Personal Analytical Calendar

by

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B.Sc., Shahid Beheshti University, 2011

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Supervisory Committee

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ABSTRACT

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Data is all around us, everywhere we go and in every activity we do. It exists in all aspects of our everyday personal life. Making sense of these personal daily data, which leads to more self-awareness is becoming remarkably important as we can learn more about our habits and behavior and therefore we can reflect upon this extended self-knowledge. Particularly, these data can assist people to learn more about themselves, uncover existing patterns in their behaviors or habits and help them to take action towards newly developed goals. Accordingly, they can either try to improve their behaviors to gain better results and trends or to maintain existing ones. Through the interviews that I conducted, I learned that "Productivity" is one of the most important personal attributes that people are very interested to monitor, track and improve in their daily lives. People are interested to learn more about the supportive or preventive causes that effect their daily productivity, which eventually can help them to improve their time-management and self-management. In this thesis, I focus on two research questions: (1) How can we design a visualization tool to help people be more engaged in understanding their daily productivity? In order for people to learn more about themselves, they need context about their living habits and activities. So I chose digital calendars as a platform to integrate productivity related information as they provide beneficial contextual information, supporting many of the questions that people ask themselves about their personal data. As the next step, I had to find an effective way of representing influential factors on productivity on the calendar. This led to define my second research question: (2) What combination of visual encodings will enable people to most easily identify a relationship between two different pieces of daily information rendered on a calendar? For finding the best visual encoding, I considered encoding Numeric data using Saturation and Length encodings, and Nominal data using Shape encoding. I designed two types of questions: Calendar related questions, to investigate the interference level of visualizations in calendar related tasks, and Visualization related

questions to identify which visualization is faster and leads to more accurate results and better user ratings. I compared the combination of Numeric x Numeric (Saturation x Saturation, Saturation x Length, Length x Length) and Numeric x Nominal (Shape x Length, Shape x Saturation) data encodings. My results demonstrated the following: for Calendar Task questions and in Numeric x Numeric category, Length x Length had the overall best results. For the same task set and in Numeric x Nominal category, Shape x Length was rated the best. For Visualization Task questions and in Numeric x Numeric category, Saturation x Saturation had the better performance overall in most of the cases and for same task set and in Numeric x Nominal category, Shape x Saturation was the fastest while Shape x Length was the most accurate. These findings along with interviews provided me with useful information for refining the visualization designs to more accurate, more user-friendly and faster visualizations which assist people in monitoring goals, trends, status, contexts, influencing factors and differences in their productivity related personal daily data and brings them more insight awareness and possibly self-reflection.

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ACKNOWLEDGMENTS

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DEDICATION

I would like to dedicate this thesis to my parents, Goli joon and Babak joon, who made me who I am today. I am thankful for having their presence, their unconditional loving kindness and motivation all through my life no matter where I am, in my every breath.

Chapter 1

Introduction

We are surrounded by data everywhere in our everyday life. Daily, we use various applications to record different data about ourselves, manually or automatically, to gain more self-insight and understanding and to be able to reflect upon them especially with widespread availability of computer and mobile devices. We record our eating habits [28], daily energy consumption [15], medical histories [37], and exercise routines [38, 36]; we set reminders of our to-do lists and daily tasks and we try to follow a daily set of tasks or routines to achieve our goals. We are even logging more data about ourselves by joining in social networks such as Facebook, LinkedIn, and Twitter, uploading pictures, updating our status and so on. Despite the huge amount of data collected daily using sensors and the applications that help people monitor these personal data, there still are many personal data that we have no insight about; we do not realize to what extent our behaviours and habits can impact our everyday productivity. According to the interviews I conducted, as described in Chapter 4, people were interested to realize how weather, mood, type of task that they were occupied with, time of the day, day of the week and other factors can influence one another as well as the people's productivity, and to what extent. In order for data related to personal productivity to be useful and effective, not only should there be a proper way of collecting them for a considerable period of time, but also they need to be visualized so that people can easily interact with these data and make sense of them. Ideally, people will need to spend only a small amount of effort and time to gain a deeper understanding of themselves.

My goal in this thesis is to investigate best practices for creating visualizations that facilitate monitoring factors that impact people's productivity. I used visualizations for data collected on a daily basis with a goal to show day-to-day measures as well as longer-term patterns or trends. I suggest that such a tool could be very helpful for people to track their personal data, gain increased knowledge about themselves, and take action to improve their productivity.

In this thesis I focus on personal use of calendars by people for self-reflection purposes in everyday life. I am tackling two main research questions: The first question is how to design a tool for providing feedback about people's personal daily activity and influencing factors for increasing self-awareness and self-reflection on behaviours, thoughts and habits? And the second question is how to best design visualizations for displaying these influential factors of productivity for efficient use? I chose to integrate productivity-related data into computer-based calendars because date- and time-based information are found everywhere in people's daily lives; widespread use of online, computer-based or mobile calendar applications such as iCalendar, Google Calendar, and Yahoo and synchronization of information among all these platforms is a clear indictor of this claim. Calendars are familiar, frequently used Personal Information Management (PIM) systems that help with activity planning, reporting, and recordkeeping. Also a calendar, by its nature, serves as useful context for productivity-related data. Because people need to enter their schedules and activities on it, it therefore automatically helps people to understand the influencing factors in their personal everyday life. An example scenario is as follows: Sarah looks at her calendar information from a month ago; she notices that one particular Monday she was very unhappy and unproductive. By looking at her daily tasks and events on that specific day she realizes that she had participated in a very long lasting meeting from 9:00 AM - 2:00 PM. After giving a bit of thought she remembers that she had an argument with her boss during that meeting that had consequences till the end of that day. Now this example shows how Sarah was able to take advantage of the primary data, working as contextual information on her calendar, to recall the reason for being sad and unproductive. Because of all these important reasons, I chose a digital calendar as the platform for visualizing influencing factors on personal daily productivity.

My intent is to design a visual *analytical* tool to help people understand their productivity, including trends and relationships of relevant casual factors, especially ones that they have been unaware of. I decided to focus on the six main questions that users ask themselves about their own data (Status, History, Goals, Discrepancies, Context and Factors) [18] as a starting point for my designs. I took advantage of design guidelines presented in previous research to find effective visual encodings that would enable people to easily perceive the information.

One of the main motivations for designing a personal productivity tool started with my initial interviews, described in Chapter 4, interviews about Personal Productivity section, where I talked to people about their understanding of their own productivity. This made me realize that a tool might be able to better support this process. The factors (e.g. mood, stress level, weather, social relationships) that directly or indirectly impact people's everyday productivity, the stage they are at for each task (e.g. studying, gardening, playing a musical instrument…), their daily progress and how they have performed over a specific period of time were some of the productivity related questions that people said would like to find the answer to.

In an interesting study [21], McDuff et al. designed a tool called AffectAura that supports how people reason in time about their emotional experiences. This study highlighted the importance and impact of mood and emotions in personal daily life. In another interesting study [34], Kamvar and Harris focused on visualizing millions of feelings for qualitative and statistical exploration of emotional data that was collected by "We are Fine" engine. This engine was fed by different websites and around two and a half million people contributed in its data collection phase by sharing their emotions. This tool collected demographic data of each user such as gender, age and location and also weather data. This study showed that not only this tool increased people's self-awareness by helping them find out more about their emotion patterns but also reported that participants have felt connection and sympathy to other people and the world around them. These works along with feedback from my interviews led me to realize that visualizing mood, as an influencing factor on personal daily productivity, could help people to find out both about the factors that effected their mood and the effect of mood on productivity.

In the end, I chose to visualize mood, weather and overall productivity on the calendar, as examples of the kinds of productivity-related data that people may wish to examine.

To sum up, I aimed to find the answers to these two questions:

1. How can we design a visualization tool to help people be more engaged in their daily productivity, gain awareness of and monitor the possible factors that influence their productivity, and consequently be able to maintain or improve their productivity level and reflect upon it?
2. What combination of visual encodings will enable people to most easily identify a relationship between two different pieces of daily information rendered on a calendar?

(This question arose because in investigating question 1, I chose to integrate productivity related information into a digital calendar.)

In this thesis, the sections are as follows: First I summarize a literature review of previous studies and applications that deal with casual users, Personal Informatics Management, calendar usage, ambient systems and visual design methods and principles. This section is followed by a design section where I describe the techniques and guidelines I utilized for my proposed design. Then I define the methodology used in my experiment and my experiment design. Following this, I report the analysis of the study results, followed by conclusion, future work, limitations and the threats to validity of the study.

Chapter 2

Related Work

In this chapter I investigate related works in fields of Personal Visualization and Personal Visualization Analytics, Personal Informatics and Personal Information Management, advantages of Calendars as the platform in my designs, different design principles for Attentionally Ambient visualizations and various practices of data encodings.

2.1. Personal visualization and Personal visual analytics

Recently, more attention is being given to research on personal analytic tools and applications as people gain an interest in developing deeper self-understanding and self-reflection about their habits and behaviors (e.g. sleeping, exercise, eating habits). These tools present and enable people to interact with their personal data through meaningful visualizations.

In a very recent study, Haung et al. [14], introduced the concept of Personal Visual Analytics (PVA), a kind of visual analytics that aims toward enabling people to gain awareness of, explore, and learn about personally relevant data in an everyday context. Personal Visualization involves the design of interactive visual data representations for use in a personal context, and Personal Visual Analytics is the science of analytical reasoning facilitated by visual representations used within a personal context. Visualization design principles for PVA are somewhat different from Visual Analytics (VA) since the tools are targeted for people who have little or no expertise in analytical tasks or visualization designs. PVA subsumes the previously described field of casual information visualization.

The key characteristic of casual information visualizations is that they should be comprehendible by normal people or casual users [26]. Sprague defines *Casual Information Visualization* (casual infovis) as information visualization related to non-work data that are captured during leisure time (E.g. pursing a hobby, playing a sport) for people who are not necessary familiar with data analysis [26]. Pousman et al. [24] addresses four differences between traditional infovis and casual infovis: (1) casual infovis includes a wider user population including non-expert users, (2) users use it more repeatedly, for non-work related tasks and for short durations each time, (3) the data is important for the person, and (4) Casual infovis provides awareness insight, social insight and reflective insight.

My Personal Analytical Calendar application is a PVA tool that aims to help people gain deeper insight into their personal productivity.

2.2. Personal Informatics and Personal Information Management

Many studies have been done on Personal Informatics (PI) and Personal Information Management (PIM). PI is a discipline that studies the collection and management of personal data and the design of tools to support this process. Li et al. in [17] describe PI as a class of system that helps people collect personally relevant information such as behaviours, habits and thoughts, tasks and activities, for the purpose of gaining self-knowledge and self-reflection. PI relates to an individual's personal life information - not necessarily private - that are collected and retrieved so in the future the person can reflect upon them [16]. PIM, introduced in 1980's [27] is a concept describing how personal information is stored, organized, maintained and retrieved to support daily tasks and longer-term plans. Effective PIM strategies help people to achieve greater self-awareness and better utilization of time, money and energy at an individual level, and help achieve better productivity and teamwork at organizational level [3].

People’s interest in exploring and understanding their personal data has led to many studies that suggest new practices, designs and applications facilitating self-knowledge and self-reflection. Examples include [11] that suggests design recommendations for home-based health monitoring technologies, helping people better understand everyday life. Work by Li et al. [19] suggests design approaches of PI systems that can increase self-knowledge using contextual information; these approaches are based on their studies in the physical activity domain.

In [17], Li et al. introduced a five-stage model of personal informatics including Preparation, Collection, Integration, Reflection and Action. They identified *Discover* and *Maintenance* as two different phases of Reflection. In another later study, explaining that there is no comprehensive understanding of what people want to know about their own data, they suggested six kinds of questions that people are interested to know about themselves: *Status*, *History*, *Goals*, *Discrepancies*, *Context* and *Factors*; while Status and Discrepancies are in the Maintenance phase of reflection, the rest are in the Discovery phase [18]. There are many applications that collect different personal data for Reflection. Examples include applications such as NIKE+iPod [38] and FitBit (designed for monitoring people’s physical activity), Daytum and Flowingdata (that represent personal data statistics), and Mint (that monitors and analyses financial activities). Another example is a toolset proposed by Schewarz et al. [25] that helps people learn more about their personal habits based on their financial data; it does so by visualizing money spending habits, money spending locations and the impact of people’s spending on the environment.

In [35] you can find a list of many such applications. A survey of those with visualization components was also presented in [14].

To date, we are unaware of any application that helps people understand their productivity by assisting them to discover influencing factors and reflect upon them. Such a tool could not only present the current status of a person's productivity in specific activities, but could also reveal a historical view and the changes in daily progress on different tasks (e.g., how today is different from yesterday in terms of productivity).

I propose a design that tackles the Reflection and Action stages, by providing visualizations for users to be able to reflect upon their personal productivity-related information and decide what actions they should take. My proposed tool provides people with features that assist them in finding new data about the six above-mentioned questions they would like to know about themselves about their personal daily data.

2.3. Why calendars as platform?

One reason to integrate productivity related information into digital calendars is because digital calendars are ubiquitous. Studies done by Tungare et al. showed that Calendars are very effective PIM tools [30]. Tungare et al. suggest that there are two main motivations for people to use calendars: the first is to find out about the activities that will happen in the near future and the second is to find about the near-future activities that require preparation. As reported in [5], 51% of 621 participants at a technology company indicated in a survey that they use computer-based calendars for their personal calendar use. Digital calendars facilitate finding, keeping, organizing, and recalling people's personal information [1, 2]. Moreover, as a PIM tool, a calendar can play an important role in a person's *learning process* [2], provide support as an external memory for all activity logs and events, and support planning and reporting [22]. Furthermore a calendar serves as a life journal for keeping one's history [30]. As one of the interviewees in [30] stated, after discovering his father's journal a few years after his death, they shared his memories by going through his calendar logs.

The studies in [5] show that 72% of 621 study participants at a technology company desired constant access to their personal calendars, either digital calendars or paper-based ones. This result shows that calendars are widely used by people continuously. Furthermore, calendar designs are shifting from supporting only office work use to being used domestically for data sharing, social and collaborative purposes *anywhere* and *anytime*. Application of digital family calendars for co-located members of a household is one example [5,7].

Calendars can also provide important context for interpreting personal productivity data. Providing context plays a major role in finding influential factors in personal life. According to a thorough study by Den [9], context is defined as: *"any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves"*. As discussed in this definition *identity, location*, *time* and *activity (who's, where's, when's* and *what's)* are the elements characterizing the situation of a particular entity. Relevant contextual information for understanding personal productivity include the primary information that people enter on their calendars such as their daily tasks, appointments, events and engagements alone or with others, at a specific time and a specific location. As another example of contextual information, Tollmar et al.

[28] developed Mobile Health Mashup, a mobile application that mines data on well-being and **contextual** data including weight, body fat, step, hours slept, time awoken, location, food intake and exercise either from manual user input or using multiple data sources such as Fitbit and Withings (an application that tracks and monitors people's health and exercise condition), phone calendar, mobile cell-id to find correlations and deviations of these data within different time scales. These statistical data are analyzed over time and are presented through visualizations in a mobile app to help people gain a deeper insight into their wellbeing. This study discussed how contextual information could play an important role in better self-knowledge and self-reflection on personal data.

Based on field studies on user engagement in data collection by Li et al. [19], when users are more engaged in entering context *manually* they have more understanding of the factors that influence different aspects of their lives. However, manual input comes with a significant time cost. This cost increases as the amount of data people input manually grows. The result of this input cost is usually a decrease in usage level of the application as time passes by. This shows that one of the challenging phases of PI is data collection, especially if the entire burden is on people [17]. The focus of this thesis, however, is on information presentation rather than data collection. In addition, and fortunately, the manually entered contextual information on personal digital calendars (primarily calendar activities) do not require any extra effort. A positive aspect of using calendars in my designs is that information that people already enter on their calendar for the calendar's primary purpose (scheduling and planning), can also serve as contextual information (activities, location, people, events) for investigating other personal data, particularly information relevant to personal productivity.

Of course for other contextual information there should be a balance between user input (e.g. mood) and automatic data collection (e.g. weather information and step counts) using existing sensors. Note that supporting the data collection phase is not our focus in this thesis; however, there are many researchers focusing on this area.

2.4. Attentional ambience

Since I am using a digital calendar as the platform, the new information displayed on it is of secondary importance and should not disrupt the calendar's primary function as a scheduling tool. Therefore, I take advantage of design principles and methods for presenting information in an *attentionally ambient* way. Attentionally ambient designs are intentionally designed to be able to move in and out of viewer's focus of attention [12] by being presented as a secondary visual layer that is not visually demanding with respect to the primary task [15], which in my case involves viewing calendar content.

Closely related to attentionally ambient visualizations are peripheral visualizations. Weiser and Brown [32] by introducing *Calm Technology*, proposed that the overloaded information located in the periphery can be transitioned to a calming format and *empower our periphery* first, if the technology enables these information to smoothly move back and forth between center of attention and periphery and second, if it provides more detailed information about our environment. Eleven years later in 2006, Pousman and Stako [23] described *ambient information systems*, also known as "ambient displays", "peripheral displays", and "notification systems". They also defined characteristics of such systems: they (1) display non-critical but at the same time important information, (2) can move from focus of attention to the periphery and vice versa, (3) delicately highlight the nondistracting changes for future reflection, and (4) are aesthetically pleasant and "environmentally appropriate".

We are surrounded by enormous amounts of data that influence our personal daily life. By taking advantage of design principles for ambient information, I would like to investigate and demonstrate ambient approaches that could be used to display productivity-related data on a calendar. The goal is to help people gain awareness insight and reflection insight about their productivity, without causing interference with normal calendar tasks.

2.5. Visual encodings

To choose visual encodings for data within the calendar cells, I consulted literature on the perceptual efficacy of different visual data encodings.

Experiments carried out by Cleveland and McGill [6] for graphical perception showed that for quantitative data *position* judgments are the most accurate, followed by *length* and after that *angle* and *slope.* And finally the *area* judgment is the least accurate one. In another deeper study [20], Mackinlay ranked effectiveness of different visual encodings using the *ordering principle*: "Encode more important information more effectively". He ranked encodings for Quantitative data as following: position, length, angle, slope, area, volume, density, color saturation, and color hue. For Qualitative (Nominal) data he suggested this ranking: position, color hue, texture, connection, density, color saturation, shape and length, angle, slope, area and volume.

To avoid interference effects, I did not use color hue for data encodings in general, although it had a better rank, because colors are extensively used in digital calendars mostly to color the activities that people enter.

For Quantitative data, I chose length and color saturation among these visual encodings. Angle, slope, area, volume and density would not be effective encodings because of very limited area for data demonstration available on calendar cells.

For Qualitative data, considering some examples of this data-type such as weather, and place, I narrowed down the encoding choices for qualitative data to only *shape*. I avoided using color saturation since it was already an appropriate alternative for Quantitative data-types and using a similar encoding for different data-types would cause interference effects. Also any other encoding with a higher rank in this category, such as position, texture, connections, density and color saturation would be an unfamiliar and strange visualization to people since they are used to seeing icons on a calendar, especially for weather. So, I avoided using these encodings as well.

One of the main reasons for using color saturation for representing quantitative data was that I attempted to take advantage of an important property of color saturation. In particular, saturation is helpful in showing patterns and summarization of data, which is very critical for this proposed tool. Results of an empirical study conducted by Correll et al. [8] showed that color encoding (colorfield design) is much more efficient and results in better performance than position (line graph design) in showing summarized data and tasks that involve finding average value, even though position encoding is more precise than color. To extend this to my own design, in a monthly view, color saturation is expected to effectively summarize personal quantitative data and reveal trends.

Moreover, as considered in a recent related experiment on on-calendar visualization [15], another important consideration is *visual saliency*, where there should be a balance between the visual layers for ambient data and the main calendar view in the background so the people can remain focused on their main tasks with calendars without interference from the additional visual displays. As explained in [31], there is a trade-off between layers of transparent displays and perceptual interference between these layers. The more separated these layers are, the less interference happens in the visualization. In an empirical study that evaluated the effect of varying transparency level and its interference by different types of content information [14], Harrison concluded that the cut-off point of interference due to transparency level is between 50% and 90% while any transparency level above 75% reduced legibility and any level below 50% worked well independent of visual displays. This study confirmed that solid background and solid object icons had the minimum interference level and “best selection performance”.

I needed to consider pattern learning guidelines explained in previous studies as well since showing patterns in data would be very important to me. The author in [31] explains the degree to which a pattern is familiar to users affects learning; therefore using familiar displays was one of the important points I considered in my prototype designs.

Chapter 3

Design Process

In this section I have explored the concepts and main research questions I tried to find answers to. I have described the entire iterative process I went through for creating prototypes. I also have described my iterations of pilot study designs as well as actual user study designs.

3.1. Concepts

My initial main research goal was to find a design that would help people understand their behaviours, habits and daily activities related to personal productivity. And the second goal (of the experimental study) was to find an effective design for such an application. I decided to narrow down my study only to people's productivity. To do so, I needed to find a proper platform to implement my design and to find an effective way to visualize the potentially influencing factors.

3.2. Interviews About Personal Productivity

As one of the initial steps, I conducted an interview with 10 people including four females and six males. Their age range was between 23 and 45 years old and the average age was 32 (please see interview questions in Appendix A). The interview was conducted informally, at people's offices, via email or phone and it took approximately 20 minutes for each session. For this interview, I tried to select people from different backgrounds and jobs such as students, company employees, university faculty members and also housewives. These people were recruited through the network of faculty members, friends from other universities and colleagues from a company where I previously worked. I asked the participants to define productivity in their daily lives, how they would measure it for their own activities, whether they were monitoring their productivity, whether they knew what factors influenced their productivity and how they would maintain their productivity level or reflect upon their productivity data for improvement in at least two or three of their everyday tasks. Participants also answered some system design questions about a hypothetical personal analytical tool, how they would use it, and whether they thought such tool would be helpful to them. I used the feedback from these interviews to create the prototypes in the next step. I concluded that among the phases of reflection, discovery and maintenance [18], interviewees were interested in discovering influencing factors in their productivity, monitoring these factors and improving them and maintain their productivity. According to [18], during maintenance people use their collected data to maintain awareness of their goal and their behaviour. During discovery, people can find out about their unknown goals or the unknown factors that impact their behaviour. Depending on the nature of the tasks and people's self-awareness, the relative importance of discovery versus maintenance may differ. Therefore, participants suggested the tool should be able to reveal influential information about their data, help them to see existing unrevealed patterns in the data and make it easy to perceive enough information about the factors at a quick glance.

I based my work on six categories of questions people ask themselves about their personal data (Factor, Goal, Context, History, Discrepancies, Status) according to the findings in [18]. Later I tried to design a tool that answers those six questions. I enumerated a similar list of questions from the interviews I conducted, and found that they did fall within these six categories. In my interviews I also observed how people transition between three modes: Discovery, maintenance and improvement of their tasks and goals (long-term or short-term) based on different influencing factors.

Activities that were productivity-related and that people were interested to track included: Playing musical instruments, gardening, family relationships and activities, doing research, doing exercise, cooking healthy, lecturing, preparation for appointments…

From interviews I understood that productivity at daily activities is dependent on many factors such as mood, weather, the working space, the time of the day, the day of the week, the intake food, the sleeping hours, and the type of the task itself. To some people it is clear how these factors influence their daily lives, and therefore they have more control over them, for improving them or maintaining their level towards better productivity. Meanwhile, it is less clear to the other group what these factors are and how much they can impact their personal lives. But both of these groups showed interest in having a tool for monitoring these data for self-insight and self-reflection.

As participants kept mentioning in the interviews, they would like to have a tool that showed them their progress level in each one of their personal activities (status), what percentage they had accomplished and how much they had left (distance to their final goal). They also wanted to discover the influential factors affecting their productivity in time (history) and how they could change or react to these factors to improve their future productivity. For some people with kids, they reported that they would like to track these productivity levels in their kids' lives as well.

Participants addressed "productivity" in their personal lives in a variety of ways:

- "Being able to accomplish a lot of the goals that I have set out in a short/reasonable period of time. When I am not productive it takes a lot of time to do something. Having some goals in advance and how quickly I would accomplish those goals."

- "Having an idea of what it is that I have/like to get done. Set goal for each day and I am productive if I reach the goals I make for that day."
- "Get up early! Does not mean I have to work for exactly for 8 hours, it means having highly efficient working hours so that I can take 1-hour break."
- "Accomplish tasks I have to do in a reasonable time so that it doesn't pinch upon my spare time."
- "Being able to complete my tasks or to-do list that I assign to myself everyday."
- "Efficiency in a task divided by spent hour for that."
- "The feeling at the end of the day that I feel satisfied from the time that I have spent and have not wasted any time during that day doing nothing."
- "Do not let things linger around for a long time."
- "Keeping up with all the stuff I need to do. The more I can do the better. But it is hard because there's too much and it is hard to keep up with everything."
- "Make sure I get done all my tasks efficiently in a certain amount of time."

Participants explained that they normally used their calendar or to-do list for recording their daily non-routine tasks and for the routine tasks they only kept those to their mind.

Based on participants' opinion about a "hypothetical personal analytical tool", I have summarized their expectations of such a tool in the below section.

One common area that all the participants agreed on was that the tool should help them organize their time more efficiently, either online or offline. It should be easy to use as people are busy to manage time to learn to work with it. They thought the tool should help them in better time management and planning, scheduling and improvement of their daily progress regardless of their location (i.e. it should be accessible through their different devices). Other functionalities that would be helpful for a system were to make suggestions and predictions, and provide reminders and motivation.

System Suggestions and Prediction: The participants stated that it would be very beneficial if the system would suggest what type of activities to do or not to do (E.g. it is a good time for biking, it is not a good time for studying) and where to go (E.g. what is the best place to study) considering some measures. These measures include trends of previous behaviors, productivity level, priority of the tasks, complexity value of each task (some tasks are easier to handle and some other are more difficult) and the fact that the user is on the right track of defined goals in the system or not. As one participant explained "… system suggestions of what could be helpful in order to make yourself move forward and not to be stuck in the situation you're stuck in. For example suggest an article to read…". Another participant stated that: "… the system should learn what my business is and what success means in the activities I am involved in…". One participant even thought it would be interesting if the tool could help him "plan a trip" by having his schedule and knowing his status in his personal life. Another participant had a remarkable note: "… the tool can help me with personal resource allocation (resource management): according to my history give me an estimation of the tasks I can do per day. E.g. I make a list of tasks for my day, then the system tells me if I can do them all in that day, how to change their order (manage them; high priority + can be done tomorrow, low priority + should be done today)..."

System Notifications/Alerts/Reminders and Motivation: participants pointed out how notifications, alerts and reminders could support their daily activities and add value to a system as well as their daily life. They suggested the tool could have these features: remind them when they are wasting time (by analyzing their tasks, to-do lists and responsibilities and their timeline) or when it is passing the person's bedtime. Participants suggested that reminders and alerts should use ambient features so they are not interfering and annoying while they bring information about changes in a person's schedule and habits. They thought it was very important not to report every slight change in a person's life pattern since this could be ignored after a while. So these reminders should be neither so many that they are ignored nor so subtle that they are not noticed at all.

One participant mentioned that existing tools give some reminders on different tasks but they are not interactive enough, are inhuman and like a machine. It is better if such a personal analytical system would announce the undone tasks for people so that they do not need to go and dig through all their activities to see what has not been done. Furthermore, one participant thought it would be interesting if the tool would remind them about the consequences of not accomplishing the tasks.

Participants stated it would be very important for the system to use pleasant, humanized and rewarding language for the purpose of motivation. For example, one of the interviewees reported that: "let's say I want to buy myself one of my favorite handbag only if I finish a specific task… this tool can remind me of my goal and the reward that I have set for myself and this can be very motivating…". As another participant explained, the tool could be rewarding in this way: "Something that comes to me like an alert or a reminder informing about my daily progress". He thought this would help him realize how much he had done during the day even if he forgot; he noted that accomplishing many tasks makes him feel happy and encouraged.

Of course, as most of the participants agreed, all these interesting features are feasible only if people are motivated enough to enter all their data into their calendars daily. Participants suggested this hypothetical personal analytical tool could be observed as "an invisible personal assistant", that is also like a modern personal diary. One of the interviewees stated that this tool can be like Data Cube for personal life by keeping three important dimensions of daily life: when's, where's and what's.

Certainly these features involve an enormous amount of machine learning techniques and also user input but I cannot say that it is impossible to achieve. The system to have such features should be intelligent enough to learn the nature of people's tasks and make such suggestions according to important parameters and measures. People usually are aware of these measures but sometimes they are not and in such cases the system can help them with discovering these hidden factors.

3.3. Scenarios

In this section I present the sample scenarios that were extracted from the real interviews I ran with my participants. I used these use cases to design the application. In the use cases, I considered three different types of people with different lifestyles. The first one is Aisa, a master student with a part time job, the second one is Sepideh, a working mother, and the third scenario is about Johnny who is a working Father. These scenarios are fictional but based on information gathered in the interviews.

Aisa - A master's student with part time job

Aisa is a master's student, busy doing research. She also has a part-time job in a lab. She likes skating regularly and never wants to miss any fun event with her friends. She is working very hard on her master's thesis and wants to publish a paper. She really values healthy food so she spends time preparing her own food. Since her parents and friends are living in another country, everyday she spends time communicating with all her friends and family members. Aisa is considered by herself and others to be a successful student who is also is very sociable. But sometimes she loses track of her tasks and forgets to do some of them. She also wants to keep track of her mood and identify how her mood can impact her productivity, to help her improve her future habits.

Aisa needs a tool to help her keep track of her life, to record how much time she spends on different activities in her life, how much progress she makes in different activities from time to time (possibly once every week). She would like a tool that makes some suggestions and highlights her progress in daily activities such as in her research and doing exercises; for example it could show the state of different activities to help her keep consistent in each one. Aisa feels such a tool would help her schedule her time more efficiently.

Sepideh - A working mother

Sepideh is an employee, manager of a team and also she has a five-year-old child. She is very serious and wants to be able to organize her life perfectly. She skips doing exercises most of the time although she knows that it is necessary for her health, since she has a very busy schedule and lots of responsibilities regarding her job and family.

Sepideh believes that she used to be more consistent with doing exercises, although her schedule hasn't changed too much, so she thinks probably it is lack of enthusiasm. So Sepideh would like a tool to help motivate her to get regular physical exercise. She would like the tool to reveal her routines and also show how many times she has broken her own rules by not going to the gym. She really values her daughter and the daughter's activities as well. She has to take her daughter to swimming, ballet and painting class and is really eager to find out how much progress her daughter makes in these activities; for example, by taking some pictures/videos of her every once in awhile.

Apart from her success at work, Sepideh's family satisfaction is important to her. She has to cook dinner every night and she wants to make sure that her food is delicious and also full of nutritious ingredients.

She needs to have a tool to help her identify her productive hours and also manage her tasks, to track the hours she spends on different activities and find the wasted hours. She hopes that this tool will help her to fit regular exercise in her busy schedule.

Johnny - A working Father

Johnny is father of two children and has an administrative role in a big company. His job and his children's progress are very important to him.

Johnny needs a tool to help him find and measure the factors related to his family and his role as a father. He wants to figure out to what extent each factor influences his productivity. He believes that he is so busy that it is hard for him to keep a record of his accomplishments in his personal life and to make a proper estimation of his progress. He values his family members' and friends' satisfaction level of himself. He wants to keep everyone happy by accomplishing his responsibilities related to family and friends (for example, constant interaction with his wife and kids through involvement in different activities with them, calling and visiting his parents regularly, and socializing with friends occasionally). So he wants to keep a record of his relationship and self-rate satisfaction status of important people in his life. Altogether, he wants to identify his productive hours during the day and his mood in different situations so he is able to evaluate himself, his tasks and his relationships and improve them.

3.4. Prototypes

3.4.1. EARLY PROTOTYPES

To start the design phase, based on the feedback from interviews, I decided to take design ideas from business dashboards where various factors are measured and visualized in different graphs and multiple views. With a dashboard, a business user can see how the process of his line of business is changing based on various variables; by analyzing the data, the user can take proper action to improve, maintain or make changes to the business. However, since I was targeting everyday people, the final application would be a personal productivity dashboard instead. One of my goals was to make sure it was easy to use and information was easily perceivable. Below you can find some of the initial dashboard prototypes.

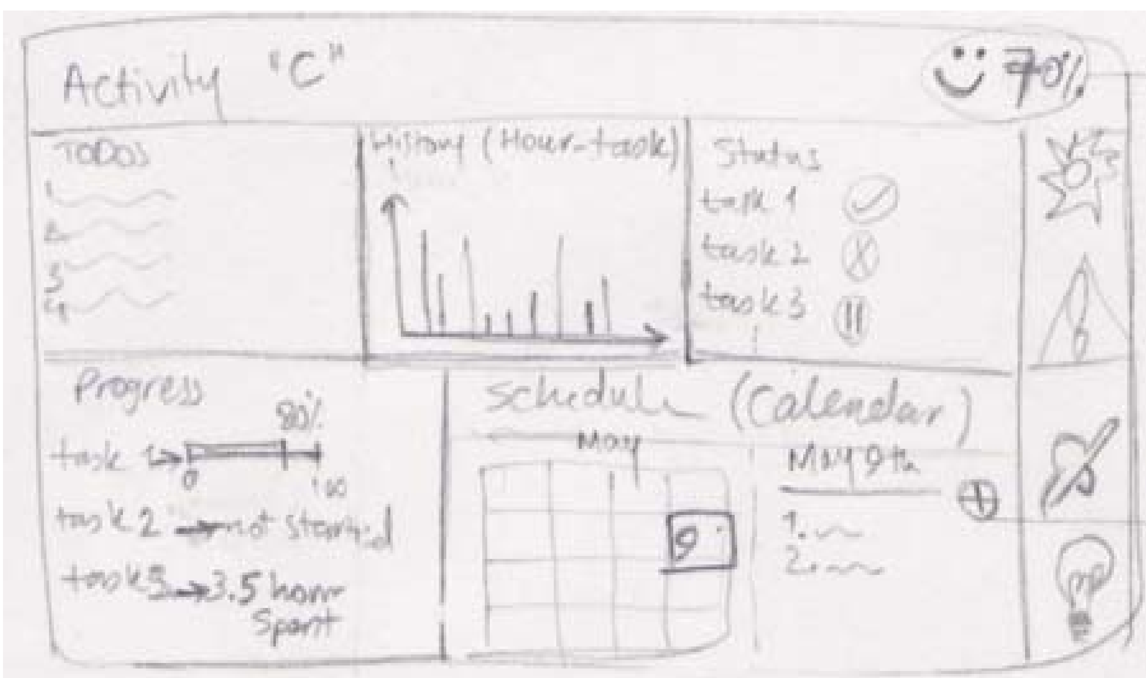

Figure 3.4.1.1 – Personal productivity dashboard – Main page 1

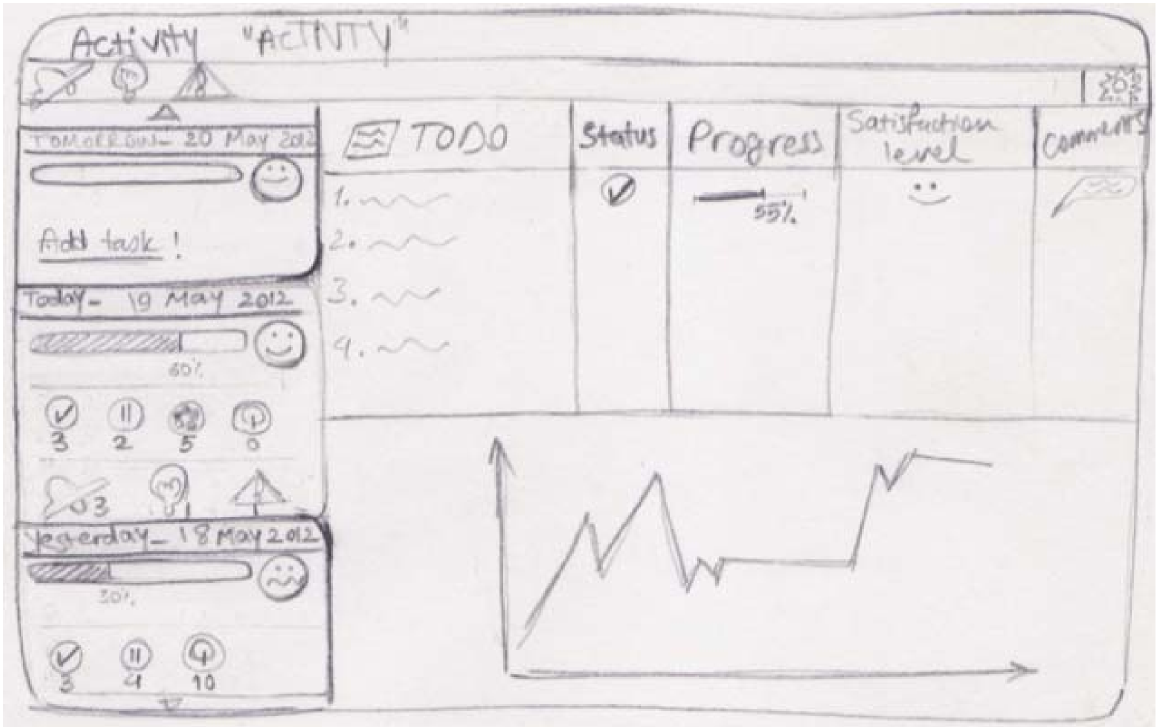

Figure 3.4.1.2 – Personal productivity dashboard – Main page 2

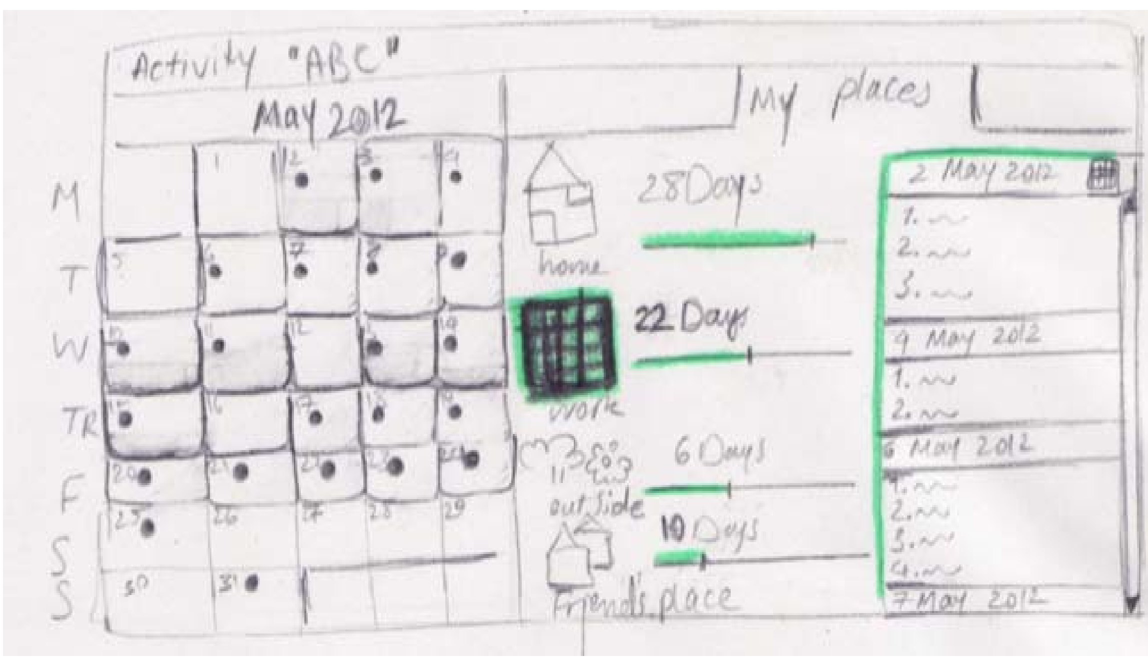

Figure 3.4.1.3 – Personal productivity dashboard – Main page 3

Figure 3.4.1.4 – Personal productivity dashboard – Main page 4

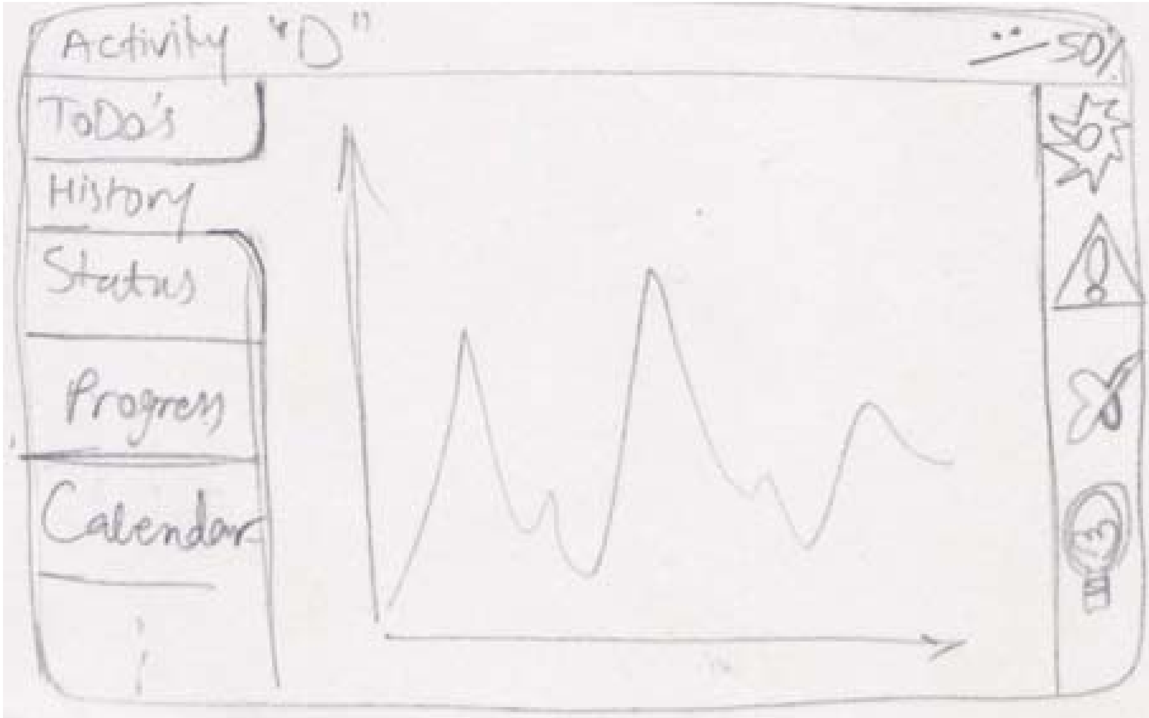

Figure 3.4.1.5 – Personal productivity dashboard – Activity History 1

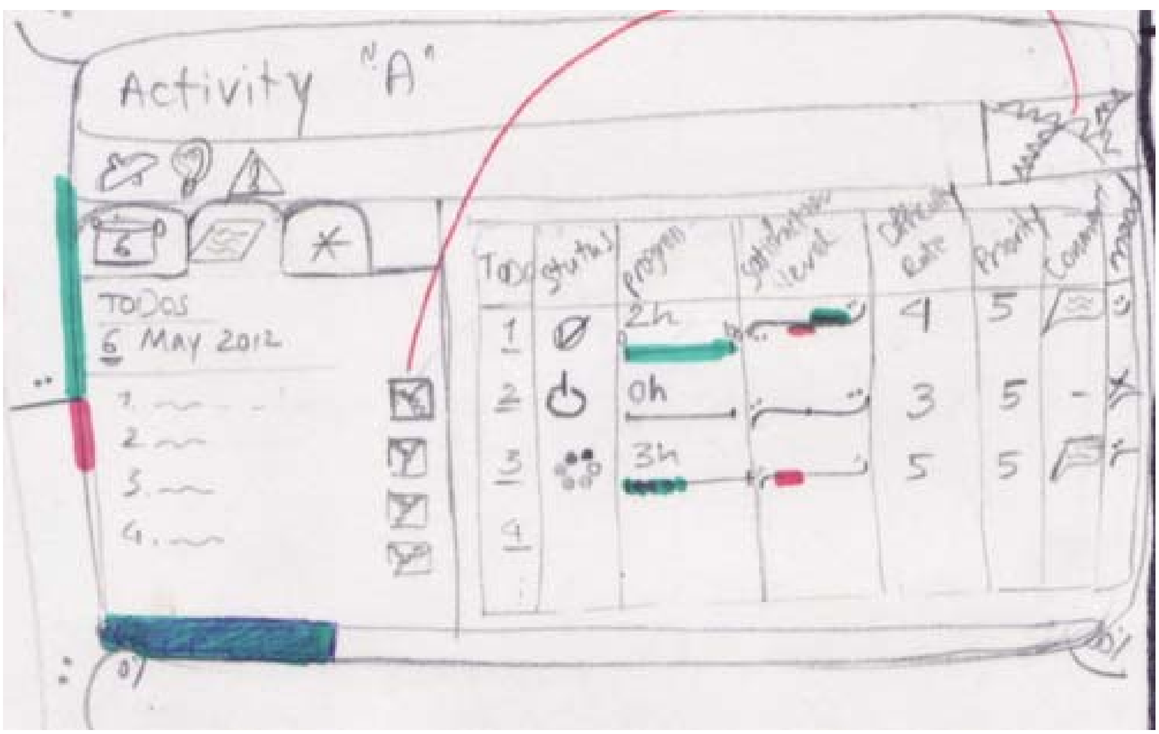

Figure 3.4.1.6 – Personal productivity dashboard – Activity History 2

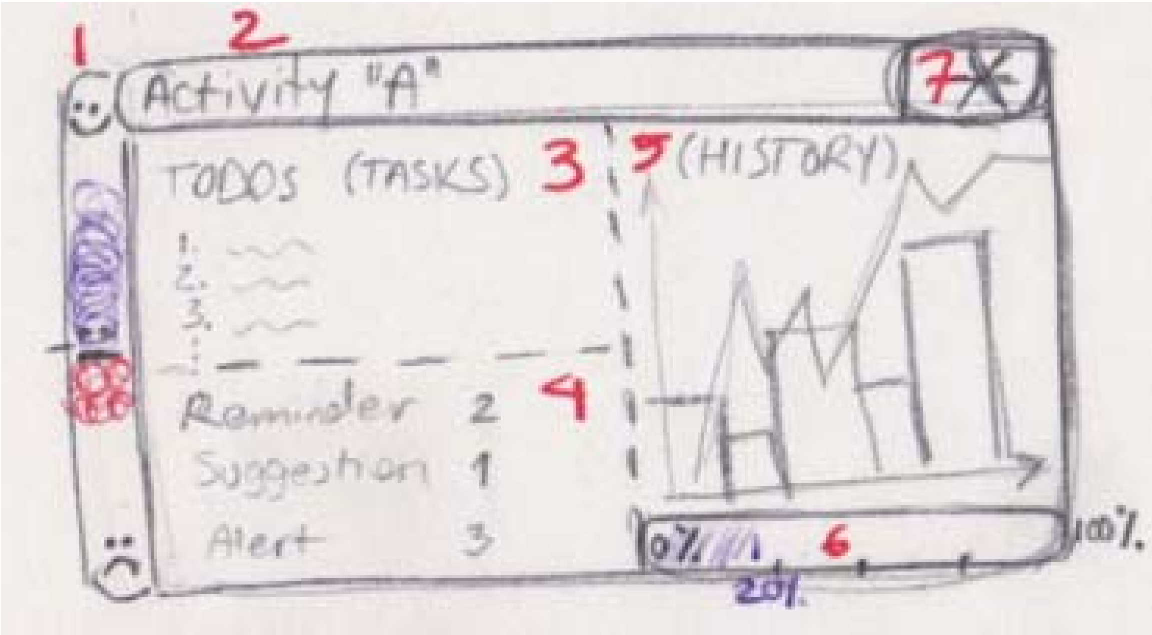

Figure 3.4.1.7 – Personal productivity dashboard – Activity History 3

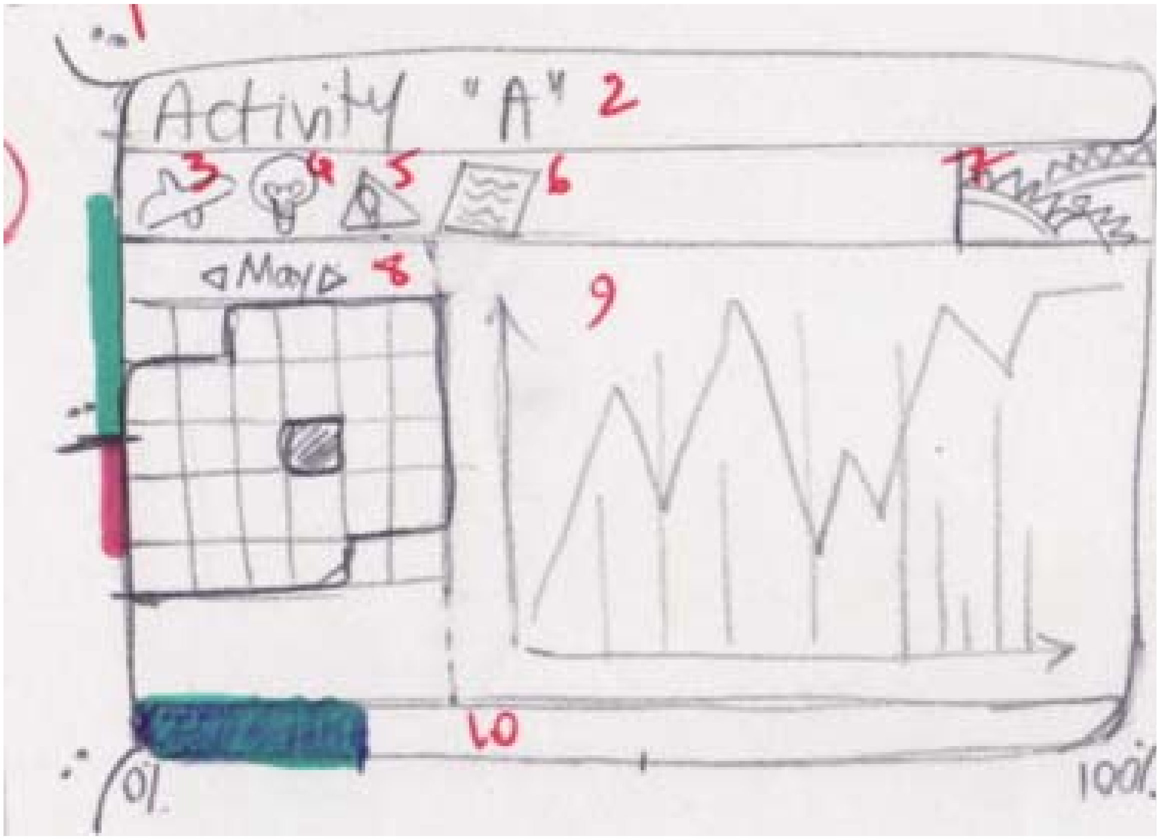

Figure 3.4.1.8 – Personal productivity dashboard – Activity History 4

While designing, as explained in related work, I realized that using Calendars could be very effective since people can navigate through different days and view their progress directly in a calendar view. Calendars figured prominently in my early prototypes, as shown in the screenshots above. According to [30] The preferred personal calendar view is weekly, however history and patterns of tasks and events are revealed more clearly in longer time duration. People can easily find relationship between events, tasks and effective factors on the calendar especially due to the rich context calendars provide. McDuff et al. realized that calendar events are very efficient at helping participants "tell a ―story about a particular day" [21].

Eventually, as pointed out in the introduction section, I defined my second research question more specifically: which combination of visual encodings makes it easiest for the user to see relationships between two different pieces of information rendered on a calendar?

I decided to observe multiple visual encodings on a calendar since I was looking to find relationships between different factors of productivity; therefore I needed to find a way to visualize more than one factor in each calendar cell. Also it was non-obvious which encodings to choose as there are various alternatives for each data type representation. Thorough explanations are given in section 3.4.2 (Pilot User Study Prototypes). According to the limited space that each calendar cell provided, I needed to investigate which combination of these visual encodings would be effective in my design.

In my future designs I migrated my design from miniature dashboard style calendar to integrating the information directly into the existing calendar tools as described in section 3.4.3. The main reason for doing this is because people already track many of their life activities on their personal calendar, and these activities provide important context for interpreting productivity-related information. Another reason for this migration was that the miniature dashboard style calendar had very small space for presenting the data in each cell along with the primary calendar data so it would be harder to work with. Also in that design, each board in the dashboard kept productivity related information of one specific activity. So depending on the number of activities that the person was interested in tracking productivity for, there would be a board in the dashboard. One negative point about this design was that it kept all the activities separated from each other even if these activities could have influence each other's productivity level, so relationships between activities were hidden. Moreover, other sections of this dashboard that were designed for reporting purposes, despite their advantage, were not the focus of this study. As a result I decided to take advantage of the interface of existing calendar tools and leave other sections as future work.

3.4.2. PILOT USER STUDY PROTOTYPES

As explained in the section (3.4.1. EARLY PROTOTYPES), I narrowed down my design to focusing on integrating data into digital calendars and I realized that I needed to explore the design space of possible visual encodings on these calendars. This section will focus on designs that integrate data into calendar applications.

Data can be classified into three fundamental data-types: Numerical (quantitative), Nominal (qualitative) and Ordinal. I decided to only focus on the first two data-types and leave the Ordinal data-type, as I did not find any application for that; none of productivity related data-types that I found were of ordinal type. Actually for this study all ordinal visual encodings would use more or less the same visual encodings as numeric. Moreover, I decided to focus on designs with a combination of only two visual encodings, as I was interested in highlighting the relationship between two different productivity-related factors, if any relation existed, in each calendar cell, leaving the other combinations for a future study. Relationships among three or more variables are inherently more complex so it is sensible to start with the simpler case of two variables. Therefore, there were three categories of prototypes: Numeric x Numeric, Numeric x Nominal, and Nominal x Nominal. I decided to not to study two Nominal data-types in my user study since iconic representations seemed to be the logical choice for nominal data on calendars and any measure of productivity (the main factor of interest) would be numeric. This left Numeric x Numeric and Numeric x Nominal for consideration in my study.

As discussed in the related work, for visual encodings I chose to use length and color saturation encodings as the best choices for numeric data types and chose to use shape as for encoding nominal data-types. With regards to integral and separable dimension pair notion [33], the visual encodings I chose were often more separable than integral meaning that there were some interference between various data values that were presented by different encodings and they often could not be regarded analytically. To be more concise, for all Numeric x Nominal combinations (Shape x Saturation and Shape x Length) and one Nominal x Numerical combinations (Saturation x Length) the encodings were separable but other two of the Numeric x Numeric combinations (Saturation x Saturation and Length x Length) were integral to some extend.

I first started with low fidelity prototypes on paper. As mentioned previously, a calendar view was chosen as the platform for our proposed application. Therefore, calendar cells would be the space for demonstrating the influencing factors on productivity.

After 5 iterations of high fidelity prototypes on paper, and trying different combinations of bars, shapes and colors, I came up with the following combinations (see Figure 3.4.2). As shown in Figure 3.4.2, using green tick-marks and red x's I decided which prototypes I would like to keep and which I wanted to omit.

According to Figure 3.4.2, Numeric x Numeric, I decided to position the bars in the header of the calendar cell (i.e. the top, next to the date) so viewers would not mistakenly relate the bars to the day below (which is possible when the bars are in the footer of the calendar cell).

I selected a diagonal representation of Saturation x Saturation as splitting the cell in half horizontally or vertically gave the calendar a very strange appearance and made the boundaries between days less apparent.

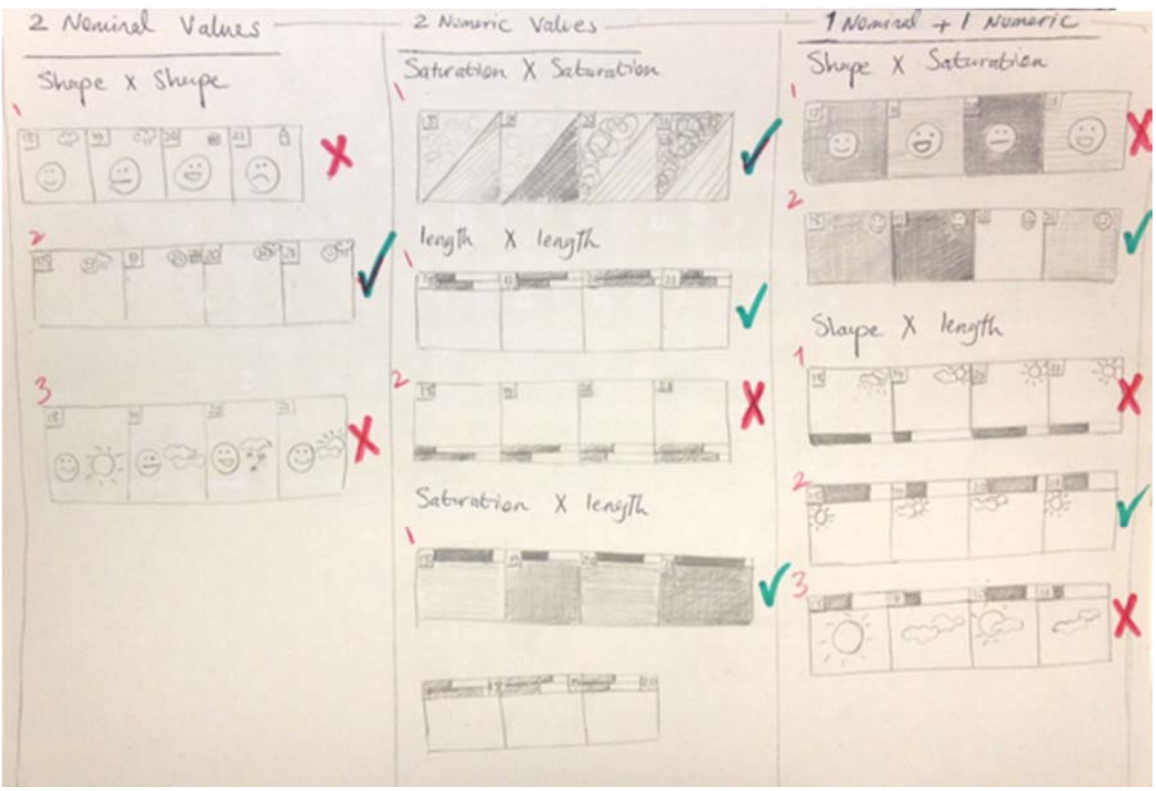

Figure 3.4.2 – Final low-fidelity Prototype Summary

For the Shapes in Numeric x Nominal, I positioned them close to the date for the same reason I did for bars. For shapes' sizes I tried to use the maximum possible size on calendar cells. I removed the options with large icons in the middle of the cell as they were interfering with primary calendar data.

I ran a pilot study on six participants: one faculty member, four masters and PhD students, and one company employee. I evaluated the pilot study results from different perspectives such as the difficulty level of the questions, the appropriate number of questions, the fatigue of participants, and the quality of visualizations. I wanted to keep the duration of the study not longer than seventy-five minutes to avoid participant fatigue since this could negatively impact the results.

The conditions for the pilot study were slightly different from the actual study. It was composed of forty-five Calendar task questions and fifty Visualization task questions. Based on user performance in the pilot study, I increased the number of Calendar task questions to sixty as they were straightforward questions and this number would not tire the participants. I reduced Visualization task questions to forty, because these tasks were more time consuming and required more cognitive effort. To simplify the study and stay focused mostly on visualizations, I removed some of the most complex question types that required more calculations and greater search effort. Therefore the Calendar question types came down to five types from six types and Visualization question types were reduced to three types from five different types.

In addition, from the pilot study feedback I made some modifications to the prototypes. For example, I added legends to each visualization for translating data encodings, as participants kept confusing which encoding belonged to which data despite my explanation at the beginning of the study. Another example was providing sample answers for each question so the users knew what they should be expecting in the multiple-choice questions in the next steps. Other examples include adding a question number to each question so the users would know how much progress they had made towards the end of the experiment, and changing the background colors and shape colors so they were more readable and less interfering with the primary data on calendar.

3.4.3. PROTOTYPES FOR ACTUAL USER STUDY

Using an open source application called Inkscape, I created high fidelity prototypes. Figures demonstrated in Figure 3.4.3.1 – 3.4.3.5 are the versions that I used in the actual user study.

As discussed previously, the changes that I made to prototypes from what I learned in the pilot studies included adding legends, making some slight changes to the shape colors and also to modifying the background colors for more readability.

I chose to work with grey-scale colors to keep the prototypes simpler and to avoid color interference with activities on the calendar. Not being able to guess what color each user would be more interested to use was another reason for choosing grey-scale.

I decided to present mood and weather as two possible influencing factors on productivity; dividing them into two groups; mood and productivity as numerical and weather as nominal. These were selected as examples of nominal and numerical data that could reasonably be related to productivity.

Figure 3.4.3.1, 3.4.3.2 and 3.4.3.3 are the samples I used for two Numerical data-types. As shown in the below section, I presented numerical values using all three combinations of bars and background colors; Length x Length (LL), Length x Saturation (SL), and Saturation x Saturation (SS). And for each prototype I created a legend as a reference.

Figure 3.4.3.4 and 3.4.3.5 are the samples I used for 1 Numerical and 1 Nominal data-types, for which I used possible combinations of shape and background color or length: Shape x Length (ShL) and Shape x Saturation (ShS).

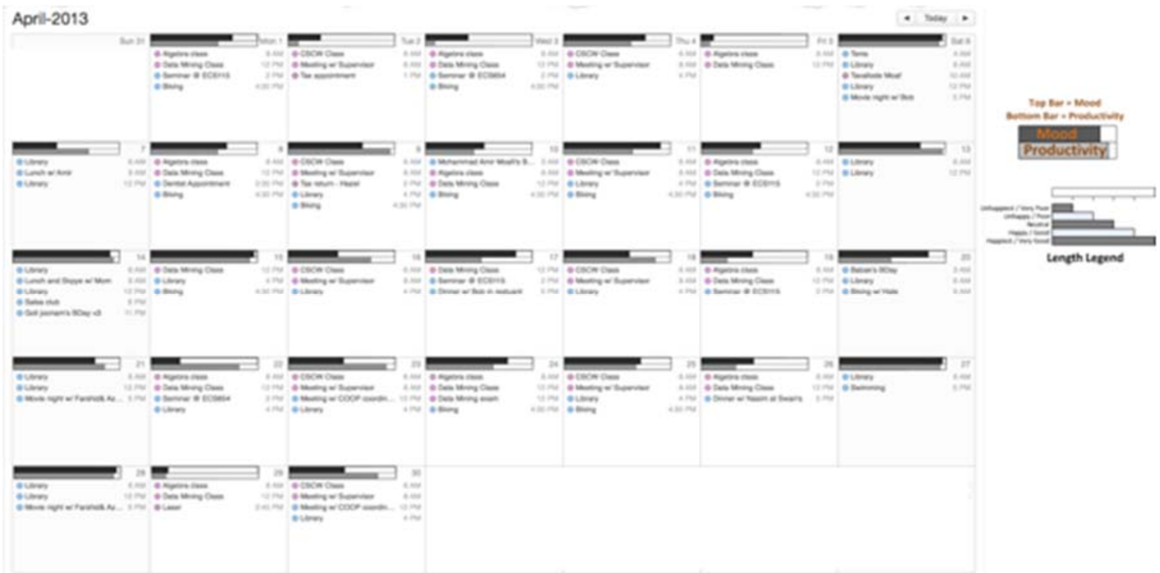

Figure 3.4.3.1 – Numeric x Numeric – Length x Length (LL)

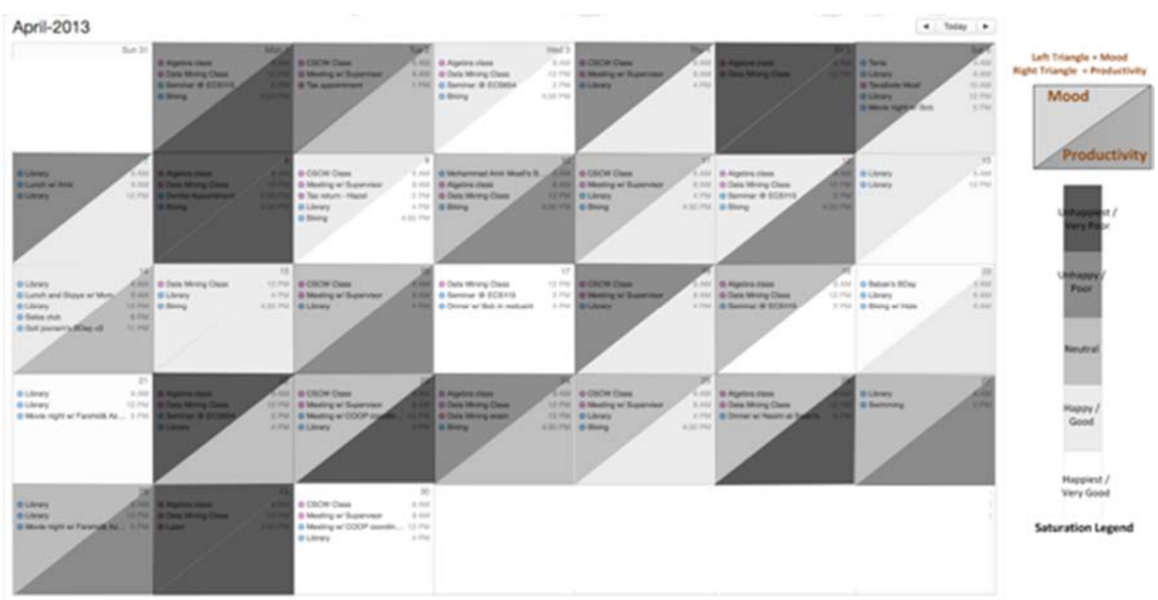

Figure 3.4.3.2 – Numeric x Numeric – Saturation x Saturation (SS)

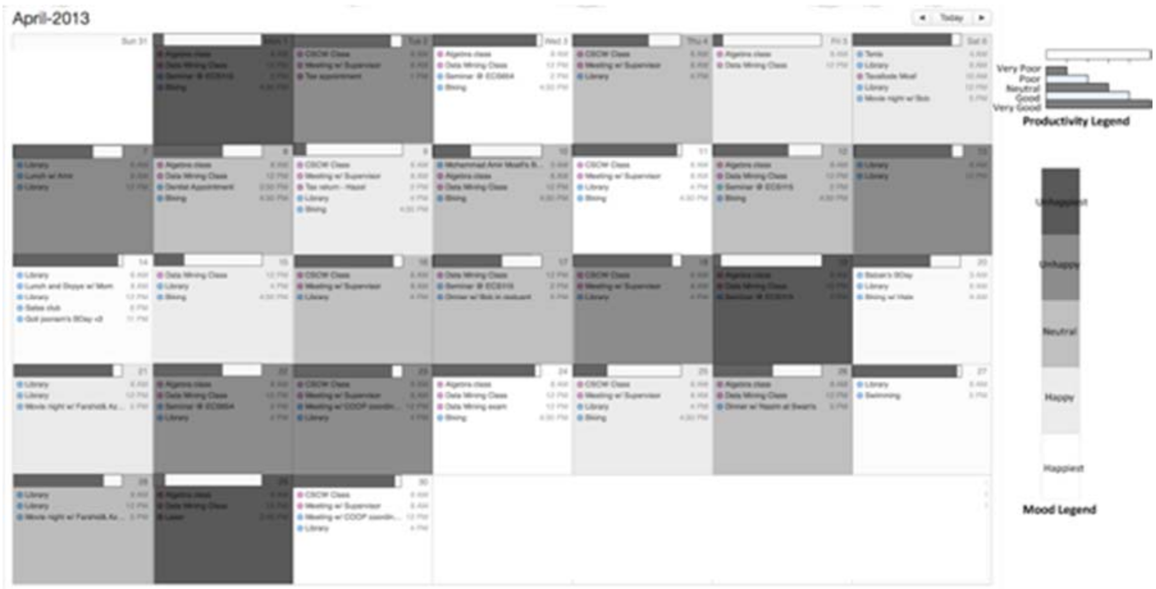

Figure 3.4.3.3 – Numeric x Numeric – Saturation x Length (SL)

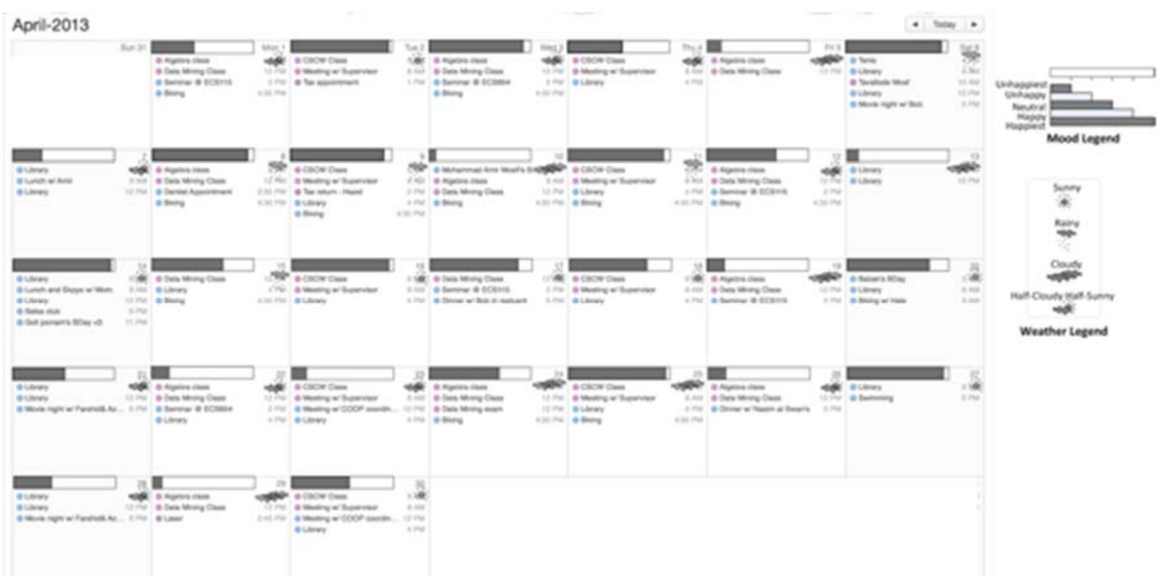

Figure 3.4.3.4 – Nominal x Numeric – Shape x Length (ShL)

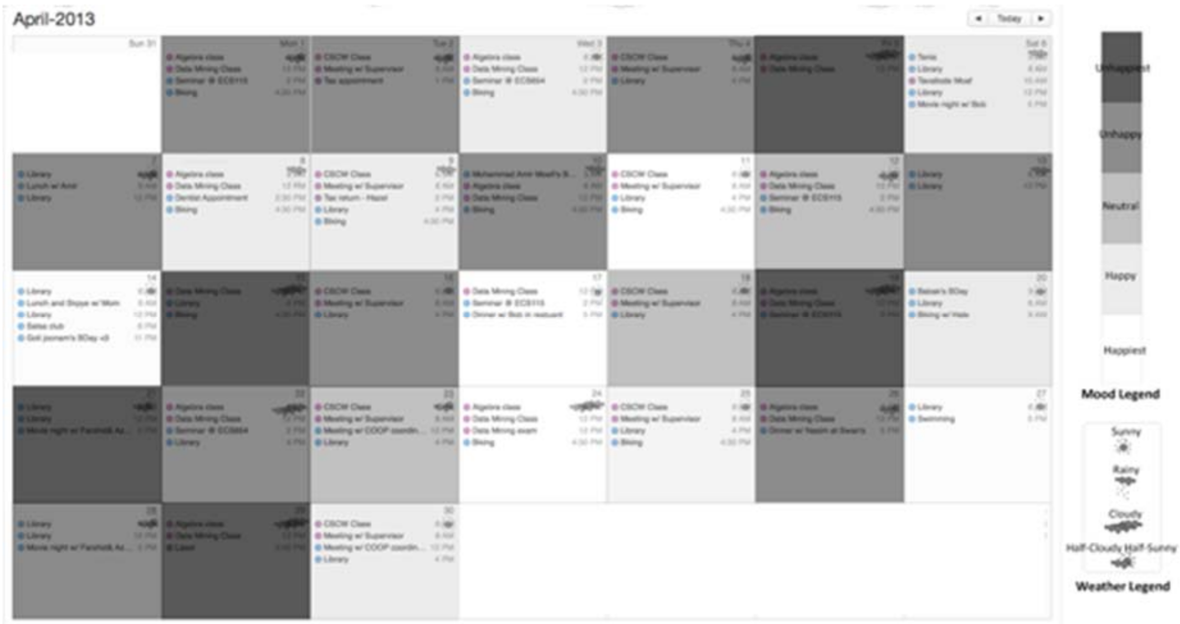

Figure 3.4.3.5 – Nominal x Numeric – Shape x Saturation (ShS)

Chapter 4

Method

This study involved four experiments. The goal of these experiments was to determine which visual encodings enable people to most quickly and accurately answer questions about calendar activities and extra data embedded in a calendar view. For this purpose, I conducted a three-week formal study involving 29 people. Each session took approximately 75 minutes and each participant was compensated with $10.

4.1. Apparatus

I provided participants with prototypes and two sets of questions: (1) Calendar Task question set and (2) Visualization Task question set, Appendix B.

Participants interacted with a custom Java-based slide show and data collection program. The application ran on a 27” iMac (2560 x 1440 resolution, 3.4GHz quad-core Intel Core i5 processor with 6MB L3 cache) and mouse was the only means of interaction. Participants selected their answers and changed the screen using a mouse.

All the calendar data were derived from real calendars of two full-time computer science students and one full-time company employee. All the prototypes were created using Inkscape, an open source drawing program. The calendar images in the background of each prototype were snapshots of iCalendar. I chose iCalendar since it uses a standard calendar layout, as I did not want to complicate the study with new unfamiliar designs.

4.2. Participants

This study targets casual users with any background. All participants were in the age range of 19 to 29 years old (the average age was 23). There were 14 males and 15 females from various backgrounds such as computer science, electrical engineering, mechanical engineering and biomedical science. They were mostly second year or above university students. I invited participants to join my user study through emails sent out through the University of Victoria and also Facebook postings.

4.3. Study Design

I narrowed down my study of the visual encodings to three visual categories (shape, color saturation and length) of two data-types (Nominal and Numerical) and the questions were designed in 2 different task sets: Calendar Task set and Visualization Task set. My goal was to evaluate the effect of visualization type on performance (search time and accuracy) within each task set.

As stated before, the study was made up of four experiments; the first two experiments focused on the effect of data encoding (Numeric x Nominal and Numeric x Numeric) on Calendar Tasks and the second two experiments focused on the effect of data encodings on Visualization Tasks. In all these experiments my intention was to study the combination of *Numeric x Numeric* variables in three different levels: (saturation x saturation), (length x length) and (length x saturation) and the combination of *Numeric x Nominal* variables in two different levels: (shape x length), (shape x saturation). The experiments can be summarized as:

- Experiment 1: Calendar Task, Numeric x Nominal
- Experiment 2: Calendar Task, Numeric x Numeric

- Experiment 3: Visualization Task, Numeric x Nominal
- Experiment 4: Visualization Task, Numeric x Numeric

I created three sets of questions. Each set was composed of identical questions but in a different randomized order for each group to make sure that the results were not dependent upon the order of questions. I randomly placed participants into three groups of 10, 10 and 9 people and assigned each group of participants to one of these sets. I designed 50 questions for Calendar Tasks and 40 for Visualization Tasks. The study was designed *within subjects* so that each participant got exposed to all study conditions. As a result, all the participants had 90 identical questions to answer, which were in random order; they first answered the Calendar task questions followed by Visualization task questions next. In each task set the Numeric x Numeric and Numeric x Nominal questions, and the different visual encodings for each case, were mixed randomly. The questions for each condition were designed as similar as possible but were not identical in many cases.

4.4. Tasks

In Experiments 1 and 2, users were asked to complete Calendar Task questions for (Numeric x Numeric) data-types and (Numeric x Nominal) data-types to identify the interference of visual encodings with normal calendar tasks. In Experiments 3 and 4 they were asked to complete Visualization Task questions for the above-mentioned data-types to investigate which visual encodings could be most easily interpreted.

To design calendar task questions I developed tasks related to work, family/personal and public events that typically fill people's calendars. These included timed events, special events that needs preparation, long duration events, all-day events, and also small to-do lists [30].

Having these criteria in mind, I designed questions that would require the users to (a) Look up details for a specific activity, (b) Search for an activity date (c) Search for a specific activity/event/schedule pattern, (d) search for the number of times (days) an activity/event has taken place and (e) Search for a specific activity.

I formulated these questions as follows:

- Question Type (a): [What time][did you do A][on X day]? (E.g. what time did you go to the gym on Fridays? [E.g. 1:00 PM])

- Question Type (b): [Which date][did you do A]? (E.g. which date did you have a dentist appointment during October? [E.g. Monday 1st])

- Question Type (c): [What did you do][every X day]? (E.g. what did you do every Saturday? [E.g. Hiking])

- Question Type (d): [How many times did you do A][in Y duration]? (E.g. how many times did you go biking in the first week of April? [E.g. 10])

- Question Type (e): [Where did you go][on X day][at Y:00 PM]? (E.g. where did you go on October 29th at 7:30 PM? [E.g. Friend's place])

I motivated my study questions based on the real questions that people are interested in and tend to ask themselves about their own personal data. Based on my interviews, the following questions about personal productivity were interesting to participants:

- "… I want to be able to analyze my mood to see what to do next…"
- "… I want to associate my mood and productivity of other activities…"
- "… I want to discover patterns of my mood and its reflection on my other activities' productivity…"
- "I want to find the connection between different factors so I realize I can change the bad situation (procrastination) and improve my productivity"
- "… I need a tool to inform me about my progress…"
- "… I would like some rewarding reminders…"
- "… I would like to know how factors like sleeping habits and doing exercises influence my productivity…"
- "… It would be interesting if there was a tool that could calculate when I was wasting time so I would start being productive or plan accordingly…"
- "… I would like to know my productivity status in every activity, so it is easier to decide what I should do next…"

- "… My current status and my performance in time reveal my weaknesses and strong points…"
- "… I think my relationship with others at home and work really affect my mood and productivity, so I would like to monitor that about myself and improve it…"
- "… My past and especially failures in the past help me learn more about my mistakes…"
- "… If I am somehow able to see the patterns in my behavior I will be able to compare my data to plan for more productivity in future…"
- "… I would like to compare my past and future, so I can see where I am productive because it is encouraging…"
- "… Keeping record of events helps me find pattern of my productivity and tracking changes in my life helps me to evaluate myself",
- "… I would like to measure how much time I spend doing an activity and about my progress".
- Etc.

From what I learned from interviewing people, I could map these questions into the six categories introduced by [18], which classifies the questions that people ask themselves about their daily personal life. I focused on designing productivity related questions from these six categories. So my main concentration was on *productivity related* context, factors, goals, discrepancies, status and history information, which would lead the users to directly or indirectly learning about different aspects of their productivity. The resulting questions required searching through exemplary data such as different productivity levels, mood levels and weather trends and realizing how these data and their relationships can impact people's productivity, helping them gain more self-awareness.

To design visualization questions, I emphasized questions that would highlight the extreme values, as people are interested to know about their extreme data, especially if these data are not visible without monitoring and tracking. I created questions that would require participants to work with visualizations but that would not be too challenging and therefore frustrating. The questions belonged to either one of these categories: (t) *the count of days* where data encodings had their *extreme values*, or (y) *specific days* that data encodings had their *extreme values* or (w) where users needed to *find a day with certain extreme value* based on an extreme value of the other data encoding in a specific time period.

I formulated the visualization task questions as follows:

- Question Type (t): [How many days in Y duration were you][most/least M][and][most/least N]? [M=productivity, N=Mood] (E.g. how many days in April were you both most productive and the happiest? [E.g. 10 days])

- Question Type (y): [Which days were you][most/least M][and][most/least N]? (E.g. which Sunday(s) were you both most productive and the unhappiest? [E.g. 10th])

- Question Type (w): [What is level of M][on the most/least N day][in Y duration]? (E.g. what was your mood on the most productive day in the second week of April? [E.g. happy])

4.5. Procedure

The study was conducted in three different steps: The first step was to gather participants' personal information such as name, age and occupation and field of study using a background questionnaire, get the participants to sign the consent form and familiarize them with the format of the study. In the second step, they answered 50 Calendar Task questions in about 30 minutes. Afterwards I explained more about the purpose of the study and then participants answered the 40 Visualization Task questions, which took about 45 minutes. In the first set, Calendar Task questions, I investigated the interference of the visual encodings on normal calendar tasks. In the second set, Visualization Task questions, I measured which visual encodings enabled people to answer questions the most quickly and accurately.

I measured *performance* for each visualization option by measuring the time and errors. Also at the end of this experiment I conducted an interview, Appendix D, with each participant to gather more qualitative feedback to understand people's reaction to the prototypes and how they would use a tool based on this idea in real life applications.

Each participant completed three practice questions for Calendar task set and five practice questions for Visualization task set to get familiar with the visualizations and understand how they should interact with them. They then started the main study. For each question, they would first see a screen that contained the question (Figure 4.5.1 – Screen (a)). By clicking READY, a new screen would show, which had the original question along with the visualization they had to use to answer the question (Figure 4.5.2 – Screen (b)). By clicking next, a screen containing the original question and the answers would show (Figure 4.5.3 – Screen (c)). Participants could click on their selected answer. I provided an example answer so that they would know what they should expect in terms of answer choices. Also each image had a legend to help the users understand what each visual encoding and their different levels meant. Below you can see screen-shots for these three screens.

Figure 4.5.1 – Screen (a)

Figure 4.5.2 – Screen (b)

Figure 4.5.3 – Screen (c)

In order to collect the most accurate data for search time, I recorded the total time that the user spent on Screen (b). Thus the search time does not include the initial time to read the question, nor does it include the time to select an answer.

After the experiment session, participants took part in a short interview. Here I gathered feedback about the usability of the design, its value in discovering and maintaining the influential factors in their daily productivity, and information about whether it would help them to find out about their *Status*, *History*, *Goals*, *Discrepancies*, *Context*, and *Factors*

[18]. In the end, I asked them to rate the all the visualizations for both Calendar Tasks and Question Tasks on a scale from one to five, in terms of how easy it was to complete the tasks. You can find the interview questions in Appendix C.

4.6. Hypotheses

4.6.1. CALENDAR TASK, NUMERIC x NUMERIC

H1: Participants will answer calendar questions more quickly and more accurately with LL followed by SL and followed lastly by SS. (I assumed that patterns in SS would interfere with their ability to read primary data on the calendar. Therefore my assumption was that the clearer the calendar was from secondary data the faster users would perform in these tasks.)

4.6.2. CALENDAR TASK, NUMERIC x NOMINAL

H2: Participants will answer calendar questions more quickly and more accurately with ShL than ShS. (Similar to the logic behind H1, I assumed that the clearer the calendar was from secondary data the faster users would be able to find answers to calendar related questions.)

4.6.3. VISUALIZATION TASK, NUMERIC x NUMERIC

H3: Participants will answer calendar questions more quickly and more accurately with SL followed by LL and followed lastly by SS.

I hypothesized that SL would be the fastest and least error-prone visualization. I expected that using two different encodings for similar data types would make the comparison task easier. I assumed LL and SS would be more challenging in comparison task since users might mix up which encoding was for which data-type.

Also using background color that covers the entire cell area results in faster and easier comparison between cells since extreme values stand out more clearly than with bars. Although, LL represents the data in more detail, I assumed the visual clutter created by many lines and bars in each calendar cell would make the task more challenging.

On the other hand, although SS uses background color, I assumed this visualization would be the most challenging one because (1) neighbouring colours will influence the perception of each colour, (2) perception of global patterns may be disrupted by having two patterns interleaved, and (3) people may confuse which area of the calendar cell represents which data value.

4.6.4. VISUALIZATION TASK, NUMERIC x NOMINAL

H4: Participants will answer visualization questions more quickly and more accurately with ShS than ShL. (I assumed that because the saturation encoding covered the entire cell, people would be able to distinguish the dominant cell more rapidly. In contrast, with the bars it might take longer to calculate and compare the bar lengths. As the task involved identifying extreme values, understanding the precise value of the variables – a strength of length encoding – was less important. Also I expected that ShS' simpler and less populated view would be more appealing and less confusing.)

Chapter 5

Experiment Results

I analyzed the *time* for answering each question, *data accuracy* (percentage of correct answers) and *user rating* resulting from post-test questionnaire responses.

I conducted a separate repeated measures analysis for each of the following experiments:

- Experiment 1: Calendar Task, Numeric x Nominal
- Experiment 2: Calendar Task, Numeric x Numeric
- Experiment 3: Visualization Task, Numeric x Nominal
- Experiment 4: Visualization Task, Numeric x Numeric

In each case, my goal was to identify whether Visualization Type, Question Type or the interaction of both of them would make a difference in users' performance.

To analyze the results, I used SPSS, a statistical analysis software package.

For data collected from each set of tasks, I did the following: (1) First I cleaned the data, removing the outliers. I defined any data-point greater than three standard deviations from the mean as an outlier. I also omitted the entire data from two participants due to their high number of outlier data points (they were either substantially slower or faster than all other participants). For the rest of the participants I then proceeded to analyze the non-outlier values. (2) I created boxplots to visually explore differences between Question type and Visualization Type conditions for each set of tasks.

In Figures 5.2.1, 5.3.1, 5.4.1, 5.5.1 units on y-axis are milliseconds. Figures 5.2.2, 5.3.2, 5.4.2, 5.5.2 plot the values with 95% Confidence Interval. (a, b, c, d, e) represent the five question types for Calendar tasks and (w, y, t) are three question types for Visualization

Tasks. S = Saturation, L = Length and Sh = Shape; therefore SL = Saturation x Length, SS = Saturation x Saturation, LL = Length x Length, ShS = Shape x Saturation, ShL = Shape x Length. The boxes show the pairs with significant differences. In each figure, the blue boxes highlight the pairs that have behaved differently from the rest of the pairs in the same experiment. For example in Figure 5.5.1 LL has often performed the fastest for Question Types (a, d, e) except for Question Type (c). That's why I presented it with blue box rather than red.

The smaller boxes in the bigger box show the visualization that had the significant difference in the group. For example in Figure 5.5.1, for Question Type (a) LL has performed the fastest.

5.1. Statistical Approaches

5.1.1 TIME DATA

I used Q-Q plots to confirm that time data were normally distributed. To analyze the results I applied *repeated measures ANOVA* on these data for both Visualization Task set and Calendar Task set.

In this approach I first ran Mauchly's Test of Sphericity and then if necessary, I later performed data correction based on the epsilon (ε) value for each factor. If $\varepsilon > 0.75$ I used the Huynh-Feldt correction or if $\varepsilon < 0.75$ I used the Greenhouse Geisser correction. The corresponding ρ value shows whether there were any significant differences in each category (with alpha set at 0.05). Following the ANOVA analyses, I did Bonferroni-corrected pairwise comparisons on each category of Visualizations, Questions and Visualizations Types x Question Types to identify significant differences between all pairs of visualization types, both overall and broken down by Question Type. I did not examine pairwise comparisons between Question types because it is neither surprising nor interesting that they would be different.

5.1.2. ACCURACY

By accuracy, I mean the percentage of correct answers. These data were not normally distributed since all the participants got the majority of the answers right. Therefore, I applied non-parametric tests to analyze our accuracy data.

For this purpose, for two-variable comparisons I ran a Wilcoxon Signed Ranks Test. For the experiments with more than two variables I first ran Friedman Tests to identify whether there was a significant difference between any visualization pair in each task set. If an overall significant difference was found, then I report output from Bonferroni-corrected Wilcoxon Signed Ranks Tests, which identify significant differences in accuracy data between each visualization pair.

5.1.3. USER RATINGS

In this section I evaluated users' rating from one to five (the easiest to the most difficult) for each of the visualization types within the Calendar task set and the Visualization task set. I treated these data as non-parametric. I used Friedman tests to find overall significant differences in the ratings and followed these with Bonferroni-corrected Wilcoxon tests to identify significant differences between each pair of visualizations.

5.2. Experiment 1: Calendar Task, Numeric x Numeric

5.2.1. TIME DATA

Time data for Experiment 1 are summarized in Figure 5.2.1.

Based on Mauchly's Test of Sphericity, Visualization Type (ε) = 0.94, Question Type (ε) = 0.71, Visualization Type x Question Type (ε) = 0.50. So for the first two (since $\varepsilon > 0.75$) I use the Huynt-Feldt correction and for the latter one with $\varepsilon < 0.75$ I use the Greenhouse Geisser correction (Please see appendix).

I found significant main effects of Visualization Type ($F(2, 52) = 17.57$, $\rho < 0.001$, $\eta^2_\rho = 0.4$) and Question Type ($F(3.21, 83.47) = 71.03$, $\rho < 0.001$, $\eta^2_\rho = 0.7$) and a significant interaction between Visualization Type and Question Type ($F(3.93, 102.2) = 10.55$, $\rho < 0.001$, $\eta^2_\rho = 0.2$).

Results of the post-hoc tests on Visualization Types showed that SL was significantly slower than both LL and SS with ($\rho < 0.001$).

The post-hoc results for the interaction of Visualization Type x Question Type (Figure 5.2.1) showed that for:

- Question Type (a) SL and SS were slower than LL ($\rho_{max} < 0.005$)
- Question Type (c), LL was slower than SL and SS ($\rho_{max} < 0.013$)
- Question Type (d): SL was slower than LL and SS ($\rho_{max} < 0.001$)
- Question Type (e), SL was slower than LL and SS ($\rho_{max} < 0.025$)
- Question Type (b), there were no significant differences ($\rho_{min} > 0.084$).

For Question Types (a, d, e), SL was the most time consuming visualization for calendar task and on the other hand, SS and LL were the least time consuming ones.

Users reported that clarity of the calendar background causes less interference, which was one reason why they claimed it was easier to work with SS and LL rather than SL. SL has a more populated background (having a combination of bars and saturation).

5.2.2. ACCURACY

Accuracy data for Experiment 1 are summarized in Figure 5.2.2.

Based on the Friedman test, I found an overall significant difference for Question Type (d) ($\chi^2 = 18.24$, df = 2, $\rho < 0.001$).

There were no significant differences for the other Question Types ($\rho_{min} > 0.135$ while I expected $\rho < 0.017$).

At a detailed level (Figure 5.2.2), Wilcoxon Signed Ranks Tests showed significant differences for Question Type (d):

- LL had higher accuracy than SL ($\rho < 0.001$, $Z = -3.626$)
- LL had higher accuracy than SS ($\rho < 0.005$, $Z = -2.828$)

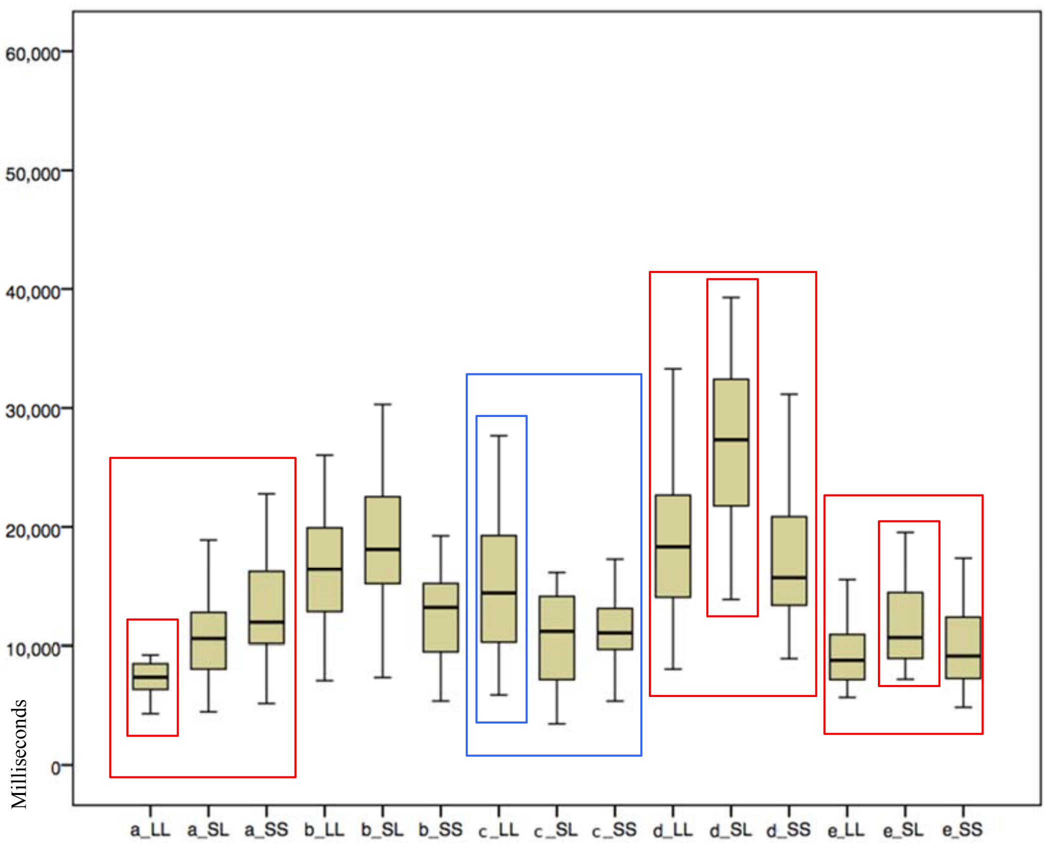

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Figure 5.2.1 – TIME DATA – Experiment 1: Calendar Task, Numeric x Numeric

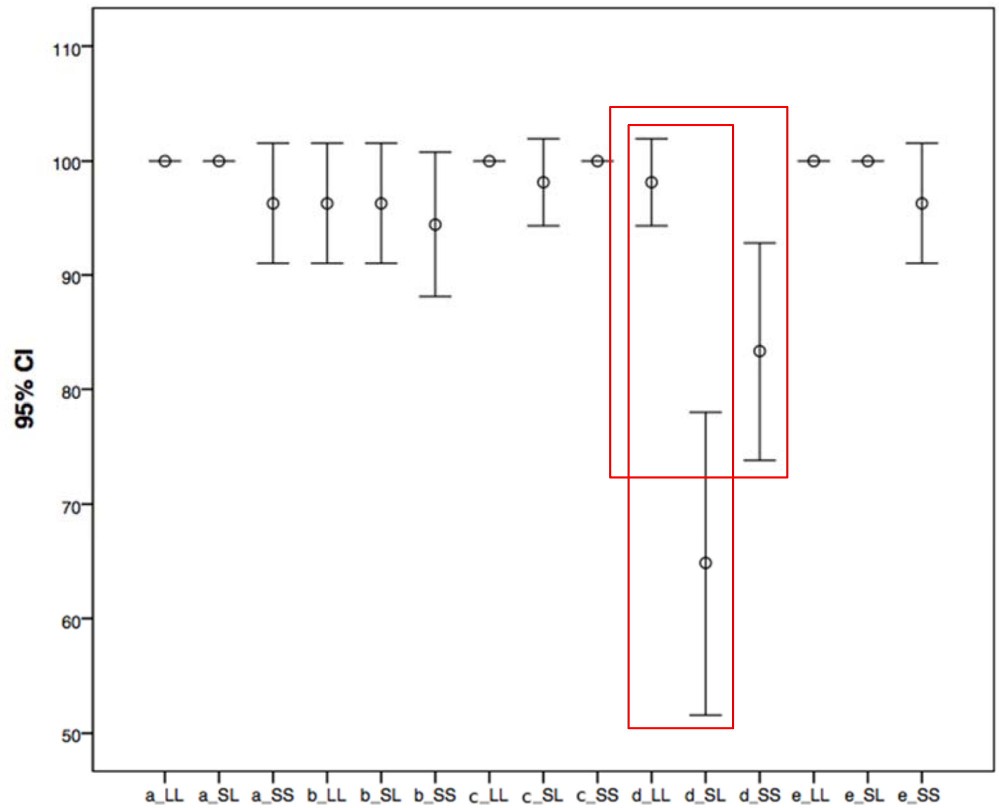


Figure 5.2.2 - DATA ACCURACY – Experiment 1: Calendar Task, Numeric x Numeric

The results showed that LL was the most accurate visualization for Question Type (d) (E.g. how many times did you go biking in the first week of April? [E.g. 10]). For this question users had to find the repetitive events on calendar, without details, whereas for other question types they had to search for more detailed information about an event like the date or the time, which are mostly over a larger time range such as two weeks to one month. This showed that for "easy" tasks LL was more accurate, but for "harder" tasks there was no difference anymore. So I observed that more errors would occur as the search became more detailed no matter which data encoding was used.

Most of the users found LL a clearer visualization. They said SL was more confusing due to interference of the bar and background color especially for extreme values.

Also they stated that both SL and SS were harder to work with because the text blended with the background, especially with darker shades.

5.2.3. USER RATINGS

Using Friedman test, we found an overall significant effect of Visualization Type (χ^2 = 37.65, df = 2, $\rho < 0.001$)

Wilcoxon Signed Ranks Test showed significant differences in:

- LL was rated to be easier than SL ($\rho < 0.001$, $Z = -4.024$)
- LL was rated to be easier than SS ($\rho < 0.001$, $Z = -4.078$)

Answering calendar tasks with Length seems to be easier than Saturation, suggesting that calendar tasks are easier with a clearer background.

5.2.4. SUMMARY

To sum up, LL often performed the fastest (faster than SL for Question Type (a, d, e)); SS was faster than SL for Question Type (d, e). LL was also the most accurate for Question Type (d). Based on user ratings, LL was rated as the easiest, probably because it keeps the calendar cell free of background colour, maximizing text contrast.

5.3. Experiment 2: Calendar Task, Numeric x Nominal

5.3.1. TIME DATA

Time data for Experiment 2 are summarized in Figure 5.3.1.

Based on Mauchly's Test of Sphericity, Visualization Type (ε) = 1.000, Question Type (ε) = 0.8, Visualization Type x Question Type (ε) = 0.77.

I found significant main effects of Visualization Type ($F(1, 26) = 14.41$, $\rho < 0.001$, η^2_ρ =

0.3) and Question Type (F (3.17, 82.43) = 15.45, $\rho < 0.001$, $\eta^2_\rho = 0.1$) and a significant interaction between Visualization Type and Question Type (F (3.07, 79.79) = 39.89, $\rho < 0.001$, $\eta^2_\rho = 0.3$).

The post-hoc results for the interaction of Visualization Type x Question Type showed that for:

- Question Type (a), ShL was faster than ShS ($\rho_{max} < 0.034$)
- Question Type (c), ShL was faster than ShS ($\rho_{max} < 0.000$)
- Question Type (d), ShL was faster than ShS ($\rho_{max} < 0.023$)
- Question Type (e), ShS was faster than ShL ($\rho_{max} < 0.002$)
- Question Type (b), there were no significant differences ($\rho_{min} < 0.685$).

ShL was significantly faster than ShS in three out of five question types. The exception was Question Type (e) (E.g. Where did you go on October 29th at 7:30 pm?). Participants explained that ShL had a clearer background, was less interfering and made it easier to answer calendar related questions. It is not clear why ShS performed better for Question Type (e).

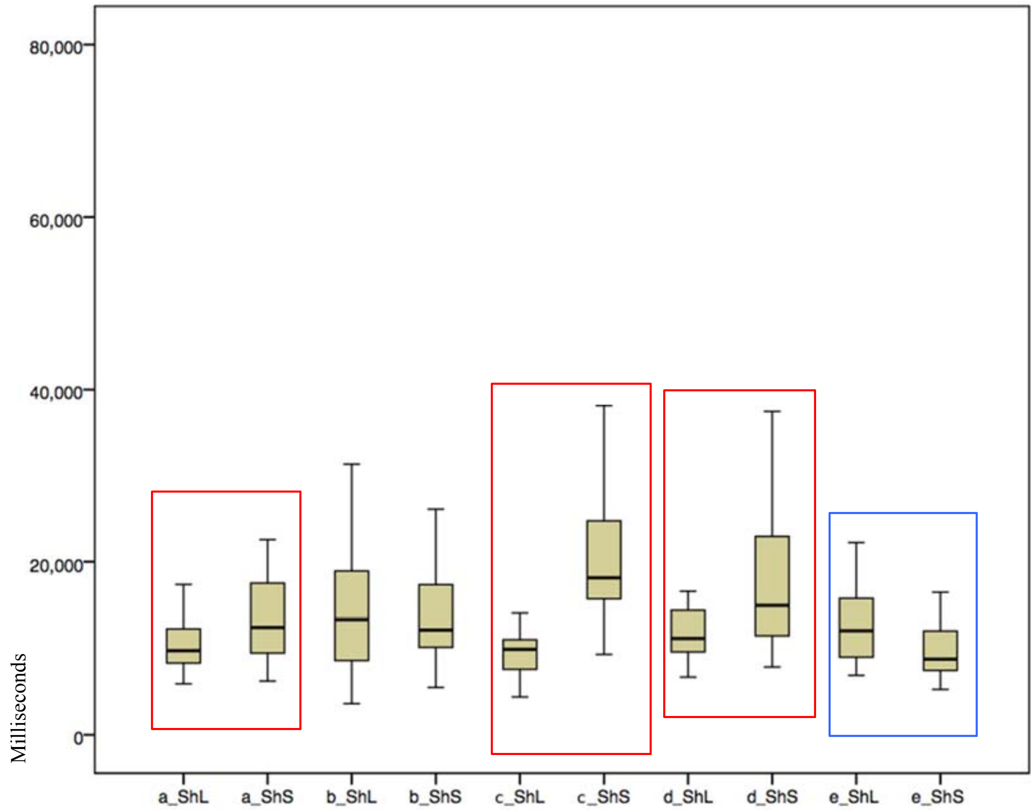


Figure 5.3.1 –TIME DATA – Experiment 2: Calendar Task, Numeric x Nominal

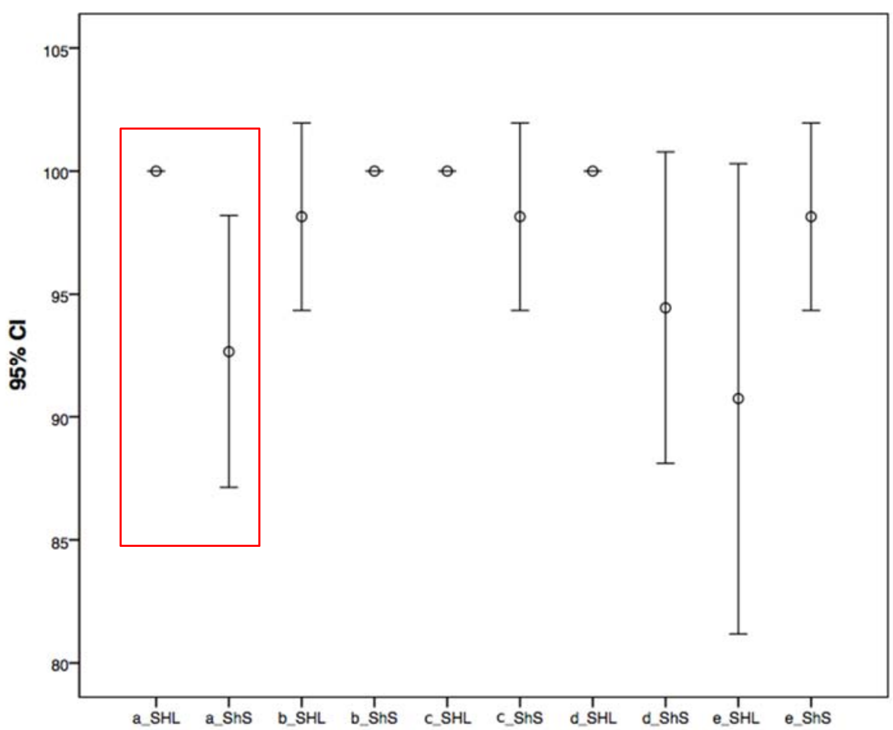


Figure 5.3.2 – DATA ACCURACY – Experiment 2: Calendar Task, Numeric x Nominal

5.3.2. ACCURACY

Accuracy data for Experiment 2 are summarized in Figure 5.3.2.

Based on Wilcoxon Signed Ranks Tests, I found a significant difference between ShL and ShS only for Question Type (a); ShL had higher accuracy than ShS ($\rho < 0.014$, $Z = -2.45$). There were no significant differences between visualization types for the remaining Question Types ($\rho_{min} > 0.08$ while I expected $\rho < 0.05$).

Like the previous explanation, the users indicated that ShL had a higher accuracy rate since it had a clearer view and as opposed to ShS, it did not cause reading difficulties due to darker shades in the background.

5.3.3. USER RATINGS

Wilcoxon Signed Ranks Test showed that ShL was rated significantly easier than ShS ($\rho < 0.001$, $Z = -4.457$), with the similar explanation for Calendar task, Numeric x Numeric (Figure 5.3.3.1 and Figure 5.3.3.2).

5.3.4. SUMMARY

ShL performed often faster than ShS for Question Type (a, c, d) and was more accurate for Question Type (a). Also user-rating data supported that ShL is easier than ShS.

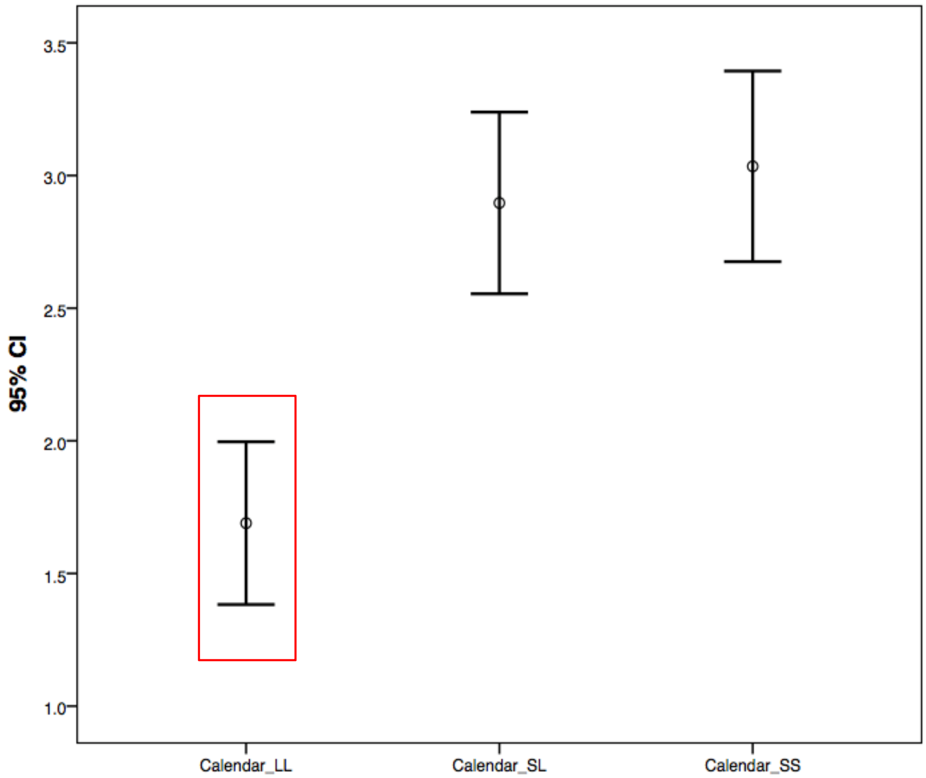


Figure 5.3.3 – USER RATINGS – Calendar Task, Numeric x Numeric

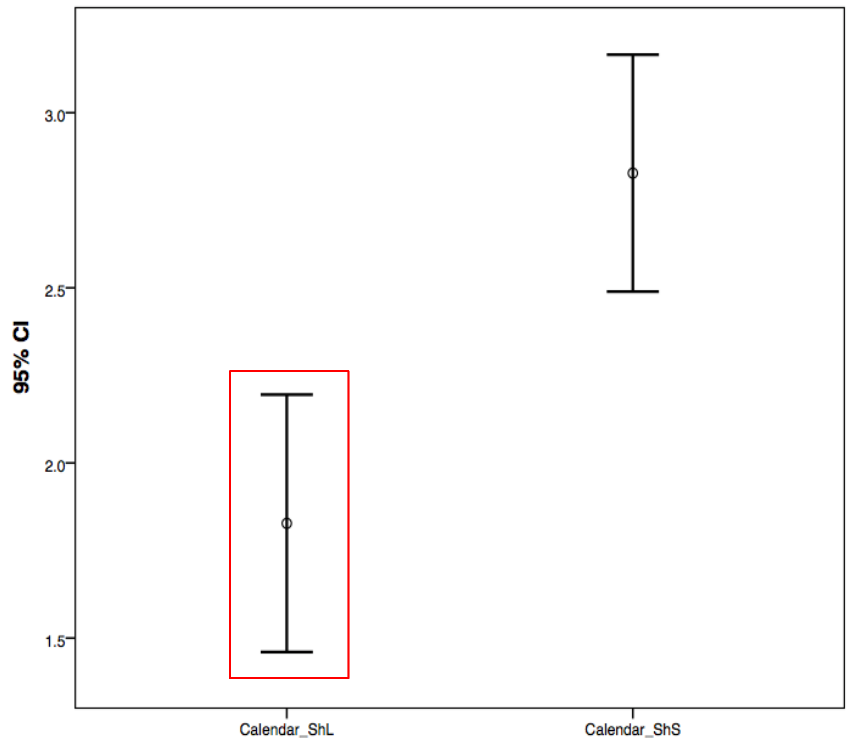


Figure 5.3.3.2 –USER RATINGS – Calendar Task, Numeric x Nominal

5.4. Experiment 3: Visualization Task, Numeric x Numeric

5.4.1. TIME DATA

Time data for Experiment 3 are summarized in Figure 5.4.1.

Based on Mauchly's Test of Sphericity, Visualization Type (ε) = 0.92, Question Type (ε) = 0.93, Visualization Type x Question Type (ε) = 0.74.

I found significant main effects of Visualization Type ($F (1.84, 47.75) = 14.15$, $\rho < 0.001$, $\eta^2_\rho = 0.3$) and Question Type ($F (1.85,48.19) = 4.54$, $\rho < 0.001$, $\eta^2_\rho = 0.1$) and a significant interaction between Visualization Type and Question Type ($F (2.64, 68.59) = 14.13$, $\rho < 0.001$, $\eta^2_\rho = 0.3$).

Results of post-hoc tests on Visualization Types showed that SS was significantly faster than SL and LL ($\rho_{max} < 0.002$).

The post-hoc results for the interaction showed that for:

- Question Type (t), SS was faster than LL and SL ($\rho_{max} < 0.014$)
- Question Type (w), SL was faster than SS ($\rho_{max} < 0.048$)
- Question Type (y):
  - SS was faster than LL and SL ($\rho_{max} < 0.001$)
  - SL was faster than LL ($\rho_{max} < 0.018$)

The results showed that SS was faster than SL and LL in Question Type (t, y) and SL was faster than LL in Question Type (y) and also faster than SS in Question Type (w).

As explained before in the Design section of this thesis, in Question Type (w) users had to choose the extreme level of the data type based on their own interpretation (E.g. what was your mood on the most productive day in the second week of April? [e.g. Happy]). This is different from the rest of the questions where they had to count days (t) - how many days in April were you both most productive and the happiest? [e.g. 10 days]) - or find specific days (y) - which Sunday(s) have you been most productive and the unhappiest? [e.g. 10th]).

Participants reported that not having a scale would make it difficult for them to identify the boundary of each mood level. For example, they had difficulty to decide with confidence whether a mood level was happiest or happy. The same type of confusion existed for SS (it was tricky to tell shades of different levels apart), but to a lesser extent.

5.4.2. ACCURACY

Accuracy data for Experiment 3 are summarized in Figure 5.4.2.

Based on Friedman test, there was no significant difference reported between the Visualization Types for any of the Question Types ($\rho_{min} > 0.02$ while I expect $\rho < 0.017$). Therefore, I cannot make any confident judgments based on these results.

5.4.3. USER RATINGS

Using Friedman test I found no overall significant difference among the visualization types ($\rho > 0.150$).

5.4.4. SUMMARY

SS performed the fastest for Question Types (t, y). SL was faster than LL in Question Type (y) and faster than SS in Question Type (w). No significant differences were found in accuracy or user ratings.

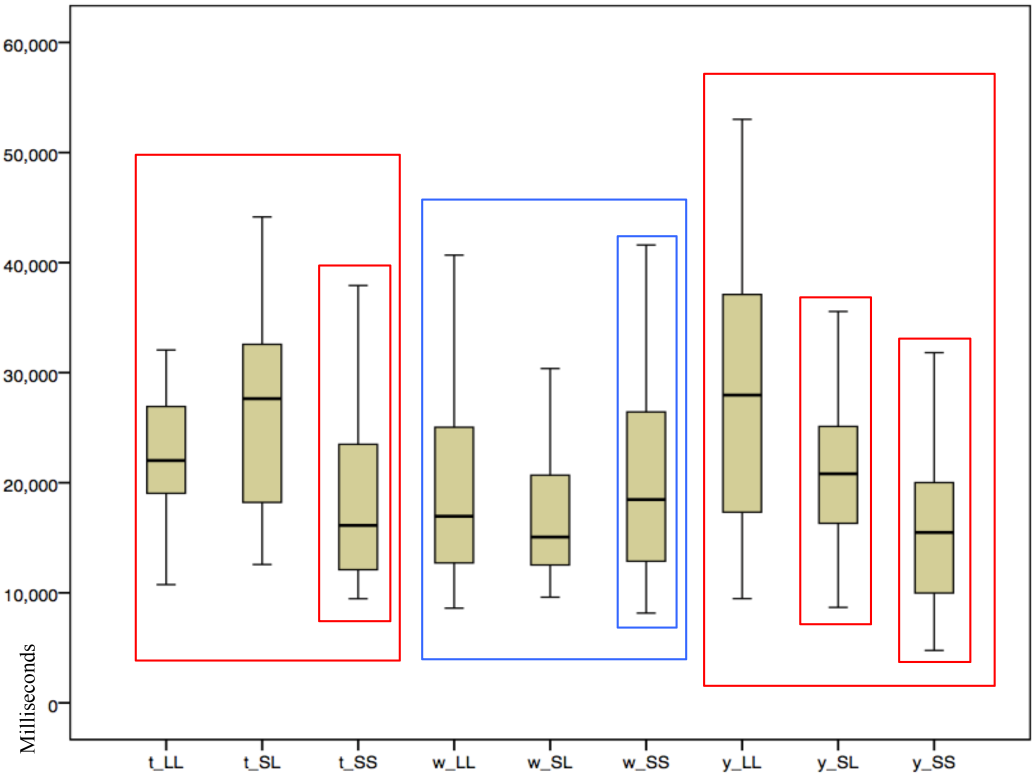


Figure 5.4.1 – TIME DATA – Experiment 3: Visualization Task, Numeric x Numeric

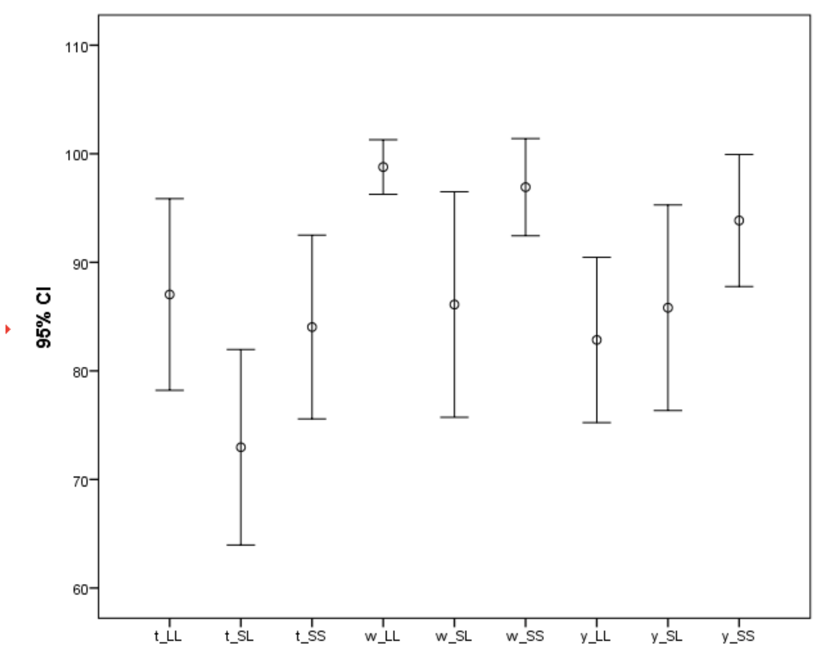


Figure 5.4.2 – DATA ACCURACY – Experiment 3: Visualization Task, Numeric x Nominal

5.5. Experiment 4: Visualization Task, Numeric x Nominal

5.5.1. TIME DATA

Time data for Experiment 4 are summarized in Figure 5.5.1.

Based on Mauchly's Test of Sphericity, Visualization Type (ε) = 1.000, Question Type (ε) = 0.99, Visualization Type x Question Type (ε) = 0.76.

I found significant main effects of Visualization Type ($F(1, 26) = 47.58$, $\rho < 0.001$, $\eta^2_\rho = 0.6$) and Question Type ($F(1.98, 51.40) = 49.38$, $\rho < 0.001$, $\eta^2_\rho = 0.6$) and a significant interaction of Visualization Type and Question Type ($F(1.52, 39.43) = 23.15$, $\rho < 0.001$, $\eta^2_\rho = 0.4$).

The post-hoc results for the interaction of Visualization Type x Question Type (Figure 5.5.1) showed that for:

- Question Type (t), ShS was faster than ShL ($\rho_{max} < 0.001$)
- Question Type (y), ShS was faster than ShL ($\rho_{max} < 0.001$)
- Question Type (w), there were no significant differences ($\rho_{min} < 0.412$).

Overall, these results show that ShS was faster than ShL. As participants reported, the large background color of each cell made it easier for them to compare different days at one quick glance rather than looking for the length of the bars that are only a very smaller portion of each cell, although I understood that the background shades need to be personalized by the users.

5.5.2. ACCURACY

Accuracy data for Experiment 4 are summarized in Figure 5.5.2. Based on Wilcoxon Signed Ranks Test (Figure 5.5.2), I found a significant difference in Question Type (w) that contradicted the time data; ShL had higher accuracy than ShS ($\rho < 0.014$, $Z = -2.45$).

5.5.3. USER RATING

Wilcoxon Signed Ranks Test showed no overall significant difference between ShL and ShS ($\rho > 0.553$), (Figure 5.5.3).

5.5.4. SUMMARY

ShS performed the fastest for Question Type (t, y). But ShL had the highest accuracy data for Question Type (w). User ratings reported no significant mean effect for any of the Visualization pairs.

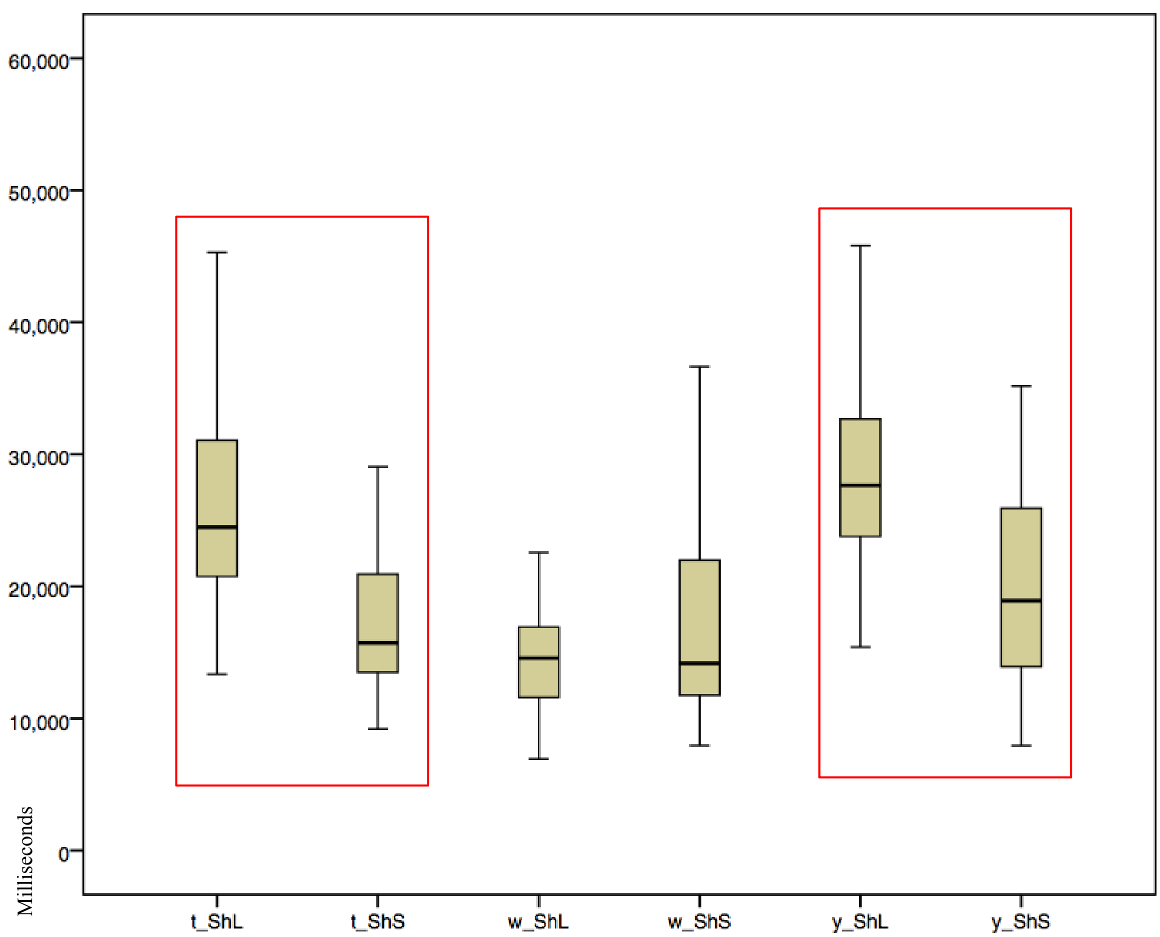


Figure 5.5.1 – TIME DATA – Experiment 4: Visualization Task, Numeric x Numeric

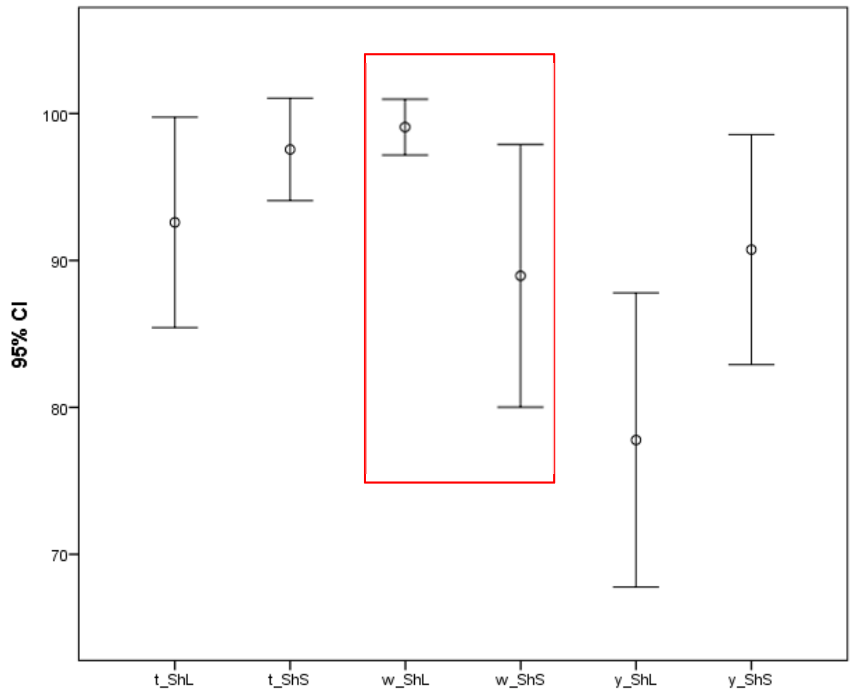


Figure 5.5.2 –DATA ACCURACY – Experiment 4: Visualization Task, Numeric x Nominal

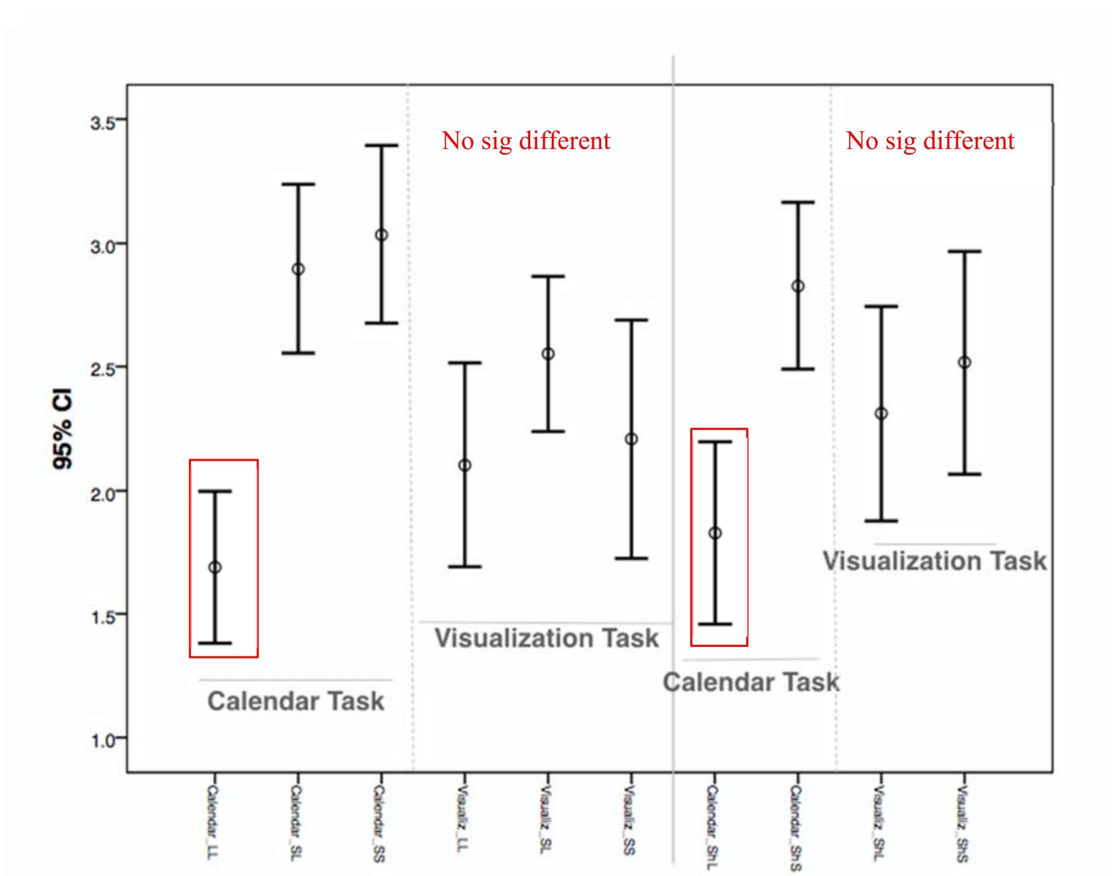


Figure 5.2.3 – USER RATINGS - Calendar Task & Visualization Task - ALL

5.6. Interview Results

In this section I will summarize and highlight the most important points from the verbal interviews with participants after the study. I organize the results by the questions asked.

1. If such a tool existed, would you use a tool like this? Why or why not?

26 out of 29 participants thought they would use it since it reveals their behaviour patterns. These participants explained that if they could understand the pattern of their mood using the tool, they could schedule for their day depending their mood and weather. For example, they might plan to do cheerful activities especially on rainy days when they normally feel depressed or they might assign more important tasks to themselves on sunny days since they are more productive on those days. Also they stated they would use it under these conditions: if they use calendars in their daily life, if the tool was a free application, if data entry was easy, if it is available on smart phones and tablets.

The three other participants who did not like the tool stated that they would prefer to use their diary since their mood changes from time to time and cannot be shown constantly in such a calendar view. One person believed that the past has passed and there's nothing he could do about it using this tool.

2. If you had a tool like this, do you think it would help you learn more about your productivity and the influencing factors?

27 out of 29 participants answered yes to this question. They thought measuring the time spent on each task would be helpful. Also most of the participants thought that they could reflect on these data after they were collected for a long period of time. One participant stated that he does not have statistical insight on his personal data. There might be some

information that the tool could reveal that he never had any insight about before.

3. If you had a tool like this, how easy do you think it would be to find a pattern in your life and behavior by using it? Why?

28 out of 29 users found it was very easy to work with this design and see trends over a two-month period. The one participant with a “no” answer was not used to using calendars in general.

4. If you had a tool like this, do you think it would help you to discover any hidden data and how?

17 out of 29 thought it would help in discovery of hidden data. Some indicated that there are many things you don’t know about yourself and this tool could help by showing patterns and trends. Nine people thought that it **might** be helpful but they wouldn’t be sure until they had worked with it for a longer period of time. Three participants did not find this tool helpful, because they thought they already had enough awareness about themselves.

5. If you had a tool like this, do you think it would help you find out more about your status in each and every day and also your current status?

Nine people out of 29 thought it would not show current status; rather, it shows overall status of the entire day as their mood changes from time to time. They explained if they would enter data three-four times a day, then that might help showing the current mood. The remaining 20 participants found the tool helpful in revealing their current status in case of regular use.

6. Are there other variables that you would like to track and display in this way?

What and why?

Here is the list of items the participants reported that would like to show in this tool: stress level, energy level, emotions, amount of sleeping hours each night, personal relationships, location, people they interact with daily (one participant stated that how people that she interacts with can influence how she feels and how productive she can be), physical activity, cheering-up activities, period dates, food/calorie/water/iron… intake, cleanliness of the environment, times of the day with highest productivity, overall mental state (how stable one can be), the time spent on each task, and friend activities (even to share with friends).

7. **Can you easily find differences between 2 or more days? (Make comparisons) How or why not?**

All of the participants found it easy to make comparisons, although they compared different views and explained how some were confusing for them and they would rather work with more colorful visualizations.

8. **Are the information and visualizations shown on the calendar enough to help you learn more about your productivity or do you think it lacks some necessary details?**

28 out of 29 participants thought the amount of presented data were enough. However, one participant thought it would be good if we could show and hide these ambient data on calendar so it wouldn't be distracting at all. Many indicated that they would prefer to visualize other factors rather than weather and productivity level.

9. **If you had a tool like this, do you think it would motivate you for your future actions?**

All the users thought it would motivate them for future actions because it could help with time-management, being more self-organized and planning more efficiently. They said that when the system reveals the patterns and trends they can identify how changing behavior makes a difference in their progress so it is very motivating, especially regarding the factors that they can control; for example they indicated that obviously there's nothing they can do about weather but there are some environmental matters they can change to improve the situation; room's tidiness was one example. Some interesting quotes are: "I can plan based on mistakes I made before and try to improve them…", "try to do the same things that I do on happy days for other days…", "use previous days as predictions for future under same circumstances…".

10. If you had a tool like this, do you think it would help you achieve your goal better? How? What do you think should be added to the tool to make it more useful to achieve your goal?

In general, like the previous question, they thought it would be helpful to set goals using this tool. Knowing yourself and the status of your tasks better helps in more efficient and organized planning, better use of time, more motivation and respectively better goal achievement.

11. If you had a tool like this, do you think it would help you to maintain your productivity and how is that?

28 out of 29 participants answered "yes" to this question especially considering the factors that they have more control over. They thought that when they see the factors presented on the calendar, they could make predictions and plan from beforehand by taking greater

control over their behaviors. One participant answered “no” since he believed people always plan ahead and cannot predict productivity beforehand.

12. If you had a tool like this, do you think it would it allow you to be able to navigate through different days and create an image of the history of your activities in your mind?

All participants thought that this tool would help navigating through the past. Some pointed out that this tool is like a summarized diary if they enter all data regularly; by presenting impacting factors, they felt that they could find out a lot about themselves. In general many participants suggested colourful background colors and task colors would help in better information perception and also would provide more motivation to work with the tool.

Chapter 6

Discussion

6.1. Discussion Of Hypotheses

In this section I will have a discussion based on these results and my proposed hypothesis.

6.1.1. CALENDAR TASK, NUMERIC x NUMERIC

HYPOTHESIS_1: I ranked the visualizations as LL < SL < SS, ranging from fastest and most accurate to slowest and least accurate.

This hypothesis was partially confirmed. As expected, LL often performed the fastest (faster than SL for Question Type (a, d, e); it was also the most accurate for Question Type (d) and was rated the best overall. Most of the users found LL a clearer visualization that caused the least interference with the main calendar information. They stated that both SL and SS were less readable and harder to work with because the text blended with the background, especially with darker shades. LL performed the slowest only for Question Type (c). Question type (c) involved finding a pattern of events or activities. I suspect that having many bars in the visualization might have interfered with this task and caused longer response time.

However, my prediction that SL would perform better than SS was not confirmed. In contrast, time results showed that for Question Types (d, e), SS was faster than SL. SS also received a better overall ranking for this task. From the user comments I understood that SL caused distraction due to contrast of bars and background color.

6.1.2. CALENDAR TASK, NUMERIC x NOMINAL

HYPOTHESIS_2: I predicted ShL to be faster and more accurate than ShS.

This hypothesis was partially confirmed. As expected, ShL often performed faster than ShS; also it was the most accurate for Question Type (a) and was rated the best overall. Participants explained that ShL had a clearer background, was less distracting and easier for answering calendar related questions. ShS has a lack of contrast between the text and the background color, making it difficult for users to read the text. Choosing a different background color, for example using pastel background colors with black text might be a solution to this issue.

On the other hand, my prediction that ShL would perform faster that ShS was not confirmed for all Question Types. In contrast, time results showed that for Question Type (e), ShS was faster than ShL. As mentioned before, the reason for this is unclear.

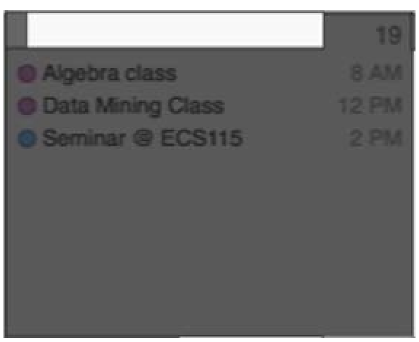
6.1.3. VISUALIZATION TASK, NUMERIC x NUMERIC

HYPOTHESIS_3: I ranked the visualizations as SL < LL < SS, ranging from the quickest and least error-prone to the slowest and most error-prone.

This hypothesis was only partially confirmed. In support of the hypothesis, SL was the fastest in Question Type (w) and was faster than LL in Question Type (y). However, in contrast to what I assumed, SS performed the fastest for Question Type (t, y) and LL preformed the slowest overall.

The accuracy and user rating results showed no significant differences.

Most of the participants reported that it was difficult for them to identify the boundary of each mood level. For example, they couldn't decide confidently whether a mood level was happiest or happy. The same type of confusion existed with shade levels for SS visualizations but to a lesser extent. So sometimes it was tricky for them to tell shades of different levels apart. They stated that SL was more confusing due to interference of the bar and background color, especially for extreme values. Consider cases where SL Visualization represents Mood with Saturation and Productivity with Length; also consider a day with low mood and high productivity. This means that the background color will be dark and the bar is full. Although these data representations made sense (to show darker shade for lower mood, and a full bar for a very productive day) but in such case the empty section of the bar gets confusing as some participants stated and they assumed that the productivity was low as well although it was at its high extreme.



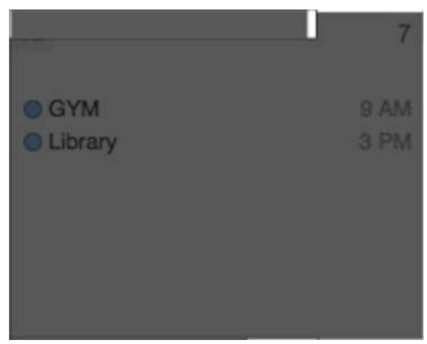


Figure 6.1.3 – Left cell (a), right cell (b)

Figure 6.1.3 is an example of what I described. In both of these figures bar is encoding of productivity level and background color is mood. In Figure 6.3.1 – cell (a) participants mistakenly thought productivity level was very high where as it was very low and in Figure 6.3.1 – cell (b) they thought productivity level was very low while it was very high.

One of our interesting findings was that SS was very effective when users were asked to find similar extreme values for data encodings, for example when they were looking for the happiest and most productive days. Notice that in these cases, they would not need to check the legend to figure out which encoding is for which data. From dimension pair perspective, as they are analytically similar to some extend they can be viewed as integral dimension pairs. On the other hand, when answering questions about extreme values of data encodings with opposite values (e.g. the happiest and least product day), SL was faster because it highlights the differences between the data types by using 2 different encodings. Again, according to dimension pair concept since these two un-similar data types are presented using separate dimensions so it is easier for participant to tell them apart from each other.

6.1.4. VISUALIZATION TASK, NUMERIC x NOMINAL

HYPOTHESIS_4: I predicted ShS to be quicker and more accurate than ShL.

This Hypothesis was partially confirmed. As expected, time data showed that ShS had a faster response time than ShL. Participants reported that the large background color of each cell made it easier for them to compare different days in one quick glance rather than looking for the length of the bars that only occupy a very small portion of each cell, although we understood that the background shades need to be personalized by the users.

However, the accuracy data showed the contrary; for Question Type (w), ShL had higher accuracy than ShS. As explained before, Question Type (w) involved *finding a day with certain extreme value* based on extreme value of the other data encoding on the same day. Based on my observations, I understood that participants were confused about what each shade represented; also it was difficult for them to tell the different shade levels apart. In addition, Length presents more detail than Saturation. I limited Saturation levels only to five different shades representing five levels of a numeric value. I thought using a wider range of saturation for more levels would increase confusion since the colors would be too hard to differentiate. On the other hand, Length can show a wider range of levels on the bar, so it is has a more detailed representation of numerical values. These reasons could explain why ShL had higher accuracy than ShS for this task.

Another unsupported part of my hypothesis is related to user rating data, where I found no significant difference between ShS and ShL.

Chapter 7

Limitations And Future Work

The major purpose of designing a prototype of a “Personal analytical calendar” was to help casual users to have a better self-understanding and self-reflection based on their daily activities and behaviors. The idea of such a tool is very promising, but my work is preliminary. Substantial future work is needed for such calendar tools to be as useful as they are intended to be.

There are some aspects of the design that still need more future work. Many of these were removed from the study in order to make the study simpler with fewer variables to focus on. For example, to avoid color interference effects, I only used gray-scale colors for background color, the bars and the shapes since the calendar activities are colored. However, the interviews revealed a serious need for using colors in these. Participants claimed that grey-scale was boring and discouraging so they would prefer to customize the aesthetics for more appealing interface. So for this tool to be more customizable, a future feature would be to add a panel that allows the user change the colors to their favorite ones.

In the current design I have only focused on encoding two data items per each calendar cell. Future studies should attempt to find the threshold at which the number of visualizations begins to substantially interfere with calendar visualization tasks. It is possible that we could show more than two visual encodings to make the tool more informative and helpful, but this requires further investigation.

The main focus of this study was to work on an effective visualization for an analytical self-reflection tool; however due to time limitations I could not focus on other critical

analytical aspects of this proposed tool. For such a tool to be effective, there is a huge demand for a *data-mining engine* and a *context-aware system* so that it could mine the daily data over a period of time and find relationships between different factors and data that the user enters or the application collects. Using the available context (collected data and their relationships) the system could provide relevant information and/or services to the user, where relevancy depends on the user's task [9]. Then this data could be visualized to help improve *discovery* and *maintenance* phases [18]. This could be achieved by creating *reports*, *reminders* and *recommendations* and other notifications to help with decision-making and self-reflection. *Reports* could be helpful by showing how weather - or any other factor - might or might not influence user's mood. This way a person could rearrange tasks for better productivity based on weather –or the other factor. *Reminders* could help in reminding the user about activities that haven't been taken care of for a long time, which might result in better productivity. *Recommendations* could assist productivity by suggesting activities based on the previous productive days. Of course, these reports and summarized information need to follow design guidelines that suit everyday use by *casual users*.

Another interesting area of future work would be to use this tool for social collaboration, where members of the same household can share their calendar and see how different factors influence them, while considering the privacy of each person. This might help with motivation, facilitate group goal setting, and better support reflection and time management. As suggested in [10], monitoring personal behavior and sharing among other users can improve personal reflection and increase motivation for steps they take towards their goals. Of course, such a sharing mechanism also needs to consider privacy issues (e.g., keep some personal events private on the user's demand).

Also, although the data collection phase is not our study's focus, easy data collection methods do need to be created in order to make this approach successful. As suggested in [18], future studies need to investigate appropriate data collection approaches that support user engagement. This means that designers should implement data collection methods that require some user involvement (since entering some of their personal data manually engages people in the process), while using other sensors that simultaneously gather the rest of these data automatically (to ease the burden on users). Moreover finding a way to integrate data from different sensors and sources that are already recording people's data into one single view is the next important design step for this tool. This will reduce the burden from the user's side by reducing the need for them to monitor their personal data from a variety of different applications (eating habits, exercise habits, etc.). For collection of the information that is not provided through existing applications one possible way would be to ask questions regarding those data daily from the user. But this data collection approach still needs future work, to see how many times a day these question should be asked, what format would be better to collect these data, etc.

A platform that can accept and visualize a variety of personal time-based data, is flexible to adapt to user demands, and utilizes effective visualization techniques to reveal trends in the data could be very powerful. Its purpose could go beyond monitoring and reflecting only on productivity; it could be extendible for viewing, gaining more insight and reflection on other personal goals. One example could be reflecting on personal relationships using this application, by monitoring your communications with your friends and family and taking necessary steps to improve or maintain them.

Chapter 8

Threats To Validity

In this section I will investigate the various threats to validity that might apply to the study design and the prototypes.

8.1. Internal Validity

Internal validity refers to how well an experiment is done, especially whether it avoids confounding factors. The less chance for confounding variables in a study, the higher its internal validity is. The results of my study and the interviews identified that when background color was used as one of data encodings, it could blend with the text and decreased the legibility. The same explanation exists for shapes in the calendar, where shapes and background color would sometimes blend and hide some parts of the shape; this could have resulted in participants taking a longer time to answer. It is possible that an alternative design, which took more care with text legibility and contrast, might have had different results.

8.2. External Validity

In a definition by Trochim [29], a *threat to external validity* is an explanation of how you might be wrong in making a generalization. Based on this definition, one of the threats to external validity of this study may lie in the transparency and hue of colors that we used as the background color. For example, we might see a different result if we had chosen other color options or lower transparency levels, rather than gray scale in the background. In particular, participants suggested that the gray scale made them uncomfortable and less motivated to work with the visualizations.

Defining questions for both the calendar task and the visualization task was a very delicate process, and included observing, categorizing and choosing questions that people really ask when working with calendars, based on my interviews. However one could still question how ecologically valid these questions were. Were they ideal representatives of what people are interested to know about their own data based on [18]? Do they represent all the types of questions that people ask themselves while working with the calendars? These issues are not fully clear and may limit the generalizability.

The proposed tool in my thesis is meant to target casual users from a variety of age ranges. However, the participants in this study were only students at the University of Victoria. They did come from different fields, age ranges, and levels (graduate and undergraduate students), but nonetheless do not represent the entire target population. Therefore, it is unclear whether my study would have such favourable results with a wider group of casual users.

While designing the study design questions, although I attempted to make the questions as similar as possible to each other across different conditions; however they were not identical so the questions designed for quantitative/qualitative with SS were slightly different from those in SL or LL. Different results might come out where all the questions are identical.

In addition, people were participating in an artificial study not involving their own data. Results might differ in a field study where people use the tool with their own data and for a long period of time.

8.3. Construct Validity

According to Brown [4], *construct validity* is the degree to which a test measures what it claims, or purports, to be measuring. I aimed to measure how well people could perform Calendar tasks and Visualization tasks. To assess this, I developed some detailed questions and measured time and error. One threat here is that the measured time and error on my questions do not really accurately represent how people perform on real Calendar tasks and Visualization tasks.

Chapter 9

Conclusion

We are surrounded by our personal data in every aspect of our lives. These personal daily data are very valuable only if we can understand them, find out about our habits and behaviors and using this deeper self-knowledge and self-insight we can reflect upon our life for more improvement in our personal activities towards our personal goals. Personal "productivity" is one of the very significant attributes that people would like to learn more about themselves and improve it is. According to the interviews that I conducted, I learned that people would like to be able to learn about the influential factors in their daily personal productivity, track and monitor them and understand how each factor and to what extend is impacting their productivity. By gaining this knowledge and understanding of their personal data then they can start reflecting upon these data by planning and setting goals for maintaining or improving their productivity level. This also helps people with more self-management and time-management.

In this thesis, I focus on two research questions: (1) How can we design a visualization tool to help people be more engaged in understanding their daily productivity? Contextual data and history about one's behaviors and habits are of the important tools to help people learn more about their living habits and experiences. According to my researches, I learned that Calendars could play a very important role as a personal information management tool, by storing and demonstrating people's daily personal data in an organized manner. Therefore, I selected digital calendars as the platform to integrate contextual information about personal daily life with productivity related information. Followed by choosing calendar as the platform, I had to find an effective way of visualizing these productivity influential factors on the calendar. This shaped my second research question: (2) What combination of visual encodings will enable people to most easily identify a relationship between two different pieces of daily information rendered on a calendar? To identify best visual encoding, I considered encoding Numeric and Nominal data-types. I chose to encode Numeric data using Saturation and Length encodings, and Nominal data using Shape encoding. I designed two types of questions: Calendar related questions and Visualization related questions. Using Calendar related questions I investigated the interference level of visualizations in calendar related tasks, and using Visualization related questions I tried to identified which visualization is faster and leads to more accurate results and better user ratings. I compared the combination of Numeric x Numeric (Saturation x Saturation, Saturation x Length, Length x Length) and Numeric x Nominal (Shape x Length, Shape x Saturation) data encodings. My results demonstrated the following: for Calendar Task questions and in Numeric x Numeric category, the overall best results were outputs from Length x Length Visualization. For the same task set and in Numeric x Nominal category, Shape x Length was rated the best. For Visualization Task questions and in Numeric x Numeric category, the best overall performance was assigned to Saturation x Saturation. For the same question set in Numeric x Nominal category, the fastest visualization was Shape x Saturation while the most accurate was Shape x Length. These findings along with interviews provided me with advantageous information for refining the visualization designs to more accurate, more user-friendly visualization that helps with faster and more efficient interaction and assist people in monitoring their goals, trends, status, contexts, influencing factors and differences in their personal data to be able to answer different questions about their daily personal productivity related data. This can provide them with more self-awareness and lead to self-reflection.

In the future studies, these visualizations can be combined with data mining techniques which creates a powerful tool with recommendation and notification features that can help users with more motivation, encouragement and self-awareness and help them to achieve their goal more efficiently by monitoring and reporting whether they are in the right track. Another area of focus in future studies can be investigating efficient approaches of personal data collections.

Reference

[1] Barreau, Deborah, Robert Capra, Susan Dumais, William Jones, and Manuel Pérez-Quiñones. "Introduction to keeping, refinding and sharing personal information." *ACM Transactions on Information Systems (TOIS)* 26, no. 4 (2008): 18.

[2] Bergman, Ofer, Ruth Beyth□Marom, and Rafi Nachmias. "The user□subjective approach to personal information management systems." *Journal of the American Society for Information Science and Technology* 54.9 (2003): 872-878.

[3] Bergman, Ofer, et al. "Personal information management." *Chi'04 extended abstracts on human factors in computing systems*. ACM, 2004.

[4] Brown, James Dean. *Testing in language programs*. New Jersey: Prentice Hall Regents, 1996.

[5] Brush, A. J., and Tammara Combs Turner. *A Survey of Personal and Household Scheduling Practices: Implications for Digital Family Calendars*. MSR-TR-2007-23, http://research. microsoft. com/research/pubs/view. asp x.

[6] Cleveland, William S., and Robert McGill. "An experiment in graphical perception." *International Journal of Man-Machine Studies* 25.5 (1986): 491-500

[7] Crabtree, Andy, Terry Hemmings, Tom Rodden, and John Mariani. "Informing the development of calendar systems for domestic use." In *ECSCW 2003*, pp. 119-138. Springer Netherlands, 2003.

[8] Correll, Michael, et al. "Comparing averages in time series data." *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*. ACM, 2012.

[9] Dey, Anind K. *Providing architectural support for building context-aware applications*. Diss. Georgia Institute of Technology, 2000.

[10] Efstratiou, Christos, et al. "Sense and sensibility in a pervasive world." *Pervasive Computing*. Springer Berlin Heidelberg, 2012. 406-424.

[11] Grönvall, Erik, and Nervo Verdezoto. "Beyond self-monitoring: understanding non-functional aspects of home-based healthcare technology." *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*. ACM,

2013.

[12] Hajizadeh, Amir Hossein, Melanie Tory, and Rock Leung. "Supporting Awareness through Collaborative Brushing and Linking of Tabular Data." *Visualization and Computer Graphics, IEEE Transactions on* 19.12 (2013): 2189-2197.

[13] Harrison, Beverly L., Gordon Kurtenbach, and Kim J. Vicente. "An experimental evaluation of transparent user interface tools and information content." *Proceedings of the 8th annual ACM symposium on User interface and software technology*. ACM, 1995.

[14] Huang, Dandan, Melanie Tory, Bon Adriel Aseniero, Lyn Bartram, Scott Bateman, Sheelagh Carpendale, Anthony Tang, Robert Woodbury. *Personal Visualization & Personal Visual Analytics*, to be submitted to TVCG, 2014.

[15] Huang, Dandan, Lyn Bartram, Melanie Tory. *Consumption Calendar: Visualization in Context*, Research Notes, GRAND 2013.

[16] Lansdale, Mark W. "The psychology of personal information management." *Applied ergonomics* 19.1 (1988): 55-66.

[17] Li, Ian, Anind Dey, and Jodi Forlizzi. "A stage-based model of personal informatics systems." *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2010.

[18] Li, Ian, Anind K. Dey, and Jodi Forlizzi. "Understanding my data, myself: supporting self-reflection with ubicomp technologies." *Proceedings of the 13th international conference on Ubiquitous computing*. ACM, 2011.

[19] Li, Ian, Anind K. Dey, and Jodi Forlizzi. "Using context to reveal factors that affect physical activity." *ACM Transactions on Computer-Human Interaction (TOCHI)* 19.1 (2012): 7.

[20] Mackinlay, Jock. "Automating the design of graphical presentations of relational information." *ACM Transactions on Graphics (TOG)* 5.2 (1986): 110-141.

[21] McDuff, Daniel, et al. "AffectAura: an intelligent system for emotional memory." *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2012.

[22] Payne, Stephen J. "Understanding calendar use." *Human-Computer Interaction* 8.2 (1993): 83-100.

[23] Pousman, Zachary, and John Stasko. "A taxonomy of ambient information systems:

four patterns of design." *Proceedings of the working conference on Advanced visual interfaces*. ACM, 2006.

[24] Pousman, Zachary, John T. Stasko, and Michael Mateas. "Casual information visualization: Depictions of data in everyday life." *Visualization and Computer Graphics, IEEE Transactions on* 13.6 (2007): 1145-1152.

[25] Schwarz, Julia, Jennifer Mankoff, and H. Scott Matthews. "Reflections of everyday activities in spending data." *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2009.

[26] Sprague, David William. *Exploring Information Visualization Use Patterns in Casual Contexts*. Diss. University of Victoria, 2011

[27] Teevan, Jaime, William Jones, and Benjamin B. Bederson. "Personal information management." *Communications of the ACM* 49.1 (2006): 40-43.

[28] Tollmar, Konrad, Frank Bentley, and Cristobal Viedma. "Mobile Health Mashups: Making sense of multiple streams of wellbeing and contextual data for presentation on a mobile device." *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2012 6th International Conference on*. IEEE, 2012.

[29] Trochim, William MK. *Research methods: The concise knowledge base*. Atomic Dog Publishing, 2005.

[30] Tungare, Manas, Manuel Perez-Quinones, and Alyssa Sams. "An exploratory study of calendar use." *arXiv preprint arXiv:0809.3447* (2008).

[31] Ware, Colin. *Information visualization: perception for design*. Elsevier, 2012. - chapter6 –page 206

[32] Weiser, Mark, and John Seely Brown. "Designing calm technology." *PowerGrid Journal 1.1* (1996): 75-85.

[33] Ware, Colin. *Information visualization: perception for design*. Elsevier, 2012.

[34] Kamvar, S. D., & Harris, J. (2011, February). We feel fine and searching the emotional web. In *Proceedings of the fourth ACM international conference on Web*

search and data mining (pp. 117-126). ACM.

[35] http://personalinformatics.org/tools/

[36] http://www.fitbit.com

[37] http://www.withings.com

[38] https://www.apple.com/ca/ipod/nike/

Appendix

Appendix A

INTERVIEW QUESTIONS FOR PRODUCTIVITY

Each day: {Activity (1): {Actionable task (1), Actionable Task (2), …, Actionable Task (n)}, Activity (2): {Actionable Task (1), Actionable Task (2), …, Actionable Task (n)}, ...}

Perception of productivity:

Define productivity in your life? What does productivity mean in your personal experience?

Define daily Activities

- In what particular activities in your daily life you want to be productive in? Name them?

- Do you currently do anything to monitor their productivity, and if so, what?

- Which one of these activities are those that you want to reflect your productivity upon? Do you have a priority of activities in mind? Prioritize them.

Define Tasks for each Activity and Factors (Discovery/Maintenance)

For each one of the named activities, separately, Answer the following questions:

- Do you know when you are being productive at that activity?

- What actionable tasks should be completed so that you can say you have been productive regarding a particular activity?

- What are the factors that affect their productivity? (In positive/negative way)

- How certain you are that the mentioned factors are influencing the task, or more generally speaking, the activity’s productivity?

- Are you sure that the above-mentioned factors are the only factors? Are you interested in finding the other influential factors by tracking your personal data?

- Do you currently do anything to maintain your productivity in that particular activity? If so, what do you do? If not, would you like to do so? How?
    - Which one is more important to you?
    - Ways to figure out the factors that your productivity is based on them? OR
    - Ways to maintain this productivity?

- Ways to improve this productivity and enhance/reduce the factors?

Defining each task/activity's category

- What type of question you have about your data? Do you want to find trends, status?

System design

- What types of information a productivity tool should monitor?

- In your opinion how can a system help you regarding the productivity of each one of your activities?
  - In discovering factors
  - In reflecting these factors
  - In maintaining these factors

- Which one of the followings in a system can help with the above issues; discovery (help you find out the activities) and maintenance (help you keep being productive)
  - Reminder
  - Alert (to notify whether you are under or over your goal estimates)
  - Notification
  - Suggestions
  - Other options (that you would like to add)

- What do you think is the best way to evaluate your daily progress?

- Are you using any self-tracking tool? What are they and for what purpose? What do you mostly like or dislike about these tools?

Appendix B

CALENDAR TASK QUESTION SET

1- What meeting did you attend on September 7th? [E.g. Department meeting]

2- What did you do on Saturday 13th? [E.g. Hiking]

3- How many times did you go to swimming in the first 15 days of October? [E.g. 10]

4- How many birthday events occurred in April? [E.g. 10]

5- How many meetings did you attend in the third week of September? [E.g. 10]

6- How many times did you go to the library in the fourth week of April? [E.g. 10]

7- At what time did you go for swimming on Tuesday 29th? [E.g. 1:00 AM]

8- What meeting do you have every weekday? [E.g. Department meeting]

9- How many meetings did you have with Jeremy in the second week of April? [E.g. 10]

10- What do you do on Wednesday nights at 5 pm? [E.g. Hiking]

11- How many times a week you have Consultant office - TA? [E.g. 10]

12- What sports do you do? [E.g. Hiking]

13- What appointment did you have on 11th? [E.g. Dentist]

14- How many meetings did you attend in the third week of October? [E.g. 10]

15- What time did you have meeting with COOP coordinator on April 30th? [E.g. 1:00 AM]

16- Which date did you go for swimming on the fifth week of October? [E.g. Monday 1st]

17- Which date did you last go swimming in April? [E.g. Monday 1st]

18- Which dates are you away for a business trip? [E.g. Monday 1st]

19- Which date did you have dentist appointment during October? [E.g. Monday 1st]

20- Which date is Aidin's Birthday? [E.g. Monday 1st]

21- What sports do you do usually on days that you have Algebra class? [E.g. Hiking]

22- What time did you go out for dinner w/ Bob in restaurant on Friday? [E.g. 1:00 AM]

23- What time are your meetings with Jeremy? [E.g. 1:00 AM]

24- What do you mostly do on every Saturday? [E.g. Hiking]

25- Who do you have regular meeting with on CSCW class days? [E.g. Sarah]

26- What sports did you do on April 27th? [E.g. Hiking]

27- What do you mostly do on every Saturday? [E.g. Hiking]

28- Which date you go to Anathema Concert? [E.g. Monday 1st]

29- How many times a week you have TA class? [E.g. 10]

30- What time does "movie night with Farshid & Azadeh" start usually on Sundays? [E.g. 1:00 AM]

31- What did you do on October 14th at 1:30 pm? [E.g. Hiking]

32- What did you do on September 19th at 07:45 am? [E.g. Hiking]

33- Where did you go on September 24th at 4 am? [E.g. Friend's place]

34- What classes do you have on Tuesday? [E.g. Chemistry]

35- Which date did you have lunch w/ Azadeh? [E.g. Monday 1st]

36- At what time do you go to gym on Fridays? [E.g. 1:00 AM]

37- Where did you go on April 14th at 6 pm? [E.g. Friend's place]

38- What sports did you do on April 6th? [E.g. Hiking]

39- What sports did you do on April 14th? [E.g. Hiking]

40- Which date is Goli joonam's birthday? [E.g. Monday 1st]

41- Which date did you go to Cinema w/ Hale and Babak? [E.g. Monday 1st]

42- How many meetings did you attend on October 30th? [E.g. 10]

43- Where did you go on Saturday 19th? [E.g. Friend's place]

44- What do you do on Thursday nights at 8 pm? [E.g. Hiking]

45- How many times did you go biking in the first week of April? [E.g. 10]

46- Which date in last week of September you had Seminar? [E.g. Monday 1st]

47- At what time does you information visualization class start? [E.g. 1:00 AM]

48- Where did you go on October 29th at 7:30 pm? [E.g. Friend's place]

49- Where do you go every Thursday at 7 pm? [E.g. Friend's place]

50- Which day of first week of April you had meeting with both Kalai and clients? [E.g. Monday]

Appendix C

VISUALIZATION TASK QUESTION SET

1- On the rainy day in the second week of September what is your mood? [E.g. Happy]

2- How many days in September you were both least productive and unhappiest? [E.g. 10 days]

3- How many days in April it has been cloudy and you were the happiest? [E.g. 10 days]

4- On the unhappiest day in the second week of April what is the weather like? [E.g. Rainy]

5- How many days in April were you both most productive and the happiest? [E.g. 10 days]

6- On the sunny day in the fourth week of April what is your mood? [E.g. Happy]

7- On the sunny day in the second week of April what is your mood? [E.g. Happy]

8- Which sunny day(s) in April you were unhappiest? [E.g. 10th]

9- How many days in April you were both least productive and unhappiest? [E.g. 10 days]

10- How many days in April were you both least productive and unhappiest? [E.g. 10 days]

11- How many days in September it has been sunny and you were the unhappiest? [E.g. 10 days]

12- Which day(s) in the first and fourth week of September you had the least productive and the happiest day(s)? [E.g. 10th]

13- Which day(s) in the first and fourth week of April did you have the least productive and the unhappiest day(s)? [E.g.10th]

14- Which Sunday(s) you have been most productive and the unhappiest? [E.g. 10th]

15- Which rainy day(s) in September you were happiest? [E.g. 10th]

16- How many days in April were you both most productive and the happiest? [E.g. 10 days]

17- Which day(s) in the first and fourth week of September you had the least productive and the unhappiest day(s)? [E.g. 10th]

18- How many days in April you were both most productive and the happiest? [E.g. 10 days]

19- Which Sunday(s) you have been both most productive and the happiest? [E.g. 10th]

20- On the happiest day in the third week of April, what is the level of your productivity? [E.g. Good]

21- How many days in April it has been cloudy and you were the happiest? [E.g. 10 days]

22- On the unhappiest day in the third week of April, what is the level of your productivity? [E.g. Good]

23- Which Sunday(s) you have been both most productive and the happiest? [E.g. 10th]

24- How many days in April you were both most productive and the happiest? [E.g. 10 days]

25- On the most productive day in the third week of April, what is your mood? [E.g. Happy]

26- How many days in September you were both most productive and the happiest? [E.g. 10 days]

27- How many days in April it has been cloudy and you were the happiest? [E.g. 10 days]

28- Which Sunday(s) you have been both most productive and the happiest? [E.g. 10th]

29- On the unhappiest day in the first week of April, what is the level of your productivity? [E.g. Good]

30- Which sunny day(s) in April you were unhappiest? [E.g. 10th]

31- Which day(s) in the first and fifth week of September you had the least productive and the unhappiest day(s)? [E.g. 10th]

32- How many days in September it has been cloudy and you were the happiest? [E.g. 10 days]

33- On the most productive day in the fourth week of April, what is your mood? [E.g.Happy]

34- On the unhappiest day in the second week of April what is the weather like? [E.g. Rainy]

35- On the sunny day in the third week of September what is your mood? [E.g. Happy]

36- On the sunny day in the first week of April what is your mood? [E.g. Happy]

37- On the happiest day in the third week of September, what is the level of your productivity? [E.g. Good]

38- On the most productive day in the second week of April what is your mood? [E.g.Happy]

39- Which Sunday(s) you have been both most productive and the happiest? [E.g. 10th]

40- Which sunny day(s) in April you were unhappiest? [E.g. 10th]

Appendix D

POST-EXPERIMENT INTERVIEW QUESTIONS

- Would you use a tool like this? Why or why not?
- If you had a tool like this, do you think it would help you learn more about your productivity and the influencing factors?
- If you had a tool like this, how easy do you think it would be to find a pattern in your life and behavior by using it? Why?
- If you had a tool like this, do you think it would help you to discover any hidden data and how?

- If you had a tool like this, do you think it would help you find out more about your status in each and every day and also your current status?

- Are there other variables that you would like to track and display in this way? What and why?

- Can you easily find differences between 2 or more days? (Make comparisons) How or why not?

- Is the information and visualizations shown on the calendar enough to help you learn more about your productivity or you think it lacks some necessary details?

- If you had a tool like this, do you think it would motivate you for your future actions?

- If you had a tool like this, do you think it would help you achieve your goal better? How? What do you think should be added to the tool to make it more useful to achieve your goal?

- If you had a tool like this, do you think it would help you to maintain your productivity and how is that?

- If you had a tool like this, do you think it would it allow you to be able to navigate through different days and create an image of the history of your activities in your mind?

Please rate the following views on a scale from 1 to 5, in terms of how easy it is to complete the tasks with that view.