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Evaluating the user experience of different representations of organizational structures

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Abstract

Information overload is a widely recognized problem in the workplace, with an overwhelming amount of information being presented from several sources constantly. By being able to visually represent organizational structures in an efficient way, it can significantly aid in making the data easier to consume, utilize and incorporate in future decision making. This master's thesis aims to contribute to research regarding information visualization, specifically in regards to visually representing organizational structures in an efficient way. The research questions that will be explored during this thesis are whether the hierarchical list or the vertical tree is a more efficient method for representing organizational structures, as well as whether the hierarchical list or the vertical tree present information in a more useful way that is easier to understand, according to users' personal preference. These questions are explored by conducting an empirical study measuring the users' efficiency in both models, as well as recording which model the users preferred in terms of ease of use and usefulness. The results indicate an overall higher efficiency of the vertical tree, of statistical significance, as well as an overall favoring of the same model by users. Thus, for representing organizational structures similar to ones used in this thesis, there is evidence to suggest that a vertical tree would perform better than a hierarchical list. However, future research would be of interest for testing different types and sizes of organizational structures, as well as analyzing whether familiarity could have an effect on the results.

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Sammanfattning

Informationsöverbelastning är ett välkänt problem i arbetsplatsen, med en överväldigande mängd information som kommer från flera källor konstant. Genom att kunna visuellt presentera organisationsstrukturer på ett effektivt sätt, kan det ha betydande hjälp i att göra datan enkel att förstå, använda och inkorporera i framtida beslutstagande. Detta examensarbete har som mål att hjälpa i forskning om informationsvisualisering, mer specifikt gällande att visuellt representera organisationsstrukturer på ett effektivt sätt. Forskningsfrågorna som kommer utforkas i detta arbete är om hieraktiska listor eller vertikala träd är mer effektiva för att representera organisationsstrukturer, samt om hierarkiska listor eller vertikala träd presenterar information på ett lämpligare sätt som är enklare att förstå, enligt användarnas personliga preferens. Dessa frågor är utforskade genom att utföra en empirisk undersökning som mäter testpersoners effektivitet vid användning av båda modellerna, samt genom att mäta vilken modell personerna föredrog gällande lätthet att använda och lämplighet för ändamålet. Resultaten indikerar en generellt högre effektivitet från det vertikala trädet, som är statistiskt signifikant, samt att användarna generellt föredrog samma modell. Således, för att representera organisationsstrukturer liknande de som användes i detta arbete, finns det bevis som tyder på att ett vertikalt träd skulle prestera bättre än en hierarkisk lista. Dock skulle framtida forskning vara av intresse gällande testning av olika sorters och storlekar av organisationsstrukturer, samt att analysera om vana skulle kunna ha en påverkan på resultaten.

Acknowledgements

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Contents

1 Introduction

The problem of information overload is widely recognized in present times. As a result of living in an "information society", there is a bombardment of information constantly, whether actively sought for or not. A similar phenomenon can be found in the workplace, where information is seen as the key to success and many have to deal with an overwhelming amount of information from different sources as a part of their job [10]. By visually representing abstract data, it can significantly aid in handling information overload and making it more digestible for users [5, p. 7].

In order to produce a more healthy work environment in the current competitive landscape, companies are starting to promote employee wellness programs [26]. These programs aim to benefit the employees both in the way they feel about their work environment as well as the way they perform their work. One attribute of a successful wellness program is the use of information technology when gathering, reporting and studying the effects of the wellness program's actions. Using visual depictions have been found to be an effective method of communication, by making the data easier to consume, utilize and incorporate in decision making [42]. One way of visually depicting the information may be by using organizational structures. Organizational structures are a tool to represent and describe the relationship between members of the organization, as well as to define, guide and anticipate organizational activities in order to increase the effectiveness of operation [11].

Tree structures are one of the earliest representations of hierarchical systems and have been deemed highly important in organizing, rationalizing and describing information patterns throughout time [16, p. 21]. One of the tree models that is the closest visually to the traditional tree is the vertical tree model, which is commonly used in depicting organizational structures, family trees, evolutionary trees, diagrams of file systems, site maps, among others [17, p. 79]. In addition to tree structures, list structures are highly prevalent in Western Society and may offer a compact, expandable and familiar method of accessing information [9]. Hierarchical lists are a popular method for representing larger amounts of data or commands, and are commonly used for command menus on operating systems, file directories, mobile phone menus, navigation menus etc [12].

This thesis aims to explore how one would most efficiently visualize organizational structures, either through a vertical tree or a hierarchical list model. This was done through a combination of research regarding how one could visualize hierarchical systems through different representations, as well as an empirical study testing two different prototype interfaces, one of a hierarchical list and one of a vertical tree, on 22 test participants. The thesis is conducted in collaboration with the company Springlife, and their product FollowApp™.

1.1 Research Goal and Limitations

The aim of this thesis is to contribute in research in regards to information visualization, specifically in regards to visualizing organizational structures. The research questions to be answered in this thesis are:

- Is the hierarchical list or the vertical tree a more efficient method for visually representing organizational structures? The efficiency in this case is measured by the amount of time to complete each task.
- Does the hierarchical list or the vertical tree present the information in a more useful way and which one is easier to use, according to the user's personal preference?

In order to answer these questions, prototypes of both models were created in the online interface design tool Figma. To answer the first question, the models were tested in an empirical study where users were timed solving a number of tasks for each model. After solving the tasks, the users were asked to rank the two models both in ease of use and usefulness and to explain their reasoning, in order to answer the second research question.

The models created for this thesis are prototypes, using connected wire frames to visualize how the system could look and act like. However, as these prototypes used for the empirical study do not have the full functionality that the complete application will have, there may potentially be some discrepancies. Furthermore, the two models selected for this thesis, based on research on information visualization, are the hierarchical list and the vertical tree diagram. However, there might be additional models that could be of interest for representing organizational structures that are not explored in this thesis.

2 Background

In the following section relevant concepts, theories and related works for this thesis are presented, as well as an introduction of the stakeholder. A major part of this thesis work consisted of a literature study in the field of Human Computer Interaction. The section will present findings found relevant in connection to the main subject of this thesis.

2.1 Springlife

Springlife is a company that develops and markets the SaaS (Software as a Service) application FollowApp^{TM} which both maps the performance potential of managers and coworkers, as well as offers proactive digital support and guidance with these so that the performance improvements happen on time. The method for achieving this has been based on previous research from professor Bengt Arnetz [35]. It involves sending out questionnaires to the employees, where they answer on a four point scale or select the statement that most aligns with them, depending on the question. The questions may concern matters such as feeling fulfilled in their work, feeling that they are able to develop both as a professional and as a person, or being able to both receive and give constructive feedback, et cetera. The results from these questionnaires are then grouped into 11 categories which are:

- Coworker power
- Workload
- Work related exhaustion
- Efficiency
- Participation
- Social Climate
- Learning through work
- Feedback
- Leadership
- Coworkership
- Quality of goals

After the results have been gathered, the managers can view the results for each unit and evaluate which unit requires changes. Springlife also offers activities and guidance to help improve the areas that require support.

Entire is a production company located in Uppsala that focuses on product development both in the form of web apps and websites, as well as native and cross-platform mobile apps. Entire is currently developing the FollowApp™ application, which this thesis will be based around.

2.2 Employee Well-being

In the current competitive environment, companies are starting to emphasize the importance of employee well-being. In order to promote a more healthier work environment, numerous organizations have begun to sponsor employee wellness programs. According to one study, more than 85% of US companies that employ over 1000 people offer some form of workplace wellness programs [26]. The components in these workplace wellness programs can vary greatly depending on the company, although the sought after effects are generally the same. These positive effects for the company may range from decreased health care costs, to reduced absence and turnover, to increased employee productivity and company image. The benefits in regards to the employees may be attitudinal and behavioral, meaning that they can have an effect both on the way people feel about their work environment (attitudinal) and affect the way people perform their work (behavioral). As the attitudinal changes refers to how the employees feel, the benefits from these may be considered less tangible, and thus harder to quantify, although they are still valued. In comparison, the benefits from observable work behavior changes can be easier to quantify and through those results measure the company's progress toward achieving its goals [42].

One way to improve employee morale and well-being is to show the employees that the company cares about their best interests. When upper-level management shows their support for employee wellness programs, it sends a positive message that they care about the employees health and well-being, which may in turn increase employee morale. Employees that are committed to their organization will exert more effort in their work, go to greater lengths when helping their coworkers and offer more creative ideas for company improvement. However, if a company is to expect its employees to perform their very best and have a strong commitment to their work, then the employees will in return call for a stronger commitment from the company. One commitment that a company could make to its employees is to work to improve the employees' personal health and well-being [42].

However, simply offering a wellness program will not guarantee an improvement of the employee's well-being. The employees must be aware that the program exists and be inclined to use it. Research found that although 85% of large companies offer a wellness program, only 65% of employees are aware that their company has a wellness program, and only 40% of employees that are aware of the program stated that they participate in it. Managers play a vital role in ensuring that their employees are aware of the company's wellness program, as well as in encouraging them to participate and create accountability for the results of the program. One study found that employees that feel like their manager truly cares about their well-being are more likely to be top performers and produce higher quality of work. The same employees are also less likely to get sick, change jobs or be injured at work [26].

Although the results of employee wellness programs may vary depending on the program and the company, there are certain similarities found in the implementation among those programs that generate a positive return of investment for the company. One attribute of a successful employee wellness program is the use of information technology when gathering, reporting and studying the effects of the wellness intervention. Using techniques that are employee accessible and require close to no human intervention have been found to be effective, as well as techniques that generate visual depictions of measurements. By using visual depictions, the data is easier to consume, utilize and incorporate in future decision making [42].

2.3 Organizational Structures

Organizational structures may be defined as representing and describing the relationships between members of the organization. They work to define, guide and anticipate organizational activities in order to increase the effectiveness of operations [11]. Organizational structure was originally only considered to be important in terms of how it might impact other attributes such as performance or productivity. However, as sociologists began to apply theoretical perspectives and research methodologies to the subject, structure started being regarded as both an independent and dependent variable. As organization theory grew, organizational structure took a prominent role in the field, resulting in the theories, methods and concepts used when studying organizational structure being continuously refined over several decades. Although structure no longer occupies center stage in the study of organizations, it remains an important and substantiated subject in organizational theory [19].

Organizations consist of several components, and differ along a multitude of dimensions such as size, performance, leadership, professionalism, culture, identity and structure. The structure of an organization is not more important than any other dimension, although that does not mean it is not important. Those that want to reform organizations in both the private and public sector continually recommend new strategies to restructure organizations. These normative directives often treat organizational structure as a one-dimensional phenomenon, when instead they could be characterized by two broad dimensions, complexity and control. Organizations can become more complex as they add hierarchical layers, create new functional units or expand their operations. Control and coordination can be achieved by increasing the relative size of the administrative body, by instituting formal written rules, policies, standards and procedures, or by centralizing the decision-making authority. Organizations may vary in nature and magnitude in each of these dimensions [19].

The design of organizational structures have evolved over time, conforming to various factors that are called "contingencies". Contingency factors are factors such as size, antiquity, technology, culture, environment, property and power. These contingencies act as a catalyst for organizations to incite the organization to respond by modifying their structures to account for further knowledge, or in other cases to confront them and turn them into competitive advantages. The organizational design is not unique or consistent, as there is no specific form of organization. However, there are several contingency factors that may affect organizational designs. Variables that are external to the company, which may affect its design, learning, behavior and evolution are not isolated, they interact and are complementary. Thus, when companies design their structures they should comprehensively analyze these factors in order to account for them and possibly turn them into advantages [11].

The issue of centralization and decentralization have several applications in matters such as decision making and process dynamics. However, they also may affect organizational structure as they contribute to the distribution of authority within the organization and thus offer a way of encapsulating the concept of structure. Centralization describes the degree to which the decision making power is concentrated to a single point in the organization. Meaning that if top executives make key decisions for the organization with little to no input from those below in the hierarchy, then the organization is centralized. In contrast, the greater extent to which lower level employees are allowed to provide input or make decisions, the more decentralized the organization is. It is of worth to point out that the concepts of centralization and decentralization are relative, and that no organization can be completely centralized or decentralized [11].

When handling changes in organizational structures, the indirect and direct factors involved must be identified. This is both in order to reduce risk, as well as to be able to develop strategies to ensure that the change is implemented successfully. One of the central ways that organizational structures may suffer when changes are made is by adaptation made to them by human resources, which may help maximize their benefits but may also make the structures more complicated. In order to ensure success when implementing changes to organizational structures, it is necessary to identify factors that could be affected by the change. As organizational changes may affect the members of the organization, it is the responsibility of administrators to identify sources or reasons for resistance in order to handle it successfully. The fundamental reasons behind resistance to change may be rational, however often they are emotional or a combination of the two. Some possible sources of resistance might be fear, created interests, lack of understanding differences of perception, lack of resources, legal obstacles or lack of training. Once factors of resistance have been identified, it is important to propose ways of managing them progressively or implementing them directly, depending on the reactions from employees and the objective of the organization [11].

2.4 Information Visualization

Information visualization is defined as the process of using computer-supported, visual representations of abstract data in order to aid in comprehension. Visualization techniques play an important role in addressing information overload and making the data more digestible for the user [5, p. 7]. A study by Larkin and Simon analyzed individuals solving physics problems using sentential representation, such as prompts in text form, versus diagrammatic representation which were indexed by location in a plane [14]. The results indicated three ways in which diagrams helped the user more easily understand and use the data. The first way was by grouping together certain information, the amount of searching was reduced. Secondly, by using location to group information about a single element, the need to match symbolic elements was avoided. Lastly, the visual representation supported a larger number of perceptual interference. For example, by using a diagram, geometric elements such as interior angles could be faster and more easily recognized. Depending on the task, visualization could make the task better or make it worse [5, p. 15-16].

Visualization can expand processing capabilities by using resources of the visual system directly. It can also aid indirectly by aiding in cognition work and reducing requirements on memory for a task by allowing the working memory to be external and visual. This may be achieved by allowing the environment to store details, such as a map storing directions and locations. Visualization can also reduce the search for data by grouping it together or otherwise visually convey relations. It can allow patterns in the data to reveal itself, such as aggregations of data revealing themselves by clustering. It can also allow some interference to be done more easily and visual representations can be used for specific operations. Visualization can therefore, arguably, enhance cognitive effort by several different mechanisms, however all depend entirely on appropriately mapping information to visual form [5, p. 16-17].

As data sets increase in size dramatically, it becomes increasingly difficult to visualize them effectively. For these cases, it is vital to be able to extract subsets and define appropriate levels of abstraction of the data in order to reduce the active data size to a more manageable level. One valuable mechanism for organizing large quantities of data and reducing the effective size is to organize it into a hierarchy [38]. Examples of hierarchical structures include organizational structures, catalogs, family ancestry structures, classification of species, object-oriented program classes and computer file systems [34]. However, in order to avoid creating meaningless hierarchies, the user should bring domain-specific and task-specific knowledge to the hierarchy specification. By organizing the data set into a semantically meaningful hierarchy, it may reveal patterns and relationships between the data, thus turning it into more usable information [38].

In order to capture all the structural information of a complex figure, many embedded layers may be needed. Consider as an example how one would characterize the perceptual structure of a human being standing up. As a whole, a person could be compared to an elongated ellipsoid-shaped object that is oriented vertically, with some scalar size. When characterizing the structure at a finer level, the parts of the body are represented, with the head, torso, two arms and two legs being portrayed. Furthermore, each one of these parts, when considered as a whole, also has global properties. The head is an ellipsoid that is less elongated than the whole body and oriented vertically, with some scalar size that is often dependent on the body's size. The analysis can go further as well, as the head has further parts such as eyes, ears, a nose and a mouth. These parts can also be represented both globally and as further sets of parts. Finally, what emerges is a multilevel hierarchical structure of parts and wholes, with each having both a representation of holistic properties and of component structure [27].

2.5 Tree Structures

Trees are among the earliest representations of hierarchical systems of thought and have been highly important in organizing, rationalizing and describing information patterns throughout time. This favored scheme, which usually highlights a hierarchical ordering with all divisions branching out from a central foundational trunk, is ultimately a universal metaphor for organizing and classifying both individuals and their environment [16, p. 21]. Trees have not only been an important religious symbol for many, but also a significant way of describing and organizing human knowledge. Even though tree diagrams have lost some of their organic features over the years by becoming more stylized and nonfigurative, many of their associated components are still used for representing parts of the hierarchy, such as roots, a trunk, branches and leaves [17, p. 49].

The representation of trees progressed naturally from a more traditional tree to a more stylized, abstract structure, with a vertical scheme that split from top to bottom becoming a common structural choice. Of all visualization models, the vertical tree (see Figure 1) is arguably the one that is closest to the traditional tree, with their vertical structure and forking from the central trunk. However, generally vertical trees are inverted with the root at the top, in order to emphasize the notion of descent and follow a more natural writing pattern from top to bottom. As one of the more pervasive structural models, vertical tree diagrams are commonly used in depicting knowledge within the taxonomy field, for example organizational structures, family trees, decision trees, evolutionary trees, diagrams of file systems, or site maps [17, p. 79].

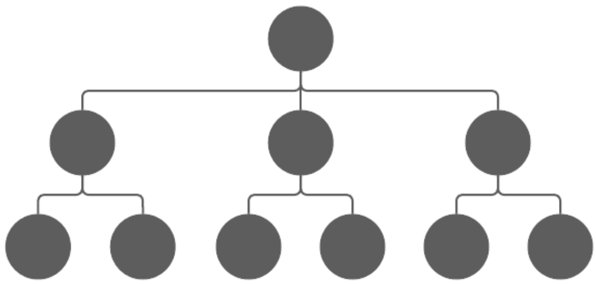

Figure 1 Vertical tree

With the adoption of a more schematic and abstract structure, that had less realistic arboreal features, sometimes the diagram would be rotated and be depicted horizontally (see Figure 2). This version of the tree model may have emerged as an alternative as it could address certain spatial constraints and layout requirements, as well as following a reading pattern that most can relate to by having its levels arranged from left to right. Horizontal trees are often used for archetypal models such as classification trees, flow charts, mind maps, dendrograms, as well as the display of files on numerous software applications and operating systems [17, p. 97].

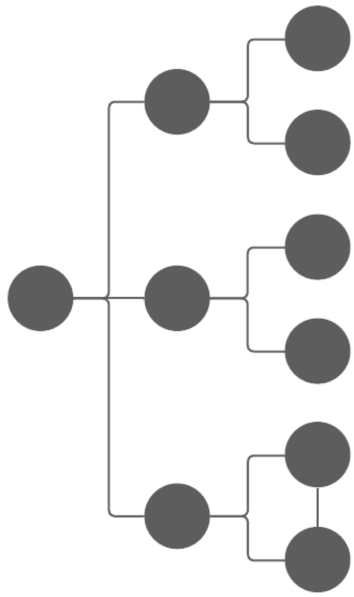

Figure 2 Horizontal tree

Another more abstract tree model is the multidirectional tree (see Figure 3), where the hierarchical branches are not rigidly ordered along a vertical or horizontal axis, but instead are more free-flowing. From the initial root node, the branches of a multidirectional tree expand towards the edges of the space. This results in an organic and unconfined appearance, although it should not be mistaken as disorganized. The advanced algorithms used for generating multidirectional trees have made it possible to map large hierarchies while effectively keeping to spatial boundaries. However, as a result of the tree model's flexible layout the inherent hierarchical structure may not be as easily observed as other more structured tree models [17, p. 111].

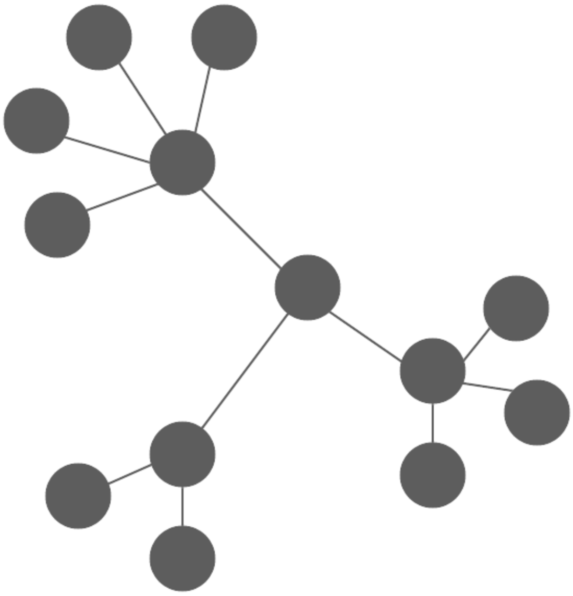

Figure 3 Multidirectional tree

Radial trees utilize the visual representation of a circle, which is an important universal visual metaphor. In this tree model, the root node is placed in the center of the circle, with the levels of branches moving towards the periphery, sometimes using guiding rings for each level. The main advantage of radial trees is its optimal usage of space, as it easily fits into the confines of a square. The model is quite popular in several areas, but is mainly used in portraying genealogical and phylogenetic relationships [17, p. 123]. There is a variation of the radial tree called the hyperbolic tree (see Figure 4), which uses centering and enlargement of certain nodes to put emphasis on them, compared to the uniformity of radial trees. Due to this magnifying feature, hyperbolic trees are useful for displaying and manipulating large hierarchies in a limited space. As this visualization model is interactive, hyperbolic trees are rarely used in print, but instead primarily used digitally [17, p. 135].

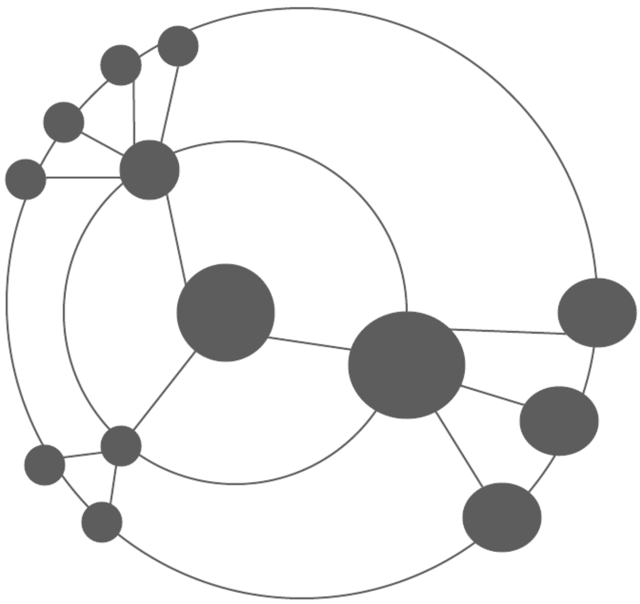

Figure 4 Hyperbolic tree

It is hard to define the appearance of a tree diagram, whether it is oriented horizontally, vertically or circularly, whether the nodes must be of equal size or distance from each other, or whether it must even resemble a tree at all. One thing all tree diagrams have in common is that they, by definition, represent hierarchically structured information. However, a tree may not always be the clearest way of displaying data. A beautiful looking tree does not necessarily represent information in the most logical matter [23].

2.6 Hierarchical Lists

Lists are very prevalent in Western society, and although the topic of lists may seem fairly neutral, there are several ways of forming lists. Depending on the structure and content of the list, it may be difficult for the reader to absorb the information. Encountering lists may be a tedious and difficult task, however there are ways that lists help the user. By breaking up information into a list, it may attract attention, support scanning, shorten the text for each item and help represent relationships between items [18].

Menu list systems are one of the most prevalent user interfaces, which offer a compact, expandable and familiar method of accessing different functionality. Some common types of menus include linear, hierarchical, cascading, drop-down and toolbar [9]. Hierarchical menu lists are a popular method used to represent larger amounts of commands or data (see Figure 5). Common examples of hierarchical menus include command menus on operating systems, file directories, mobile phone menus as well as navigation menus. The appearance and properties of a hierarchical menu list vary depending on the location and the intended usage, for instance a phone menu needs to fit the smaller screen size of the device. However, the hierarchical menu should have a standard representation that is familiar to users of corresponding systems, particularly when used in computer programs. When using hierarchical menus for websites, the design process is subject to less rules and thus gives more leeway for playing with the creative development of the structure. Hierarchies are widely adopted for larger structures, such as a large website directory where the two-level hierarchical menu displays both the category and the underlying subcategory. Generally, the efficiency of menus are calculated by the time taken to access a required element. The solution is to find a menu design consisting of a certain amount of hierarchical categories which ensures the lowest access time. However, for a certain set of elements there exists numerous ways of grouping them together in hierarchies, and the hierarchical design must also ensure that the categories of groups are suitable for the usage situation [12].

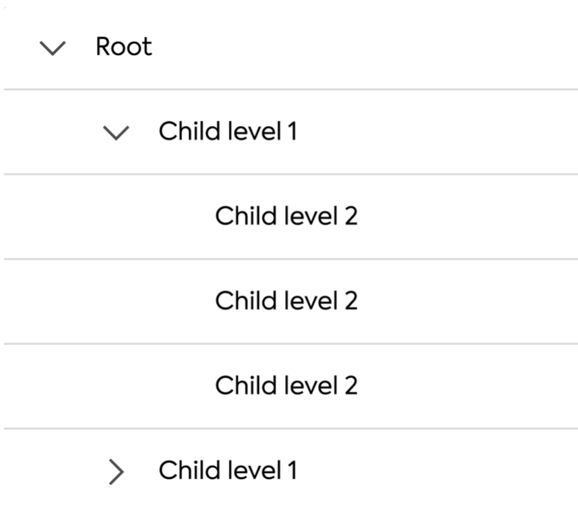

Figure 5 Hierarchical list

In order to convey information in an efficient way, it is important to design hierarchical menus carefully. One advantage of using expanding hierarchical indexes is that they maintain the full context of the selection within the hierarchy. Meaning that the hierarchical list is fully displayed while the user is browsing, instead of taking the user to a new view that only shows the current level elements when dropping to deeper levels in the hierarchy. Using expanding hierarchical indexes allows the user to at any point have access to both higher and same level categories. However, as the hierarchy increases in the number of levels, using expanding hierarchical indexes might not be beneficial, as the resulting longer lists of elements might be difficult to search through for the user [41].

There have been several research studies in hierarchical lists comparing the efficiency of navigating through different deep structures containing few items per level with more shallow structures that contain many items for each level. Miller [22] examined the time taken to select one item from 64 options in structures of varying depths from one to six levels and 2 to 64 items per level. When analysing the resulting acquisition time against the number of choices per level, Miller found a U-shaped curve (see Figure 6), where the best performance was found at medium depth with eight items at each of two levels of depth. The items in this study was randomly ordered at each level of the hierarchy. Snowberry, Parkinson and Sisson [33] replicated Miller's study, however adding a condition which used four stable categorized item groups, instead of the random ordering Miller used, within a one-level structure of 64 items per level. The study also added a prescreening of the participants for memory and visual-scanning capability, in order to analyse if the capabilities could predict user performance. The results of this replicated study supported those of Miller, but the added condition yielded the fastest time of acquisition of all. The researchers stated that their results indicate an advantage for broader structures when maintaining a categorical grouping across hierarchies. Furthermore, they showed that prescreened measures of the participants' visual-scanning capability was able to predict the user performance, and that memory measures was not [8].

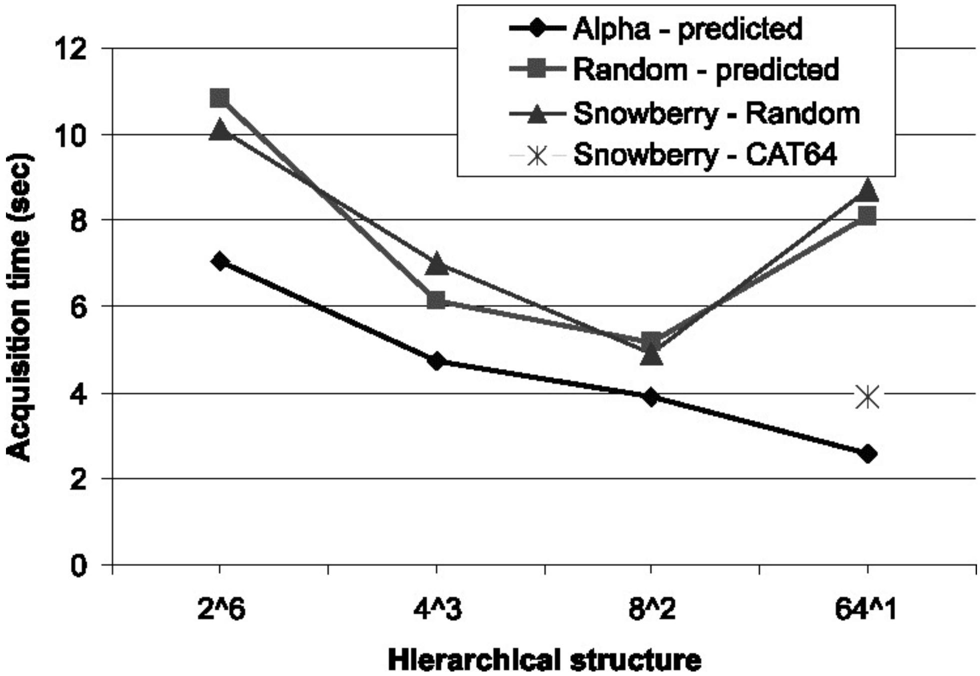

Figure 6 Predicted acquisition time for the 64 item structures in the studies by Miller [22], Snowberry et. al [33] and Kiger [13], which accurately reflect the trends shown in the studies. Note that Snowberry's data for the random condition is also shown.

There are several factors to consider when examining the topic of depth versus breadth trade-off. The navigation problem, i.e. when a user gets lost or uses an inefficient pathway to the intended destination, becomes more and more hazardous as the depth of the hierarchy increases [40]. In one study, it was shown that error rates increased from 4.0% to 34.0% as the depth increased from one level to six [33]. However, familiarity with the content and structure may reduce user disorientation, as users are less likely to become confused or lost, and are less likely to use a trial-and-error method to reach the target destination [7]. In addition, users that have a level of familiarity with the content have less search time, and can pay more attention to important information while ignoring irrelevant information.

2.7 Related Work

There are several other studies which have examined different ways of representing hierarchical structures. A study by Xiang et al. compared visualizing criminal relationships through a hierarchical list and a hyperbolic tree. The study developed a prototype system called COPLINK Criminal Relationship Visualizer, which included both a hyperbolic tree view and a hierarchical list view to visualize the criminal relationships. Experiments were then conducted to test and compare the effectiveness and the efficiency of the two views, where the results indicated that the hyperbolic tree view was more effective when a user needed to identify an element, as well as in tasks regarding association of different elements. However, it was also found that the users generally considered the hierarchical list easier to use, as they felt more familiar with that structure. When asked about the usefulness of the two views, the participants were split. Half of the participants believed the hyperbolic tree to be more useful, while the other half thought the hierarchical list was more useful. Overall, the results indicated that both views could be helpful when visualizing criminal relationships [39].

Another study by Risinger and Tinnerholm evaluated the navigation and understandability of the software development environment Arctic Studio, including the hierarchical list view Autosar Navigator. An interview based user survey was conducted in order to find potential areas of improvement, as well as in order to understand how users use the environment. From the survey it was found that users wanted an overall less complex system, and from that be able to navigate the models more easily. In regards to the Autosar Navigator, it was decided to change the view from a hierarchical list to a hyperbolic tree for the new prototype. This was mainly a result of the users wanting clearer visualization of the connections between components, as well as reducing the cognitive load that the list view created according to the survey [31].

These works are relevant for this thesis in various ways. Both the study by Xiang et al. and the one by Risinger and Tinnerholm evaluate the user experience of data visualization in a hierarchical list and a tree diagram. Although the studies come to different conclusions in regards to how to effectively display the data, it reflects the sentiment that different representations are better for certain situations. Both the studies use hyperbolic tree structures as an alternative to the hierarchical list, however as vertical trees are more common and thus more familiar for representing organizational structures, this thesis decided to use vertical trees instead [17, p. 79].

3 Method

The following section will outline the methodology that was used to analyze the efficiency and user experience of using a vertical tree diagram versus a hierarchical list to visually represent an organizational structure. First, two prototypes were designed in accordance with the design requirements, as well as in regards to previous research on information visualization and the two structural models. When the prototypes were finished, an empirical study was carried out in order to evaluate and compare the efficiency as well as the user experience of the two models.

3.1 Prototypes

Based on previous research on information visualization, as well as preexisting design systems, the following prototypes were made (see Figures 7 and 8). Similar studies evaluating the user experience of different visualization models used hyperbolic trees and hierarchical lists [39] [31], however one also has to consider the use case for the models. As vertical trees are more commonly used when representing organizational structures, i.e. more familiar and thus better suited for the setting, that model was deemed more appropriate for this thesis compared to the hyperbolic tree [17, p. 79]. The prototypes were made using the online interface design tool Figma, and use the same sample organization structure to not affect the results of the usability tests in any way.

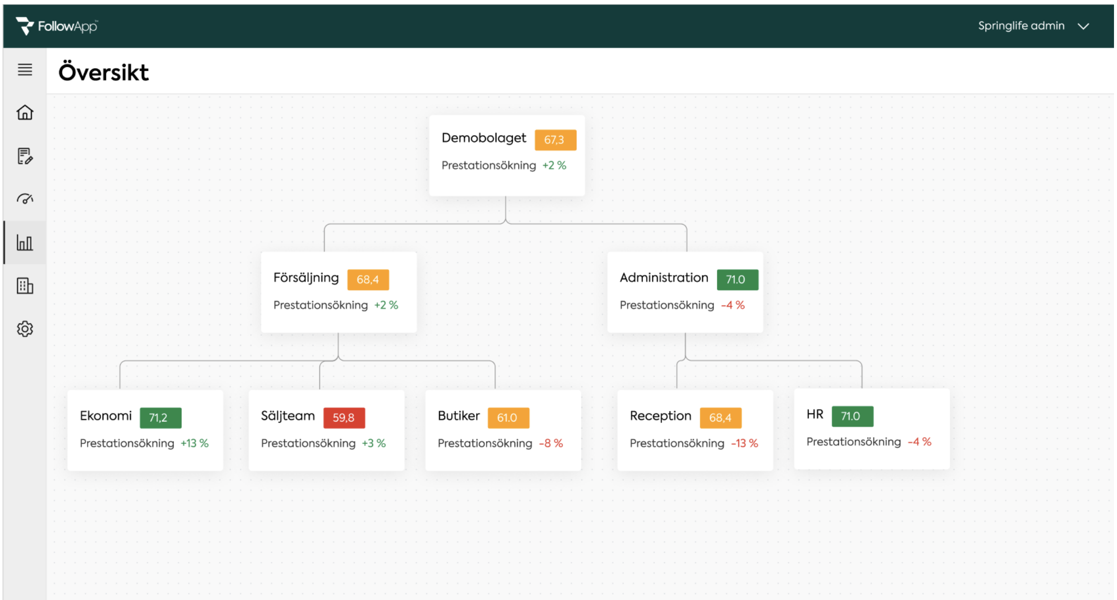

Figure 7 The tree model prototype

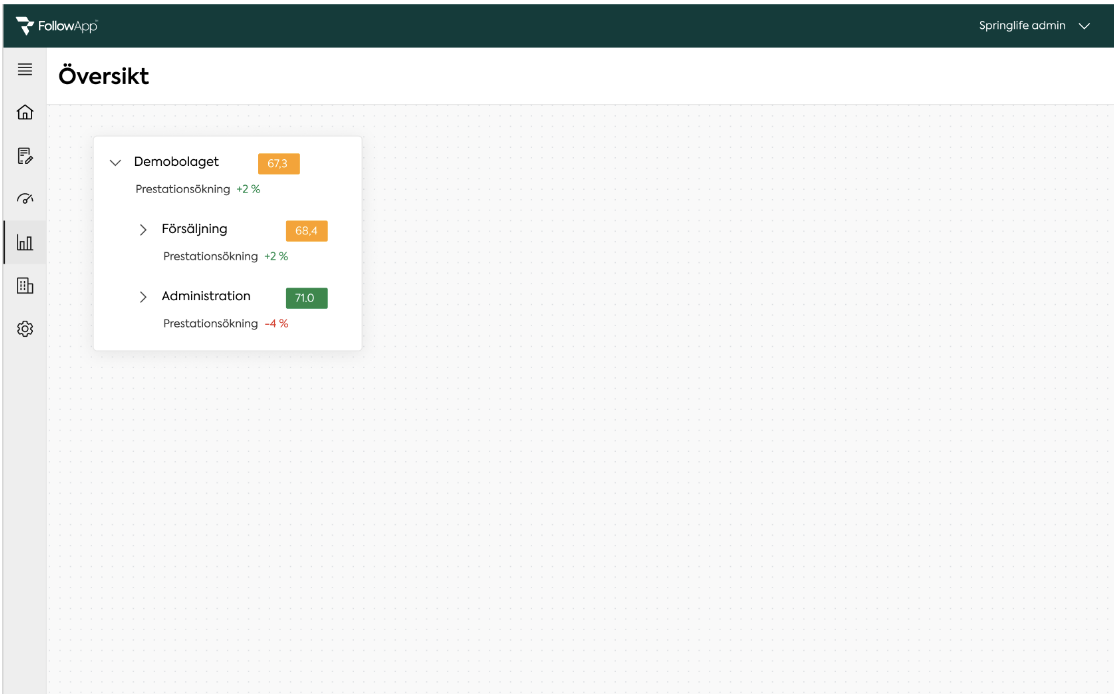

Figure 8 The hierarchical list model prototype, default

The list model is expandable, with arrows next to the unit that will expand or close the subunits when pressed (see Figure 9). The default view shows the highest hierarchical level as well as the second highest, from which the user can decide to either expand more levels or close. The arrows will rotate based on if the hierarchical level is expanded or not, in order to convey the information to the user. If a level does not contain any subunits, the arrow will not show.

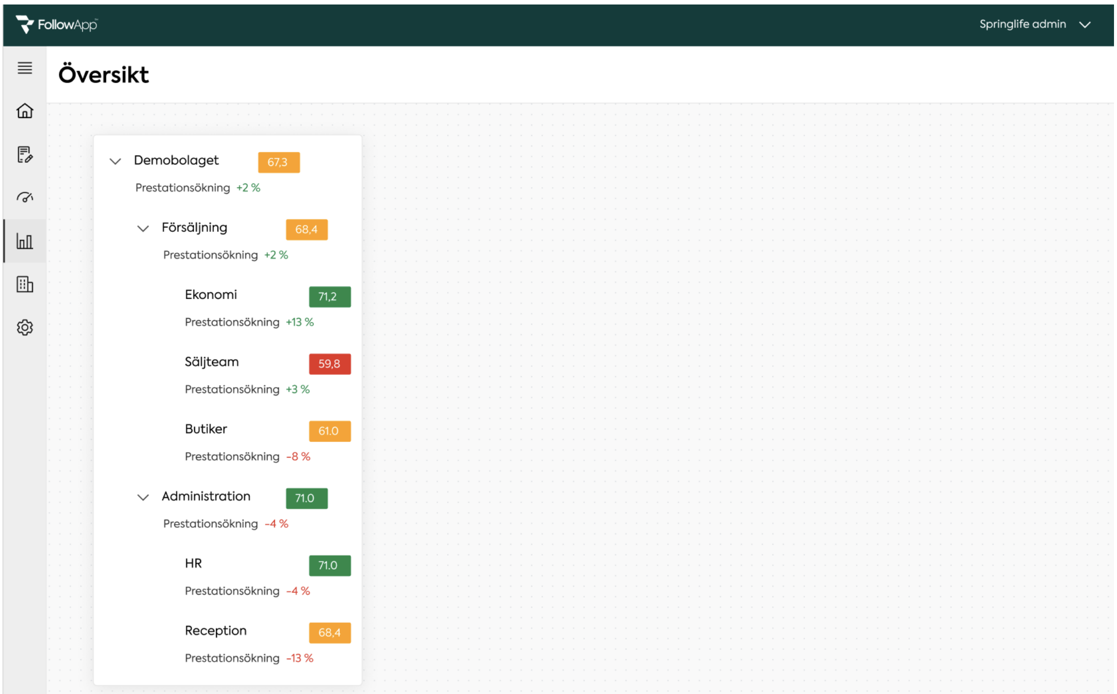

Figure 9 The hierarchical list model prototype, expanded

Both the vertical tree and the hierarchical list present the same information in regards to the units. There is the name of the unit, the performance value with a color coded background and the percentage of increase in performance value since the last survey. In addition to this information, the user can also press on the performance value and get a popup with more detailed information. This detail view is the same across the two models, however it is placed differently as a result of the difference in layout between the two models (see Figures 10 and 11). For the tree model, the detail view is placed as an overlay on top of the tree structure with a greyed out background behind the overlay. For the list model, the detail view is instead placed next to the content. The view contains three tabs, the first being an overview page with a list of each area of performance, as well as a list of activities to improve the unit's performance value. The second tab shows a diagram of the performance value over time (see Figure 12), and if the unit has subunits there is a third tab listing the most critical subunits (see Figure 13). The criticality of the subunits are measured in regards to their performance value, and the page also details the two lowest scoring area of performance for each subunit.

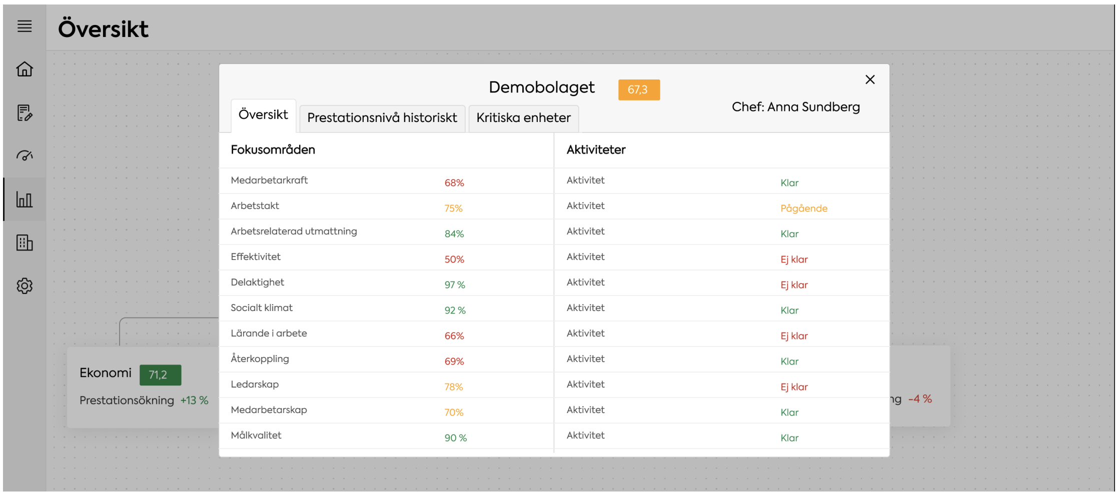

Figure 10 Detail view, tree model prototype

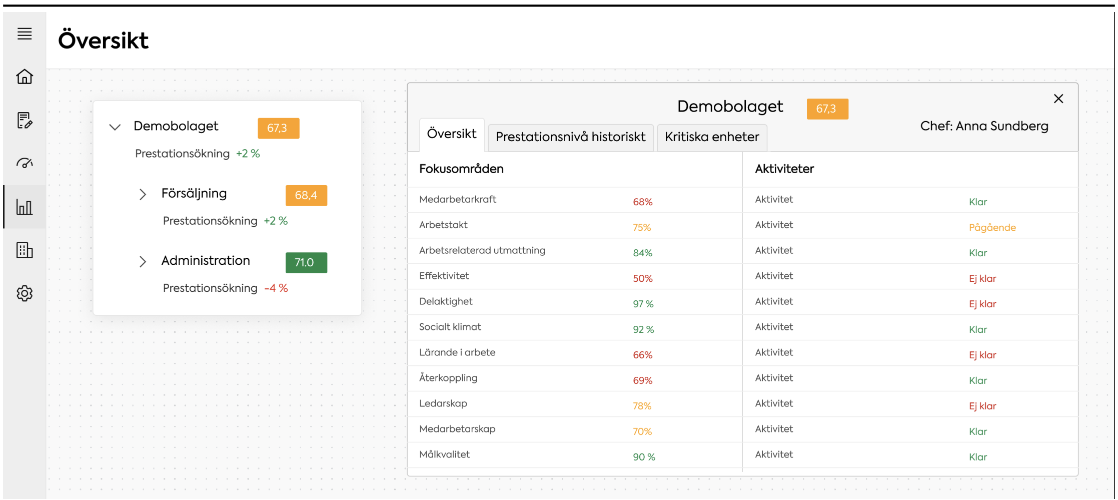

Figure 11 Detail view, list model prototype

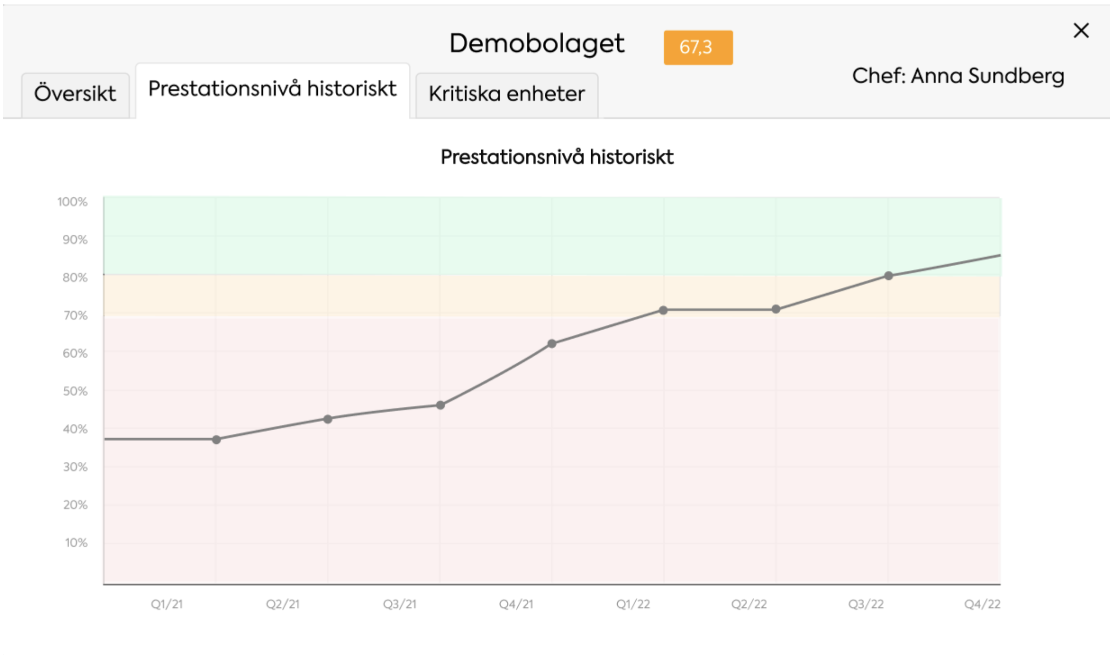

Figure 12 Detail view, second tab with graph showing performance value over time

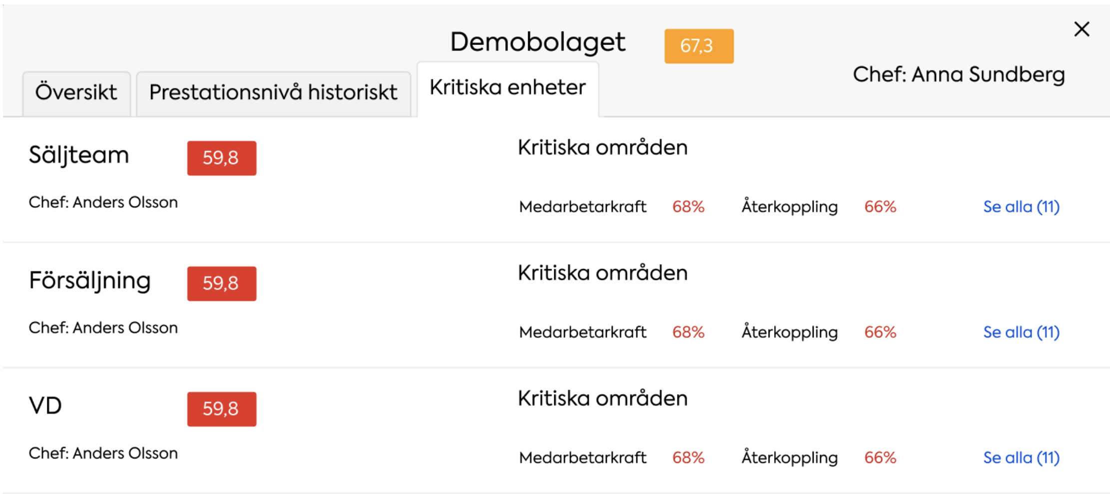

Figure 13 Detail view, third tab with list of most critical subunits

3.2 Empirical Study

As the study set out to evaluate the efficiency of two different visualization types, a user-centered approach was adopted when defining the tasks. For this approach, it is more beneficial to design tasks that outline perceptual acts performed by the user, such as distinguishing entities in the system, rather than data-centered tasks such as matching the measurement levels to compatible display dimensions [24]. Wehrend and Lewis [37] have devised a low-level, domain-independent classification of tasks that users might perform in a visualization system. From Wehrend and Lewis' classification of tasks, the following task types were chosen based on the expected perceptual acts that the user would perform in the system:

- *Locate* covers interaction techniques that allow the user to find certain data elements that are already known about. An example of a locate task would be to find the HR unit in the system.
- *Identify* is similar to locate however in this case the user is asked to find and describe an element that is not previously known. An example of an identify task would be to find a unit with the performance value of 61,0.
- *Cluster* allows the user to find clusters within the data elements based on visual similarity. An example of a cluster task would be to find all subunits under the Administration unit.
- *Rank* type of tasks involve users finding the extreme, i.e. the best and worst, cases. An example of this type of task would be to find the tasks with the highest and lowest performance value.
- *Compare* covers interaction techniques that allows the user to compare and contrast elements based on the certain attributes of the element. An example of a compare task could be to compare the performance value of the HR unit and the Reception unit.

Altogether the test consists of 20 tasks, divided into two sets of 10 tasks for each model. The sets are designed to be equivalent, with two tasks per task type. Furthermore, half of the users will start with the tree model and half with the hierarchical list model. This is in order to avoid the users awareness of the organizational structure from the previous set of tasks affecting the results. In the usability tests, the dependent measure of performance is the total time taken to complete each task type for the visualization model, as well as the time taken to complete the entire set of 10 tasks. In addition, there will be a measure of preference where the user will compare and rank the models against each other based on ease of use and usability, and explain their reasoning.

There was a total of 22 participants in the study. The users conducted the tests either through video chat or in person, with a supervisor administrating the tasks and taking the time. The supervisor also asked the participants the questions regarding usefulness and ease of use after the tasks were finished, and wrote down the answers.

3.2.1 Qualitative and Quantitative Analysis

In regards to scientific research, one may use a quantitative or qualitative approach. Quantitative analysis focuses on objectivity and data that can be quantified. It is especially appropriate when collecting quantifiable measures of variables from a sample of the targeted population. The data in this method is collected systematically and an analysis of the data is performed by statistical procedures. Compared to quantitative analysis, qualitative analysis is not concerned with numerical representativity but instead with the deepening of understanding the given problem. The objective of qualitative research is to create in-depth knowledge in regards to understanding the various dimensions of the problem. Because of this, qualitative research is more concerned with aspects that cannot be quantified [29]. This study will mainly focus on quantitative analysis, in order to produce comparable results in regards to the two models. The time taken to complete the tasks, as well as the users' personal preference, will be analysed statistically and compared between the models in order to find which model produced better results. In addition, the users' reasoning behind of their personal preference, both in regards to ease of use as well as usefulness aims to create a greater understanding of the quantitative results.

4 Results

Below table (see Table 1) shows the results of the empirical study. The average efficiency, measured in seconds, for completing the total test set as well as for each task type is shown for the vertical tree and the hierarchical list. There were 22 participants in total, where each participant provided one data point for each task comparing the two models. A two-sided statistical hypothesis test was conducted in order to analyze the difference in efficiency between the vertical tree and the hierarchical list, where a null hypothesis states that there is no relationship between the two data sets, meaning that it occurred by random chance. The following formula is used [25]:

$$T_{obs} = \frac{Y_1 - Y_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where T_{obs} is the observed T-value. Y_1 denotes the mean of first set of values, which in this case is the results from the vertical tree, and Y_2 the mean of denotes the second set, i.e. the results from the hierarchical list. Likewise, $s_1{}^2$ and $s_2{}^2$ denotes the variance of the vertical tree and the hierarchical list. Lastly, n_1 and n_2 are the number of samples in the sets. Hence, the p-value is calculated as follows [25]:

$$p - value = P(T > |T_{obs}|)$$

The resulting p-value, or probability value, from the hypothesis test describes how likely the data would have occurred by random chance, i.e. that the null hypothesis is true. The level of statistical significance is often expressed as a p-value between 0 and 1, where a smaller value signifies stronger evidence to reject the null hypothesis. A p-value below 0.05 means that there is less than 5% probability that the null hypothesis is true, which is typically considered strong evidence and statistically significant. A statistically significant result cannot prove that the alternative hypothesis is true, i.e. that one model is more efficient than the other, it can only give evidence for rejecting the null hypothesis. However, a statistically significant result may indicate that for one model being more efficient, although one cannot be certain as there is still a slight probability that the results occurred by chance and the null hypothesis was correct [21].

Task type	Vertical tree	Hierarchical list	p-value	$\lvert T_{obs} \rvert$
Total	66.023	78.432	0.011	2.861
Locate	10.146	13.408	0.006	3.114
Identify	13.828	16.690	0.066	2.129
Cluster	12.388	14.793	0.006	2.884
Rank	13.205	14.289	0.526	0.678
Compare	16.440	19.233	0.036	2.350

Table 1 Efficiency results of empirical study, measured in seconds

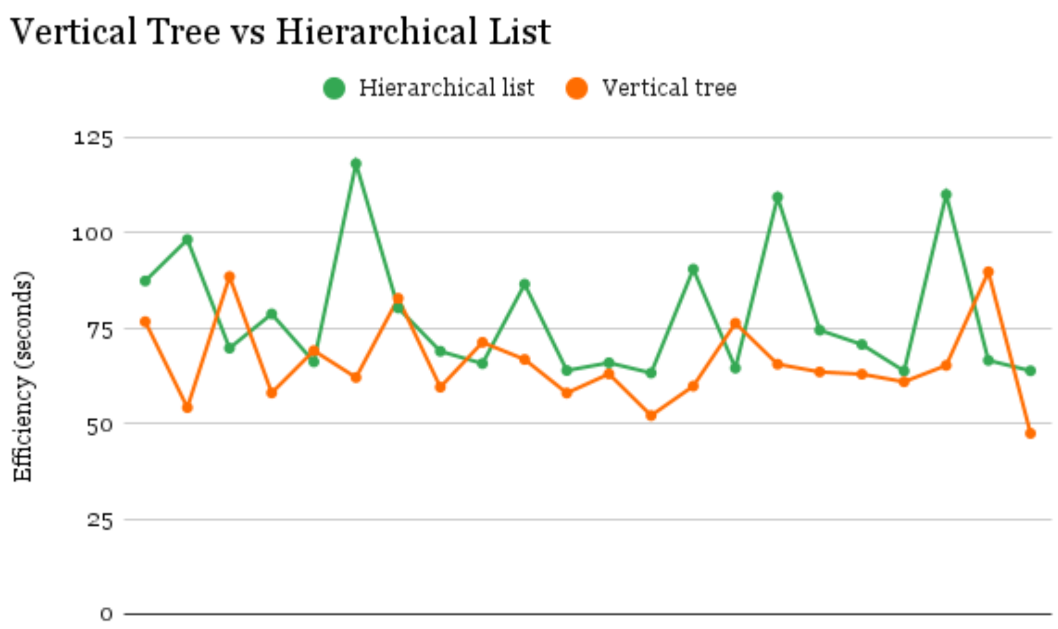

Figure 14 Graph of results for each participant

The graph above (see Figure 14) shows the total efficiency for each participant, both for the hierarchical list and vertical tree. Furthermore, the standard deviation for each task type was calculated for both models, and is shown in Table 2.

Task type	Vertical tree	Hierarchical list
Total	11.053	17.080
Locate	2.699	4.106
Identify	3.534	5.219
Cluster	2.041	3.338
Rank	3.803	6.457
Compare	2.809	4.816

Table 2 Standard deviation of results

The total test time, averaging at 66.023 seconds for the vertical tree and 78.432 seconds for the hierarchical list, shows a significantly higher efficiency for the tree model with a p-value at 0.011. This p-value indicate a statistical significance and strong evidence to reject the null hypothesis, which only has 1.1% probability of being true. In addition to this, the fastest total test time was 63.200 seconds for the hierarchical list, which 11 different test subject were faster than for the vertical tree. The fastest total time for the vertical tree being 47.360 seconds.

For the locate task type, averaging at 10.146 seconds for the vertical tree and 13.408 seconds for the hierarchical list, the vertical tree model had a higher efficiency when compared to the hierarchical list, and the difference was significant with a p-value at 0.006. However, the identify task, averaging at 13.828 seconds for the vertical tree and 16.690 seconds for the hierarchical list, did not have significant difference with a p-value at 0.066. This p-value indicate that there is not a low enough probability of the null hypothesis to reject it.

The cluster tasks had an average efficiency of 12.388 seconds for the vertical tree and 14.793 seconds for hierarchical list. This is a statistically significant difference with the p-value at 0.006, which is enough to reject the null hypothesis. The rank tasks however, with a p-value of 0.526, do not have a statistical significant difference enough to reject the null hypothesis between the average efficiency of 13.205 seconds for the vertical tree and 14.289 seconds for the hierarchical list. Lastly, the compare task had an average efficiency of 16.440 seconds for the vertical tree and 19.233 seconds for the hierarchical list. The p-value of 0.036 shows that this is a statistically significant difference in efficiency, which is enough to reject the null hypothesis that the results occurred at random.

It was found when analysing the total test time for each participant, that the majority performed faster during testing of the second structure compared to the first. This may be a result of the contents of the structure being the same, so the user has learned the content by the second set of tests. However, this was accounted for beforehand and as a result, the first structure to be tested was switched for each participant such that 11 participants started with the list and 11 with the tree, in order to produce as fair results as possible. Furthermore, it was found that those that started with the list produced significantly faster results for the tree, compared to the time difference between the first and second structure when the participants started with the tree. The participants that started with the tree were on average 2.114 seconds faster with the list, whereas the ones that started with the list were on average 26.993 seconds faster with the tree. This produced a p-value of 0.004, which is less that 0.05 and thus indicate a significant difference.

For the last question in regards to the users' personal preference between the two systems, both in terms of ease of use and usefulness, there was a clear favouring for the vertical tree model. 18 out of the total 22 participants preferred the vertical tree over the hierarchical list both for ease of use and usefulness, citing mainly that it was easy to get an overview of the entire structure and that the tree optimized the website space better than the list. Out of the other four participants, two favoured the list, one was split for both ease of use and usefulness, and one favoured the tree for ease of use but thought the list was more useful.

Although the participants largely favoured the tree, there were arguments both for and against the model when asked to expand their reasoning. Several participants mentioned that, although the tree was better for this example structure, it may not be the best for larger structures, as one cannot minimize levels in the tree compared to the list. In regards to utilizing the website space, the tree was favoured, however some participants mentioned that for mobile usage the compactness of the list may be advantageous. Several users mentioned that the tree gave a better overview of the structure, and mainly cited that there was no scrolling in the tree, the units on the same level were next to each other which eased readability, and that it was easier to understand the hierarchical structure. Multiple participants also mentioned that the tree was easier in a testing situation where they were first time users, and that it would be very useful for presentations where the audience are not familiar with the structure, however for knowledgeable users that are familiar with the structure, the list may be advantageous as one can focus on one level at a time. Some participants also mentioned that the vertical tree model was easier to use as that model was more commonly used for representing organizational structures, and they were thus more familiar with that model. In regards to the readability of the two models, although several participants mentioned that the structure was more easily comprehensible with the tree, some participants stated that the list was easier to understand as it was organized in a similar way as how one would read a text.

5 Discussion

The results show evidence suggesting that the vertical tree is overall more efficient than the hierarchical list, and is more favored by users. The total time to complete all tasks was significantly faster for the tree, with half of the participants having a faster time for the tree than the fastest one for the list. In addition to this, the p-value demonstrates a 1.1% probability of the results occurring at random, which is low enough to reject, indicating that there is a significant difference between the two models. Furthermore, although there were comments both for and against the two models, 18 participants out of 22 stated that they favored the vertical tree both in ease of use and usefulness over the hierarchical list.

When analyzing each task type, the results varied greatly. For the locate, cluster and compare tasks, the vertical tree was more efficient, with a p-value lower than 0.05 suggesting a significant difference between the models. However, for the identify and rank task types, the same cannot be said. The identify task type had a p-value of 0.066, which is only slightly higher than 0.05 but still high enough to not be able to reject the null hypothesis. It is puzzling why the identify tasks did not show a significant difference between the two models when the locate tasks did, since one could argue that the types are similar. Both task types involve scanning the units in the hierarchy in order to find one fitting the criteria, although identify is finding based on a trait and locate is based on the specific unit itself. One hypothesis could be that the vertical tree is easier to grasp at first glance, which correlates to the users' accounts of it being easier to get an overview of, and thus is faster for the first locate tasks. As the identify tasks follow the locate, the users might already have gotten an overview of both structures and know where to search for the desired unit. It would be interesting to test this hypothesis by switching the order of task types between tests, and seeing if that would have an effect on the time for each task type.

For the rank task type, the vertical tree was slightly faster than the hierarchical list, however not enough to be of statistical significance. With a p-value of 0.526, one cannot reject the null hypothesis. Similar to the identify task type, it is puzzling why the rank task type did not show a significant difference between the two models. The rank task involves scanning the whole hierarchy in search of the unit with the highest and lowest performance score. Perhaps as a result of completing previous tasks, the users have gotten familiar with the structure and are able to scan it equally fast, or already know which units have the highest and lowest scores. It would therefore be of interest in this case as well to perform tests with different order of task types.

When comparing the results in this thesis to a related study by Xiang et al [39], where some of the same task types were used to test a hyperbolic tree versus a hierarchical list for visualizing criminal relationships, it is interesting to find that the results differ. The other study also used task types identify, cluster, rank and compare, however it found that none of them showed a significant difference in efficiency for their models. The only task type that showed a significant difference between the models was associate, which involves linking units together based on relationships. The different results between this thesis and the other study show that the context and structure could play a role when analyzing the efficiency of different models.

5.1 Future work

There are several factors that could have had an effect on the results, and thus are important to consider during analysis. For future testing, it could be of interest to consider these factors, and vary them between tests in order to evaluate their significance.

For the sample organization used in the prototypes, it was decided to have the units randomly ordered within each level of the hierarchy. This is in accordance with previous studies involving access times of hierarchical structures, such as ones by Miller [22] and Kiger [13], where both decided to use randomly ordered items within each level of the hierarchy. However, studies investigating the difference in search time between ordered lists compared to randomized ones have found that randomized lists have resulted in slower search time. Although ordered lists have been found to result in faster search times, there are inconsistencies in regards to which type of organization is optimal. A study by Barnard, Morton, Long & Ottley found that the menu arrangement that resulted in the fastest search time varied both across and within user groups [1]. When given a list of European countries, either organized in alphabetical order or on a map of Europe, it was found that postgraduate engineering students searched faster using the map while a group of Cambridge housewives had faster results when using the alphabetical list. In a second experiment however it was found that the housewives were faster with the categorical sorting rather than alphabetized when the list consisted of grocery items instead of countries. Another study, by Card, compared performances of users on three different versions of menu lists [6]. One version was ordered alphabetically from top to bottom, one was arranged in random order and the final version grouped categorically similar items together. Each subject was tested for 12 sets of 43 tests with one of the arrangements. For the first set, the alphabetized order performed significantly better than the other two, with a mean search time of 0.47 seconds compared to 0.85 for the categorical and 0.98 for the randomized. As the sets continued, search time for all three versions decreased with practice and differences between the versions were no longer consistent by the fourth set [28]. This indicates a slight advantage for using a non-random ordering of the hierarchical structure within each level, as it improves the initial search time, although it does not greatly affect users familiar with the system.

Several participants commented that, although they favored the vertical tree for the organization in the prototype, the results may be different for a larger organizational structure. A larger structure is used in a similar study by Xiang et al [39], comparing a hyperbolic tree to a hierarchical list, where the results indicated that both models could be of use. Although, the models used in the study were not for representing organizational structures but criminal relationships. For this study, it was decided to use a vertical tree instead of a hyperbolic tree, as they are more common for representing organizational structures [17, p. 79]. The sample organization was chosen to have three levels, as although the hierarchical structure varies between organizations, organizations are cited to typically have three levels of management, top-level, middle-level and first-level. The structure resembles a pyramid as there are generally many first-level units, fewer middle ones and fewest at the top. However, there are numerous changes within organizations that affect the hierarchical structure of the organization, such as increasing use of teams, a prevalence of outsourcing and the flattening of organizational structure [32]. In addition, there are organizations which are significantly larger than the sample organization, and thus have a greater number of hierarchical levels as well as a greater number of units within each level. Because of this, it could be of interest to replicate this study with different types and sizes of organizational structures, in order to find if different models could be better suited for different structures.

If one was to test different types and sizes of organizational structures, there could be other types of visualization models that could be better suited rather than the hierarchical list or the vertical tree. Some participants commented that for larger structures, they would want to be able to minimize and expand parts of the tree, similarly to the list. This could be achieved by having a model similar to the hyperbolic tree, where the user can zoom in to certain branches [17, p. 135]. This model is used in a study by Xiang et al., where the application would be for larger structures used for visualizing criminal relationships [39]. For larger structures, it could be harder to find the desired item, and thus being able to zoom or filter is crucial.

Furthermore, it was decided to use the same organizational structure for both models. This could have arguably affected the results, as it was found that the second model was typically faster than the first. However, this effect was accounted for by switching which model the user started with for each user, so that half of the participants started with the hierarchical list and half with the vertical tree. When comparing this method to other studies which set out to compare two different models, it seems that there is no definite procedure for ensuring fair results. In the study by Xiang et al., comparing hierarchical lists and hyperbolic trees for visualizing criminal relationships, it is stated that the same database is used for both models. In addition, it is not explicitly stated whether the first model is switched between tests, but it is hinted at that the users start with hierarchical list view and then the hyperbolic tree view [39]. Another study by Zaphiris et al., comparing expandable indexes and sequential menus for searching hierarchies, seem to follow a similar procedure as this thesis. During testing, half of the participants worked with the expandable menu first and the sequential menu second, whereas the other half worked with the sequential menu first and the expandable menu second. Furthermore, although the study tested three different levels of hierarchical depth for both menu models, the same hierarchical structure was used as the basis [41]. For future testing it could be of interest to use different structures for the two models, and thus not have to vary which model the user starts with. Although, in order to obtain reliable results, the two structures must be equally complex, so that one is not more difficult to search through.

The target audience for the application are managers of organizations, ranging from CEOs to department heads and team leaders. Hence, for the empirical study part of this thesis, 22 participants all working some form of managerial position were selected to partake. The participants were of a wide variety of ages and experiences, in order to represent a wide range of potential users. In a study by Tullis and Wood with 168 participants, it was found that a card sorting test with only 20-30 participants could yield an average correlation coefficient of 0.9, with diminishing results when having beyond 30 users [36]. Although the testing for this thesis does not involve a card sorting test, it can be argued that the testing methods are similar as both are quantitative testing methods that carry themes of information visualization and organization. Because of this, an initial set point of 20-30 participants was established. However, the number of participants may also depend on the type of testing and the diversity of the user population. If the targeted user type is believed to be homogeneous, the results could be greatly similar for all participants and thus only a small set of participants are needed. For cases where there is uncertainty in regards to the diversity of the user group, the study may begin with a smaller number of participants and then expand that number by recruiting more participants until the same responses are starting to be repeated with very little new information [2]. For this study, it was therefore decided to not recruit 20-30 participants immediately, but instead to have continuous recruitment and testing until a pattern of repeated responses and little new information was found. This led to a final number of 22 participants.

However, the number of participants in a quantitative study is a highly debatable topic. Some argue that UX related studies should aim for having 40 participants [4], while other sources recommend having around 100, 200 or more participants [3]. Therefore, it would be interesting to conduct a similar study to this thesis with a larger number of participants in order to test if different results are found with a larger user group.

Although the participants all had worked or are currently working in a managerial position, and thus could have used similar systems previously, no participant had prior experience with the system used during testing. Before starting the tasks, there was a simple and brief introduction of the testing procedure, as well as the information displayed. As a result of this, the participants had to understand the hierarchical structure in order to efficiently search for the desired units for each task. This is in accordance with studies by Parkinson et al. [28] and by Larson and Czerwinski [15], where the participants had little to no information or training prior to the tests. Larson and Czerwinski reason this by comparing with previous studies by Miller and Snowberry, where the participants were given the hierarchies to study for extended periods of time, and given extensive feedback during testing regarding the participant's choices when searching. These factors could have influenced the participants to rely more heavily upon a learnt behavior rather than their instinctive choices. Furthermore, it has been shown that familiarity has significant effects on performance. A study by Malinowski and Hübner investigated the effects of familiarity on visual search, by having German and Slavic participants find the target within a set of distractors. In order to avoid any ambiguity between familiarity and visual difference, N and И were used for target and distractors. The German participants were only familiar with the N, whereas the Slavic participants were familiar with both symbols. The results show that the searching was difficult only in the case where the Germans had to find an N among Иs. In any other case the results show that the search was efficient. This indicates that familiarity does have an effect on visual search performance, as it improves distractor grouping [20]. There are also other studies which indicate a strong correlation between the speed and accuracy of visual target search and familiarity, showing that searching through unfamiliar elements is much more difficult for users than searching through familiar ones [30].

As there is a strong correlation between familiarity and efficient visual searching, it would be beneficial to test this in future studies. Perhaps the most efficient hierarchical structure model could be a different one for users more familiar with the system. Additionally, the targeted users would ideally be working with the application for an extended period of time, in order to improve the employee well-being to a great extent. Thus the users of the application would likely be familiar with such a system.

6 Conclusion

The aim of this thesis was to gain insights into the field of information visualization, by researching and conducting tests regarding visualization of hierarchical structures. The objective was to evaluate whether a hierarchical list or vertical tree was more beneficial when evaluating their efficiency in searching, as well as the users' experience regarding ease of use and usability. An empirical study was set up in order to produce comparable results regarding the efficiency of the two models. The 22 participants involved in the study completed search-based tasks related to the expected actions that the user would perform in the application. Afterwards, the participants were asked to rank the two views in regards to their perceived ease of use and usability. The overall results indicate that the vertical tree is more efficient than the hierarchical list, with a 1.1% probability of the results occurring at random. Furthermore, the vertical tree was favored by 18 out of the 22 participants. When evaluating the study, there were factors that could have had an effect on the results, and could be of interest to analyze further. The hierarchical structure used had a random ordering within each level, however studies show slight advantages for using non-random ordering for improving initial search time. For users familiar with the system there is no significant difference. The study only tested the models with one sample structure, however it could be of interest to evaluate with different types and sizes of organizational structures in order to find if different models could be better suited for different structures. Lastly, it could be of interest to test if familiarity could affect the results. The participants in this study were not familiar with the structures beforehand, however the targeted users would ideally be working with the application for extended periods of time, and would therefore have a level of familiarity with the organizational structures. Thus, it could be beneficial to do additional testing with users familiar with the organizational structure they are performing the tasks on, in order to evaluate whether a different model could be more efficient.

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