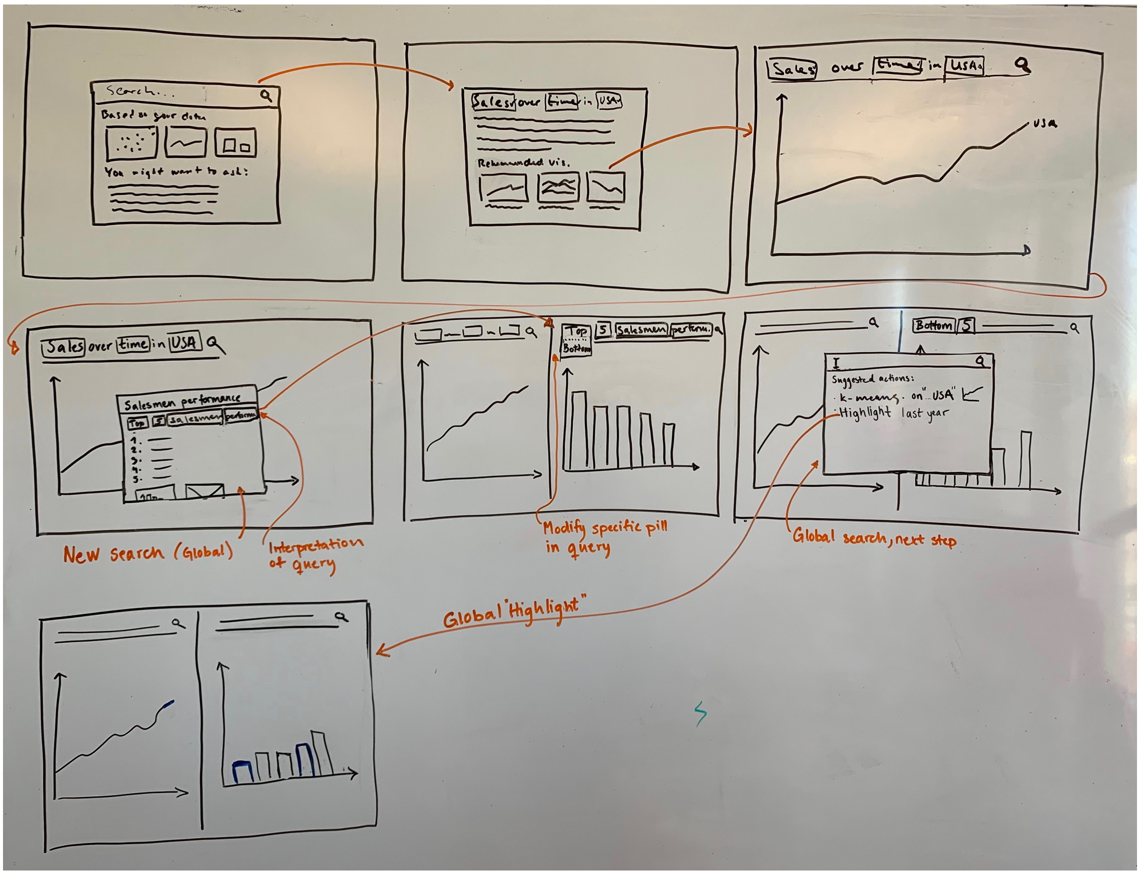


Figure 5.3: Sketch of Concept 1 describing how visualizations can be added to an analysis from the global search system.

5.3.3.2 Duplicate to Make Changes

The second concept displays the idea of a search system where the user starts from an empty dashboard, with recommendations being displayed based on the data that has been loaded into the analysis, see Figure 5.4. The user can create new plots by either clicking the plus sign to enter the search system or by duplicating existing ones and modifying them to move forward in the analysis. Similarly to the first concept, each new visualization is added together with its own search field and query, which can be modified to dynamically alter the visualization. In addition to this search system for creating visualizations, a second, global search field allows for the possibility of reaching tools and actions in the software.

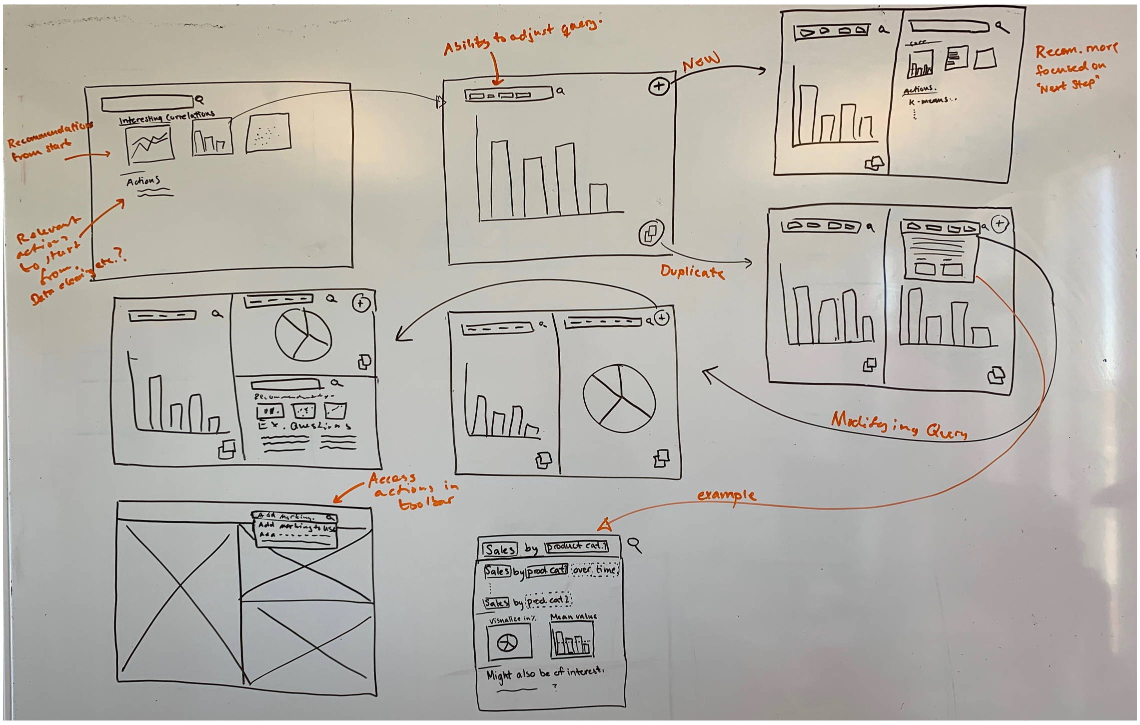


Figure 5.4: Sketch of Concept 2, showing how to add new visualizations or duplicate existing ones in order to make changes.

5.3.3.3 Queries as Layers

The third concept takes inspiration from describing visualizations using layers, with each layer describing certain properties of the visualization. As a first step, a new visualization is added through a global search system, and clicking on a result will add a visualization to the analysis. The query that represents the added visualization will then be the base layer of the visualization, seen in the top right corner of the visualization. As can be seen in Figure 5.5, layers can then be added or removed by adding queries through a local search field specific to the visualization. The plot is dynamically updated as layers are added and removed, and queries that represent a layer of the visualization can be toggled between on and off. The layers can be hidden in a sidebar or similar.

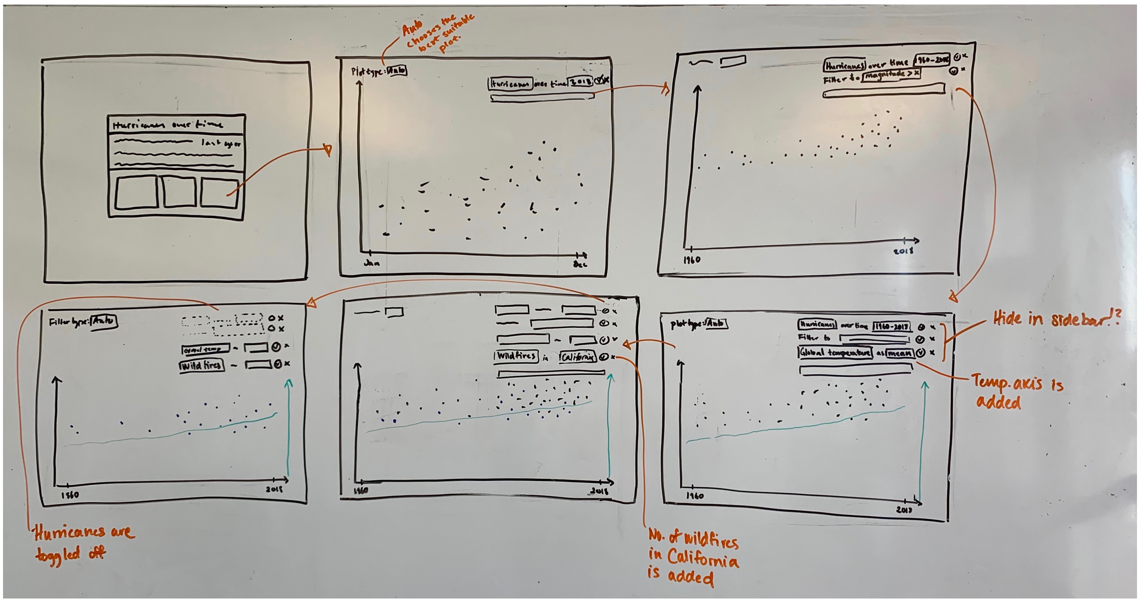


Figure 5.5: Sketch of how to add queries as layers to describe a visualization in Concept 3.

5.3.3.4 Lasso Principle

The fourth concept allows the user to create new visualizations and perform actions from a global search system, as seen in Figure 5.6. What the concept aims to capture is the ability to have a flexible search scope, by allowing marking using a lasso tool to specify data of interest, or to search based on one plot specifically. The user will be given notice that the search is performed based on the data that has been marked and will be given results and recommendations on how to move forward that considers the specified search scope.

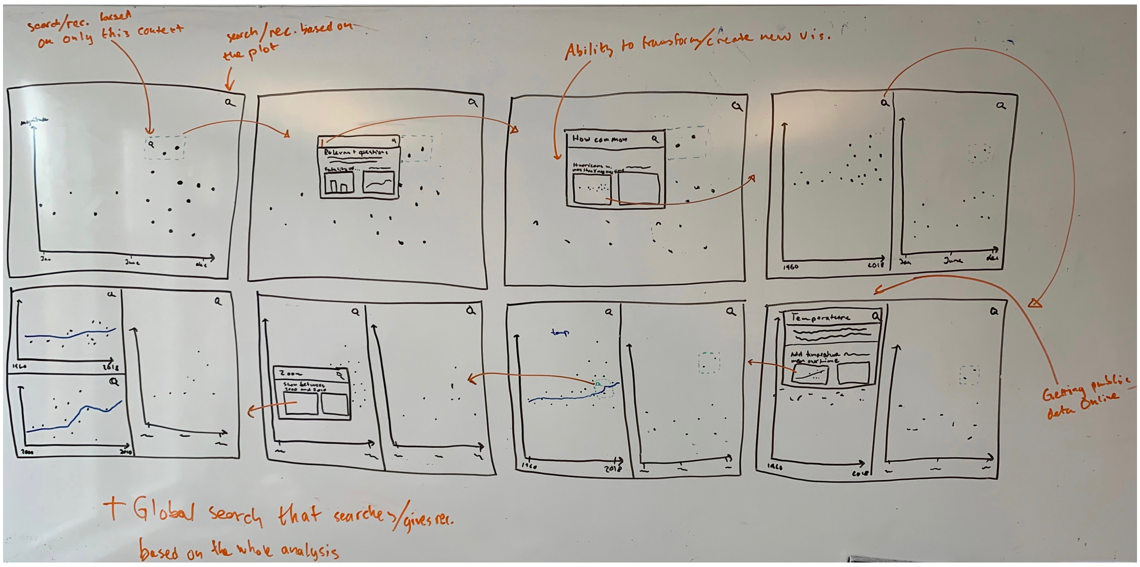


Figure 5.6: Sketch of Concept 4 that explores the idea of targeting specific data points or plots with a question, by letting the user specify data of interest.

5.3.3.5 Chatbot

In the fifth concept, inspiration is taken from the use of chatbots, where the search UI helps the user forward in a step-wise manner by stating follow-up questions and presenting alternatives, as seen in Figure 5.7. The idea is to make it easy for a user to start by being presented with different modes and alternatives that can be entered, to narrow down into a subset of more relevant query suggestions and more tailored recommendations.

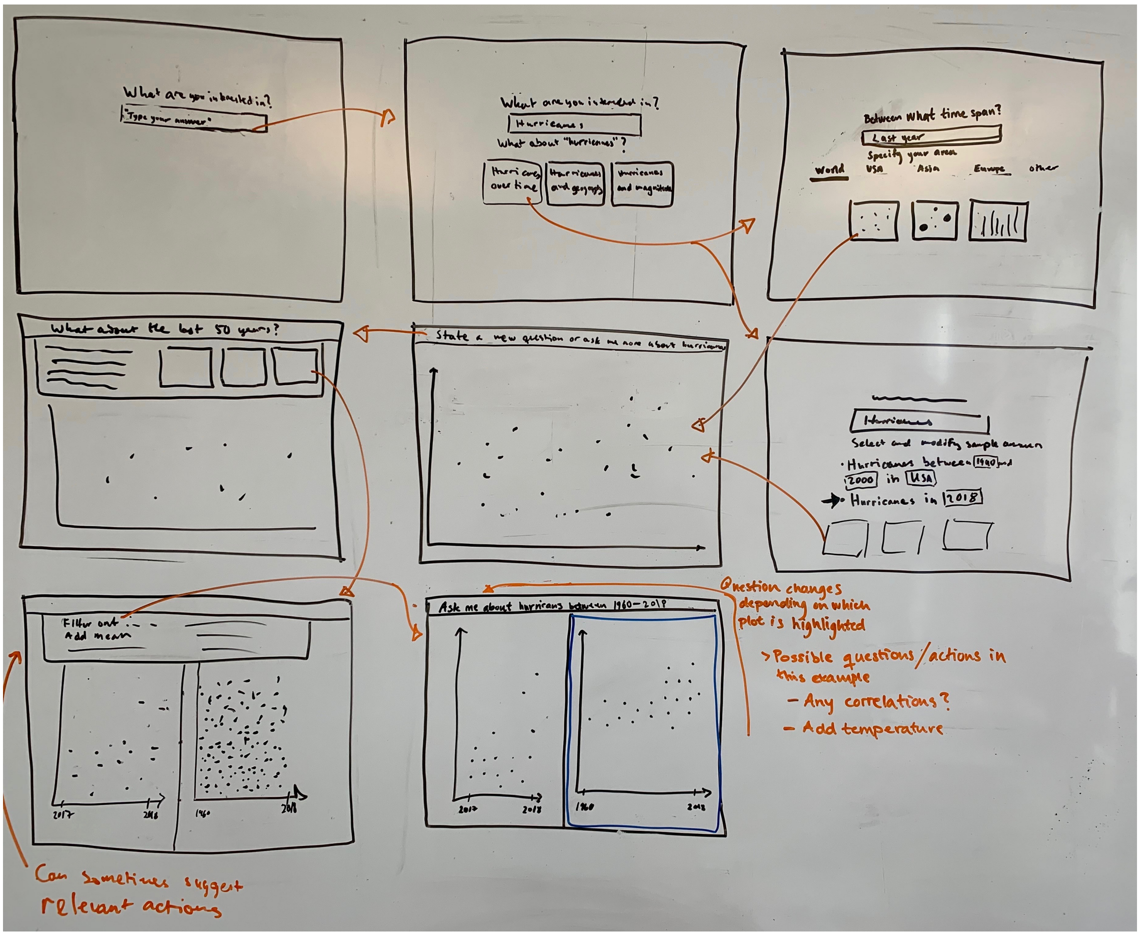


Figure 5.7: Sketch of Concept 5 that takes inspiration from the idea of a chatbot by presenting alternatives and follow-up questions when searching.

5.3.3.6 Search the Universe

The sixth concept highlights the idea of having the possibility to, through search, reach files outside of the analysis. The search system is located in a fly-out menu, as seen in Figure 5.8. Based on the data in the user's library, the system presents different topics or types of data that can be explored, which can help the user to get more specific query recommendations. In addition to this, the user is also presented with recommendations for visualizations, based on an analysis by the system on the available data. Hence, the user is not only given help in what can be done with data that has been loaded into an analysis, but also in the process of discovering what data might be worth exploring. When having added visualizations and reentering the search system, the user has the ability to go to different tabs in the search UI, depending on whether the user wants to continue to explore the current path or continue in a different direction.

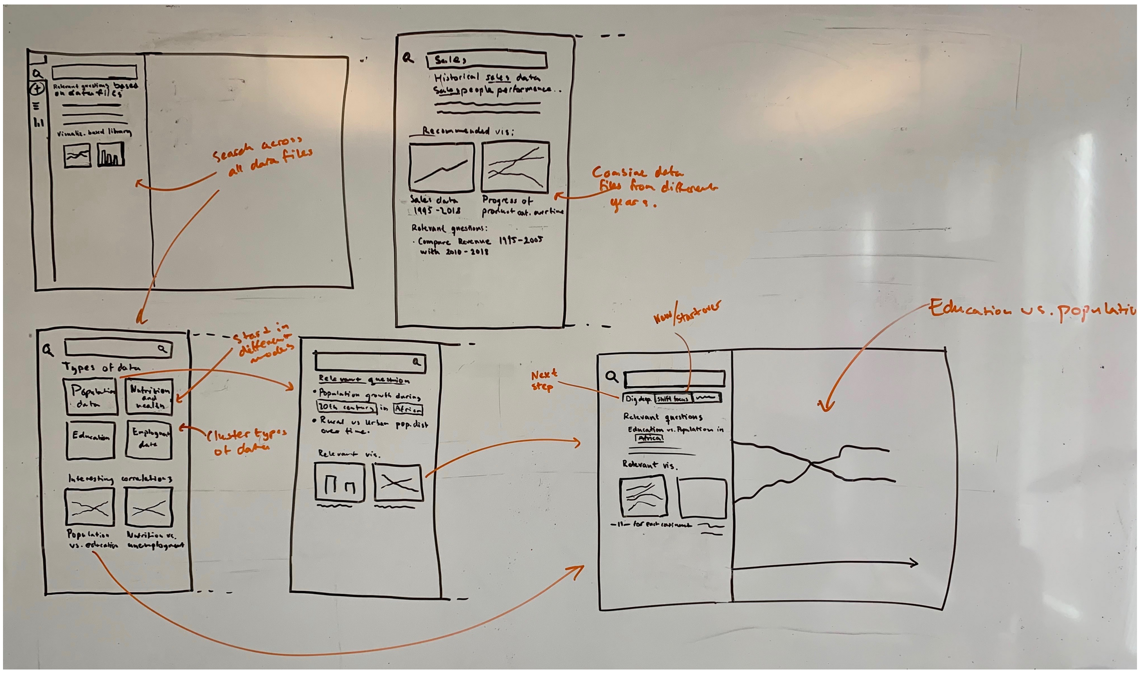


Figure 5.8: Sketch of Concept 6 and how the search system can be used to help the user discover relevant data in a user's library.

5.3.4 Evaluation through Guidelines and Design Critique

In order to move forward in the design process from a large number of concepts, an indication was needed as to how well the different approaches would support new users in exploring data through search. Partly, this could be done by estimating how well the different concepts supported the literature findings that had been summarized into preliminary guidelines. This was done by looking at each of the concepts separately and going through the different guidelines that had been established. The result was a list of strengths and weaknesses for each concept, based on both the initial set of guidelines as well as other thoughts and considerations that had arisen during the concept sketching. The full list of this can be found in Appendix A

However, to estimate how well the different concepts supported an analytic workflow and the various needs inherent in data exploration, it was considered appropriate to get expert opinions on the different concepts. Hence, in addition to the evaluation through guidelines, a design critique session was set up with user experience designers at the Company, who could give their views on potentials and drawbacks with the different concepts. Another aspect that was considered important as a component of designing search in analytics was that of finding a good integration with the rest of the analytic software to create a holistic solution. Since the concept was to be integrated and tested as a part of the Product, including the viewpoints of people with sufficient knowledge of the Product was therefore also a factor to consider.

The design critique was held together with two user experience designers, as well as the head of UX at the Company. Before the session, a short introduction was held that described the current stage in the design process and what kind of feedback that was considered valuable. This meant not going into details as for what pertains the interface design, but rather focus on the overarching flow of interactions and how it ties into the analytic workflow. Each of the six concepts was then presented and discussed in the group for 10-15 minutes, while notes were taken to summarize the discussion. At the end of the session, the group presented some concluding thoughts on the concepts and how they related to one another. Similarly to the results from the evaluation through guidelines as described previously, the results from the design critique consisted of a list of reflections for each concept. This included the general stance on the potential for each concept, what parts were good and bad and how parts from different concepts could potentially be combined in order to find a stronger solution. The cumulative results from the evaluation through guidelines and the design critique were finally summarized into a list of what to bring forward. This list and the results from the design critique can be found in Appendix B

5.3.5 Takeaways

The takeaways from this phase mainly concerned the design work and how to move forward from a large number of concepts. From the evaluation in this phase, two concepts were seen as having the most potential, namely Concept 1: Query as Widgets and Concept 4: Lasso Principle. From Concept 1: Query as Widgets, the following potentials were identified:

- The idea of representing a visualization through a query was seen as promising, in that it could allow the user to move back and forth in the construction of a visualization, based on feedback from the system. This makes this concept support the guideline *Allow for an incremental construction* well.
- Representing information such as columns as widgets and being able to manipulate these could be a good way to help the user discover related column, speed up interaction and give affordance for manipulation.

As for Concept 4: Lasso principle, the following things were seen as promising in the design:

- The ability to specify one's interest and search within a smaller search scope, as in specific data points or a data space, was seen as especially promising for this concept. It makes it support the guideline *Allow for a flexible search scope*, by being able to drill down on specific facets. Further, it supports the guideline *Allow for an incremental construction*, albeit with a different design solution than in 5.3.3.1, by being able to ask followup questions and breaking

down complexity into manageable parts.
- Having a hint in the search field that changes if something is marked can indicate that the user can search based on marking, helping the user discover the feature and indicate the capabilities of the tool, as described in the guideline *Convey the right expectations*.
- Specifying intent through marking a subset of the data makes it possible to derive a lot of intention from the user by looking at what is being marked and how the marking has been performed, which can be a powerful way to help the user by anticipating actions.

Other considerations and ideas to bring forward included:

- The software should preferably not have two or more search systems that have different purposes but strive to combine them into one. This does not force the user to have a clear picture of the type of answer before entering the search field, but rather have the possibility of posing more open questions and being served the appropriate result.
- If allowing the user to search in a subset of the data, the user might be interested in both the data points themselves and to drill deeper into their characteristics, or how they relate to the rest of the data. Therefore, both of these options should be available, meaning that the search scope is not technically limited to the specified data points. The system should also be careful to communicate to the user what scope is being searched in, as the novelty or the feature might otherwise make the search system confusing to the user.
- The idea of allowing the user to go into different modes, as in Concept 5: Chatbot, can potentially be interesting when asking followup questions, to help the user by presenting different directions.

The design ideas found in the various concepts that are not mentioned where not to be taken forward into the next design phase. Further, evaluating the concepts also entailed reflecting on the scope of the project. The idea of using search to discover new data that has not been loaded into an analysis, as seen in Concept 6: Search the Universe, was considered interesting but was decided to be left out of the project to keep the scope at a manageable size. Using search to include discovering new data would involve looking into an entirely different type of search compared to what had been studied previously and was deemed to add too much complexity. Hence, the guideline *Search for data discovery* was removed from the list. In addition, some new insights could also be included in the guidelines, based on comments and observations made by the analytics experts during the workshops. The insights added to the guidelines can be summarized into the following:

- The guideline *Allow for an incremental construction* was considered important for search in analytics to let the user build upon or modify a question that has been asked.
- Similarly, the guideline *Allow for followup questions* was also highlighted as important to support the user in exploring data.

- The ideas related to the guideline *Allow for flexible search scopes* were seen as having potential, giving support to the application of the guideline in analytics.
- The importance of being able to go back and forth between searching and other types of activities in the analytic software was highlighted, which concerns the guideline *Unify modes of discovery*.
- If aiming to support *Allow for flexible search scopes*, it was important to communicate this to the user.

5.4 Iteration Two: Low-Fidelity Prototyping

5.4.1 Ideation

From the design critique session, it became evident that mainly two of the concepts seemed promising, with some ideas from the other concepts being worth considering. As the concepts had only been conceived on a superficial level, a more detailed exploration was required to understand the potentials and constraints of the design ideas. Hence, in order to have time to reach higher fidelity in the design, narrowing down the scope and focusing on one concept that could be iterated was deemed important. The first activity was therefore to determine which conceptual design to move forward with, or how they could be combined, in order to be able to dig into details of the various interactions.

When trying to merge the two concepts together it became apparent that there was a conflict regarding how the search field should behave in different situations. As mentioned in Section 5.3.5, representing visualizations through queries that can be modified and built upon were promising. However, it was not fully compatible with having a flexible search scope because of the difference in their interaction models. Concept 1: Query as Widgets, was based on the interaction of *modifying, adding* and *deleting* in an already existing query while Concept 4: Lasso Principle, focused on *asking questions about the data*, which entailed constructing new queries from scratch. It was evident that it might be confusing for a user to have these two approaches merged in one solution, at least how it was suggested in the concepts. Offering the functionality of representing visualizations as a query with widgets that can be manipulated, together with the ability to ask direct questions through marking, would mean that the user would need two separate search fields – one for describing the visualization and one for asking questions.

With the conflict in mind it was decided to focus merely on Concept 4: Lasso Principle, as the concept was considered to have great potential and was more distinguished from the already existing ideas in the analytics industry that were explored in the research phase. Especially the ideas of letting users proceed in the analytic process by pointing towards a subset of data, supporting follow-up questions, and the possibility to derive intent and present tailored suggestions were considered to be of great interest to explore. It was also clear that adhering to the guideline *Allow for an incremental construction* – well supported in Concept 1, as of modifying, adding and deleting – could potentially be achieved in another form in Concept 4, by having flexible support for follow-up questions about a visualization or other subset of the data. Hence, a decision was made to continue with the development of Concept 4. Analyzing the concept on a holistic level, we identified that the design could be broken down into smaller parts that would each be ideated separately. These were then put together in the following list.

- How to provide results
- Placement of search field
- Name on "search" and visual representation
- Autocompletion and suggestions
- Feedback from the system through a recast
- Recommendations given to the user in empty states
  - Before creating the first plot
  - Creating a new plot in general
  - Asking about a plot
  - Asking about a marked area
  - Asking about an object

With the identified areas at hand, it was decided to generate several ideas on solutions for each area by creating paper sketches, see Section 4.4.1. This was done by working individually within the project duo for a fixed amount of time, typically ten minutes, and then comparing and combining the ideas. During the ideation, a lot of time and effort was focused on the areas *Feedback from the system through recast* and *Auto completion and suggestions*, and the various aspects of helping the user communicate in natural language such as resolving ambiguities in the written query, as described in Section 2.4. Additionally, a substantial amount of time was also put into conceiving ways in which the system could study intent in order to present recommendations to the user. The ideation resulted in a variety of ideas on solutions, which were evaluated as for their respective pros and cons. After each area had been evaluated a decision was made regarding which solution would be a part of the low-fidelity prototype.

5.4.2 Prototyping

The low-fidelity prototype was built with the online prototyping tool Balsamiq (see Section 4.7.2) to be able to test the functionality of the solution during a usability test. With the online tool, it was possible to cooperate in the same file while still being able to create a prototype in digital format. The tool also allowed for basic interactions, used during the usability test, which permitted the participants to click through the prototype. To facilitate the development of the prototype, a scenario was conceived (see Appendix C), which also would serve as a basis for the usability test later. A scenario-based design approach was helpful in elaborating the flow of interactions and bringing the different ideas that had been sketched on paper into a consistent design. It also helped to spot problems and considerations in the design that needed to be addressed, which at several occasions entailed a need to go back to ideating specific details in the design. Hence, the ideation phase and the prototyping phase were partially blended together as the low-fidelity prototype was constructed, rather than being two strictly separate activities.

5.4.3 Design 1.0

The first version of the design arose from constructing a low-fidelity prototype based on the ideas from the ideation phase, with the purpose of being able to evaluate the design towards users. The design presents a concept of a search tool that aims to provide a new way of interacting in data analysis, combining the ability to use natural language queries with marking data in the analysis to specify interest. Also, the search tool aims to help and direct the user by presenting tailored recommendations that can be beneficial for the user when exploring data.

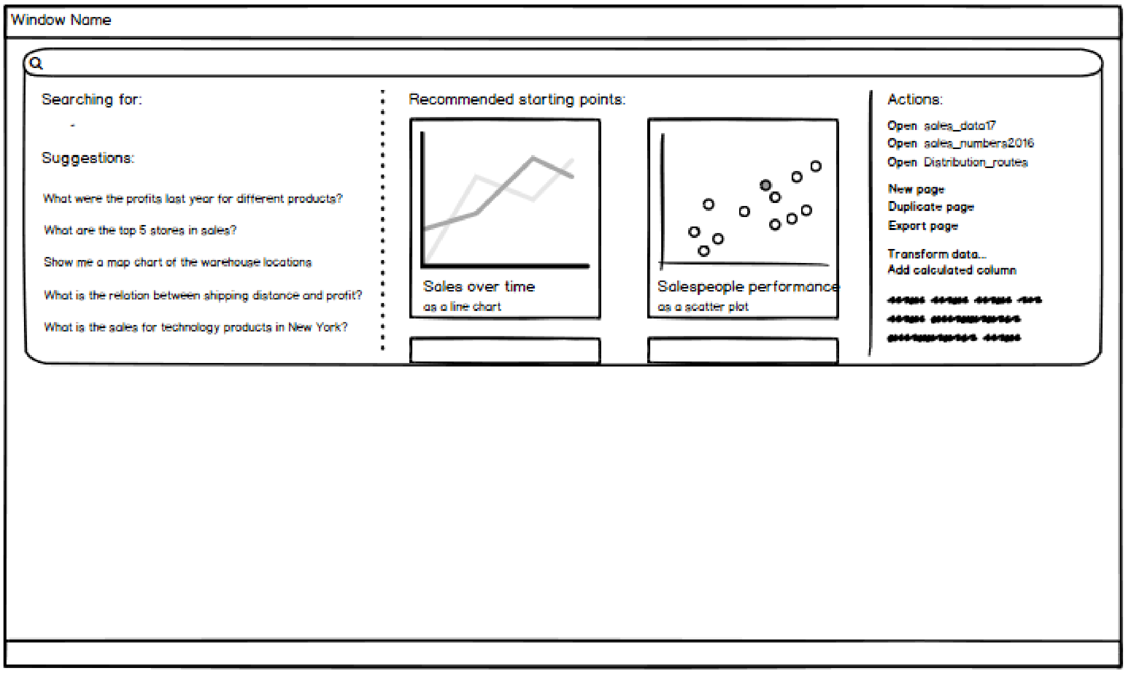


Figure 5.9: Empty state with information based on data loaded at the start of an analysis.

In the analytic software, the search tool can be found at the top of the window, above the analysis that holds the visualizations that are added. When the search tool is accessed from an empty analysis, see Figure 5.9, the first empty state is presented, shown to the user before anything has been typed into the search field. The empty state contains *Suggestions:* of queries to the left, *Recommended starting points:* with visualizations in the middle, and *Actions:* to the right. This content is based on data that has been loaded into the analysis at the beginning, done previously by the user. The query suggestions on the left are formulated by the system based on column names identified in the loaded dataset, aimed to give the user a perception of what language can be interpreted by the system. The visualizations presented are thought to give a jump start, for instance by providing the user with recommendations based on previous activity, insights in the loaded data that are detected by the system, etc. The actions on the right-hand side are aimed to suggest actions that might be relevant at the current stage in the analysis.

As a formulation of a query takes form, see Figure 5.10, the empty state is removed to give the user results on what has been written. The query suggestions on the left now act as autosuggestions presenting how to keep building upon the query, based on what has been written. In both Figure 5.9 and Figure 5.10, *Searching for:* does not display any content. This section of the search interface is aimed to give the user feedback on what has been interpreted by the system from the query and thus also what the results for visualizations are based upon. As nothing of significance – such as column names, values etc. – that can be interpreted by the system, has yet been written the section will remain empty, as well as the results section of the interface.

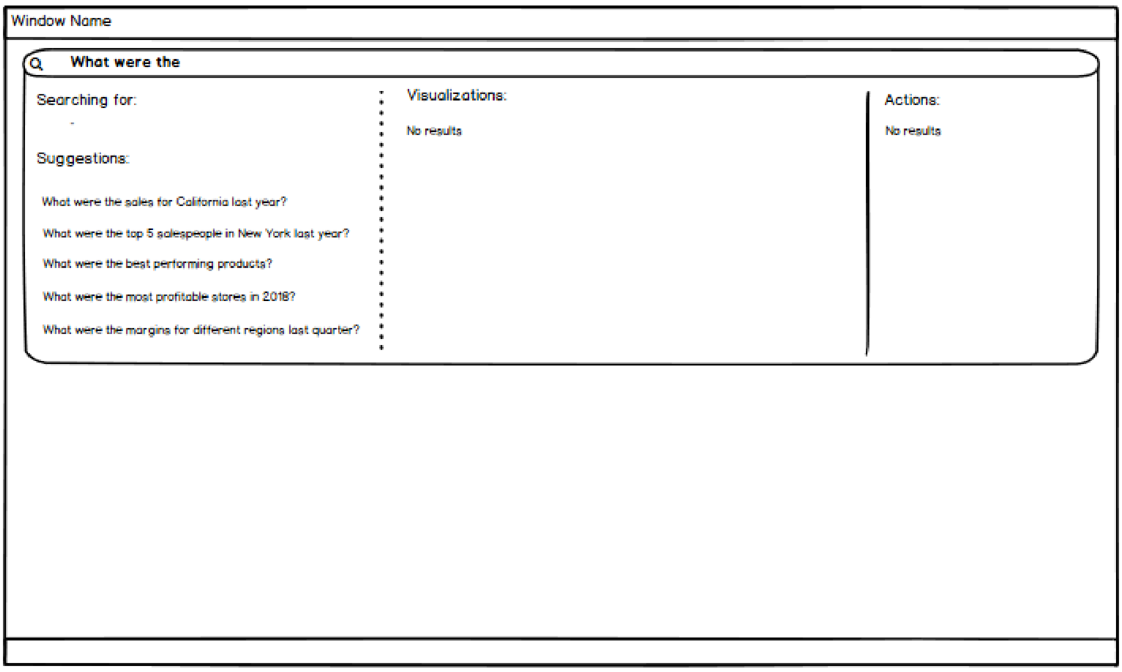


Figure 5.10: Auto suggestions, based on the query in the search field, presented while writing.

However, as can be seen in Figure 5.11, the search system will notice the word *profit* in the written query and recast *Gross profit* as it can be found as a column in the data set. As the language can be ambiguous, with the system making assumptions about what is intended by the user, this aims to establish two-way communication between the system and the user of what has been understood. At this point, the result section will therefore also present visualizations based on the column *Gross profit* in the dataset. To add a visualization to the analysis, the user clicks on a result.

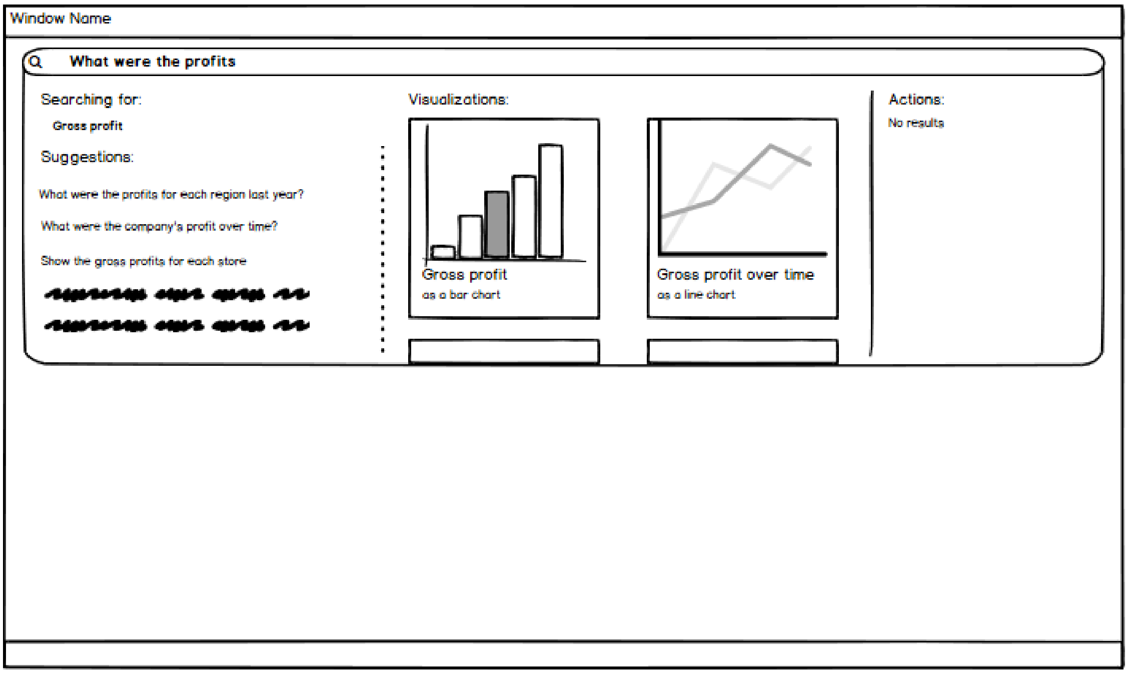


Figure 5.11: The search system displaying a recast to the user with the written word *profit* being interpreted as *Gross profit*.

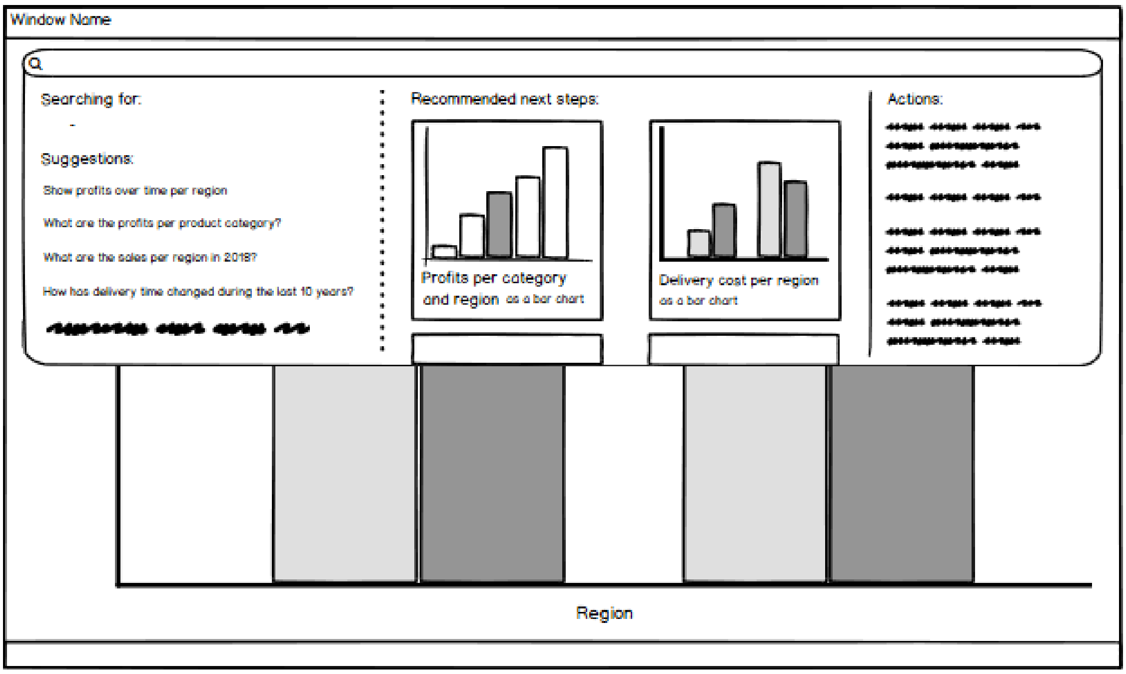


Figure 5.12: Empty state with recommendations based on a previously added visualization.

When having added a visualization to the analysis, the user will be presented with a slightly different empty state when reentering the search tool, as can be seen in Figure 5.12. While the different sections of the search interface are dedicated to the same purpose as in the first empty state, the information presented is now based on what has previously been done in the analysis, with recommendations being given on how to continue. In Figure 5.12 the recommendations for visualizations are placed under the header *Recommended next steps:* and are based on the previously added visualization in the background showing *Gross profit per region*. The query suggestions on the left side are also updated with recommendations on how the user might potentially move forward in the analysis. As for actions, the action results are crossed out since action search has not been explored in the scenario and in the prototype.

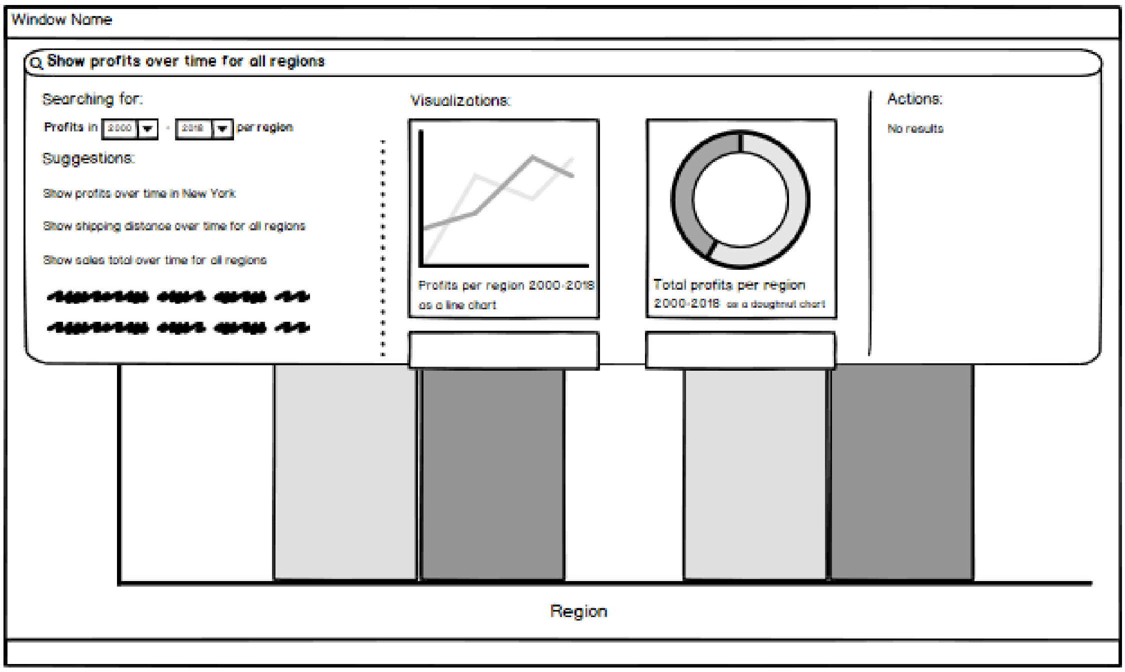


Figure 5.13: Recast with ambiguity widgets being presented to let the user clarify *over time*.

From the list of query suggestions, the query *"Show profits over time per region"* is chosen by the user. As can be seen in Figure 5.13, the system will then recast the interpretation beneath *Searching for:*, which includes presenting widgets in the form of drop-downs that are used to resolve ambiguity. In this case, these so-called ambiguity widgets display two different years – 2000 and 2018 – as an attempt to resolve the ambiguity from *over time*, stated in the query. The ambiguity widgets allow for an easy modification by a user through the drop-down as shown in Figure 5.14, if preferred by the user.

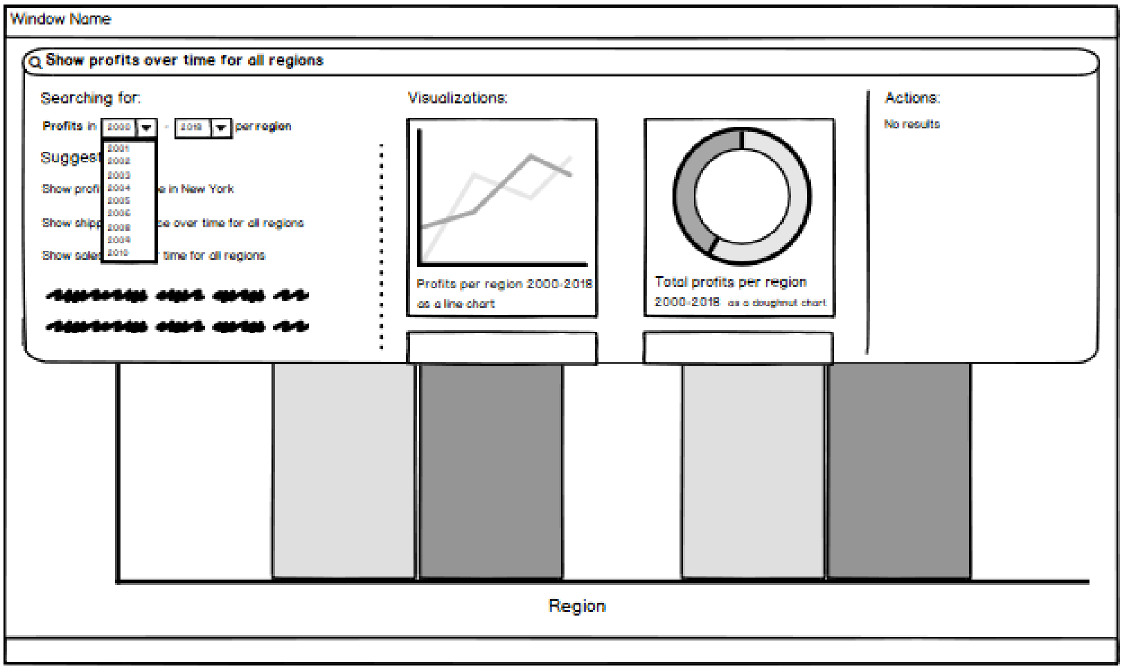


Figure 5.14: Interaction with widgets to modify ambiguity.

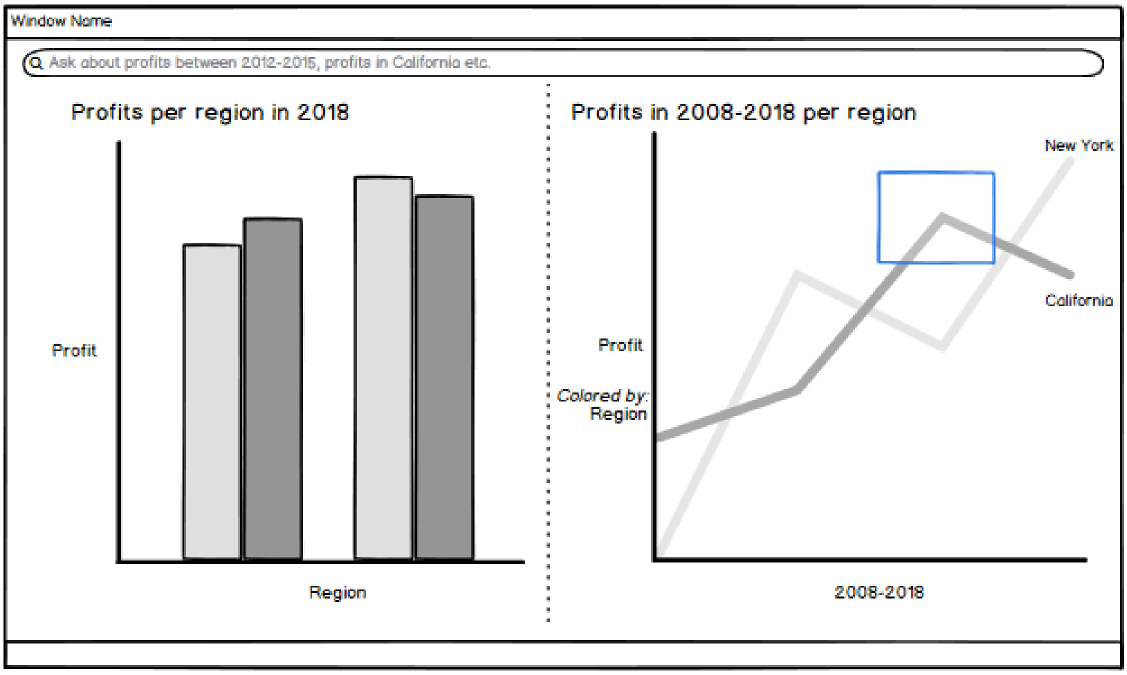


Figure 5.15: The hint in the search field has changed to indicate what search scope the marked subset of data is targeting.

In Figure 5.15, the marking tool is used to specify interest in a given part of the visualization and later on ask a question about it, in this case, a portion of one of the lines in the visualization. When a marking has been performed, the hint in the search field changes from *"Ask about your data"* to *"Ask about profits between 2012-2015, profits in California etc."*. The adaptation of the hint is aimed to clarify that the search scope has been adjusted according to the marking. Another example of marking is presented in Figure 5.16, where the complete plot is marked. Other types of markings are also thought of to be possible to perform, such as marking objects like lines and bars, or ranges by marking a portion of an axis. The type of marking could potentially inform the system of the user's intent and help the system display more accurate results and recommendations.

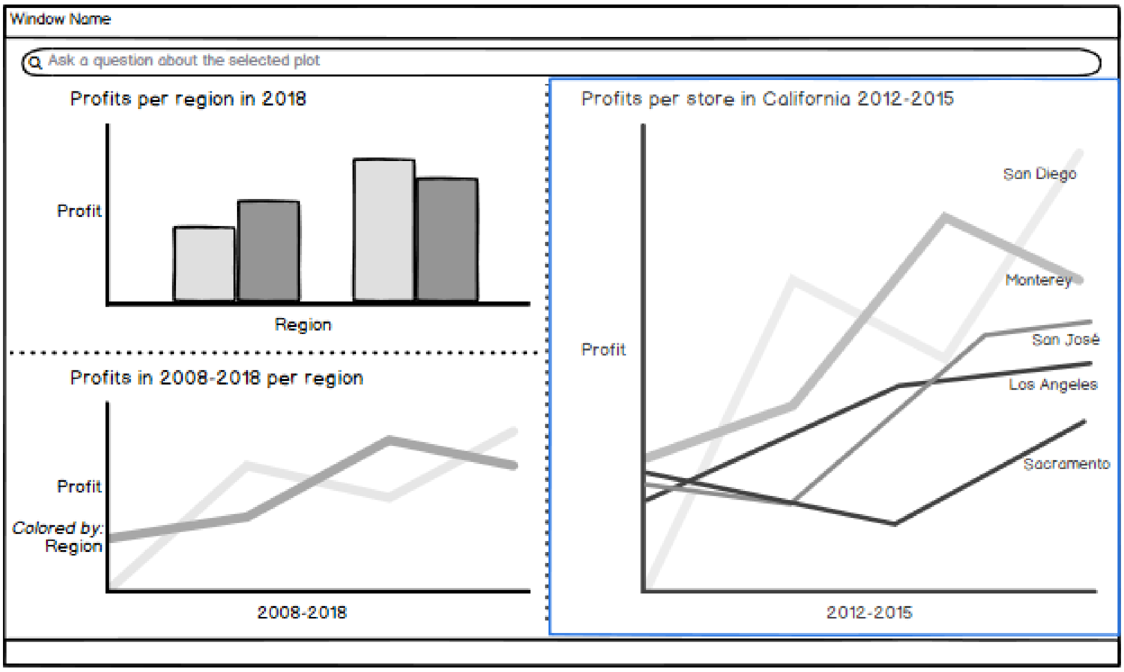


Figure 5.16: Example of marking a plot.

Once again, an empty state is presented when the search field is accessed to ask a question about a marked area, seen in Figure 5.17, in this case with recommendations based on having marked the line corresponding to the profit in California. Again, *Searching for:* appear empty. By marking a subset of the data, there are numerous directions that could be aimed for as a user, creating an ambiguity as for what might be intended. In the case of performing a marking on a line, as seen in Figure 5.15, the interest from the use can vary. For instance, the user might be interested in the entire line, a portion of the line, the data space on various dimensions, etc. Various recommendations can be given to the user in the form of query suggestions or visualizations, that explores and highlights these potentials to the user. When starting to type, as seen in Figure 5.18, the system will try to resolve this ambiguity based on the information given by the user. Also, ambiguity widget will appear for the ambiguities that cannot be resolved algorithmically, letting the user clarify intent if needed.

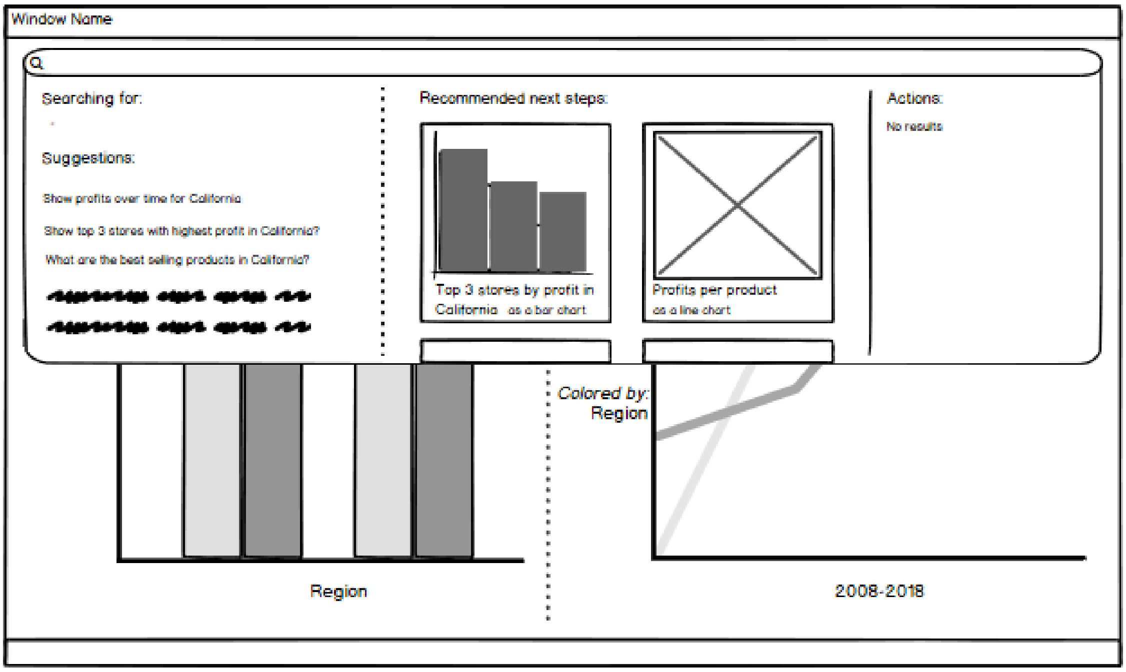


Figure 5.17: Empty state when entering the search tool after having marked data.

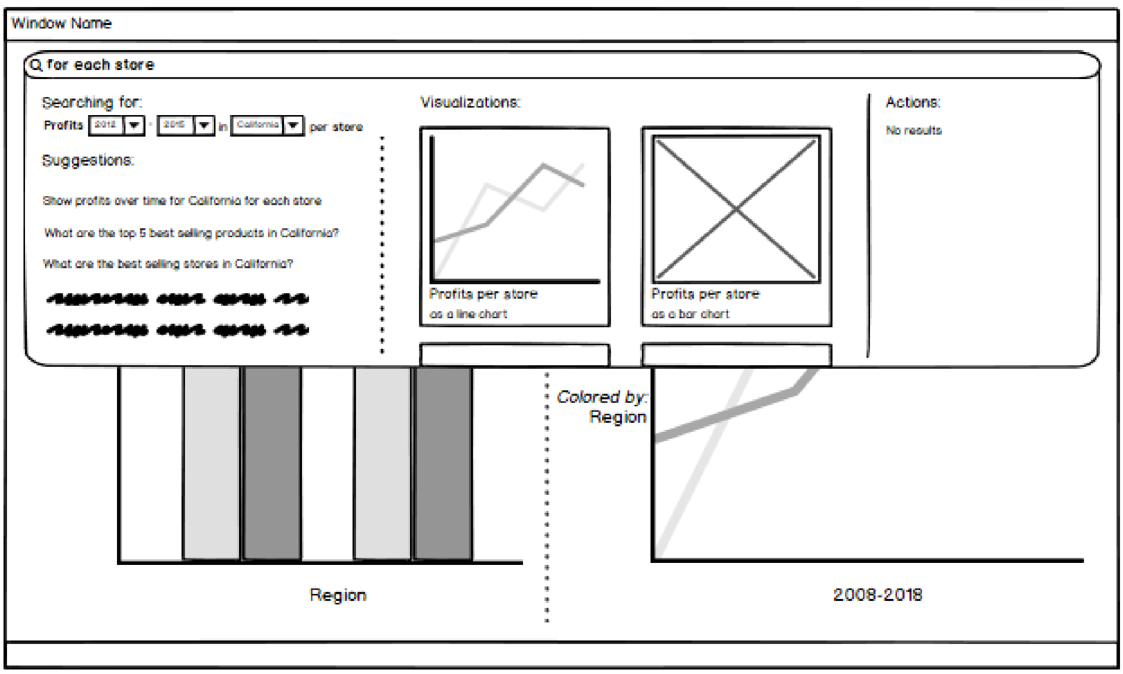


Figure 5.18: Empty state for marked data, when a query has been specified.

A similar empty state as the previous one is shown in Figure 5.19 but presented to the user when enter search after marking a complete plot. Highlighted in this case is the potential for the search system to use computation to study the data and present insights to the user based on interesting occurrences. While all technical aspects were not considered at this point, a conceptual example of this is shown in Figure 5.19, where the system has found a correlation in the marked data with another column in the dataset. A visualization is recommended to the user including a descriptive hint to inform about this insight. This aims to help the user to discover patterns and occurrences in the data that might otherwise have been overlooked, or simply speed up time to insight.

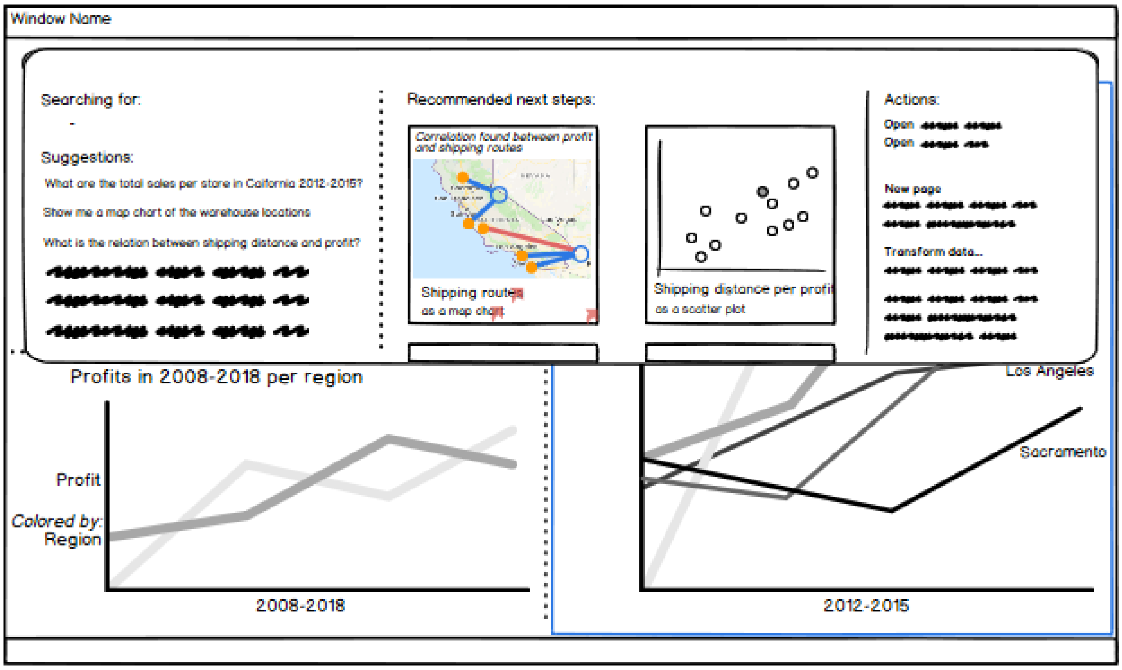


Figure 5.19: Empty state from marked data, with found insight.

5.4.4 Usability Testing

The usability test was conducted with seven participants, of which five where inexperienced users of analytical tools and two had previous knowledge about the Product. The main purpose of the usability test was to explore how the concept of search was experienced in a first-time interaction, and if the various parts of the concept had potential in helping a new user of analytics. The usability test also aimed to evaluate the relevance of the guidelines. The participants were presented with a scenario, containing four main tasks with additional subtasks that they had to solve. As the prototype had some limitations in the interactivity, it meant that the participants did not have large freedom of interaction and needed to be steered in a given direction. During the test, the participants were asked to express their thoughts verbally by using the think-aloud method, see Section 4.6.1, and as the fidelity of the prototype was low, the participants were specifically asked to communicate how they would like to proceed and express themselves in certain stages. For instance, the participants could not themselves control what was being written in the search field but were given static screens. Therefore, it was considered important to let them verbally express their intention beforehand. Both audio and screen was being recorded during the usability tests to enable going back and analyzing the tests later.

5.4.5 Analysis of Usability Tests

From the usability tests, a number of significant insights were found, both from positive and negative experiences. Each test was transcribed and analyzed by extracting quotes and observation, describing the participants' experiences, that were considered being of value. A summary of the findings are summarized below, but a full overview can be found in Appendix D

An apparent finding involved the interaction through query formulation and the participants' perceptions about the query suggestions given from the system. It varied among the participants how they instinctive preferred to formulate their questions before they were presented with suggestions on how to move forward, where some used keywords while others tried to formulate a full question. Regardless of the difference, the participants seemed to learn the language used to formulate a question and were positive about the query suggestions in that they also gave them an insight in what data they had in their analysis. Some participants also expressed insecurity in which scope they were searching in due to the lack of knowledge about what the query suggestions were based on. This insecurity was not only reflected in the query suggestions but was apparent in general. The prototype was not transparent enough about what the results had been based on, especially recommendations given in empty states, which sometimes were dismissed by the participants.

The empty state contained various categories of information, which was also pointed out during the test. At first sight, the participants felt an information overload and did not know where to start, which also meant that they missed important information given to them. However, when they looked closer and took the time to read what it said they realized that the information was helpful. The ambiguity widgets, recasting what had been understood by the system, got a positive response by the participants and the interaction between them went by naturally. Still, some improvements could be done, as some participants expressed that the widgets' placement interfered with the query suggestions and were thus not fully connected with the written query and the results.

Feedback regarding asking about a marking was mostly positive, especially when the participants realized they had the possibility of asking a direct question about what had been marked. It was perceived that the search field changed its hint depending on marking, but the need for greater visual feedback was still seen as evident. There was once again a transparency issue where the participants did not fully understand if they had entered a new search scope or not.

Feedback was also received regarding the section containing *Actions* and the layout in general. Actions were not in focus during the test and thence proved to be confusing since the participants did not fully understand the meaning of it. The general layout of the search field – with a rounded search field and the iconic magnifying glass – contributed in combination with the participants' expectations on the search system, to a conflict between the mental model of using a regular search system and the intended use of the search system. However, one participant expressed the feeling of interacting with an assistant, which was more in line with what was aimed for.

5.4.6 Takeaways

Based on the findings from the evaluation, parts of the design needed to be iterated in the upcoming design phase. This can be summarized into a few areas that needed to be reconsidered before creating a high-fidelity prototype, namely:

- How to represent the scope that is being searched in when having specified data of interest.
- The layout of the search tool, as in the placement of different design elements to improve their spacial relationship.
- The visual expression of the search tool, in order to create the right expectations.
- How to present recommendations from the system, to help the user differentiate between recommendations in the empty state and results based on typing, as well as explain why certain recommendations have been presented.

Several insights were also gathered during the design phase that could give input to the previously formulated guidelines. For starters, it was seen during the test that there is a big variation in the way a user expects or prefer to formulate a question to the search system without the need to enter the search tool, with several test participants showing a natural preference to ask similarly as if one would ask a person. This indicates that questions in natural language come easy for many users, which is something that supports the guideline *Allow expressions in natural language*. Further, the variation in how people think they can communicate with the system shows that it is, as stated in the guideline, important to *Convey the right expectations* to indicate to the user what kind of queries the system can process successfully. Additionally, it was seen during the evaluation that giving feedback of the users' input and the system's interpretation was reassuring for users, supporting the guideline *Design for a two-way conversation*. The mainly positive feedback in regards to marking data to specify interest indicates that it can be natural for users to use follow-up questions and pointing toward a subset of the data to continue in the analytic process. This points towards the advantage in following the guidelines *Allow for flexible search scopes* and *Allow for follow-up questions*. Another guideline that was shown to have importance was *Have transparency in results*, where it was seen as especially important to indicate why recommendations given by the system are presented and how they might help the user.

In addition to support for a number of existing guidelines, other aspects were also discovered that might have relevance for search in analytics. Getting insight into what data is available and how it can be used, exemplified in the low-fidelity prototype in the query suggestions, was appreciated during the evaluation and helped users to move forward while typing. This gave inspiration to another guideline on this matter, which was not formulated up to this point, namely *Provide insight to the user in what data is available and the possibilities to interact with it.* Further, given that the concept of flexible search scopes is incorporated as a solution, there is a need to indicate the scope that is being searched in to the user in order to avoid confusion. Hence, the guideline *Clearly indicate to the user what scope is searched within* was created.

5.5 Iteration Three: High-Fidelity Prototyping

In order to be able to elaborate on the design in more detail and further evaluate the design guidelines, the concept was to be prototyped in higher fidelity. Through this, it would be possible to achieve a more natural interaction with the search tool compared to that with a low-fidelity prototype, which would more accurately represent the end use of the system. Further, through creating a prototype in high-fidelity, the concept could be communicated easier and in more detail to the Company.

5.5.1 Ideation

Before transferring the ideas from the low-fidelity prototype into a high-fidelity prototype, the feedback and insights from the previous phase were to be taken into consideration. Also, the design needed to be constructed more granularly based on the outline created in the low-fidelity prototype. As stated in the takeaways from the previous phase, four areas were to be iterated in a new ideation based on feedback from the evaluation, namely:

- How to represent the scope that is being searched in when having specified data of interest.
- The layout of the search tool, as in the placement of different design elements to improve their spacial relationship.
- The visual expression of the search tool, in order to create the right expectations.
- How to present recommendations from the system, to help the user differentiate between recommendations in the empty state and results based on typing, as well as explain why certain recommendations have been presented.

As for the first area regarding indicating the search scope and what is being searched for, some challenges were presented. By specifying interest through marking, an ambiguity will appear as to what the user might consider relevant in the marking, as discussed previously. This is not to be confused with the possible ambiguity inherent in a written query, such as syntactic or semantic ambiguity. To exemplify, by marking a two-dimensional data space in a visualization, the user might want to specify interest in a range of only one of the dimensions, or in both. Alternatively, the user might not be interested specifically in the dimensions themselves, but rather the data points that are contained inside the marking and their characteristics. Ambiguities like these then have to be resolved, either by understanding intent algorithmically or by letting the user specify intent through interaction. To find ways to solve this, a discussion session was held with two UX designers from the Company, whereupon new ideas were sketched that could solve the challenge at hand.

As for the three other areas, sketching sessions were conducted to explore different possible solutions. This continued into the prototyping phase, alternating between testing out ideas rapidly through sketching screens and interaction flows and including the ones who were deemed to be successful in the high-fidelity prototype.

5.5.2 Prototyping

For creating the high-fidelity prototype, the prototyping tool Axure RP was used, see Section 4.7.1. The choice of software was based on its potential to simulate a credible interaction that resembles that of an implemented solution, especially when typing in a search field and getting results. Besides, the tool presents opportunities to embed HTML into the prototype, which made it possible to have the rest of the Product being presented in the background. This enabled a credible environment in which the concept for the search tool would be placed in. To conclude, the goal was to create an experience for test participants that would induce similar behaviour and expectations as if they were to interact with a finished product.

Similarly to the low-fidelity prototype, the prototyping was based on following various scenarios that were to be used later during usability testing. For the prototype, this meant creating a number of states, with different visual representations, that the test participant was to go through for each scenario. The states changed based on a set of predefined interactions that the test participant made, such as clicking on certain objects or typing in the search field. The logic behind the actual searching, as in typing a query in the search field, were basic filtering functions that presented different results based on keywords that were found in the query. This changed the different query suggestions that were given, added widgets to the recast, as well as updated the results given. Going forward in the analysis by clicking on a visualization results caused the embedded HTML that represented the Product to change in the background, which presented a new visualization for the test participant. Once the intended functionality of the prototype was in place, visual styling was also applied according to style guidelines from the Company. This was in order to visually create an integration between the prototype and the Product that was as seamless as possible.

5.5.3 Design 2.0

During the third iteration, the design was represented in a high-fidelity prototype. In this phase, the prototype became more granular in its design and a number of changes were made based on feedback from the previous phase, which will be described in this subchapter.

In accordance with the different scenarios that were intended for the usability test, the first encounter with the search tool is when creating a new visualization from scratch from the launch view in the Product. When clicking on the search field, the user is presented with the view that can be seen in Figure 5.20. Unlike in the low-fidelity prototype, the search field has now been placed in the toolbar of the Product. The main reason for this is to achieve better integration with the rest of the Product and make efficient use of space within the software, while still being easily available and discoverable. The overall layout of the search tool has also been altered slightly, based on usability issues that were spotted in the low-fidelity prototype. The left side of the search tool now has a dedicated side panel for showing query suggestions, which is now more disconnected from the results and recommendations view. Similarly, the different results and recommendations on the right side of the search tool have been changed to feel more connected. Placement and wording of headers are also changed at several places throughout the prototype. For the recommended visualizations, an icon has been added which communicates to the user the type of recommendation that has been given, in this case being based on visualizations created in previous sessions. A textual explanation will appear when hovering on the icon to make this clear to the user and following the guideline *Have transparency in results.*

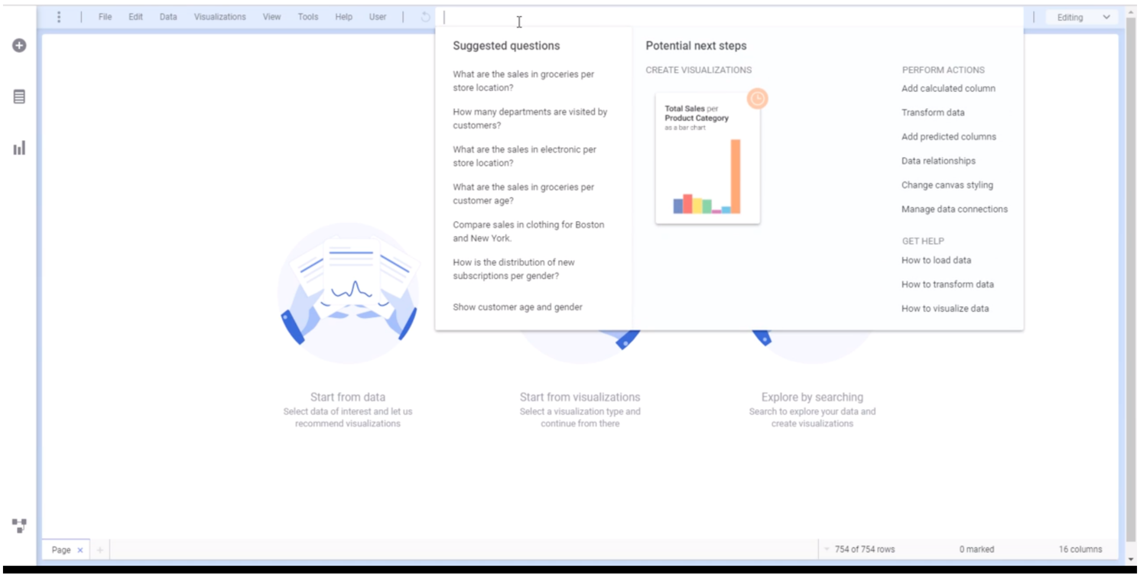


Figure 5.20: Empty state when using search from the launch view in the high-fidelity prototype

Similarly, the recommendation can also be seen in Figure 5.21, with an icon that symbolizes a light bulb, explaining that the system has an insight to share with the user. In this view, the query suggestions have also changed in that they have been divided into the categories *Drill down* and *Shift focus*. This was inspired by the takeaways from iteration one, and helping the user by being presented with different directions when asking a followup question. *Drill down* will, for instance, narrow down the subset of data that is being investigated or split the data by adding another dimension. *Shift focus* will, on the other hand, help the user to find other interesting patterns in the data by presenting the opportunity to diverge from the current focus, for instance by swapping one dimension for another.

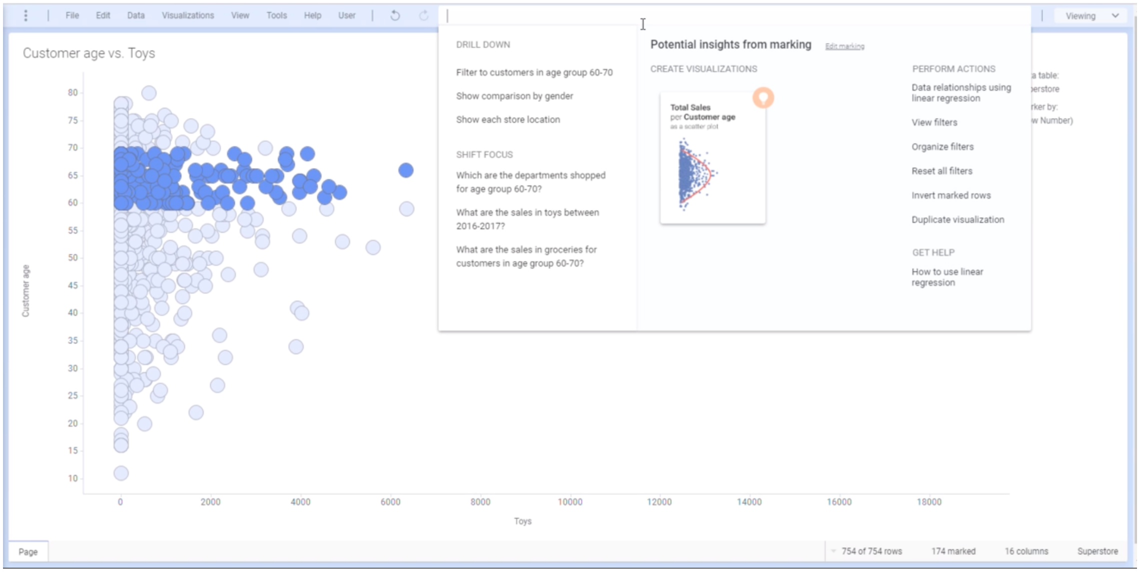


Figure 5.21: Empty state when using search in combination with marking in the high-fidelity prototype

When typing in the search field, the view that is being presented to the user, seen in Figure 5.22 has undergone some changes since the low-fidelity prototype. Mainly, this concerns the recast that is being presented to the user and the various widgets that represents the system's interpretation of what has been written in the search field. Firstly, the recast has been relocated compared to the layout in the low-fidelity prototype. Instead of being placed directly beneath the search field, above the given query suggestions, it is now presented in the results view to indicate that the results for visualizations are based on what the system has interpreted from the query. Thus, the query suggestion panel is not divided by the recast, making the suggestions act more naturally as autosuggestions when typing.

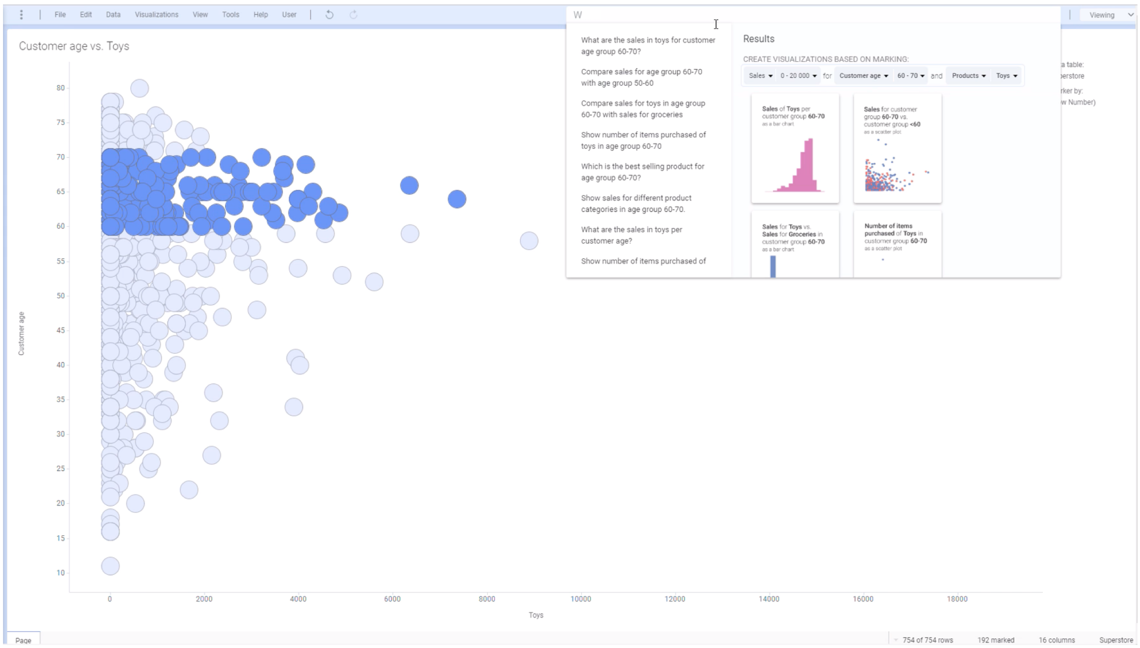


Figure 5.22: Using search in combination with marking in the high-fidelity prototype

The design of the widgets has also been altered during the iteration. All the columns that the system has identified are now represented as widgets, having similar functionality as a drop-down menu. This can be compared to the previous design, where only ambiguities were presented as widgets. The reason for this is due to the ability presented to the user in clicking on one of the widgets and quickly switching to a related column that might be of interest. This behaviour strives to have the design follow the guideline *Allow for incremental construction*, by letting the user modify details of a query through simple interactions. In the case of specifying interest through marking, as seen in Figure 5.22, the results presented to the user will take the marked data into consideration and also have the specifics of the marking displayed to the user. The widgets that represent the marking will be boxed in visually by a light blue border to separate them from the widgets that have been added as a result of typing in the search field. In this case, this means that *Sales* and *Customer age* together with their specified ranges, as well as *Products* and its corresponding filter *Toys* are boxed in since they represent the marking. However, when typing *products* in the search field, the user will be presented with the view shown in Figure 5.23. In this case, the widgets that are added through typing in the search field are placed outside of the box, such as the dimension *Products* in this case. Further, the filter *Toys* have been discarded and replaced by all product types available in the data set, due to the user's specified intent. Figure 5.23 also shows the interaction with one of the widgets, in this case the range for *Customer age* that had been specified earlier through marking. Each widget is thought to present a suitable drop-down when clicked, depending on the types of alternatives available. This makes it possible to tweak the results without having to go back, in this case to change the marking.

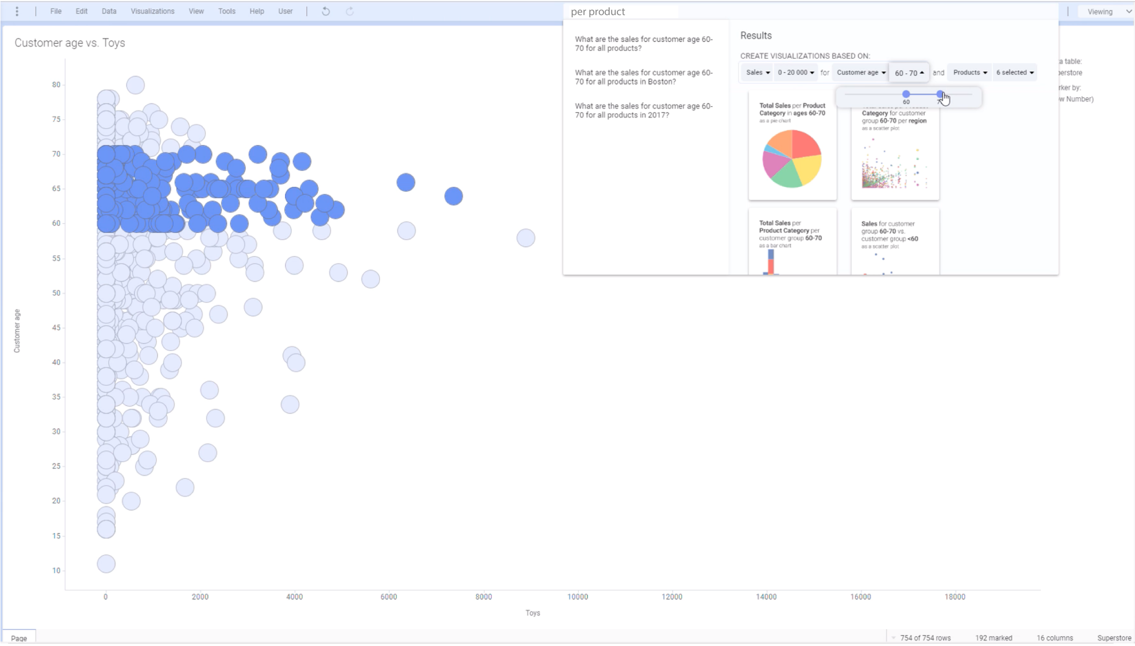


Figure 5.23: Interacting with widgets in the search tool in the high-fidelity prototype.

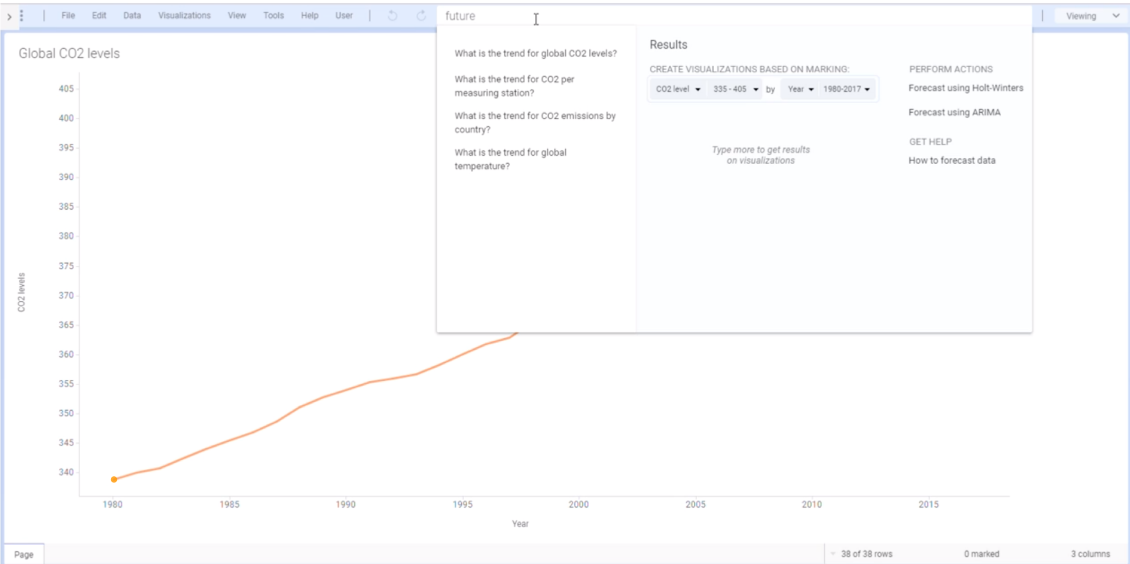


Figure 5.24: Searching for actions based on marking in the high-fidelity prototype.

An additional aspect of the design that needed testing was the ability to reach actions and other categories of results that did not entail creating new visualizations since that was not included in the low-fidelity prototype. Additionally, ideas had arisen during the design process that were inspired by the idea of lowering the barriers to analytics by making analytical functions more accessible to new users, summarized into the design guideline *Support analytical functions through search*. As seen in Figure 5.24, the user is suggested to use built-in forecasting functions when the user has selected the line for global CO2 levels and simply typed "future". Additionally, the idea is inspired by the guideline *Allow expressions in natural language*, by not requiring the use of technical language to reach appropriate results. The guideline *Support learning* has also inspired the feature, since the user can expand its analytical knowledge and capabilities by being presented with functions and features that might previously have been unknown. This guideline is further exemplified in the way that the system presents appropriate help to the user based on what has been written, such as suggesting *How to forecast data* in the case seen in Figure 5.24.

5.5.4 Usability Testing

The usability test of the high-fidelity prototype differed from the previously conducted usability test. It was conducted with five participants, four inexperienced users and one who was familiar with the Product. For the test, the main purpose was to evaluate the guidelines against the prototype. Compared to the test on the low-fidelity prototype, the evaluation was not as formative by nature, since no significant changes were planned to be made to the design. However, these potential findings were still relevant to future work. As for the scenario used during the test, it differed as well. Instead of leading the participants through the test with guided tasks, the scenario targeted three main areas where the participants were supposed to prove or disprove a statement by using the prototype. To exemplify, one task was to prove or disprove the statement *"Children aged 10-15 buy the most toys"* when exploring data for sales of different product categories. The approach was inspired by Gao et al. (2015), as a way of avoiding the test participants to merely parrot the statement in the task when typing a query. For instance, if the task would have been formulated as *"Find out which age group buys the most toys"*, the test participant could simply have typed in *"Which age group buys the most toys?"* to get relevant results on visualizations based on the columns *customer age* and *product category: toys*. Giving a statement hence made it possible to find out how the test participants thought about constructing a query based on a given problem, without explicitly handing them the column names that were sought after. Since the prototype was made in Axure RP (described in Section 4.7.1), the participants had greater freedom in the interaction compared to interacting with the low-fidelity prototype. After each task, a brief discussion about their experience was held before taking on the next task. Once again, the participants were asked to express their thoughts verbally according to the think-aloud method (see Section 4.6.1), which were captured through screen and audio recording.

5.5.5 Analysis of Usability Tests

From the usability test of the high-fidelity prototype, valuable insights were gathered and compiled in order to evaluate and update the guidelines. An overview can be found in Appendix E

Once again, with the prototype now allowing for more freedom in how to interact, it was seen that it varied a lot in how test participants preferred to express themselves, ranging from very natural language to more keyword-based queries. Nevertheless, the participants were able to express themselves regardless of preference, to prove or disprove the statements. In the earlier part of the test, some participants expressed the feeling of being constrained to having to use more verbose queries even if they preferred keywords, but as the test continued they became aware of both possibilities. Being able to use synonyms, to for instance column names that were supported in the high-fidelity prototype, was seen to be of assistance for all participants.

The feedback presented by the system as a consequence of typing a query received overall positive critique. Recasting the system's interpretation supported the participants in various situations, such as in bringing the trust of being correctly interpreted when formulating a query, or in the aspect of selecting a visualization where it was helpful to know if the result was relevant or not. Besides the recast, query suggestions were also mentioned as an appreciated way of receiving feedback. When acting as autocompletion the participants expressed gratitude towards being able to get examples of how to formulate or build upon a query. Once again it was mentioned how it gave them the confidence that the system had interpreted their intent correctly, even before they had completed their query. Another factor that contributed to this was the ability to easily preview and browse the results as the query was being formulated. The users could easily validate whether the results were satisfactory or if an adjustment to the query needed to be made, a detail expressed as being beneficial by several of the test participants.

Further response on recommendations, both through query suggestions and visualizations, was how valuable it was to be presented with new perspectives and viewpoints of possible directions within their analysis. After a while, some participants understood that recommendations could be presented based on insights made by the system in the analysis, before stating a query. However, this behaviour of the search system was not fully understood at first sight, which entailed missing out on recommendations.

Regarding marking subsets of data and asking a question, the functionality in itself got positive feedback. It was, however, still not clear for all of the participants that the search scope depended on the marked area. At first sight, the hint in the search field was not always perceived, but the further the participants got, more often did they perceive the change of the hint and gradually started to understand its meaning. The participants who did understand that the search scope was dependent on marking data, easily expressed themselves when asking their questions since the system knew what had been marked and no unnecessary query statements were needed.

The interaction with *Actions* was not explicitly tested in the earlier usability test and hence, the received feedback on the subject was not extensive. During the second usability test, participants got the opportunity to reach for analytical functions through NLQ, which proved to not be a problem. The goal of the task was to access a *Holt-Winters forecast function*, which they did by using synonyms to *forecast* in their query.

5.5.6 Takeaways

The insights gathered during the analysis proved that there were still some changes in the design left for future work.

In the analysis, it was mentioned how the current visual communication when changing search scope was not clear enough, at least not for all of the participants. It was obvious that the marking feature lost some of its value when it was not clear that a new search scope had been accessed. This difficulty of indicating the search scope was present during the second iteration as well and again proved to be of importance. However, those participants who did notice and understood how the search scope was connected with the marking were very positive about it. Therefore, the guideline *Clearly indicate the search scope*, was once again seen as having importance if the design allows for flexible search scopes.

The analysis also showed a lack in communication regarding what type of results the participants could expect from the search system and it was thought that this lack of understanding was mostly based on an absence of previous knowledge of such systems. In general, it was evident that certain novel functionality might require some form of introduction, was especially evident in the aspect of searching based on marking, presenting recommendations from the system and being able to search for actions. Regardless of how this would be communicated to the user, it was decided that a new guideline was to be formulated that takes this aspect into consideration, namely *Clearly indicate the types of results that can be given by the search system.*

Similarly to what was shown in the low-fidelity prototype, a number of guidelines were proved to still be of relevance. Seen from how the participants formulated their query it was evident that *Allow expression in natural language* opens up for larger freedom in how users can express themselves. Pertaining to this topic, the guideline *Convey capabilities and constraints* was also seen to be of importance to make sure the user knows how to communicate with the system. Additionally, the feedback from the usability test regarding recasting the system's interpretation confirmed that *Allow for a two-way conversation* might be a relevant guideline. Regarding the ability to go back and forth between typing a query and browsing to evaluate the results, which was shown to be of importance during the test, it touched upon the concept of *Unifying modes of discovery*, where the user could move seamlessly between the different modes in the search interface.

During the test, the participants also got the opportunity to search for analytical functions, a functionality that was welcomed by the participants. Being able to reach such functionality, which would potentially not have been explored by the user otherwise, gave support for the guideline *Support analytical functions through search.* Regarding asking about marked data, it was also shown that allowing the user to point at subsets of the data and ask follow-up questions can be a natural and powerful way to continue in the analysis, giving support to the guidelines *Allow for follow-up questions* and *Allow for a flexible search scope.* How the participants interacted with the prototype, by often using a trial and error approach when constructing their queries, supports the need of the guideline *Allow for an incremental construction*. Further, the guideline *Have transparency in results* was seen to have importance when presenting insights and results that are suggested, since it might give the user confidence towards the results and not dismiss recommendations that are given by the system.

5.5.7 Guidelines: Refinement

As a last activity in the process, the guidelines were to be formulated in a final version as a way of summarizing the insights that were gained during the thesis. During this activity, the different findings from each phase were gathered, based on which the initial set of guidelines were reconstructed. This entailed formulating the guidelines to be less general and instead more specific for search in analytics, adding guidelines that were deemed important but not covered in the initial set of guidelines, as well as removing guidelines. The removal of guidelines was mainly due to certain topics not being studied and hence instead be subject to future work, or not finding an interpretation for a guideline that diverged from general guidelines for search and hence not specific enough to search in analytics.

The following guidelines were reformulated:

- **Unify modes of discovery:** The concept of unifying modes can be seen as applicable to the modes present while having entered the search interface, such as typing, adjusting the results and browsing results. Hence, the more descriptive guideline *Provide the user with the possibility to move freely between constructing a query and previewing results, to let the user examine its type and evaluate its analytical relevance* was constructed. This was shown to have importance in the usability test with the high-fidelity prototype, as described in Section 5.5.6.
- **Allow for a flexible search scope:** The guideline was reformulated into *Allow the user to have a flexible search scope by pointing towards a subset of data.* in order to be more specific to analytics. Also, the guideline **Allow for followup questions** was deemed to fall under the newly formulated guideline, since enabling the user to search by pointing towards a subset of data opens up for the possibility to ask followup questions. This ability was highlighted as having potential in the evaluation of concepts, see Section 5.3.5. It was also seen in the evaluation of the prototypes to be a natural way of continuing to in the analytic workflow, once the idea of a flexible search scope was understood.
- **Allow for incremental construction:** The guideline was reformulated into *Allow the user to construct questions incrementally by building upon previously made visualizations* to make it more specific to analytics. This guideline can be seen as integral as the foundation for several other guidelines, and its importance was highlighted both in the design critique, see Section 5.3.5, and in usability tests, see Section 5.5.6.
- **Understand user intent** and **Create possibilities for serendipity:** The guidelines were combined and reformulated into the more descriptive guide-

line *Consider having the system use contextual information to interpret user intention and provide best guesses on desired results.* This was seen from the evaluation of the usability tests, seen in 5.5.6, where participants expressed their appreciation of receiving suggestions based on their activity. Also, some test participants were positive about receiving recommendations from the system that could highlight potentially valuable insights or in other ways help them in their analytic process.

- **Convey the right expectations:** The guideline was reformulated into the more descriptive guideline *Indicate the search system's capabilities and constraints as to how one should interact in order to be correctly interpreted by the system.* This was shown to be of great importance during both of the usability tests, see Section 5.4.6 and Section 5.5.6.
- **Allow expressions in natural language:** The guideline was reformulated slightly to the new guideline *Allow the user to construct queries in natural language using less technical vocabulary*, which importance became clear in both evaluations with the two prototypes, see Section 5.5.6 and Section 5.4.6.
- **Design for a two-way conversation:** The guideline was changed to the new, more descriptive guideline *Confirm and correct the user's input in order to create an understanding of the system's interpretation.* The guideline was seen to be important in both usability tests, see Section 5.5.6 and Section 5.4.6.
- **Support analytical functions through search:** The guideline was reformulated slightly to *Allow users to access analytical functions in the system through natural language.* Support for the guideline was given in 5.5.6.
- **Have transparency in given results:** The guideline was shown to be of importance during both of the usability tests, see Section 5.5.6 and Section 5.4.6. To make the guideline more descriptive and to include recommendations given by the system to the user, the guideline was reformulated to *Be transparent as to why specific results and recommendations are provided.*

The following guidelines were added to the final set:

- *Provide suggestions to the user in how to continue in the analytic process:* The guideline was formulated based on the positive feedback regarding query suggestions and recommended visualizations from the usability tests, see Sections 5.5.6 and 5.4.6, in that they besides communicating how to formulate queries, also provide help in how one can interact with the data to move forward in the analysis.
- *Provide insight to the user in what data is available and the possibilities to interact with it:* The guideline was added based on positive feedback from test participants during usability tests, see Section 5.4.6.
- *Clearly indicate to the user what scope is searched within:* The guideline was added as a consequence of providing the opportunity to search within different search scopes. The need for the guideline was highlighted in the usability tests, see Section 5.5.6 and Section 5.4.6.
- *Clearly indicate the types of results that can be given by the search system:* The

guideline was added as a consequence of being able to get different types of results through the search system. The need for this was mainly highlighted in the usability test with the high fidelity prototype, see Section 5.5.6.

The following guidelines were removed:

- **Allow for an exploratory approach:** From the initial set of guidelines, the guideline was seen as having an apparent relevance for search in analytics, due to the exploratory nature of analytics in itself, but not specific enough to inform design decisions. Further, it could be seen that applying certain other, more specific, guidelines could be a way of facilitating an exploratory approach. The guideline was therefore removed.
- **Support learning:** Similarly to the previous guideline, the guideline is considered relevant but not specific enough as for how this should help designers in constructing a search system. The consideration to support learning was instead included as a rationale for other guidelines.
- **Search for data discovery:** As described in Section 5.3.5, it was decided that the guideline was to be left out of the scope of the thesis.
- **Provide hierarchical search results:** This guideline was removed due to not finding a more specified interpretation that concerns search in analytics. Hence, it remains as a general recommendation for search systems.
- **Provide actionable search results:** The topic was not explored during the thesis and is hence left for future work.
- **Provide alternating views:** This was another guideline that was not explored during the thesis and is hence also left for future work.

6

Results

The results from the thesis work, presented in this chapter, include both a concept for a search system in analytic software, realized into a design prototype, as well as a set of guidelines that aims to provide guidance for designers of search systems in analytics in the future.

6.1 Prototype: Final Design

The final design is a concept for a search system that aims to support new users of analytics in their data exploration. By being able to communicate in natural language, the search system helps the user to easily communicate intent at different stages in the analytic process. Further, the search system aims to leverage the possibilities inherent in interactive data analysis by being able to use marking in combination with search to specify points of interest, and thus facilitating the use of followup questions. In addition, the search system uses available knowledge about a user and its activities to understand intent and provide relevant results and recommendations that can speed up time to answer or help the user discover relevant insights. The design has been realized in a prototype, constructed in Axure RP, as a result of following the iterative design process described in chapter 5.1. The following subsections will describe the design in detail by going through its usage step by step.

6.1.1 Placement of the Search Tool

The search field is located in the top right corner in the toolbar of the Product. The choice of placement is based on the belief that a prominent search field is easier to discover and also more inviting for the user. In the search field, a greyed-out hint can be found which helps to indicate what the user can expect from the search system. The hint will change depending on certain activities performed in the prototype, activities that will be specified further down.

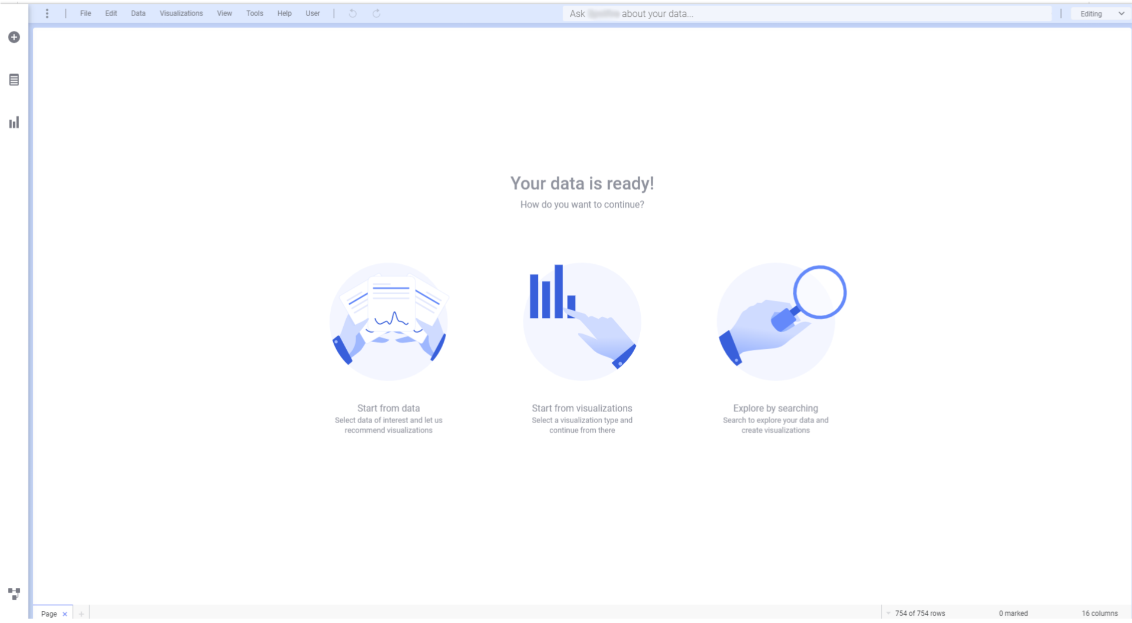


Figure 6.1: The search field is located in the top right corner.

6.1.2 Starting an Analysis from Search

Opening the search field before any visualizations have been added will present the view seen in Figure 6.2. To the left-hand side, "Example questions" are shown based on the data the user have loaded into the analysis at the beginning. With these example questions, the user is given a hint about what type of data the user has available, and how to use it when formulating a query.

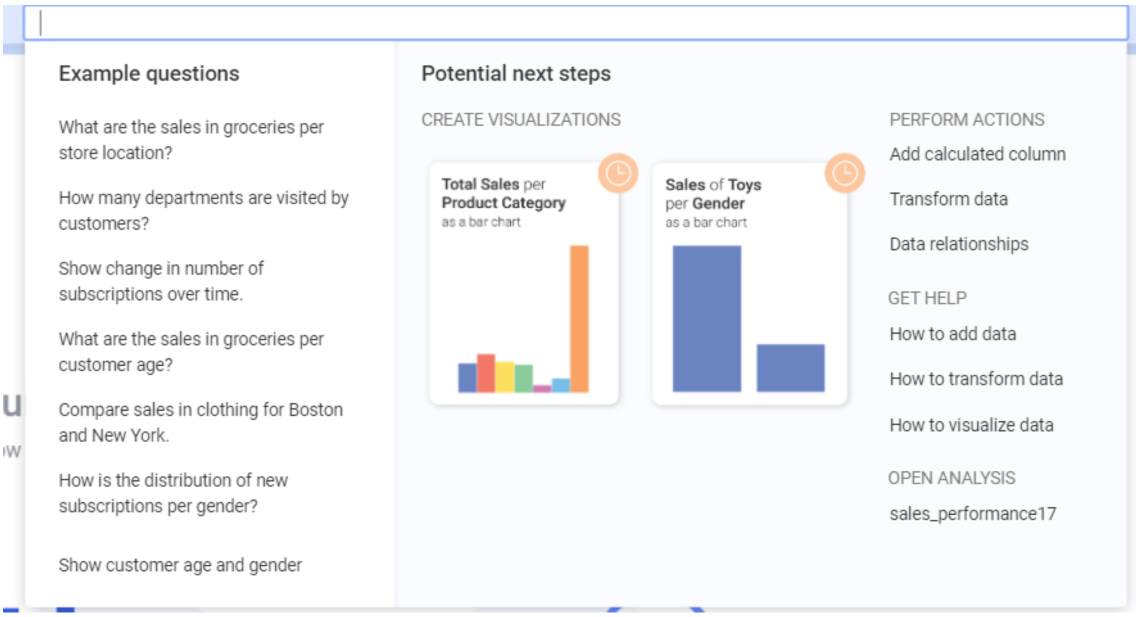


Figure 6.2: A so-called empty state of the search interface is presented before the user have typed in a query in the search field.

If one of the questions corresponds to what the user is seeking, that question can be chosen directly to give the user a head start, or as a query that can be built upon or modified. Next to "Example questions", a section called "Potential next steps" is presented together with two cards containing visualizations. In the top right corner of the two cards, there is an orange clock symbol with a visible tooltip (see Figure 6.3) which indicates when hovered that these two visualizations have been recommended based on the user's latest session within the software. If the user considers one of the suggested visualizations to be of value for what is sought after, a visualization can be chosen and created at an instant. To the right, next to potential next steps, a section called "Actions" is presented that contains short cuts to performing analytical functions, tools, other analyses or help and documentation. These suggestions given to the user are meant to be tailored based on the current activities in the analysis. More about "Actions" will be presented in detail in section 6.1.8.

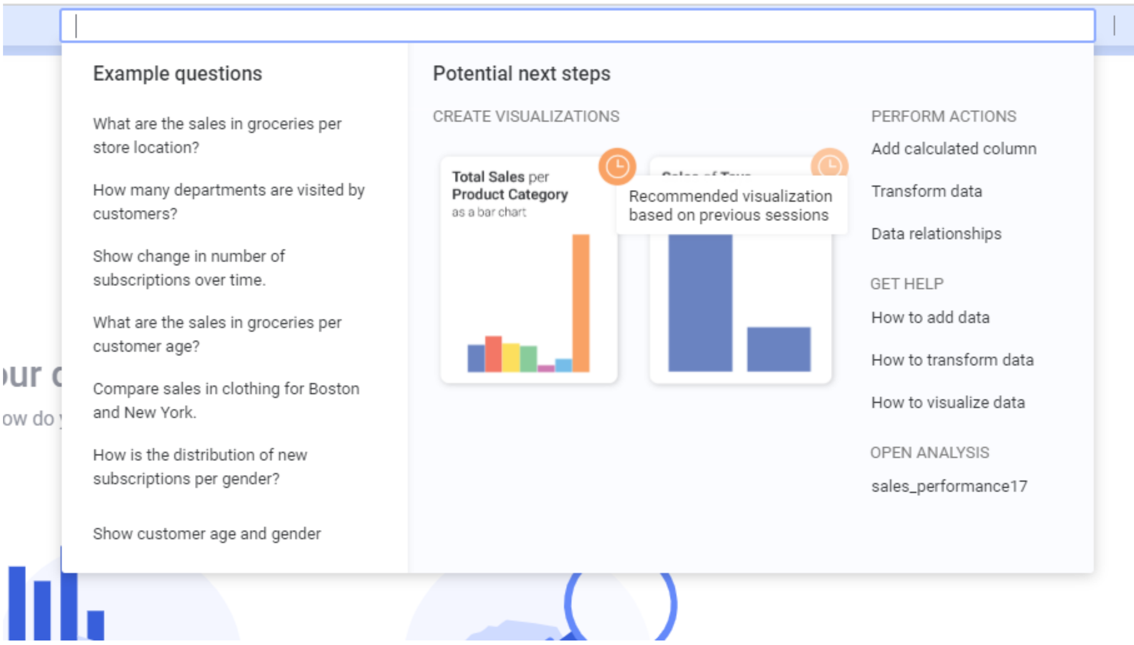
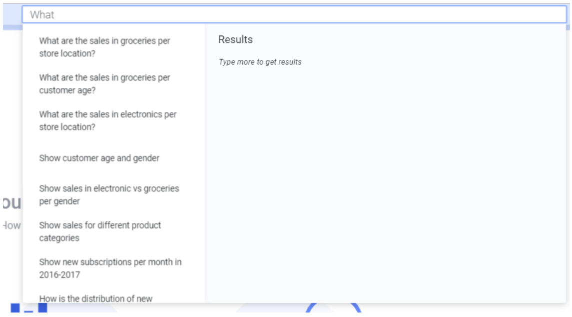


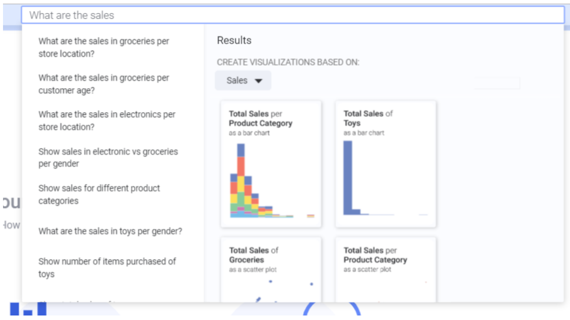
Figure 6.3: When hovered, a tool tip is visible to explain why the visualization is recommended.

6.1.3 Formulating a Query

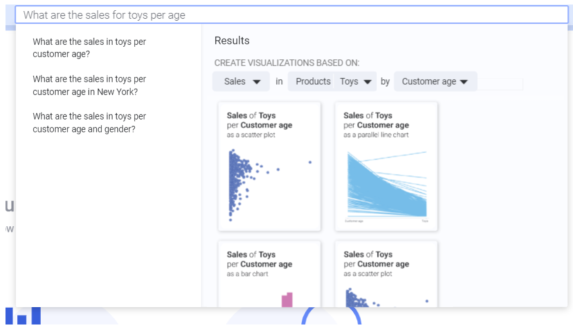
The user can formulate a query to the system by either start typing in the search field, or by using one of the example questions suggested as a starting point that can be built upon or modified. If the user decides to start typing, the side panel that is initially dedicated for example questions will start to present auto-suggestions to the user, based upon the user input, see figure 6.4a. These suggestions can also be clicked to speed up building the query.



(a)



(b)



(c)

Figure 6.4: a) The search system presents auto-suggestions for the user on how to build upon the query written in the search field. **b)** *"What are the sales"* **c)** *"What are the sales for toys per age"*

When an input is added that is recognized by the system in that it can start giving results of visualizations, the system will also give a so-called *recast*, reflecting the interpretation that the system has made of the written query (see 6.4b). The recast is constituted of one or several *widgets* that represent what has been found in the loaded dataset based on the query, such as columns, values, categories or attributes, as well as linking words that represent their relationship, see figure 6.4c. Additional information specified in the query, besides that of what is feedbacked to the user in the form of widgets, can however have relevance as for what results are given, for instance by indicating a comparison or relationship. In addition, typing "What were the" as in the example shown in figure 6.4a, can also give the user help through suggesting appropriate ways to continue formulating the query.

6.1.4 Getting Results on Visualizations

As mentioned in the section above, the results given to the user will be based on the interpretation made by the system, represented in a recast that is made up of widgets. As can be seen in Figure 6.4c, the widgets have a similar appearance as drop-down menus, giving affordance for interaction. This mainly serves two purposes, where the first purpose has to do with the ambiguity that may exist in a written query. This ambiguity can be present at different levels, such as when a query is under-specified by the user, as explained by Gao et al. (2015). An example of how this is handled in the design can be seen in Figure 6.5, where the word *customer*, as specified in the query, is under-specified since both the column *customer age* and the column *customer gender* can be found in the data set.

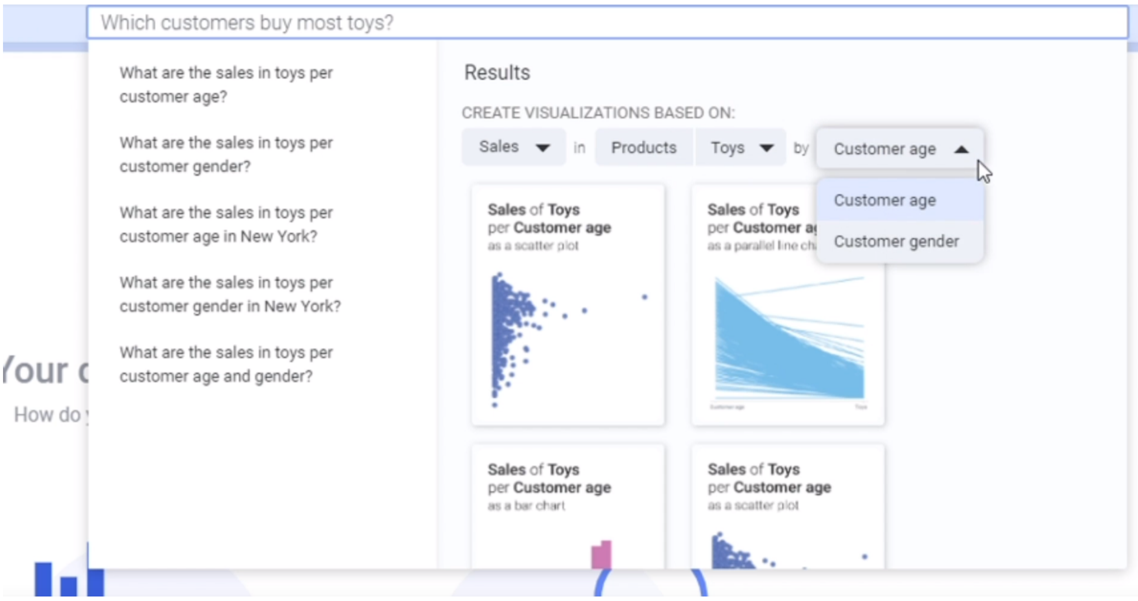


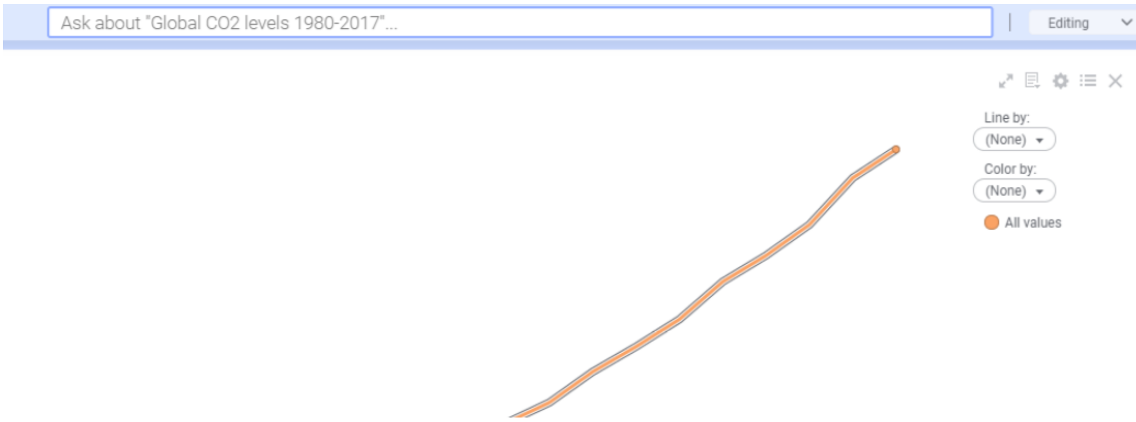
Figure 6.5: Resolving ambiguity in the written query through interacting with widgets

In cases like these, where the ambiguity is too big for the system to determine the user's intent algorithmically as for which column is of interest, the system will make a best guess on what is intended but also provide the user with the possibility to resolve the ambiguity through interaction. As seen in figure 6.5, the user can click on the widget to display other alternative interpretations. The other purpose for the widgets lies within the possibility to discover related columns, attributes or categories by being able to switch this through a dropdown. While this has not been explored extensively in the prototype, potential is seen in being able to give helpful suggestions and alternatives to the user, support exploration and speed up the interaction. Interacting with the widgets will then update the results given in the area below. The results for visualizations are represented as cards, with a preview of the visualization as well as a descriptive title of what it represents. The results will be ordered according to what visualization type is considered the fittest to visualize the specified data, according to an already existing so-called *recommendations engine* in the Product. Being able to browse and preview results as a user will also resolve another type of ambiguity described by Gao et al. (2015), as in what type of answer is relevant to the user and its visual representation in chart type. If the user is satisfied with a result, clicking on a visualization card will add the visualization to the analysis.

6.1.5 Specifying Intent Through Marking

A function within the Product that has been used for the prototype is the possibility to mark subsets of data in visualizations. With marking, the user can look deeper into data of interest and ask follow-up questions, explained in more detail in section 6.1.7. Depending on what the user is marking, as well as how the marking is performed, the search system has the possibility to interpret different intent from the user.

(a) *Hint in the search field suggesting to "Ask about Customer age 60-70, Sales in Toys between 0-20 000 etc."*



(b) *Hint in the search field suggesting to "Ask about Global CO2 levels 1980-2017"*

Figure 6.6: The hint changes in the search field depending on marking to communicate current search scope.

When the user formulates a query based on this marking, what has been marked and the way in which it has been marked will be used to resolve the ambiguity in what the user intends with the question, which ultimately helps to provide better results. Further, from marking data, the system has the ability to use automated algorithms to look for correlations or other potentially interesting insights in relation to the specified data. This creates the potential of presenting system generated recommendations to the user when entering the search tool. To communicate to the user that the search system has recognized the marking and that the search scope has been modified, the hint in the search field changes. In Figure 6.6a, an example is shown of the hint when a subset of the visualized data in a scatter plot has been marked, while Figure 6.6b presents an example of a hint displayed when the user has marked an entire line.

6.1.6 Getting Contextual Recommendations/Entering Search from Marking

Entering search after data has been marked, the search system presents a slightly different empty state (see Figure 6.7). Recommendations at this state are based on contextual information, gathered by the system from the marking, aimed to clarify what scope the user will search based upon, as well as to present possible paths that the user can explore. The sectioning is similar to previously presented empty states, but with a few differences. The query suggestions on the left side serve the same purpose as earlier, of guiding the user forward in the analytical process, but are divided into two subsections – *Drill down* and *Shift focus*. Since the marking can both indicate interest for delving deeper into the selected subset, or imply a search for relationships with other columns, the user is presented with suggestions leading down both paths. In Figure 6.8, a visualization card is presented as in previously presented empty states, however with a different symbol in the top right corner. The light-bulb serves as an indication that the system has found an insight that is based on what data that the user has marked. In this case, a correlation is found between *Sales in Toys* and *Total Sales*. By presenting an insight to the user before a query have been formulated, this might result in finding answers to questions not thought of from the start, or simply speed up time to getting the desired answer.

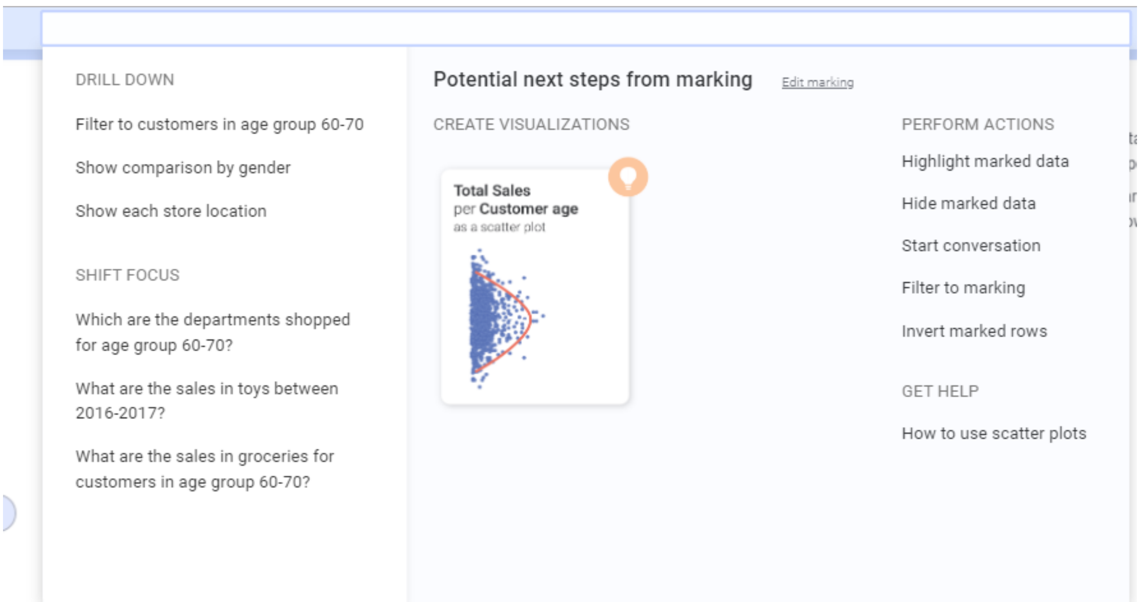


Figure 6.7: Empty state displayed to the user upon entering the search tool after having marked data.

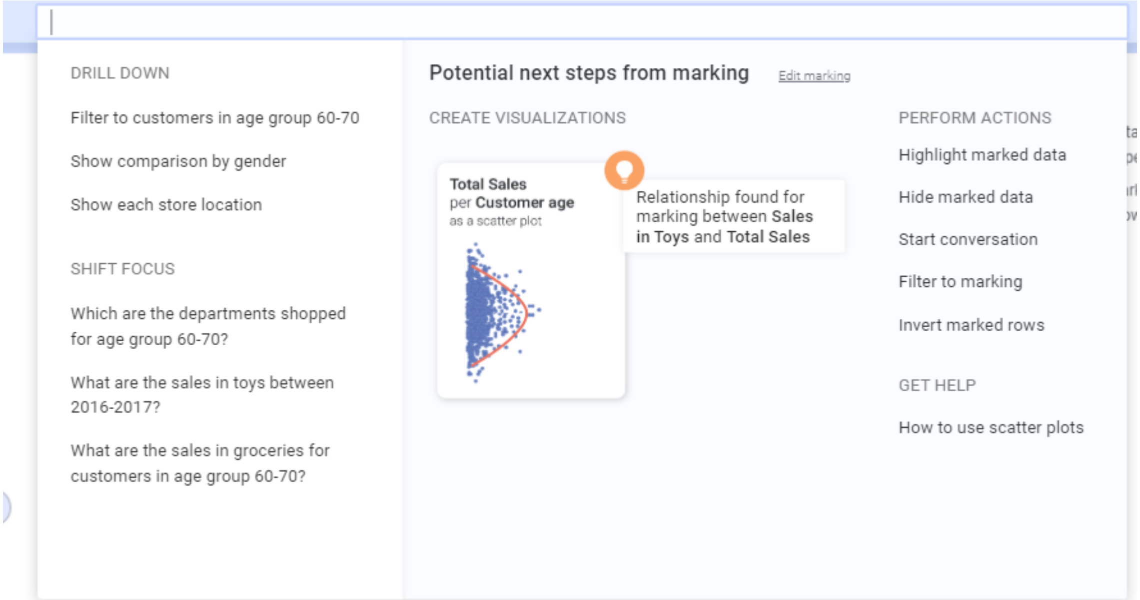
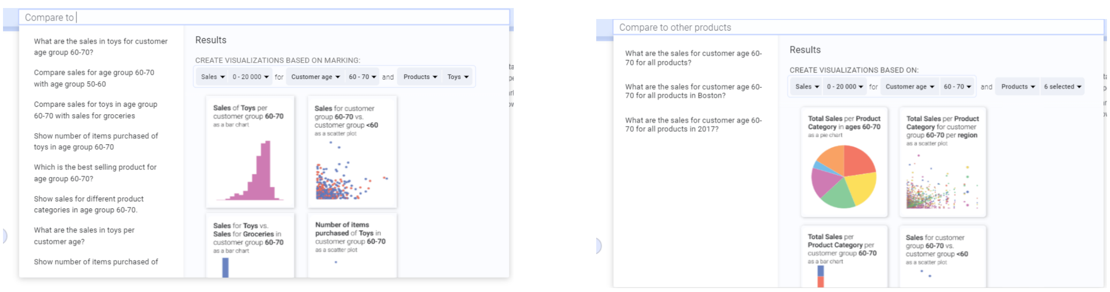


Figure 6.8: When hovered, a tool tip is visible to explain why the visualization is presented.

6.1.7 Formulating a Query Based on Marking

As soon as the user starts formulating a query, the widgets appear encircled by a blue line, indicating what scope the search will be based upon. This aims to communicate that the results will take the marking in consideration and that already specified information does not need to be stated in the query. By adding "other products" to the query, the search system gets new information regarding the user's intent, which is communicated by a modification of the encircled line. The difference can be seen in the appearance of the widgets in Figure 6.9a and Figure 6.9b. Results on comparisons based on *Sales* and *Customer age: 60-70*, from the marked area, shown by *Products: 6 selected*, as specified by the user, are presented as results from the stated query.



(a) *The user has typed "Compare to "*

(b) *The user has typed "Compare to other products"*

Figure 6.9: The widgets are encircled by a blue line, indicating how the search is affected by the marked data.

In Figure, 6.10 the system has interpreted the marking as *Customer age: 60-70*, but with the risk of inconsistency with what the user intended when marking the data, there is a need to being able to adjust this. If the user is not satisfied with the age span in the column *Customer age* or changes its interest from age 70 to age 75, the user is able to modify this without the need of leaving the results view. Instead, a drop-down menu from the widget *Customer age: 60-70* is opened, revealing a slider which helps the user to update the results dynamically. If the column or the range is not of interest at all, there is also a possibility to remove the widget entirely.

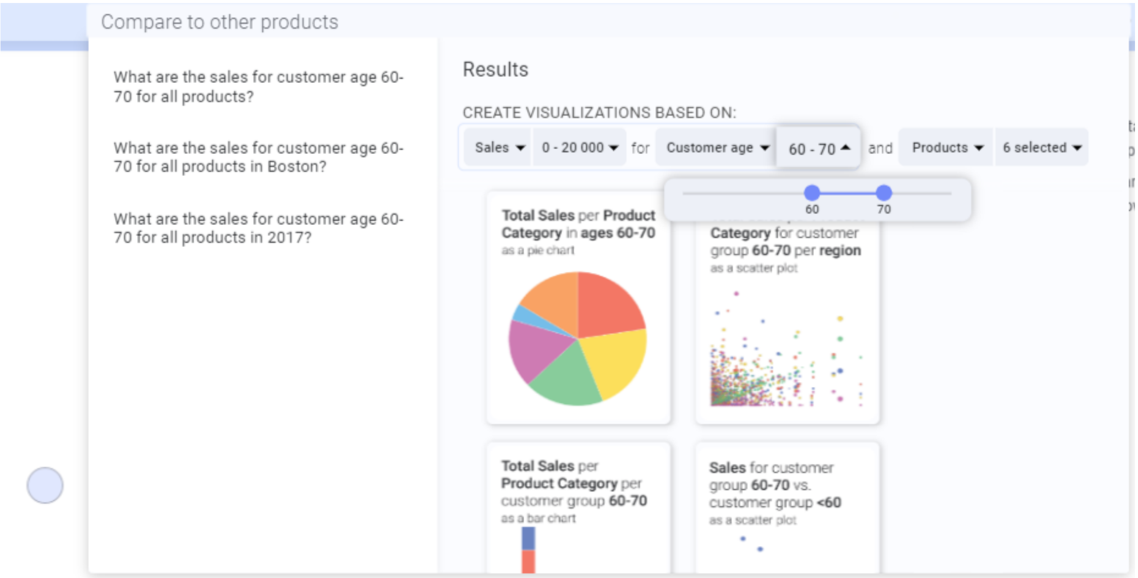


Figure 6.10: Modifying the age span through a slider in the widget.

6.1.8 Getting Other Types of Results

In the previous sections of this chapter, the focus has lied on how to move forward in the analytic process by creating new visualizations. While this can be considered the major use case of the search tool, there are other types of results that can be reached through using search. The types that have been explored during the thesis, other than visualizations, include *actions*, *help and documentation* and *analysis files*. As for actions, this includes so-called *analytical functions*, defined as an overarching term in this thesis for describing various actions that the user might perform within an analysis, as well as tools and options located in the toolbar in the Product. Help and documentation describe certain topics within data analysis and how to use them in the Product. Analysis files are files located in a user's library that can be reached through searching.

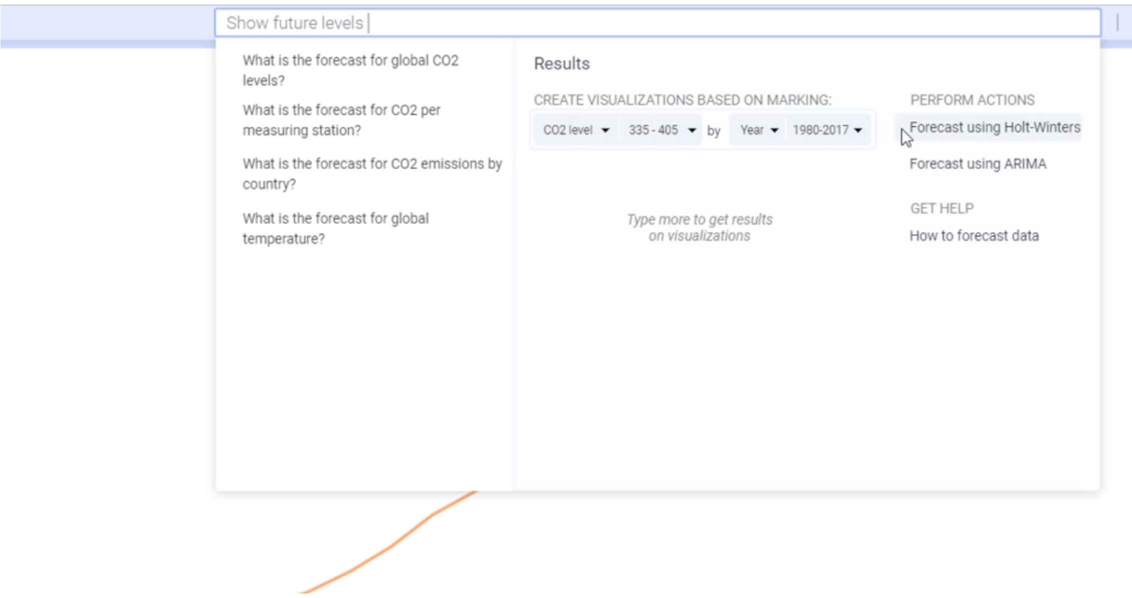


Figure 6.11: Being recommended relevant actions and help by communicating intent in everyday language.

Other than the basic functionality of being able to use more conventional searching to reach these results, as in typing the name of the action, analysis file or help and documentation page, the idea of reaching results such as these through natural language is also explored. As new users of analytics might not know the exact terms or names that should be used to access functions in the Product, the user is able to get recommendations from the search system through communicating intent in less technical language. An example of this is demonstrated in the prototype, seen in figure 6.11, where the user has examined a line chart visualizing historical data of Global CO2 levels. In the example, the user wants to see a prediction of future levels of CO2 and uses the marking tool to specify interest in the line. When asking about the line, the user types in the query "future levels", whereupon the system recommends actions based on its interpretation, in this case certain forecast functions. In addition to this, the relevant help and documentation on the topic is also presented to the user. This aims to lower the barriers of accessing such functionality in the software, and strives to help the user in learning more about analytic tools and their applications in large.

6.2 Guidelines: Final set

In the following section, the final set of guidelines developed during the thesis work will be presented. These are grouped into three thematic areas, namely *Supporting an Analytic Workflow*, *Natural Language Interaction* and *Providing Results*.

6.2.1 Supporting an Analytic Workflow

GUIDELINE 1:

Allow the user to construct questions incrementally by building upon previously made visualizations.

Often times, users do not have a clear picture of their end goal or how to formulate a question in order to reach it. The guideline is based on the concept incremental construction, described by Morville & Callender (2010), that describes the possibility to start small and gradually build upon a search query as the user feels more confident. This is seen to be of high relevance in the context of analytics to support its exploratory nature, where the system should facilitate a conversation between asking and getting insights from the data, as well as allowing a trial and error approach in the exploration. Further, as analytic questions can be complex, an incremental approach can allow the user to break down the complexity in smaller parts. Hence, by being able to use visualizations as a reference to bring a question forward, the user can continue based on questions that arise without having to start over. An example on the application of this guideline can be found in the design, where the user can use marking of a visualization and ask followup questions to bring the question forward.

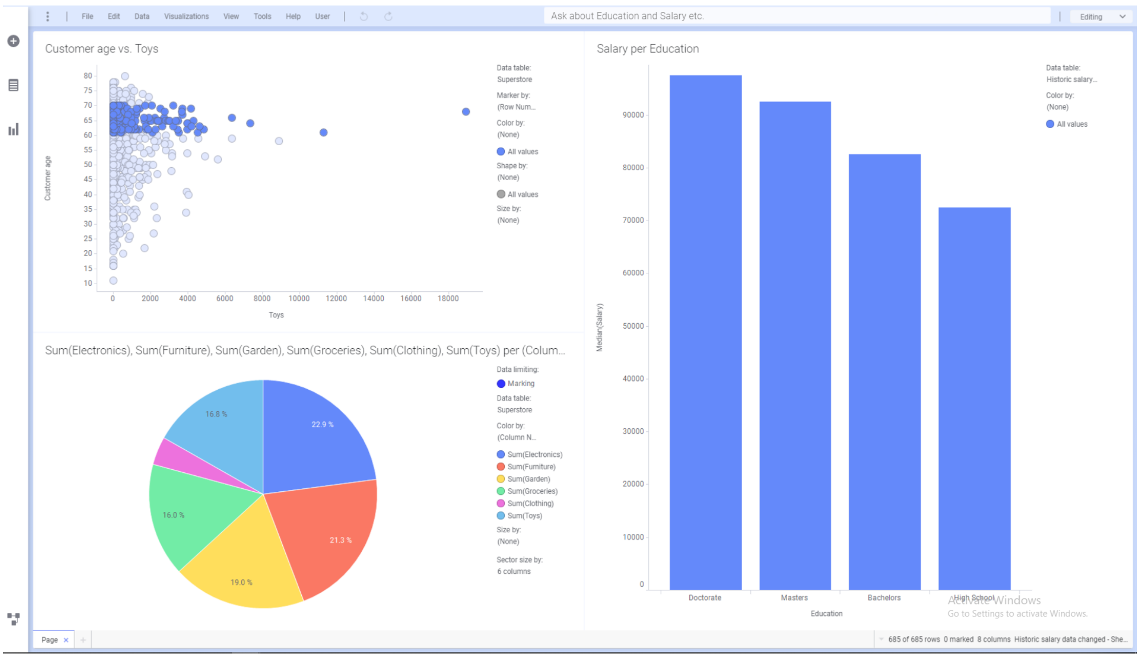


Figure 6.12: Supporting incremental construction by being able to build upon a visualization through marking and asking.

GUIDELINE 2:

Provide suggestions to the user in how to continue in the analytic process.

A search system can, by providing hints and suggestions, invite the user and lower the threshold of entering search even if there is an uncertainty of what is sought after (Morville & Callender, 2010). Communicating the possible paths a user can take within the system can help the user find inspiration for how to take the analysis further and which questions that can be asked. Using this guideline in combination with guideline 12, pointing at using contextual information, will be beneficial in the sense that suggestions can be augmented through knowing about a user's activities and the current stage in the analytical workflow. This is exemplified below, where the empty state presents suggestions divided into the categories *Drill down* and *Shift focus*, guiding the user towards possible directions to explore within the data.

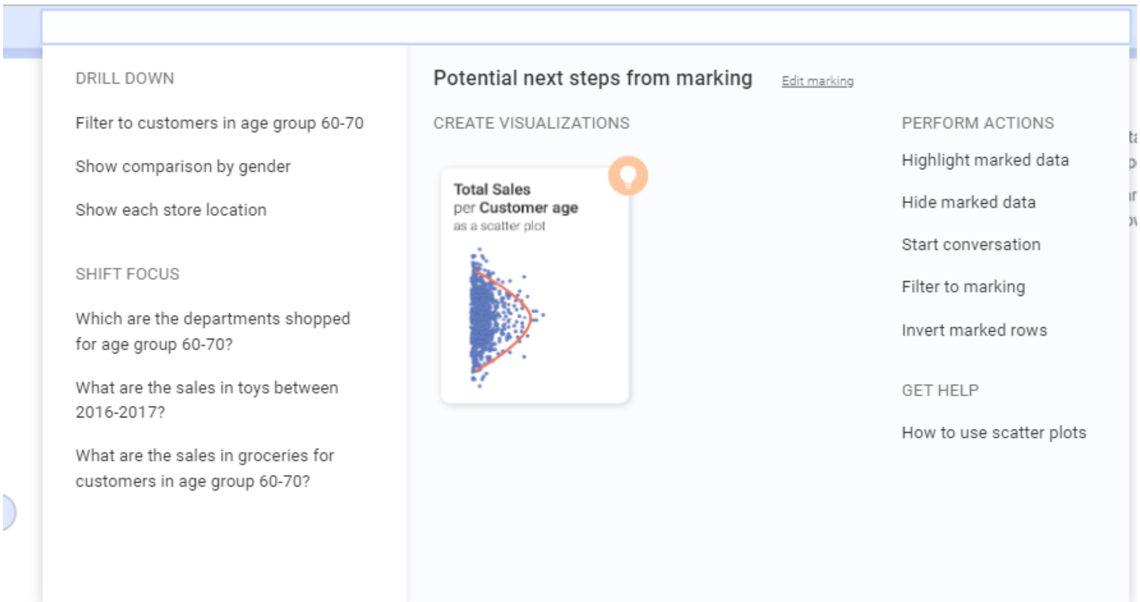
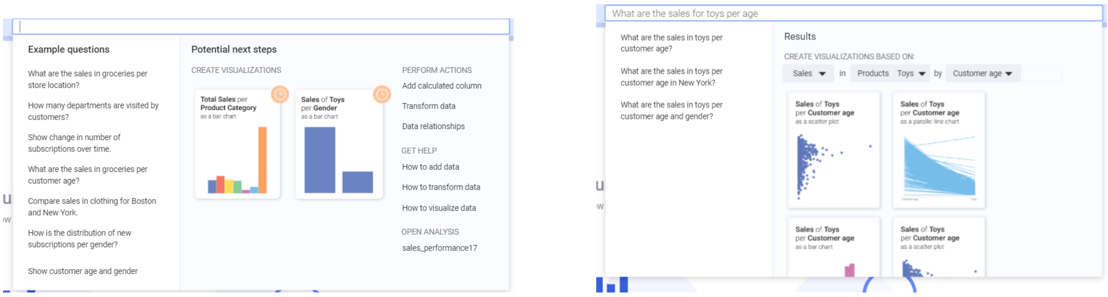


Figure 6.13: *Drill down* and *Shift focus* guides the user towards further exploration in different directions.

GUIDELINE 3:

Provide insight to the user in what data is available and the possibilities to interact with it.

Similarly to what is discussed in guideline 2, where suggestions are given that aims to provide possible directions to a user, there is also potential in surfacing the data that has been loaded into an analysis to help the user in how to interact with the data. In an early phase of an analysis, this might entail showing which columns can be relevant to start exploring. Further, when continuing to explore the data, such functionality might help the user to build upon a query to drill further into the data, or diverge and look at other columns that have not yet been explored. There can be various ways of applying this, with two examples are shown below. In Figure 6.14a the user is noticed about some of the data available, and in Figure 6.14b the system suggests how to build upon the current question by looking specifically on the category "New York".



(a) (b)

Figure 6.14: Insights about available data and how to interact with it. **a)** Available data in the analysis **b)** Split by categorical column; *New York*.

GUIDELINE 4:

Allow the user to have a flexible search scope by pointing towards a subset of data.

Filtering out unnecessary information and providing users with parts of information over time will, as stated in the theory by Morville & Callender (2010), allow for a flexible search scope that helps the user to ignore irrelevant paths and keep the focus on the desired ones. In analytics, this is of great importance due to the handling of large data sets with thousands of data points. Flexible search scopes also support the exploration of data with a direct and hands-on approach. In combination with natural language interaction, it could be an effective way to communicate with the system and specify which data is of interest. One example can be seen in the design (see Figure 6.15) where the user can specify interest in a subset of the data in order to facilitate asking follow-up questions.

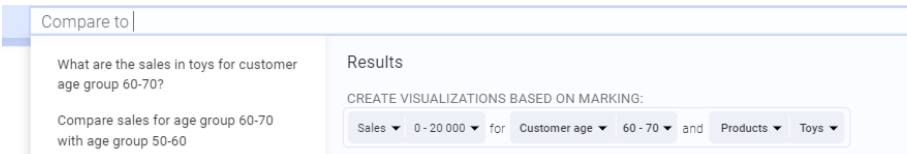
Figure 6.15: A subset of data has been marked and a follow-up question have been stated in the search field.

GUIDELINE 5:

Clearly indicate to the user what scope is searched within.

Given that the user is able to search in different scopes, it is important to communicate which scope the user is currently searching in to create an understanding of what the results are based on and to avoid potential confusion. There can be several examples of how to indicate a search scope, whereof two are exemplified below. In Figure 6.16a the scope is defined by marking and indicated with the hint in the search field while in Figure 6.16b it is indicated by the widgets.

(a)



(b)

Figure 6.16: Two examples of how to indicate search scope. **a)** With a hint in search field. **b)** With widgets corresponding to marking, encircled by a blue line.

6.2.2 Natural Language Interaction

GUIDELINE 6:

Indicate the search system's capabilities and constraints as to how one should interact in order to be correctly interpreted by the system.

When exploring a system, it can be difficult for a user to determine the system's level of intelligence in what it is capable of performing. Due to the novelty of natural language search, there are no set conventions as to how a search system in analytics typically behaves and what to expect from it as a user. Further, by being exposed to various kinds of search systems on a daily basis, users have been observed to often have preconceptions of the purpose and capabilities of a search tool, which might diverge from what is intended by designers of search in analytics. Indicating the system's capabilities and constraints is therefore integral in order to create the right expectations, with too high expectations creating a risk for a negative experience, as well as not having the system be used to its fullest potential in the case of too low expectations (Noessel, 2017). One application of the guideline can be found in the example below, by having the system suggest ways that the user can formulate oneself when asking questions to the system.

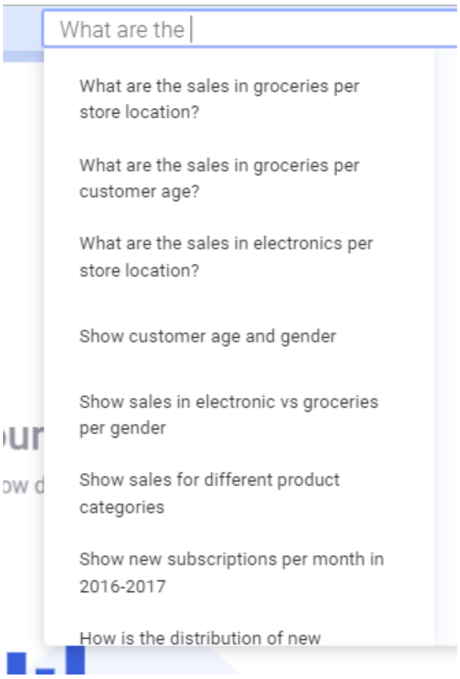


Figure 6.17: Auto-suggestions of how the user can formulate and build upon a query.

GUIDELINE 7:

Allow the user to construct queries in natural language using less technical vocabulary.

Natural language interaction has the potential of making analytics accessible to a broader audience when allowing the language to be more colloquial and expressed in the user's own vocabulary. Being able to interact with natural language can hence be a powerful way for less experienced users to communicate their intent (Dhamdhere et al., 2017). In addition, having to know the exact terms and column names might defeat the purpose of providing a search tool if the user has to know the names of the columns in the dataset before accessing the search tool. Allowing the user to communicate using synonyms and more colloquial language can therefore be an important factor in lowering the barriers to analytics. By letting the search system do the heavy lifting instead of forcing the user to translate a thought to the system's language, searching can be a fast and easy way for the user to get to the right answer. Exemplified below, the user can reach visualizations by stating a question in natural language, using synonyms to column names in the dataset.

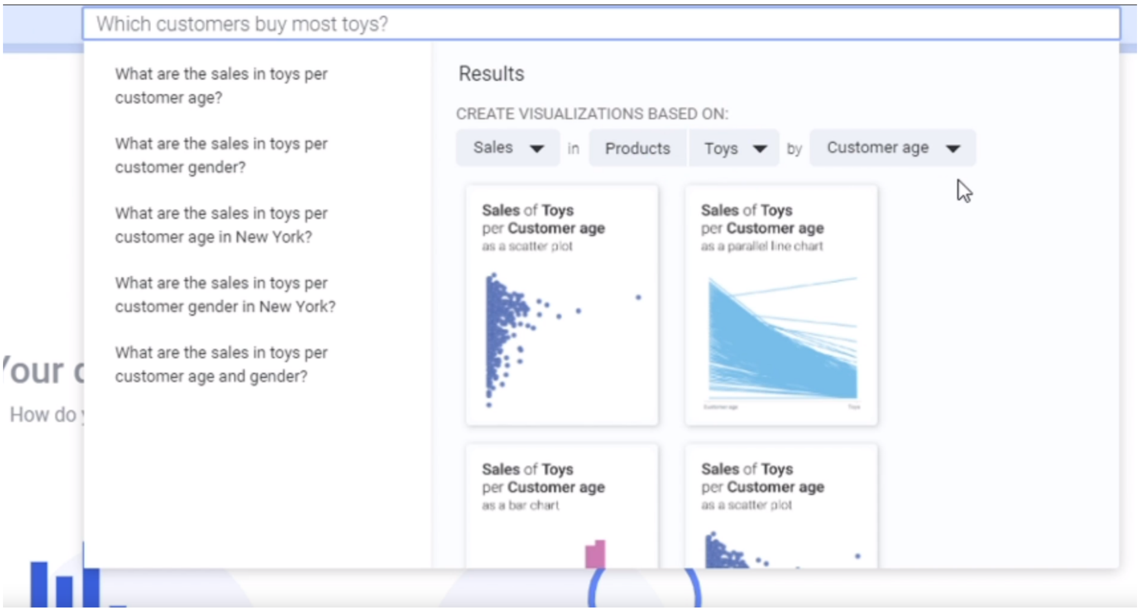


Figure 6.18: A question, stated in natural language, is interpreted by the system where *"buy"* is interpreted as a synonym to the column *"sales"*.

GUIDELINE 8:

Confirm and correct the user's input in order to create an understanding of the system's interpretation.

When querying in natural language, the input that can be correctly interpreted depends on the sophistication of the system. In addition to communicating this sophistication, as described in Guideline 7, the system should give feedback to the user of how the query has been interpreted in order to have the user ensured that the right results are presented. Such a two-way conversation can then inform the user of how the query has been interpreted and how it possibly differs from the user's intent, by noticing relevant content and communicating what cannot be understood. Further, this insight into the system can also help the user develop an understanding of how to communicate with the system effectively. An example of this can be found below, where the system displays its interpretation of a query by presenting so-called widgets.

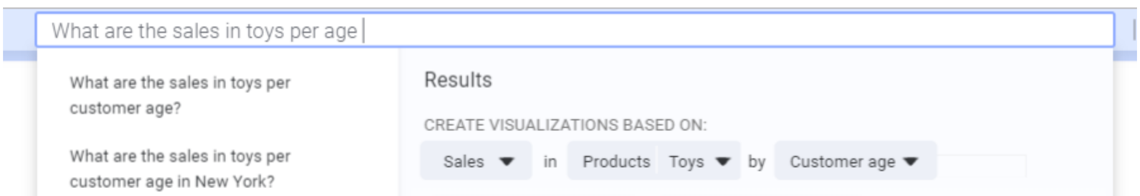


Figure 6.19: The interpretation of the user's query is represented by widgets, where each widget corresponds to a column name in the dataset.

GUIDELINE 9:

> In cases where ambiguities exist in a query that the system cannot resolve, enable the user to specify intent through interaction.

In natural language interaction, there is room for ambiguity on many levels regarding the interpretation of the intended meaning of a user's query, for instance due to the query being underspecified by the user. To varying degrees, a system might be able to do algorithmic best guesses on users' intent. However, there will still be instances where the ambiguity will be too high to accurately draw conclusions of the user's input. In cases where such ambiguities arise, the system will benefit from allowing the user to resolve this ambiguity through interaction. An example of applying this guideline can be seen below, where the user is provided with the possibility to resolve ambiguity through interacting with widgets.

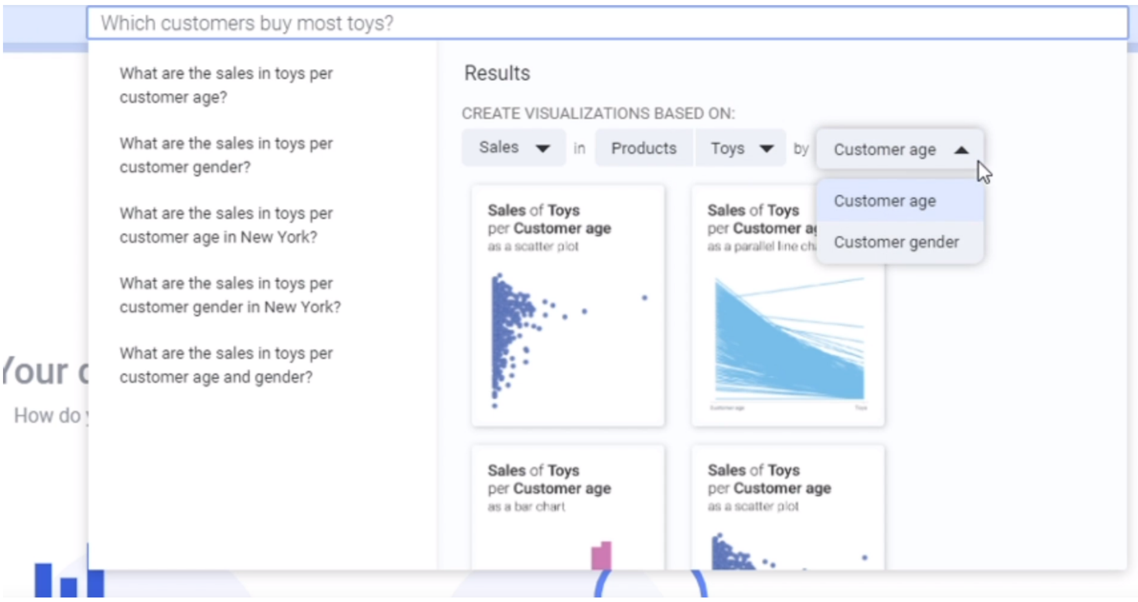


Figure 6.20: Providing the user with the possibility to resolve ambiguity in a query through interaction.

GUIDELINE 10:

> Allow users to access analytical functions in the system through natural language.

Since the knowledge about what one can do with an analytical tool is limited for inexperienced users, providing the opportunity for users to express what they want to do in everyday terms might lower the thresholds of finding such tools. The idea of providing new users in analytics with the opportunity to access analytical functions through natural language proves promising, since getting exposed to such tools can show the user the potentials within the analytic software, while also helping the user become a better analyst by discovering relevant actions. One example of this is shown below where the user poses a question about the future, after marking a full line in a line chart, and is being recommended to use a Holt-Winters forecast function. Additional examples of questions that would preferably reach other analytical functions are questions like "Is there a seasonal trend?" or "Are there any outliers?".

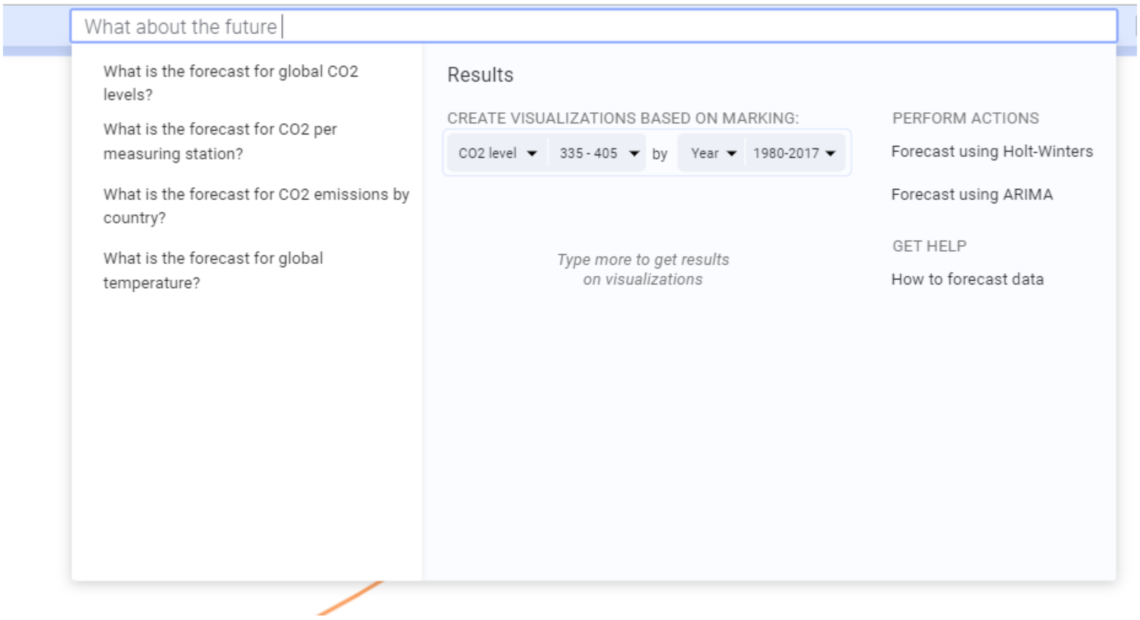


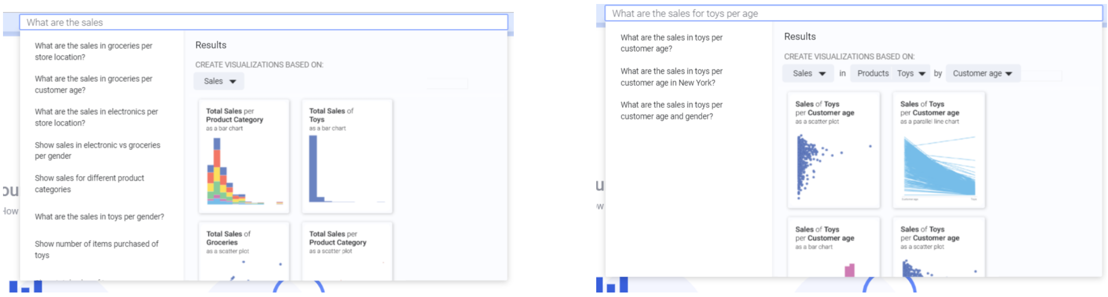
Figure 6.21: Analytical functions are accessed from a question stated in natural language.

6.2.3 Providing Results

GUIDELINE 11:

Provide the user with the possibility to move fluidly between constructing a query and previewing results, to let the user examine its type and evaluate its analytical relevance.

In analytics, the workflow should preferably be a conversation between finding, learning and asking. Moving fluidly between activities such as asking a question and previewing provided information, and perhaps filter out what is not relevant before deciding to continue with a result is to be considered valuable. The ability to preview results while formulating a query can help the user to quickly determine whether results are relevant or not, providing the ability to easily continue building upon or modifying the query. In the example shown in Figure 6.22, the results are updated dynamically as the user is formulating the query, which allows the user to have a trial and error approach until the desired visualization is presented.



(a) User having typed *"What are the sales"*

(b) User having typed *"What are the sales for toys per age"*

Figure 6.22: The results are updated dynamically as the query is formulated.

GUIDELINE 12:

Consider having the system use contextual information to interpret user intention and provide best guesses on desired results.

Trying to derive the intention from what previously has been done can reveal a lot about the user's interest. The system can take notice of the interest that has been specified by the user and present tailored recommendations that will help the user forward in the analytical process. Session data and contextual information about the user's current stage in the analysis, can potentially increase the accuracy in the provided results and allow the user to discover results which were not initially sought after. Session data are based on previously performed actions such as loading new data, creating new visualizations or marking a subset of the data. Below, the guideline is exemplified in the design by having the system provide recommendations of possible next steps.

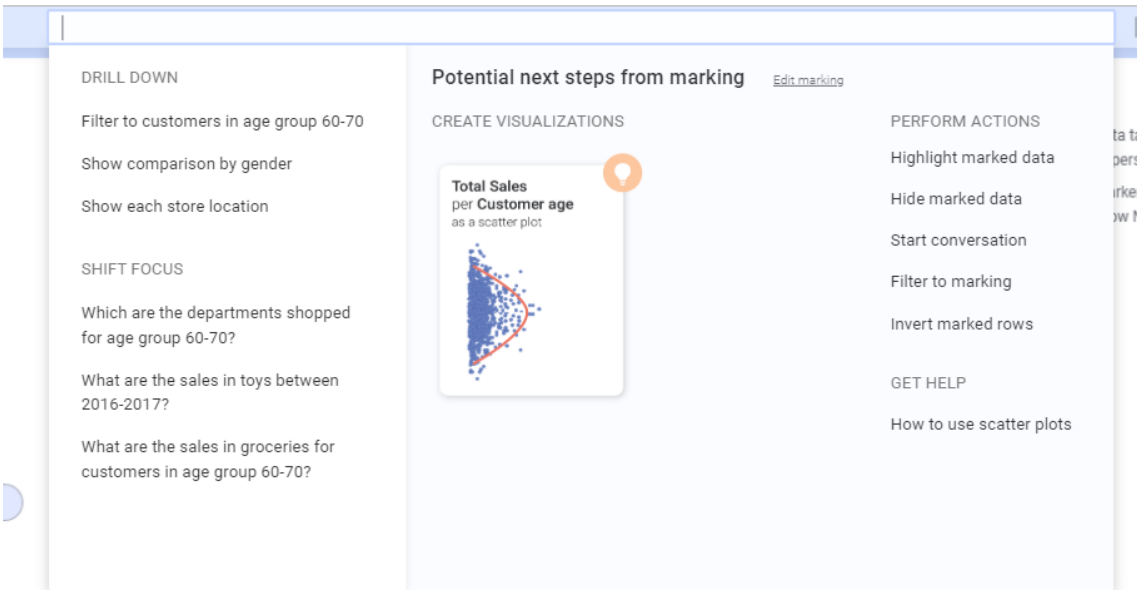


Figure 6.23: Recommendations of how to continue from a marked subset of data.

GUIDELINE 13:

Be transparent as to why specific results and recommendations are provided.

When presenting results and recommendations to the user, it should be clear what these are based upon. While it can be easier for a user to derive this in the case of receiving results based on a written query, it might be harder when the system presents results and recommendations that were not explicitly asked for. Hence, given that a system presents intelligent recommendations, having transparency as to why such results are suggested can be considered important, as providing the user with a result that is not expected presents the risk of having the result getting dismissed. When used properly, the user should be confident that the results provided by the system are valid, and understand the relevance that they might serve. In the example shown in Figure 6.24, the system has found an unexpected correlation that could be advantageous to explore, which is explained using a tooltip.

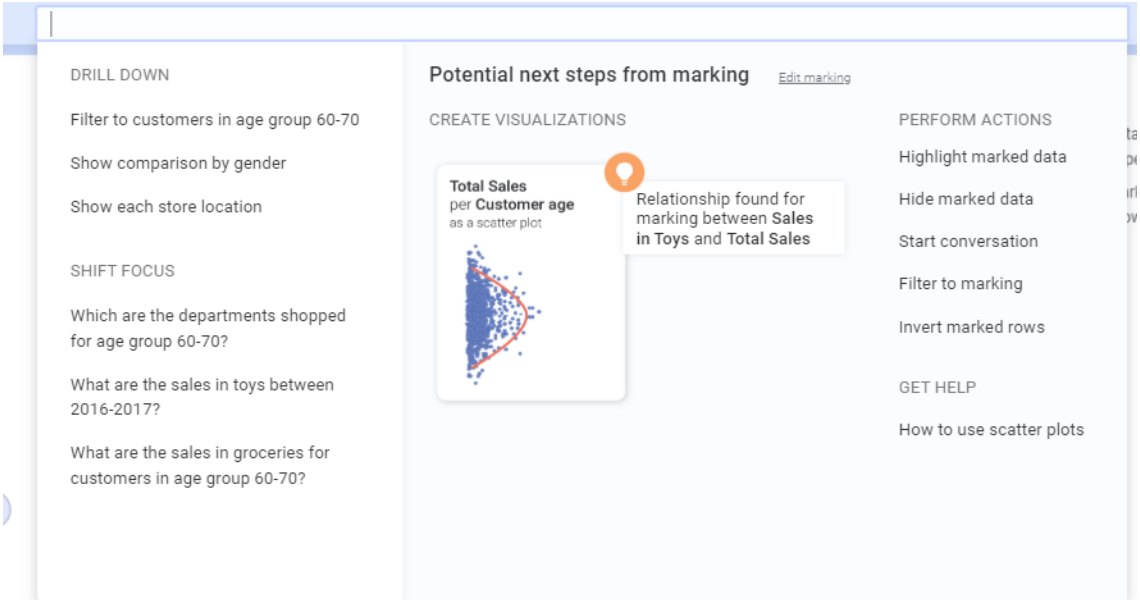


Figure 6.24: The tool tip provides information about why the visualization is recommended by the system.

7
Discussion

In this chapter, a discussion is held around the thesis, concerning its execution and process, its results, including the final design and the developed guidelines, as well as suggested future work.

7.1 Execution and Process Discussion

One factor worth discussing that most likely affected the outcome of the results, concerns that of how the usability tests were carried out. During these, the participants were more or less thrown into performing tasks with the prototype without any extensive introduction to neither analytics nor how to interact with the product or the prototype. This is of interest to discuss since this type of usage with analytical software in real-life cases can be considered unlikely. It can be presumed that the probability of inexperienced users not seeking information about a certain software or its purpose is rather low, particularly since users typically have a goal of what they want to achieve and have some knowledge of what data is being used. One of the benefits of letting the participants interact with the prototype without previous knowledge, however, was the ability to truly test how self-explanatory the design was, creating high demands on the usability of the prototype. Testing the prototype with this premise exposed the design for what can be considered a worst-case scenario, where the participants were almost forced to have a trial and error approach. Hence, it was evident that the participants' mental model of how to interact with a search system affected their interaction with the prototype. Since their expectations were more in line with what to expect from Google's search engine, it took some time for them to replace those expectations with what was appropriate for the search system at hand. It could be argued that more reliable results would have been gathered with the approach of giving the participants an introduction to analytics in general to put them in the right mind-set before the test. However, it was evident that the interaction with the prototype became easier during the test as the participants learned what to expect from the system, which could give an indication of the level of learnability in the system and the ability for users to grasp the concepts and interaction models introduced in the design.

Since the design was evaluated with inexperienced users of analytics, given predefined tasks, the focus was put on testing interaction flows rather than on how the design concept might support real-world analytical problems. For instance, the participants were asked to use certain features in the design rather than to explore whether the features introduced would be a natural way for them to approach the problem according to their mental model. It could, therefore, be argued that the validity of the design and guidelines is lacking due to the fact of not involving real users describing their needs. An attempt to work around this was to invite employees at the Company – with previous experience from analytics and the Product – as test participants, as well as to include experts within user experience and analytics in the process that could give an indication of which considerations that were of importance when applying search in analytics. Another difficulty with analytics is to find applicable test scenarios, particularly when the test participants are not true users of the Product. Validating against users with a genuine analytical problem, instead of creating a problem for the participants to solve, would probably give other insights since the test participants would not have to focus on understanding the problem. It can, therefore, be stated that a fair validation of the concepts and guidelines might only be possible to get once applying the search system in its natural environment.

7.2 Results Discussion

The following section discusses the results presented in the thesis, including both the design prototype and the developed guidelines.

7.2.1 Final Design

The thesis work strives to create an intelligent search system that supports the user in the analytical workflow, partly by giving system generated recommendations and insights based on the data. As a part of this, it has been tentatively explored how to suggest recommendations and actions based on previous steps. However, these ideas are still left quite open and further exploration is needed to understand which features and technologies that can be incorporated. How the design handles searching for actions and analytical functions should therefore be seen as a suggestion based on the limited knowledge acquired by the thesis owners, even if the idea behind it proved to be promising. Further, another feature in the design that was not fully perceived by the test participants was the communication of insights found by the system. The guideline regarding having transparency in the results argued for it to be of importance, and the design of the feature could need further refinement to be more prominent. The same applies for indicating which search scope the user is currently searching within. From the usability tests, approximately 50 per cent perceived this indication in the design, which implies that supplementary work would be needed.

Previously, it has been discussed how some test participants had problems in their first-time experience with the prototype, with their mental model of searching being conflicting to the intended use of the search system and some features being problematic to use initially. One could therefore possibly argue that the final design is not custom-made enough for the inexperienced user. However, while these problems arose initially, it could be seen during the tests that the design proved to have a good level of learnability, as test participants grasped the various concepts and ways of interacting during the short period of time that they spent time with the prototype. Although the target users were inexperienced users of analytics, not only the first-time experience can be considered to be of value in software where expertise might take significant time to build. With this said, there is still a need to examine if the design proves to be powerful once the user gets comfortable with using it.

To conclude, the prototype is a design concept, created to explore how search can be used in analytics, for the sake of constructing and evaluating guidelines. Implementing the prototype in the Product would require further exploration into technical aspects of the various features suggested, as well as a deeper understanding of the Product.

7.2.2 Guidelines

As a means of delivering an answer to the posed research question, guidelines were formulated and iterated during the course of the thesis, based on insights that were gained, mainly from evaluating the design prototype. The result was a set of guidelines that aims to take a rather broad perspective on how to apply search to support data exploration for new users of analytics, in order to produce considerations that can be generalized to other contexts. However, as the work followed a research through design approach, with a design concept being developed in parallel with the guidelines, based on which the guidelines were inspired. Hence, the direction of the project, as in what design was produced, undoubtedly has a strong influence on the focus of the design guidelines, as to what they pertain to and the resulting recommendations that they communicate. Therefore, it can be argued that some guidelines can be considered more easily applicable to a larger variety of design cases, whereas others mainly concern the design solutions that take a similar approach on search like the one taken in the thesis. For instance, some guidelines are dependent on the fact that the search system handles natural language queries in some way, or that the user has the possibility to search in different scopes. Further, the precondition that the Product has been used as the analytics tool upon which the design is built, among other surrounding factors, has also influenced various decisions throughout the course of the thesis, which might, in turn, have influenced which topics that have been explored. Hence, this set of guidelines should not be seen as covering all aspects of search in analytics, but rather as a foundation to build upon.

As a means of informing the guidelines, several types of evaluations have been made iteratively using the design prototype, in combination with a comprehensive literature study. Most of the guidelines are based on concepts that have support in the literature, which have been modified to be applicable to analytics. While some of the guidelines have apparent support from both literature and usability testing, others should be seen as more tentative in nature, with an indication of their relevance in analytics. Hence, further research should preferably be done to validate the findings.

To conclude, it is believed that the guidelines can work well as tentative design considerations for search in analytics and general enough to be applicable to a large range of cases. However, they should not be considered a full and final set, but further work is needed in evaluating them and possibly expanding the breadth of guidelines to cover other areas. In addition, several of the areas should preferably be explored in more detail to reach a higher level of specificity.

7.3 Future Work

As a design concept was developed that explored how to integrate search in the workflow of data analysis, a wide range of ideas was explored that helped form design guidelines relating to various topics. However, as the design was held on a conceptual level, the thesis project did not explore many of the various topics touched upon in detail. Hence, by exploring certain areas in detail, specific considerations could be formulated to support designers and developers of search systems in analytics. In addition to this, some topics were deliberately left out of the thesis to keep a manageable scope, which are still of relevance for search in analytics. Below follows suggestions for future work to be explored further.
While some previous research has been found on enabling the use of Natural Language to explore data, as described in Section 2.4, additional work is needed to explore the specific potentials and constraints of interacting with Natural Language in a workflow suggested in the design concept. Specifically, this concerns leveraging the potentials of natural language search with other types of interactions, such as specifying interest in data through marking as a point of reference when asking questions. Matters include investigating what intention can be derived based on marking and how ambiguity can be resolved by combining this with questions in natural language, something that is only touched upon in this thesis. Further, a more comprehensive study of what queries are of relevance when asking about marked data and how that can help users in their data analysis is also needed.

Another topic that could benefit from being explored further is related to that of *search as a piece of agentive technology*, described in section 2.6, as in how search can understand user intent to present relevant results and recommendations. While the topic was explored to some extent in the thesis, more investigation would be relevant into how to make use of data, such as session data and user data, to present more relevant and tailored results to users of search in analytics.

One delimitation set for the scope during the process was to not investigate how search can be used for data discovery, where the results only deal with searching as a way of finding data that is loaded into a user's analysis. As a final suggestion for future work however, it is deemed relevant to explore how search can be expanded into being used for the purpose of discovering data. This way, the user can not only distil and visualize the relevant data from a data set but also discover what data is relevant to examine.

8
Conclusion

The purpose of this thesis has been to explore how search functionality can be applied as a tool in analytic software in order to effectively support the analysis of data, aiming to answer the following research question:

What should be considered when designing a search function in order to give its users a powerful advantage in their analytic process?

The work included investigating when and how search can be used as a tool in the analytic workflow, as well as how to present and use results to speed up the time to insight. In the outset of the project, the scope was narrowed down to predominantly consider how search can be used to support inexperienced users of analytics. To answer the research question, the thesis work followed a research through design approach. This implied building upon previous knowledge within the subject of search in general and its application in data analysis, in order to prototype design solutions and analyze the design with target users. Through this approach, the thesis aimed to contribute with theoretical knowledge and insights gained through design practice, with the findings from these explorations being communicated in a set of guidelines that were formed and iterated during the project.

To lay a foundation for the guidelines and the upcoming design work, a literature study was conducted on the topic that identified relevant concepts for search systems, upon which an initial set of guidelines was formed. In addition, existing solutions for search in analytics were examined and analyzed in order to identify current practices and conventions in the industry. To further understand the context of analytics and its requirements for search, interviews were conducted with internal stakeholders at the Company together with usability tests on the current solution for search in the Product. To be able to develop and examine which guidelines were relevant for designing search in analytics, practical design work was carried out by following an iterative process of three design iterations. During the first iteration, a number of concepts were generated that presented different approaches for search in analytics. These were evaluated using the identified guidelines based on literature, as well as with the viewpoints of experts in analytics. For the upcoming two design iterations, the most promising concept was elaborated and refined by first producing a low-fidelity prototype that evolved into a high-fidelity prototype. Both prototypes were evaluated by conducting usability tests with users from the target group. For each design iteration, insights were gathered to help the construction of a final set of guidelines. During the design process, guidelines were added, removed or reformulated, which finally produced a refined set of guidelines adapted for the design of search systems in analytics.

The design serves as a concept for a search system in analytics that aims to support inexperienced users in exploring data by enabling the use of natural language to communicate intent at different stages in the analytic process. The search system also aims to facilitate questions about the visualized data in an analysis by allowing the use of search in combination with existing interactive tools such as marking to specify points of interest. In addition, the concept includes using available knowledge about a user and its activities to understand intent and provide relevant results and recommendations that can speed up time to answer or help the user discover relevant insights.

The final set of guidelines, divided into three focus areas, are the following:

Supporting an Analytic Workflow:

- Allow the user to construct questions incrementally by building upon previously made visualizations.
- Provide suggestions to the user in how to continue in the analytic process.
- Provide insight to the user in what data is available and the possibilities to interact with it.
- Allow the user to have a flexible search scope by pointing towards a subset of data.
- Clearly indicate to the user what scope is searched within.

Natural Language Interaction:

- Indicate the search system's capabilities and constraints as to how one should interact in order to be correctly interpreted by the system.
- Allow the user to construct queries in natural language using less technical vocabulary.
- Confirm and correct the user's input in order to create an understanding of the system's interpretation.
- In cases where ambiguities exist in a query that the system cannot resolve, enable the user to specify intent through interaction.
- Allow users to access analytical functions in the system through natural language.

Providing Results:

- Provide the user with the possibility to move fluidly between constructing a query and previewing results, to let the user examine its type and evaluate its analytical relevance.
- Consider having the system use contextual information to interpret user intention and provide best guesses on desired results.
- Be transparent as to why specific results and recommendations are provided.

The guidelines are believed to work well as tentative design considerations for search in analytics but should not be considered a full and final set. Further work is needed in evaluating the guidelines in other contexts and possibly expanding them to cover other areas that were not explored in detail or were left out of the scope.

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Appendices

Disclamer: The following Appendices are compiled and put together in order to provide the reader with detailed information about certain steps. However, the Appendices concerning the usability tests (Appendix C to Appendix E) are in Swedish due to testing with Swedish participants.

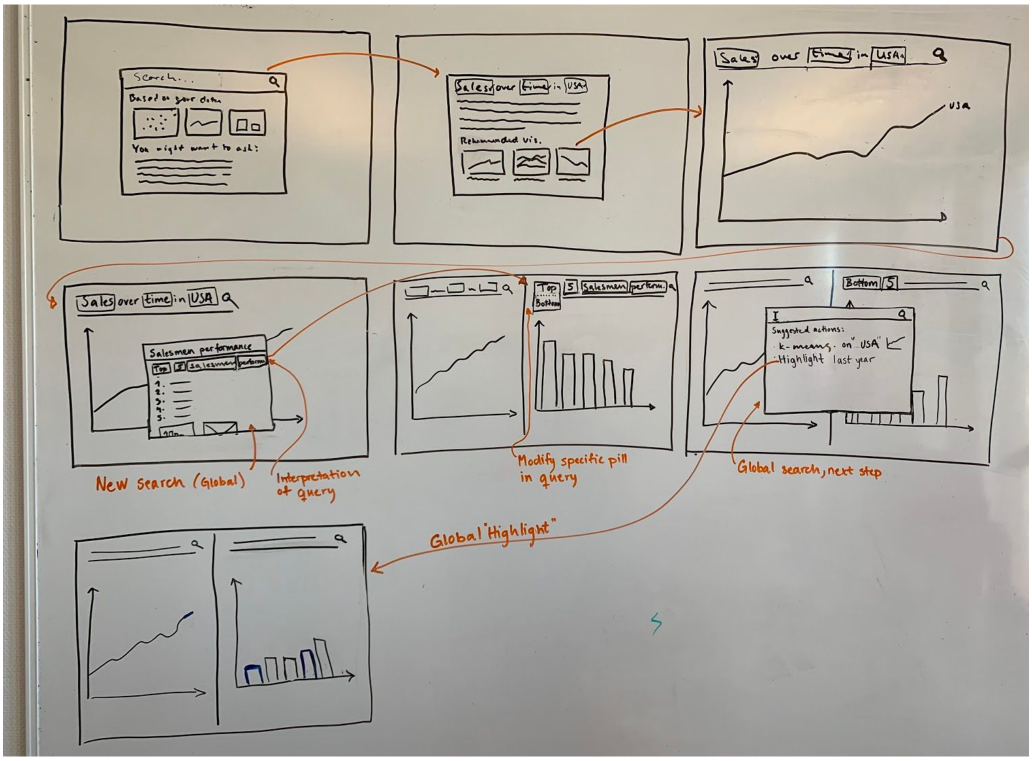
Appendix A - Concept Evaluation

Concept 1: Global to dynamic update

Create new visualizations from a global search. Global search: Targets the whole analysis. Can potentially be located somewhere else. “Global” actions can also be made from the global search. Takes all plots into account when recommending new actions and visualisations. Dynamic update of queries as you manipulate a plot. Corresponds to the state of the plot. Potential for each plot to be “search driven”.

Why:

- Allows incremental construction(one query for each plot)
- Exploratory search
- Iterate between **finding** - **learning** - **asking**
- Support switching seamlessly between modes
- Possibility for contextual questions/recommendations/insights
- Global search can use contextual information of the whole session. Faceted search has knowledge of the specific plot.



Considerations:

Global vs. local action search

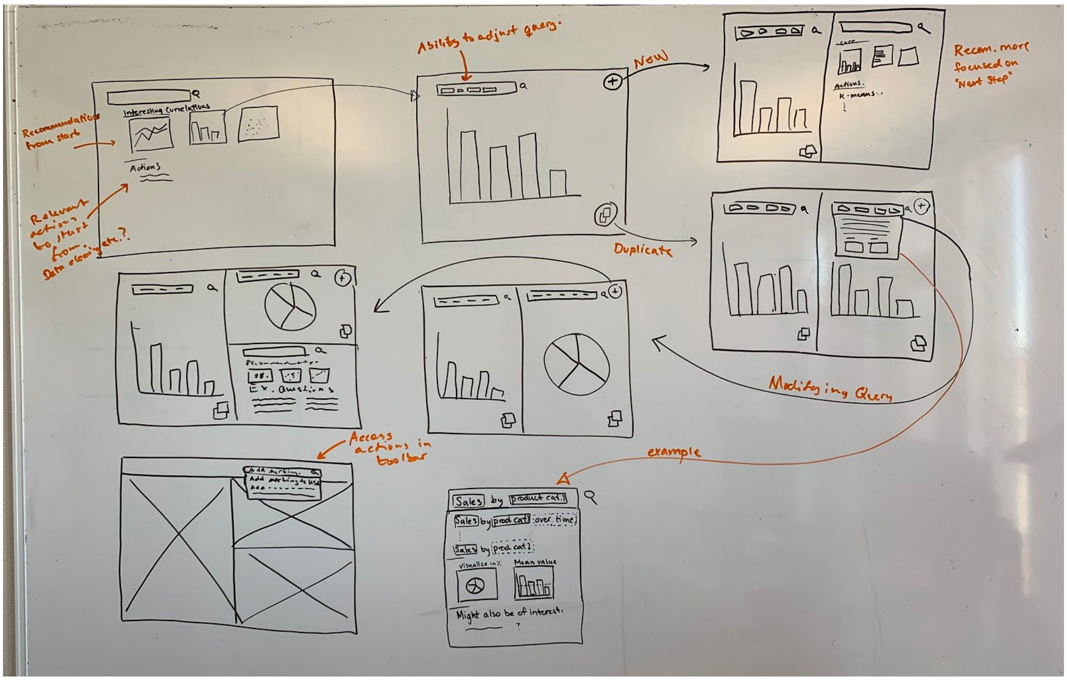
- Global action search can give a suitable next step if the user does not know exactly what to do next.
- Global search could potentially analyze based on the plots at hand (don't know exactly what this could be)
- Local action search could suggest based on the current plot and its data and what actions are relevant to perform.
- Global actions can do things across several plots, like marking. Have to investigate how many actions this is relevant for

Concept 2: Duplicate and make changes

Start from empty dashboard, except from recommendations based on your data. No global search where you can create visualizations. Create new visualizations by duplicate (*not yet fully decided how, see considerations*) existing ones or click + sign. Move global action search to toolbar. Can perform certain actions through natural language. Dynamic update.

Why:

- Allows incremental construction(one query for each plot)
- Exploratory search
- Iterate between **finding** - **learning** - **asking**
- Support switching seamlessly between modes
- Possibility for contextual questions/recommendations/insights
- Different interaction model than last concept: A rather neat model that the query is not pasted into the page after the global search, but stays in the same place. This might make it easier to understand that the same query can be manipulated again and hence support incremental construction.
- Duplicate and modify **might** be a useful interaction pattern, but we don't really know.



Considerations:

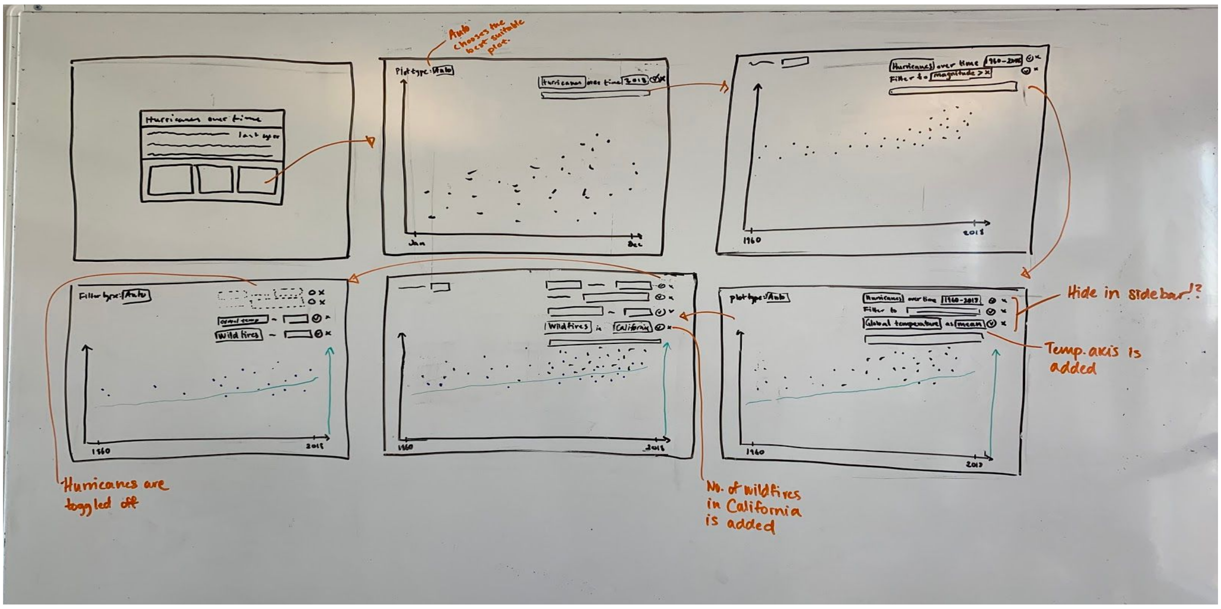
- Window size will change depending on when you create a new visualization and how much space is left
- Will the user be interested in “next step” or “analysing input” when creating a new visualization?
- What is the mental model of the user of how the duplication should be made?
- Two different types of “next step” - one global and one local?
- The ability to access tools through global search (as previous) is not possible in this concept → will have its own search field
- What about library/other sources of data?
- Maybe the user does not know beforehand if a new visualisation should be made in the next step, if the current should be modified or an action performed.

Concept 3: Queries as layers

The plot is dynamically updated by the query written in the local search field. Queries are transformed into layers which can be toggled off. New queries can be added to make updates or actions in the existing plot. The layers might be hidden in a sidebar or similar.

Why:

- Allows incremental construction (one query for each plot)
- Exploratory search (i.e. the toggle option)
- Iterate between **finding** - **learning** - **asking**
- Support switching seamlessly between modes
- Possibility for contextual questions/recommendations/insights
- Ability to breakdown complexity into more manageable parts
- Ability to toggle query layers
- Speed up the search process. Don’t need to state the same queries over and over.



Considerations:

- There will be pills or dimensions that change the whole plot. Like if the x-axis is a time scale that is specified “first layer”, is will determine the look of the whole plot(you don’t have to specify the time for the other plots). However, there might be layers that adds a new axis, being independent of all the other layers. Regardless, you should not be able to have conflicting layers, like two time scales.

Concept 4: Lasso principle

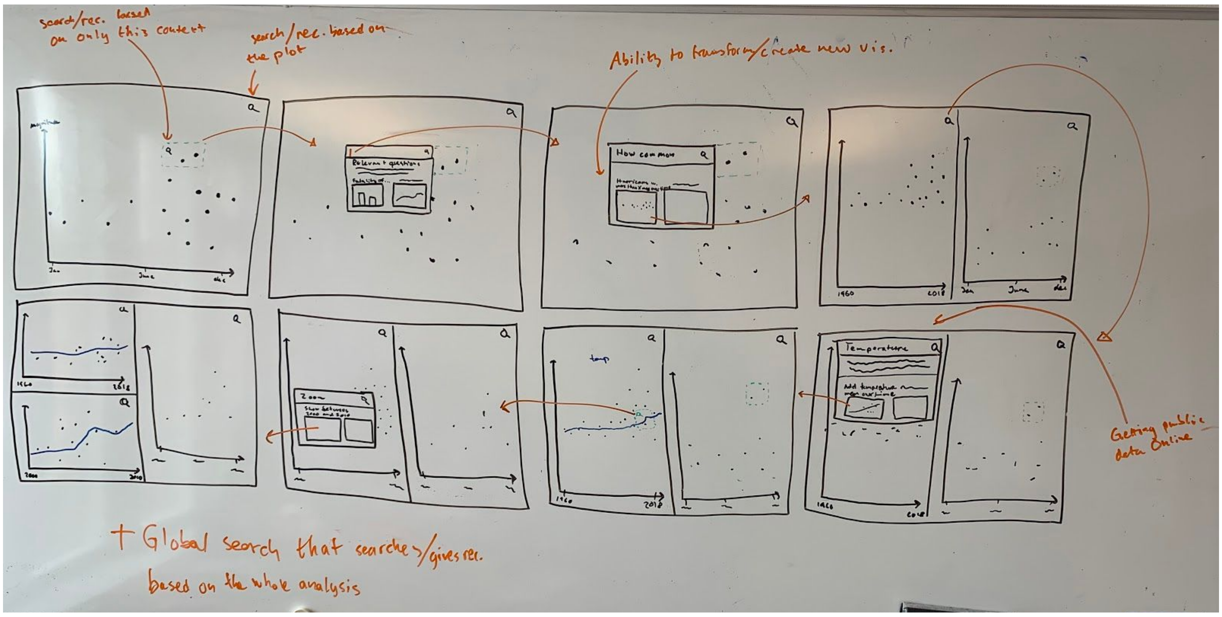
Create new visualizations and make global actions from global search. Flexible search scope where you can search in one visualization or ask questions about parts of a visualization by marking using a lasso tool.

Why:

- Ability to delve deeper into specific data points with pin-pointed questions.
- Exploratory search (the ability to mark specific data points)
- Easy to create new visualisations on a subset.
- Iterate between **finding** - **learning** - **asking**
- Possibility for contextual questions/recommendations/insights
- Might be a nice combination of searching and navigating by combining the modes
- Allows different types of questions than if you build on and modify a query. Like Why-questions
- Faceted navigation and progressive disclosure. Ability to breakdown complexity into more manageable parts.

Considerations:

- Will recommendations from "lasso search" be added as a new visualization or modify the existing one?
- Three different places for search input might be unnecessary. Semi-local search could be included in the global search or vice versa



Concept 5: Chatbot

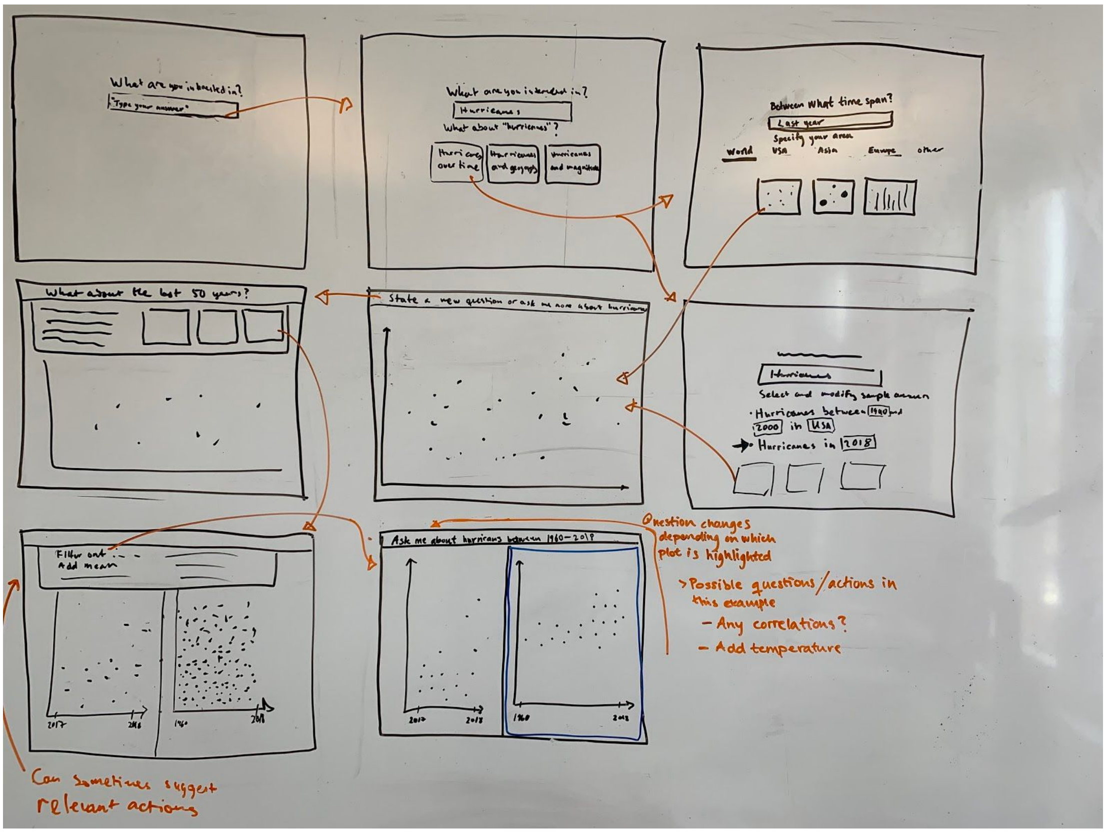
A chatbot helps the searcher forward by stating follow-up questions and present alternatives. Easy to start and narrow down into the relevant possible questions to get more tailored recommendations. Focus: Conversational UI

Why:

- Guides the user through the analytic process. Very suitable for beginners.
- Start from the goal. Support task based asking by going into different modes based on the data.
- Possibility to ask a wide range of followup questions from a “blank” search bar.
- Iterate between **finding - learning - asking**
- Possibility for contextual questions/recommendations/insights

Considerations:

- Where and when should there be follow-up questions?
- Might be a bit cumbersome and a lot of steps.
- Where should the “chatbot” be located?

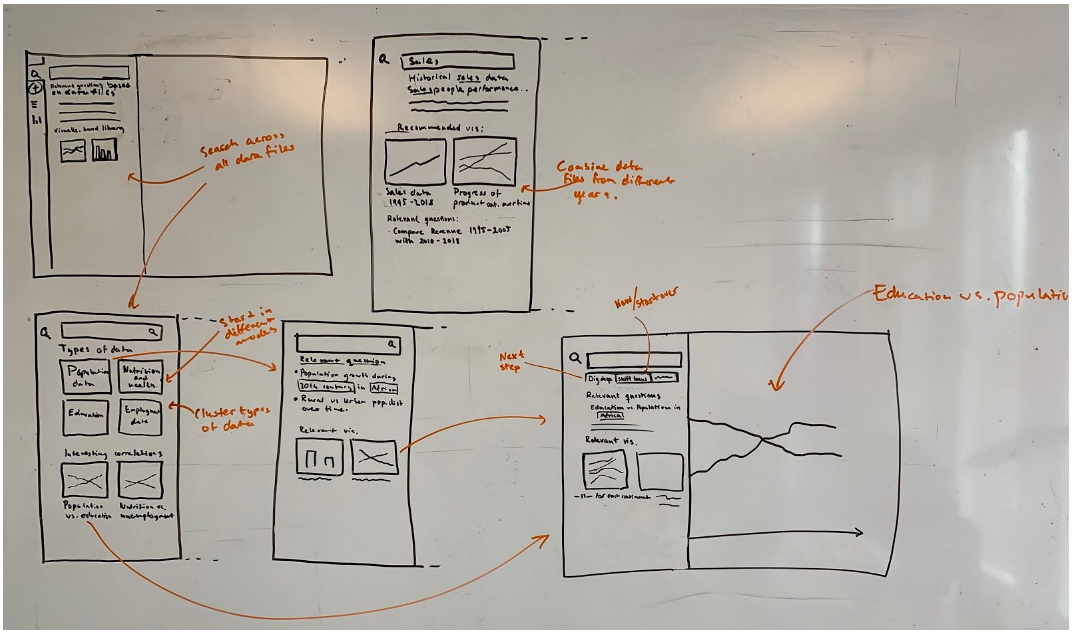


Concept 6: Search the Universe

Have the possibility to reach files within library. A bit more futuristic. What could be possible if you could search and give recommendations from more stuff. Recommendations, next step-suggestions and analysing input is dependant on the library files as well. Search is located in the flyout. How could search allow to be expanded into this behaviour in the future?

Why:

- One area for all search input
- Start from the goal.
- Give recommendations “one step ahead” before even choosing the data. Combining data sources.
- Search within “themes”. Data from different data files (in the library) is clustered together



Appendix B - Post design critique

What to bring forward

- The idea of representing a visualization through a query should if possible be in the final concept (concept 1, 2, 3). This supports incremental construction (*from guidelines 1.0*) of queries and exploration as the user can go back and modify based on the feedback given by the system.
- Representing entities that can be changed as pills might be a good idea, giving affordance for manipulation.
- Support unifying modes of discovery. Going back and forth between navigation and search.
- Highlight “duplicate” might be a good idea to support those use cases (concept 2)
- Do not divide “action search” from “creating new visualizations”. It decreases the discoverability of certain possibilities. The user is not always certain of the best suited next step, whether it is actions or visualizations/answers. Therefore, the user should not have to explore two separate search functions. Supporting the goal. Task focused? (*from guidelines 1.0*)
- What if the query had a visual and a hidden part, where the hidden part contains more detailed information. This could be displayed under a detail view. (concept 3)
- Layers can potentially support complex queries and break down complexity into more manageable chunks. However, we should not make this too complex. Then it will not become search anymore but more a panel for properties. In order to cater to the new user, this might not be of highest priority. Maybe it is better to show a simplified view. (Concept 3)
- Have the ability to pin-point your search scope. Be able to delve deeper into specific data points, data space or a more narrow context (Concept 4). Allows for faceted navigation and progressive disclosure. Ability to breakdown complexity into more manageable parts.
- We should think about whether the user is interested in the data points specifically or how they relate to its context/data space. What should recommendations be about?
- Contextual suggestions in the search bar that is changing depending on marking.
- Look more into the use of counter questions with follow-up answers (concept 5), confirm input etc. If there is information missing from the user input, this could be a good way of not leaving the user with no answer, but asking for more information.
- Different modes might be interesting when stating follow-up questions (concept 6). Present options for possible directions based on a context such as drill down, relax and shift.
- Search to reach library is something to keep in mind for future possibilities. However, it is not part of the scope now.

Universal insights

- Who is search for? Make decisions based on the target user
- Find a value with creating visualizations
- How can we present what is possible get answers for in a visualization. Maybe the user cannot see the answer just by looking. Not always next step as in a new visualization.
- What is the best/most suitable way of expressing “next step”
- Delve deeper into: Which qualities enlights the different concepts?
- Our concepts offer solutions based on what Spotfire knows about the user and her data set. *It is a good thing!*
- More natural questions than UI-choices
- Balance in how to convey what has been understood, “keeping the magic” vs. keeping natural language when you give feedback. Also, when you recast to the user and when the query is representing the plot, you also want to balance how powerful it is and how simple it is. What should be shown in terms of dimensions, axises etc? Should you transform the query that was originally written to something better/more efficient/more complex? This might also defeat the purpose that is being able to go back and change the query.
- We have to be aware of how easy it is to forget that we are designing for search and for users that are new to analytics. It’s easy to fall into solutions solving complexity and effectiveness

Concept 1

- A lot of positive feedback
- Is the user interested in the search result in itself, or the next step?
    - “Show top 5” - What is relevant to build upon?
    - What do you want to bring with you into the next step?
    - How to handle complexity?
    - What happens when you add more to the visualization?
    - How will the query develop?
    - Can it transform into something more representative rather than stating each action that has been made → reformulate?
    - Can you add other meanings, truncate the text
- Everything can possibly be expressed in query form
    - All calculations and actions could be described
    - How complicated should we do it?
    - Are we making it easier for the beginner user? Find the balance!

Concept 2

- Duplicate might be of greater importance than it is today

- We prefer to not have the product totally search driven. [Don't want to limit the possibility to access actions.]
- Will the user understand the difference between the different search bars
  - Better to keep it to one! (Gustaf)
- Problematic to know the difference of the search bars if there are several and with different meaning.
- We should think about the scenarios when users are looking for values. [Might be problematic if action search is more hidden]

Concept 3

- This means "Less magic, more syntax"
  - How should the query be represented?
  - When should it not be represented? I.e. filters, do they need to be visualised in the query?
  - Find the balance between what to show and what not
- Is there a value in re-formulate the query into natural language (by the computer or the user), but still keep the option of seeing the technical syntax? I.e. when clicking on it
- The concept with the types of queries looks like made for quite advanced users (robot language).
- Can potentially support complex queries and break down complexity into more manageable chunks.
- We should not make this too complex. Then it will not become search anymore but more a panel for properties. In order to cater to the new user, this might not be of highest priority. Maybe it is better to show a simplified view.
- What if the query had a visual and a hidden part, where the hidden part contains more detailed information. This could be displayed under a detail view.

Concept 4

- A lot of positive feedback. Would support a lot of use cases.
- Can be combined with concept 1.
- Difficulties with knowing from which angle the question is asked from
  - Are you interested in the data points specifically or how they relate to its context
  - Recommendations should include all aspects/angles
- Searching on different components specifically. This is interesting. Everything does not have to do with the whole plot surface. Either you want to search for something that is specific to the data points, like having the same dimensions. Or, you want to search the data space rather than properties of specific points. Depending on how you mark, you might be able to derive intention from the user. E.g. marking one point could indicate that the dimensions/data of that point is interesting, whereas marking a range on an axis could indicate that the data space is more important.

Concept 5

- Takeaways: Look more into the use of follow-up questions, confirm input etc.
- May not work as well as a concept on its own but could be combined with other concepts.
- They liked the “contextual sample question” that is changing depending on marking.

Concept 6

- Could also work from the pop-up search.
- Might be very useful, like adding data that is missing.
- Companies have a library with files they have used that we could use.

Appendix C - Scenario and Questionnaire Usability Test (low-fidelity)

Data: Säljdata
Användare: Relativ nybörjare inom analytics
Mål: Testa förstagångsupplevelsen (first time experience) av Spotfire

Målet med testet är att undersöka ett koncept för ett sökverktyg i en analytics produkt. Detaljgraden är just nu skissartad och vi vill se hur konceptet uppfattas i en förstagångsinteraktion, om de olika delarna av konceptet har potential för att hjälpa en ny användare av analytics osv. Vi ska gå igenom fiktiva scenarion, där tanken är att vi ska ha en diskussion av hur du uppfattar det du ser, vad du skulle vilja göra osv. Att uttrycka detta verbalt är viktigt eftersom att du inte kommer ges så mycket frihet att interagera med prototypen.

Du jobbar på en amerikansk varuhuskedja som säljer teknikprylar, elektronik, vitvaror och liknande. Din roll på företaget innebär delvis att du undersöker siffror och lägger fram beslutsunderlag för strategiska förändringar i företaget. Detta har ofta skett genom att använda excel, där du kan sammanställa data och skapa enklare visualiseringar. Detta är dock väldigt tidskrävande, och i takt med att företaget har valt att satsa mer på datadrivna beslut så har man valt att ta in en mer dedikerad analytics-produkt. Analytics-produkten är ny för företaget och analytics är ganska nytt generellt för ditt företag. Därför är det inte direkt någon som du kan fråga om hur programmet funkar. Du här därför ingen aning om hur man på bästa sätt använder sig av programvaran och eftersom att detta bara är en liten del av dina arbetsuppgifter har du inte heller tid med inlärningsmaterial osv. Du tittar på en snabb introduktionsvideo och dyker sedan rakt in i produkten för att testa dig fram.

Som en början hade du tänkt att undersöka säljsiffror för att eventuellt se anledningar till vad som är bra eller vad som bör förändras. Du har däremot ingen tydlig bild av vad man bör titta noggrannare på utan detta är en del av analysen. Du vill därför börja med att undersöka hur vinsten har gått det senaste året för de olika regionerna.

1. Om du utgår från sökfältet, hur hade du velat börja? Utan att ha klickat i fältet än, hur skulle du vilja formulera din fråga?
   (Klickar i sökfältet)
2. Utifrån det du ser nu, hur hade du velat formulera dig? Förklara hur du tänker.
3. För testets skull säger vi att du har en färdig fråga i huvudet som du ska formulera (Ger dem en query som ska skrivas - *“What were the profits last year for different regions?”*)
4. Så om vi börjar med att skriva *“What were the ”,* hur tolkar du det du ser när du börjar skriva?

5. Vad hade du velat göra nu? (Fortsätta skriva/ välja ett alternativ)
   (Fortsätter skriva - “What were the profits“)
6. Hur tolkar du det du ser nu? (Finns nu ambiguity widgets)
7. Vad hade du velat göra nu? (Fortsätta skriva/ välja ett alternativ)
   (Skriver klart frågan)
   Hur vill du göra för att komma vidare?

1. Nu ska du lägga till ytterligare en visualisering för att ta reda på hur det har gått tidigare år - Hur hade du gått tillväga?
   (“Show over time” skrivs i sökfältet - ingen tolkning visas eftersom ingen visualisering är markerad. Dock visas “Show profits over time for all regions” som en suggestion, vilket tolkas som “profits in 2000-2018 per region”)
2. (Utför detta åt dem) Du vill egentligen bara ha för de senaste tio åren. Hur skulle du gå tillväga?
   (Ändrar via Ambiguity widgets och får upp rekommendationer på visualiseringar)

1. Du ser att försäljningen i Kalifornien har gått ner~~ och du undrar vad det kan bero på~~. Du undrar om det är någon skillnad på hur de olika affärerna har presterat. Hur skulle du vilja göra för att ta dig för att ta dig vidare härifrån? (Markerar området kring linjen)
2. Hur tänker du att du går vidare nu?
   (Klickar i sökfältet, får upp rekommendationer och exempelfrågor)
3. Vad skulle du göra som nästa steg om du vill ta reda på hur det gått för varje affär?
4. Av visualiseringen att döma kan du se att vinsten för framförallt en affär i Kalifornien har sjunkit drastiskt.

1. Du vill jämföra de olika affärerna i Kalifornien och se vad som eventuellt skiljer dem åt, hur skulle du då i så fall göra? (Om man inte fattar) Om jag säger att man kan markera en plot och fråga om den specifikt.
   (Klickar i sökfältet. Rekommendation på kartvy visas - “Outlier spotted for shipping distance - Create map chart with shipping routes”)
2. Hur skulle du vilja gå vidare härifrån?
   (Om man inte hittar det - “Varför tror du att du inte valde detta alternativet?”. Om man hittar det - “Hur kommer det sig att du vill välja detta?”)
3. (Klickar på kartvyn)
4. Genom kartvyn så ser du att den affären som har minskat i vinst även fraktar onödigt långt bort ifrån.

Frågor efter testet **Datum:__________**

1. Under testets gång, hur upplevde du att interaktionen med sökverktyget var?

Mycket svårt		Varken eller		Mycket enkelt
1	**2**	**3**	**4**	**5**

2. I början av testet, hur upplevde du att det var att formulera din fråga för att besvara din frågeställning?

Mycket svårt		Varken eller		Mycket enkelt
1	**2**	**3**	**4**	**5**

3. Hur upplevde du att detta förändrades under testets gång?

Mycket svårare		Oförändrat		Mycket enklare
1	**2**	**3**	**4**	**5**

4. Hur stor hjälp upplevde du att du hade av rekommendationerna(tips på frågor och visualiseringar)?

Ingen hjälp		Varken eller		Mycket hjälp
1	**2**	**3**	**4**	**5**

5. Fanns det något du tyckte var otydligt?

   ____

   ____

   ____

6. Har du några förslag på förbättringar?

   ____

   ____

   ____

7. (Om detta inte framkommit) La du märke till att texten i sökfältet förändrades beroende på vad som var markerat i analysen?

   Ja **Nej**

Appendix D - Findings from Usability Test (low-fidelity)

1.Under testets gång, hur upplevde du att interaktionen med sökverktyget var?
(1:Mycket svårt - 3:Varken eller - 5:Mycket enkelt)
2.I början av testet, hur upplevde du att det var att formulera din fråga för att besvara din frågeställning? *(1:Mycket svårt - 3:Varken eller - 5:Mycket enkelt)*
3.Hur upplevde du att detta förändrades under testets gång?
(1:Mycket svårare - 3:Oförändrat - 5:Mycket enklare)
4.Hur stor hjälp upplevde du att du hade av rekommendationerna(tips på frågor och visualiseringar)? *(1:Ingen hjälp - 3:Varken eller - 5:Mycket hjälp)*
[5, 6]
7.(Om detta inte framkommit) La du märke till att texten i sökfältet förändrades beroende på vad som var markerat i analysen? *(Ja/Nej)*

Fråga	Pilot	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
1	3,5 - 4	2	4	4	5	3	4
2	4	4	2	2	4	4	4
3	5	2	4	5	4	2 (4)	3
4	4	3	4	5	4	4	4
7	Ja *(efter att Nils sa det)*	Ja	Ja *(men ej super-tydligt)*	Ja	Ja	Ja	Ja

5.Fanns det något du tyckte var otydligt?

1. Vad var Actions? Det tog ett tag innan jag fattade vad Suggestions representerade.
2. Sökbarens scope & Recommendations
3. Hur mitt-kolumnen fungerade. Den skiftade mellan att visa visualiseringsförslag till att ge rekommendationer. Call-to-action efter att ha genomfört sök och fått fram visualisering.
4. Om jag byter ut eller lägger till en ny visualisering.
5. Just what functionality it had. But it was good at leading me via the recommendations and suggested visualizations.
6. De första rekommendationerna kändes väldigt stökiga. Många intryck att ta in. Korrelationen mellan inputfält, t.ex. år, och det man faktiskt sökte på.
7. Drill-down kunde vara tydligare med avseende på sökfältsplaceringen

6.Förslag på förbättringar?

1. Vissa grafgrejer var inte supertydliga. Hur data delades upp, kontra vad axlarna representerade kunde ha gjorts med tydligt uppmärkta.
2. Visa scope & visa tydligt att det finns recommendations.
3. Snabbåtkomst till att förändra vals visualisering. Gå från bar- till line chart istället, byta x-axel etc. Tydligare koppla markering till sök (kanske blir tydligare med färger i hi-fi prototyp)
4. Kanske ytterligare hjälptext i rutan utan resultat.
5. Link to "Show me" information page or example
6. Svårt att säga eftersom det bara är en mock-up
7. Drill-down kunde vara tydligare med avseende på sökfältsplaceringen

Pilottest

Saker vi förändrade innan nästa test:
Vissa enklare och mindre förändringar. Ändra till rubriker så att det ska vara enklare att se vad som är resultat och inte. Står nu "Recommended starting points", "Recommended next steps", samt "Visualizations" beroende på vilket steg man är i. Kan behöva göras enklare, men detta var en snabb och enkel förbättring. Vi lade till ett par extra screens för att göra det tydligare att man börjar söka och hur resultaten/rekommendationerna förändras. Vi ändrade även den interaktiva prototypen i Balsamiq så att alla figurer följde med. Vi tog bort drop down-menyer i visualiseringen då detta drog uppmärksamhet och skapade förvirring.

Test at the Company

Saker vi förändrade innan nästa test:
Vi förändrade scenariot lite, framförallt för att korta ner testet. Uppgift 2 "snabbspolar" vi förbi lite genom att vi visar mer vad som händer och så får dem reagera på det. Har även strukit vissa avsnitt där användaren ska fundera själv inför nästa steg. Detta gjordes främst då vi ansåg att användaren från the Company har en större grundkunskap inom programmet och analytics att det inte är lika kritiskt vad dem tänker är ett lämpligt nästa steg.

Key Findings (analysis)

(Query) Suggestions:

- Det varierar hur användarna tänker sig att de ska formulera sina frågor innan man ser query suggestions. Någon tänkte att man ska söka på en term till att börja med, andra var färgade av att söka i databaser. Några hade klarat av att formulera en fråga utan suggestions medan det hade varit svårt för andra. De med erfarenhet av analytics var mer rätt ute.
- Positiv respons från flera testanvändare i att det hjälper användaren att formulera sin fråga. I princip alla uppskattade att få hjälp med detta.
- Användarna verkar generellt sätt lära sig språket som ska användas för att formulera sin fråga i och med att de får interagera mer. Detta understryks av att många tyckte att det blev lättare över tid.
- Det påtalades av flera att det var bra att få en inblick i vilken data som fanns.
- Några användare uttryckte osäkerhet i vad man sökte i för scope, vad suggestions var baserade på(om man fortsatte med en session eller började om på nytt). Detta kan behöva förtydligas, exempelvis genom att indikera om användaren går djupare/tar ett annat fokus.

Next step/recommendations

- Transparency issue
    - Måste vara mer tydliga med hur systemet kommer fram till sina svar och varför de visas. Är man inte beredd på att få en viss rekommendation kan den riskera att avfärdas om man inte presenterar den tydligt.
- Många verkade inte förstå innebörden av de olika rekommendationerna som gavs i början av en sökning, vad för resultat som kan komma upp och varför/vad de baseras på.

Resultatvyn

- Information overload
    - Flera uttalade att det blir något av en overload med information vid första anblick och att det var svårt att veta var de skulle börja för att hitta vad de sökte.
- Det var uttalat av ett par testanvändare att layouten inte var helt förstådd, vad de olika delarna innebar osv. En trodde att man skulle göra något i tre olika steg exempelvis.
- Searching for/Recast
    - Generellt sett var recast och ambiguity widgets något som användarna interagerade med på ett naturligt sätt. Det var ett par testanvändare som tyckte att det inte var optimalt med att ha två ställen för input och inte riktigt fattade poängen med detta sätt att interagera.
    - Placera tillsammans med visualiseringarna. Uppstod viss förvirring kring hur detta hör ihop med resultaten, speciellt i början när man skrev. Det upplevdes av någon testperson som att det var i vägen för suggestions och att den inte hörde ihop med dessa.

    - Byta namn?
    - En användare hade hellre kunnat ändra i recasten snarare än att gå tillbaka till queryn som var mer "luddig"
- Actions
    - Denna var inte så väl undersökt i testet men var generellt mest förvirrande. Många reagerade på att de inte förstod innebörden av actions. Om man ska ha kvar det som rubrik är det nog bäst att omformulera sig.
    - Byta namn/alternativt ta bort från resultatvyn?
- Många förstod inte direkt att man lade till visualiseringar och inte modifierade. Dock visade det sig snarare komma som en positiv överraskning och inte en negativ
- En användare uttryckte att man skulle vilja gå tillbaka när man skapat något, om man kan ändra detaljer såsom år. Kan kopplas till incremental construction-guidelinen.
- "No results" borde kanske bytas ut till något mer förklarande, svårt att veta vad dock då anledningen kan variera. Också kopplat till *Transparency*

Layout

- Layouten på sökfältet(rundat), språket som används för att beskriva sökningen(sökfunktion), ikonen(förstoringsglas) bidrar i kombination till att användaren har vissa förväntningar på hur det ska fungera, något som observerades i flera test. Dessa faktorer bidrog till att användarna hade förväntningar som påverkats av hur mer traditionella sökverktyg fungerar. Detta skapade en krock mellan förväntningar och verklig funktionalitet.
- Assistent vs sökfunktion
    - En användare refererade sökfunktionen till att vara mer av en assistent, att hen förde ett samtal snarare än sökte, vilket är mer vad vi strävar mot. Genom att referera till det som en assistent snarare än ett sökverktyg kan användaren gå in med uppfattningen om att programmet är mer kompetent än vanligtvis. Detta är dock riskfyllt då det sätter större krav på att programmet/sökfunktionen kan hantera uppgifter och kommandon av en högre svårighetsgrad. Måste hitta balansen.

Markering

- Flera av användarna uttryckte vilja att markera data, framförallt genom att markera en linje(Kalifornien) för att ställa en fråga om den datan. Detta indikerar att markering i kombination med sökning kan vara en naturlig interaktion som kan uppfattas vara intuitiv.
- Visuell feedback
    - Även om de flesta testanvändare uppfattade att hinten i sökfältet ändrades behövs eventuellt ännu större visuell tydlighet mellan markering och sökfält. Det är viktigt att användaren förstår att sökfältet ändrar sitt scope i samband med vad som är markerat. Att man kan dyka djupare samtidigt som man kan "zooma ut" (query relaxation).
    - Viktigt med visuell feedback av **vad** som har markerats och hur detta eventuellt förändras. Detta gäller bland annat när man skriver i sökfältet/ändrar i widgets etc.

- “Ta med sig” scoopet
    - Flera användare uttryckte förvirring i om man tog med scoopet in i sökfältet eller inte. Detta var inte representerat tydligt nog i prototypen.
- Dynamisk uppdaterad markering
    - Markeringen och texten bör vara sammankopplade och uppdateras dynamiskt, förändras en av dem ska den andra också förändras. Hänger till viss del ihop med transparency eftersom det hjälper användaren att förstå att scoopet förändras och hur programmet tolkar de ändringar man gör.

Takeaways till nästa fas

- Förändra och göra det tydligare hur man tar med sig scoopet i en sökning.
- Ändra visuella layouten på resultatvyn
    - Hur skiljer sig “vanliga” resultat med rekommendationer av systemet?
    - Skala ner/bort startvyn - tooooo much info
    - Förbättra terminologin
    - Flytta recasten och koppla tydligare till resultat.
    - Dela i suggestions i kategorier (göra det tydligt när man byter fokus eller drillar down etc.)
- Ändra visuella layouten (form, ikon, benämning) av sökfältet från prototypen.
- Visuell tydlighet för att koppla ihop sökfältet med markeringen
- Visa mer informativ text när man inte får resultat
- Förklara bättre varför rekommendationer visas i next step och starting points (transparency of results)

Appendix E - Findings from Usability Test (high-fidelity)

1.Under testets gång, hur upplevde du att interaktionen med sökverktyget var?
(1:Mycket svårt - 3:Varken eller - 5:Mycket enkelt)
2.I början av testet, hur upplevde du att det var att formulera din fråga för att besvara din frågeställning? *(1:Mycket svårt - 3:Varken eller - 5:Mycket enkelt)*
3.Hur upplevde du att detta förändrades under testets gång?
(1:Mycket svårare - 3:Oförändrat - 5:Mycket enklare)
4.Hur väl förstod du vad du kunde använda sökverktyget till?
(1:Inte alls - 3:Varken eller - 5:Helt och hållet)
5.Hur stor hjälp upplevde du att du hade av rekommendationerna(tips på frågor och visualiseringar)? *(1:Ingen hjälp - 3:Varken eller - 5:Mycket hjälp)*
[6, 7]

Fråga	Pilot	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
1	3	3	3	2	3		
2	4	2	4	4	3		
3	4	5	4	4	4		
4	3	4	4	5	4		
5	*4*	5	*5*	5	5		

6.Fanns det något du tyckte var otydligt eller mindre bra?
1. Kanske svårt att förstå kopplingen att markera och söka “Windows-gem” fast mindre lame kan kanske vara bra.
2. Att jag kunde interagera med visualiseringarna hur jag skulle göra detta och hur det påverkade nästa sökning (eller att den gjorde det)
3. Lite oklart i början hur markeringarna influerade sökrutan
4. It is quite new for me to use a search-input field for manipulation of a chart. But if this is not necessary, something negative after a few times using it, it felt quite natural.
5. -

7.Förslag på förbättringar?
1. -
2. Tydliggör att det påverkar, visa vad som är interaktivt
3. Göra det mer tydligt hur markeringarna influerar sökningen
4. At the beginning the connection for manipulating the chart becomes a bit unclear maybe work with gestalt laws and more white space to bring things into a clear order.
5. -

Key Findings

- Flera testanvändare uttryckte att det var bra att få hjälp med hur man kunde formulera sin fråga. Det uttrycktes även som en bra grej att det kunde snabba på skrivandet av en fråga då man inte behövde skriva hela sin fråga själv.
  - *Indikera vilket språk man ska använda för att kommunicera med sökverktyget genom queries. (eventuellt convey capabilities and constraints också)*
- Det är tydligt att flera av testanvändarna har mycket av en trial and error approach och att man testar det som kommer upp som resultat utan att dubbelkolla (pilot).
  - *Incremental construction: Viktigt att kunna gå tillbaka, fråga på nytt, ändra osv. Gäller nog vid både preview läge men också efter att man testat att skapa en vis. som vi kan se. Skulle kunna vara att man börjar med total sales och sedan lägger till dimensioner genom följdfrågor.*
-
- En användare uppskattade att viss text (kolumnamn i detta fallet) var skriver i bold på vis.korten då det gjorde det enkelt att skumma igenom och snabbt uppfatta vad de innehöll.
  - ***NY?*** *Guideline: Lyfta fram den mest relevanta informationen i resultatet*
- Verktyget verkar kommunicera känslan av en assistent som man kan fråga om många olika saker och att den inte är begränsad till en viss typ av fråga/resultat
  - “[you can use it] for everything. Its like a free style tool. You have a thought and you type it in and get recommendations on how to manipulate, waht othe people have typed etc. Like an intelligent system. You ask someone and he a says what you can do.“

Natural Language

- Testet visade på vikten av att hitta en balans mellan NLQ och enstaka söktermer. Hur användare väljer att uttrycka sig varierar också stort.
- En användare uttryckte att “jag skrev in som om jag hade ställt frågan till en person. Det är ofta så man vill ställa frågan”.
- “I think that since we live in an age of intelligent systems, I think I can mark it and just type ‘buy more than others’.”
- Andra användare fastnade på hur de skulle uttrycka sig i naturligt språk, när valet av NLQ egentligen grundar sig i att man vill hjälpa de användare som inte är vana vid enstaka söktermer. Efter att ha interagerat insåg dessa dock att man kunde skriva även baserat i keywords och att programmet förstod detta.
  - *Natural language interaction: Användare ska kunna uttrycka sig på olika sätt beroende på preferens(Allow expressions in natural language). NLQ ska inte*

begränsa de användare som hellre vill uttrycka sig i enstaka söktermer(keywords).

- För i princip alla testpersoner var det behjälpligt att systemet kunde hantera synonymer, alternativt att systemet inte kunde göra det i vissa fall när testanvändare hade behövt det. Exempel är att använda "buy" när det handlar om sales, prediction/future om det är forecasting osv.
  Support the use of colloquial wording: Allow for synonyms of that can be matched to the correct terms used for columns/functions etc. (kan lägga in här hur man skulle kunna göra detta, såsom att ge frihet att lägga in egna synonymer, ha ett bibliotek av synonymer som kan ändras av användare etc.)
- En skrev direkta frågor såsom "who buys the most toys?"
  - ***NY?*** *Guideline: Lyfta fram den mest relevanta informationen i resultatet*
  -
  - *Kan också vara relevant för ovanstående guideline om att folk uttrycker sig olika.*

Feedback/Recast

- Två användare uttryckte att det var bra att det blev lättare att ställa frågor genom att systemet visste vad man hade markerat och att man inte behövde lägga till många ord. Förstod att scopet hade uppfattats av systemet. Detta utnyttjades med ökad effektivitet som följd(exempelvis genom att bara skriva forecast). Alla användare upptäckte dock inte detta direkt. Detta kan delvis vara för att suggestions inte indikerar att man kan skriva så i alla lägen.
  - ***NY!*** *Någon guideline om att kunna använda vad systemet vet om ens intention för att underlätta naturligt språk. Det är smidigt, effektivt och naturligt att, likt HHI, kunna peka på saker och fråga om det. Skulle kunna gå under flexible search scopes på något sätt och att man utnyttjar att man vet vad användaren söker i.*
  - *(under typ convey capabilities ...)Suggest that the user does not need to type in the whole question when a marking is active.*
- Två användare uttryckte att det var bra att se vad man kunde skriva som exempel samt att man kunde se hur man skulle bygga vidare genom att lägga till exempelvis år eller plats.
  - *Convey constraints and potential-ish: Visa vad som är möjligt att tolka av NLP:n genom att använda exempel.*
  - ***NY****(få inblick i sitt dataset)/Serendipity: Ge exempel på datakolumner/kategorier etc. för att ge möjlighet att upptäcka nya sätt att interagera med sin data(såsom att splitta på kategori). Ytterligare vägar man kunde ta när man formulerade sin query.*
- Fyra användare uttryckte vikten av att få feedback av systemet vid sin sökning för att vara säker på att systemet uppfattade vad man menade.Det ansågs även vara till stor hjälp att användaren inte behövde slutföra sin query för att få upp resultat, utan systemet kunde hjälpa dem på vägen. En uttryckte att det var bra att man kunde "provställa" en fråga och få hjälp tillbaka genom feedback.

- *Two-way conversation: Ge feedback tillbaka till användaren gällande vad som har tolkats och för att försäkra användaren om att systemet förstått rätt.*
- *Incremental construction: Att kunna testa sig fram med en fråga och se hur systemet tolkar resultaten*

- Det verkar som att folk förstod att visualiseringarna baserades på recasten. Antingen sas det explicit, eller kommenterades det inte som oklart. Testpersonerna lyckades på ett naturligt sätt interagera med dessa när man skulle förändra resultaten. En person sa uttryckligen att han förstod att man kunde ändra till någon annan dimension.
  - *Guideline: Ett gott exempel för att designa "a two-way conversation".*
- Feedback är inte bara viktigt för att visa på att programmet har tolkat rätt, utan även för att visa för användaren att programmet har uppfattat att användaren har skrivit något överhuvudtaget. En användare nämnde framförallt detta och drog paralleller till windows loading symbol. Autosuggestions (som reagerar på det man skriver) är ett bra exempel på att visa hur programmet jobbar.

Rekommendationer

- En användare visade uppskattning för att systemet gav rekommendationer på saker man eventuellt inte hade tänkt på. "Tänk såhär istället"
  - *Serendipity: Använd kunskap om användarens intention och kontext för att ge insikter som man eventuellt inte annars hade upptäckt(man skulle kunna bryta upp detta i mer specifika saker såsom personalisering, AI etc.).*
- Efter att ha blivit varse om systemets sätt att rekommendera visualiseringar verkar vissa testpersoner efter ett tag förstå att man kan få resultat presenterade för sig utan att behöva skriva in i sökfältet. Detta är dock oklart för många vid första anblick och rekommendationerna läggs ofta inte märke till. Det behöver dock inte vara ett problem om användaren har en tydlig bild av vad som ska skrivas. Då ska man heller inte bli avbruten.
  - *Transparency of results: If results are auto generated from the system in a way that tries to act upon the intent of the user(could be based on personalization, AI insights based on data correlations etc), make sure to make it stand out from other search results and inform the user about why the recommendation is being presented. Make it easy to interpret the intention of the system "at a glance" in order to not dismiss the result(seen in the tests that some users are sceptical). Handlar mycket om att bygga upp ett förtroende hos användaren.*
- Flera användare förstod inte att det var systemet som hade rekommenderat actions och andra saker till dem. Att systemet rekommenderar detta går emot förväntningarna av ett liknande system och bör därför förklaras tydligare. En testperso uttryckte det som "Jag är ovan vid att en mjukvara kan tänka mina tankar."
  - *Se ovan om om transparency*
- Flera användare uttryckte att rekommendationer och previews hjälpte en att förstå vad resultatet innebar (innan de hade klickat på det).

- *Guideline: se ovan(specifikt för visualiseringar och manipulationer att de bör visualiseras genom en preview)*

- Vi lyckas inte helt kommunicera vad som är möjligt att söka efter(kategorier av resultat).
  - ***NY**! Indicate search scope (?): Indikera vad man kan söka efter för typer av resultat.*
- Två användare visade uppskattning för ambiguity widgets och möjligheten att ändra sitt scope efter markering utan att lämna sökverktyget. Alla testanvändare förstod hur man skulle interagera med widgets för att ändra årtal.
  - *Incremental construction: sänka tröskeln för att det måste bli rätt direkt, framförallt viktigt vid markering då det inte är säkert att man kan se exakt vad som markeras. Ger ett exempel på hur man kan stödja denna guidelinen i sin design.*

Markering

- Att markering sätter scoopet för sökverktyget är inte helt självklart vid första anblick.Det skiljde sig åt mellan testanvändarna om de uppfattade det från början eller inte.
- Flera användare uttryckte att det var lite otydligt om man sökte i en markering eller ej. Även hur man tog sig ur det.
  - Faceted search: indicate the current search scope and make it possible to modify
- Hinten i sökfältet är inte tillräcklig, vilket flera av testanvändarna nämnde. EN testanvändare uttryckte att han tyckte att de inte var tydligt sammankopplade. Däremot så förstod testanvändarna det mer och mer under testets gång. Angående denna interaktionsmodell så uttryckte flera att det nog bara är ovant och att det verkar bara rimligt när man lär sig.
  - *Support learning: Verktyget har just nu en ganska bra nivå av learnability. Ju längre testet går desto mer förstår användarna hur verktyget fungerar och hur dem ska interagera med det.*
  - *Transparency: Användaren måste få veta vad verktyget baserar resultatet på. Verkade dock som att när användaren öppnade sökverktyget så fanns det ytterligare hintar som gjorde att de började förstå att de befann sig i ett snävare scope.*
  - ***NY**! Indicate search scope (?): clearly indicate what scope that the user is searching in.*
- Testanvändarna litar inte fullt ut på att de förslag (insights) som ges av verktyget stämmer. Ligger antagligen djupt rotat att man som användare inte är van vid ett program/dator kan "tänka själv"
  - *Transparency: Tydligare i denna prototypen än i lo-fi, men det tyder på att det här är en väldigt viktig guideline!*
  - ***NY?** Guideline: Bygga upp ett förtroende för produkten*

- En testanvändare uttryckte att det kunde bli svårt att interagera med en slider och att kanske hade varit bättre med något annat sätt. En annan sa att det var uppsakattat med just en slider.

Actions

- Två testanvändare uttryckte att det var svårt att förstå action-delen av resultat och vad det innebar, samt vilken relation det hade till andra delar av sökgränssnittet. Dock förstods hur suggestions och results skiljde sig. Två användare uttryckte att det kändes som en sidopanel och inte som ett resultat på samma sätt. Detta kan också vara anledningen till att andra testanvändare trodde att action-kolumnen manipulerade resultaten.
    - ***Eventuellt ny guideline****: Kommunicera vad man kan nå för resultat genom att använda sökverktyget(om detta hade varit tydligt hade man kanske inte undrat vad actions innebar).*
    - *Guideline: Kommunicera vad en interaktion med ett resultat leder till(vissa trodde exempelvis att "Filter" innebar att filtrera i resultatlistan).*
    - *Future design work: Få till så att de inte är så separerade från resten av resultaten.*
- De användare som fick i uppgift att testa actions verkar kunna hitta forecast-funktionen även om de kanske har skrivit något annat än just forecast. Även om de inte har använt Holt-Winters forecasting så vill de testa detta.
    - *Support learning: Gällande inlärning av produkten och analytics i stort så är det rimligt att säga att verktyg som detta stimulerar användaren att hitta vägar att analysera sin data som man tidigare inte visste om. Att uttrycka något i naturligt språk och sedan få rekommendationer på detta i hur man ska göra analytiskt skapar sannolikt lärande. Det är rimligt att anta användaren skulle utnyttja detta lärande senare i sin dataanalys.*

- Såg under testets gång att **en del funktionalitet hade krävt någon form av introduktion**, t.ex. *markeringsverktyget* – hur det funkar och att de sätter scoopet, *insights* – att programmet jobbar i bakgrunden och kan ta fram relevanta förslag genom givna datapunkter, *actions* – att dem finns och att de är en del av resultatet. (Kanske några fler?) Verktyget ska fungera både som en hjälp för nya användare men även som en genväg för mer expertanvändare. De problem som testanvändarna stötte på verkade grunda sig i att de inte visste hur de skulle förhålla sig till dem och hade bland annat kunnat undvikas genom en introvideo. Gällande sättet att evaluera på så ska det sägas att vi testade hur väl användare kunde interagera vid en första anblick och utan introduktion. Detta ger bra usability-insikter men är samtidigt kanske inte det mest naturliga scenariot för en riktig användare(som vet att de vill skapa visualiseringar och vet att de har en viss data).

    - *Bra diskussionspunkt någonstans i rapporten*.
- Märkbart att val av rubriker påverkar testanvändarna i hur de tror att de olika delarna fungerar. Ex. en användare trodde att *suggestions* var alternativ som han var tvungen att använda sig av och förstod inte att det mer var som inspiration. Hade kanske varit bättre att använda en rubrik som “Example questions” istället eller liknande.
- En testanvändare upplevde att det inte var jättetydligt att man var i statet att man skulle skriva när man hade klickat på sökfältet. Det är lite gömt.
    - *Sökfältet hade behövt “poppa” lite mer när man klickat på det. Eventuellt med en border eller liknande.*
- En testanvändare upplevde att empty states var lite överväldigande. Han sa dock även att det troligtvis är nödvändigt.