Finding the Right Sleep Goals Together

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Abstract
Many people have problems with sleeping nowadays. Different approaches for improving sleeping quality have been attempted. In this project, a sleep dataset collected by Philips was used to design meaningful information products to enable people to improve their sleep. The designed visualizations enable a patient and a caregiver to work towards the right goals and actionable insights for improving sleep, while monitoring progress. Two views were created, one for the patient and one for a professional caregiver. Extensions to other users like a clinical professional and a data scientists were explored to enable further analysis and variable exploration.

Introduction
Good sleep is vital for good health. Nonetheless, many people do not get a proper night's rest often enough. This results in people feeling drained of energy during the day and being unable to perform their tasks as they would like to. Health problems like poor self-rated health, depression and anxiety, chronic medical conditions and all-cause mortality have been associated with sleep problems. It has been shown that sleep loss makes people perform worse on tasks that require spontaneity, creativity and flexibility (Kuppermann et al., 1995). It can safely be said that helping people improve their sleep would be valuable, as it would probably improve their overall quality of life.

The question is, how might we help people improve their sleep? People could go to a doctor for a diagnosis, but very often sleep problems do not directly relate to sicknesses, and therefore a doctor is not always capable of helping out. Also, structural or lifestyle problems might not always be detected during a one-time consult. A solution for this could be to track sleep data over a longer period of time, to be able to detect patterns. This is exactly what Philips did in an attempt to design products that help improve sleep. They collected sleep data of 26 non-diagnosed patients. The patients recognized that they had a sleeping problem, for example because they were night owls or went to bed late, and they had the intention to improve. The data mostly consisted of the start and end time of sleeping sessions over a period of twenty days, as well as the sleep stages that people would go through

during such a sleeping session (awake, light sleep, REM sleep and deep sleep).

The current paper describes an attempt at designing visual information products with and around this Philips sleep dataset, to help people improve their quality of sleep.

Related Work
Researching existing work in sleep visualization, SleepCycle[1] was discovered as one of the leading tools (although not strictly accurate in the way the measurements are collected). This provided inspiration, validation for our initial concepts, and set a benchmarking standard for our designs.
SleepCycle pro enables the user to visualize almost everything, including: how the going to bed time evolves in days.

Figure 1: SleepCycle how the going to bed time evolves in days

It also provides some basic summary statistics of the nights.

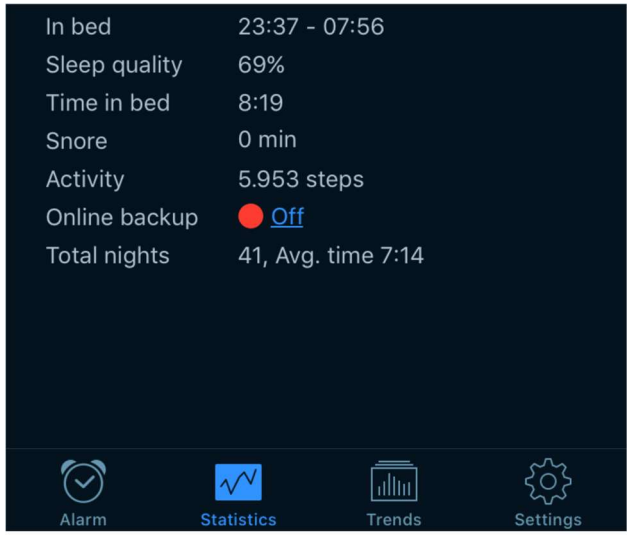


Figure 2: SleepCycle basic summary statistics of the nights

Context and Visualization Goals
In order to design a value proposition around the dataset, a use case had to be defined. The patient should be the main user of the information product.

[1] https://www.sleepcycle.com/

The patient might have different specific goals that they want to achieve with the help of the information product. Some possible general goals might be to improve the overall quality of sleeping, or to improve or change their sleeping habits.

The information product could help the patient to break down these general goals into smaller, more specific goals, so that they can eventually achieve the large goals. In order to do this, they might need help from the information product, or from a professional who has more knowledge about sleep. In the current project, a second user was defined, who could help the user through the information product. This user is a professional caregiver, someone who has experience with nursing and some professional knowledge about sleeping behavior. Even though this professional caregiver might not have a lot of time to spend on individual patients, they might still have or want insight into the general lifestyle of their patients, to take care of them as good as possible. Their main goal would be to help their patient achieve their goals (subjective help), as well as to help the patient be as healthy as possible (objective help).

In order to facilitate the communication between these two users, two different views of the information product had to be designed. The eventual goals of the visualizations would be to enable patient and caregiver to collaborate to gain insights, as well as to enable them to understand each other's goals and perspectives. In interacting with the information product, both users would constantly have to redefine the sleep-related goals of the patient, to ultimately find the optimal sleep goals together.

Insights from Philips experts

Since the dataset was received from Philips and the assignment was in collaboration with them, they gave us some interesting insights that were used in the further development of our designs. First of all, the data received was comparatively reliable, because it was collected from people sleeping in there natural habitat. Usually, sleep data comes from more sophisticated sleep-labs, which might have influenced the sleep of the participants. The data was collected from people living in San Francisco, a city with a heavy nightlife, in particular during the weekends. This might explain 'weird' sleeping patterns or habits. In the data, an important asset is sleep onset time: the time between the moment someone goes to bed and starts trying to sleep and the moment someone actually falls asleep. Onset time in general is known to be related to the quality of sleep.

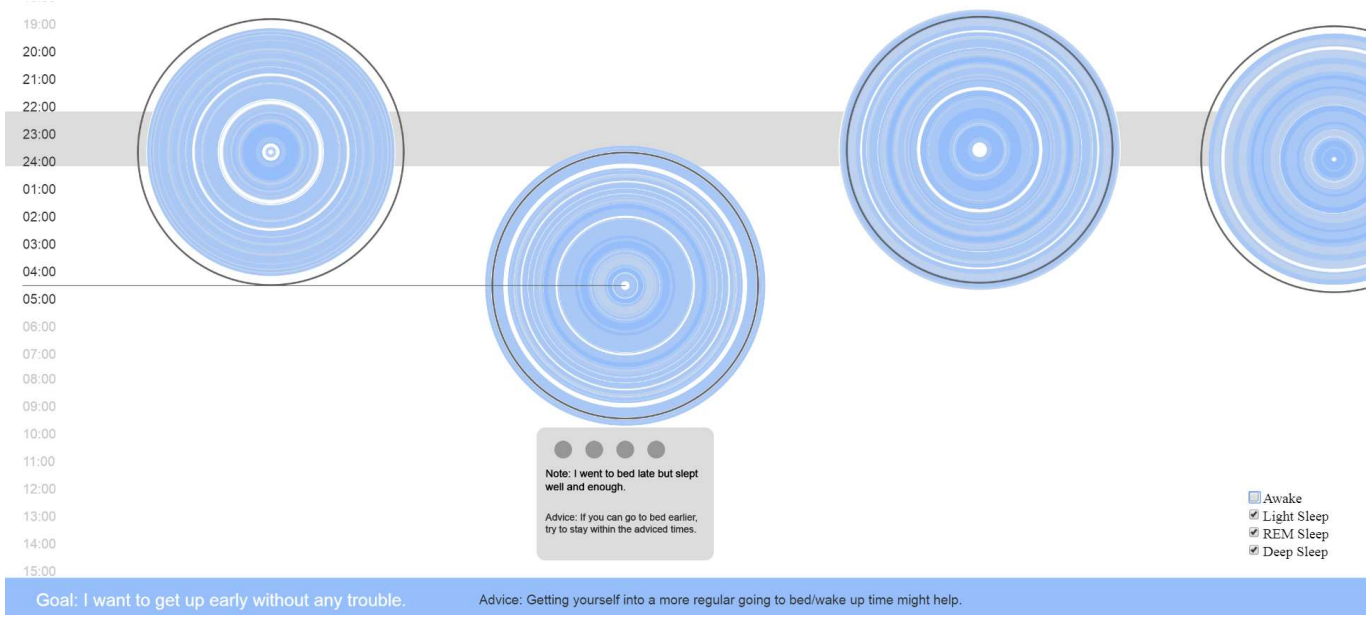
A downside of the dataset is that it only contains quantitative data, and no measure of how well the people felt they slept or how well rested they were the day after. The qualitative experience of a night can differ wildly from the quantitative data.

Concept

Patient View

The most important activities to be conducted by the patient with the information product are to collect and immediately view their data, and to set their goals based on the advice of the caregiver. For this, the interface in figure 3 was designed and implemented as a working prototype. Each circle represents one sleep session, where the different colors of the circles represent the different sleep stages. This representation was chosen because the patient should have access to their own sleep data in a friendly looking manner, as the patient should not be overwhelmed by scientific data. The circles move away from a scientific representation of sleep, and instead make use of the visual elements to get an overview of nights in an abstract way. The visualization includes filters on the different sleep stages, to make sure patients can visually compare the patterns and amounts of certain sleep stages across different nights. Patients are unable to directly influence the sleep stages that appear in their nights, but they might still understand advice given by the caregiver to a larger extent because they can see what happens.

Figure 3: Patient view



The factors that patients can act upon are duration of sleep and going to bed time. The grey circle around the blue sleeping session-circle indicates the preferred duration of sleep, as advised by the caregiver. The height of the middle of each circle shows the time the user went to bed, where the grey bar indicates a range of advisable going to bed times. With these two quantitative advice indications, the patient can quickly see which nights met the requirements.

Since the focus of the information product is for a large part on goal setting, some qualitative measure should be added to the quantitative data to get to more detailed, tailored goals for the patient. For that reason, upon hovering over a sleep session, a box with a rating for the subjective quality of sleep and a qualitative note about the sleep appears. The patient can add both the rating and the note to enable the caregiver to understand the life of the patient and give tailored advice based on that. Next to that, at the bottom of the visualization a general goal can be specified.

The visualization gives more of a 'per-sleepsession' view, rather than an overview across nights. It was designed like this because for patients, it is most relevant how their current nights are, and how these need to be improved. This has to be translated into clear actionable insights by the patient and caregiver together.

Professional Caregiver View

The aim of the professional caregiver view is to provide the caregiver with tools to identify problems. Compared to the patient view, it has a higher focus on analytics and is less concerned with representing the information in a friendly manner. Essential are showing a complete picture of the data in context, and interactive controls to analyse different aspects of it.

The visualisation displays information on two levels : per session and overview across sessions. The overview is contained in a large scatterplot which combines different variables. The horizontal and vertical axes hold timelines, and dots mark the points where the person fell asleep and woke up. A line extending to the left from the dot shows the 'onset time', the period it took the patient to fall asleep. Diagonal lines show the duration of the sleep, where the thicker reference line in the middle represents eight hours, which is considered a good amount. Each subsequent line is an hour more in the upper half or an hour less in the bottom half. A goal for start/end time can be set and is visualized as a white circle which the dots should fall within.

The interface provides different interactions. Using two sliders series of sessions can be selected to compare against each other. They can be distinguished by the colors of the dots, red for one series and yellow for the other. If the series overlap the dots are orange. While not implemented in the working prototype, other views of the graph should also be possible to for example incorporate qualitative data. An example is a heatmap using colored dots to represent a rating the user gives of their sleep quality.

The final interaction in the overview is hovering over dots to select the corresponding sessions. Upon selecting a session several information sources adapt. Firstly the overview graph isolates that session and the preceding and succeeding one and links them together to show the context of the night.

The other elements also change, the session details box fills with statistics about the session and notes that the patient added. The hypnogram bar displays the hypnogram for that session.

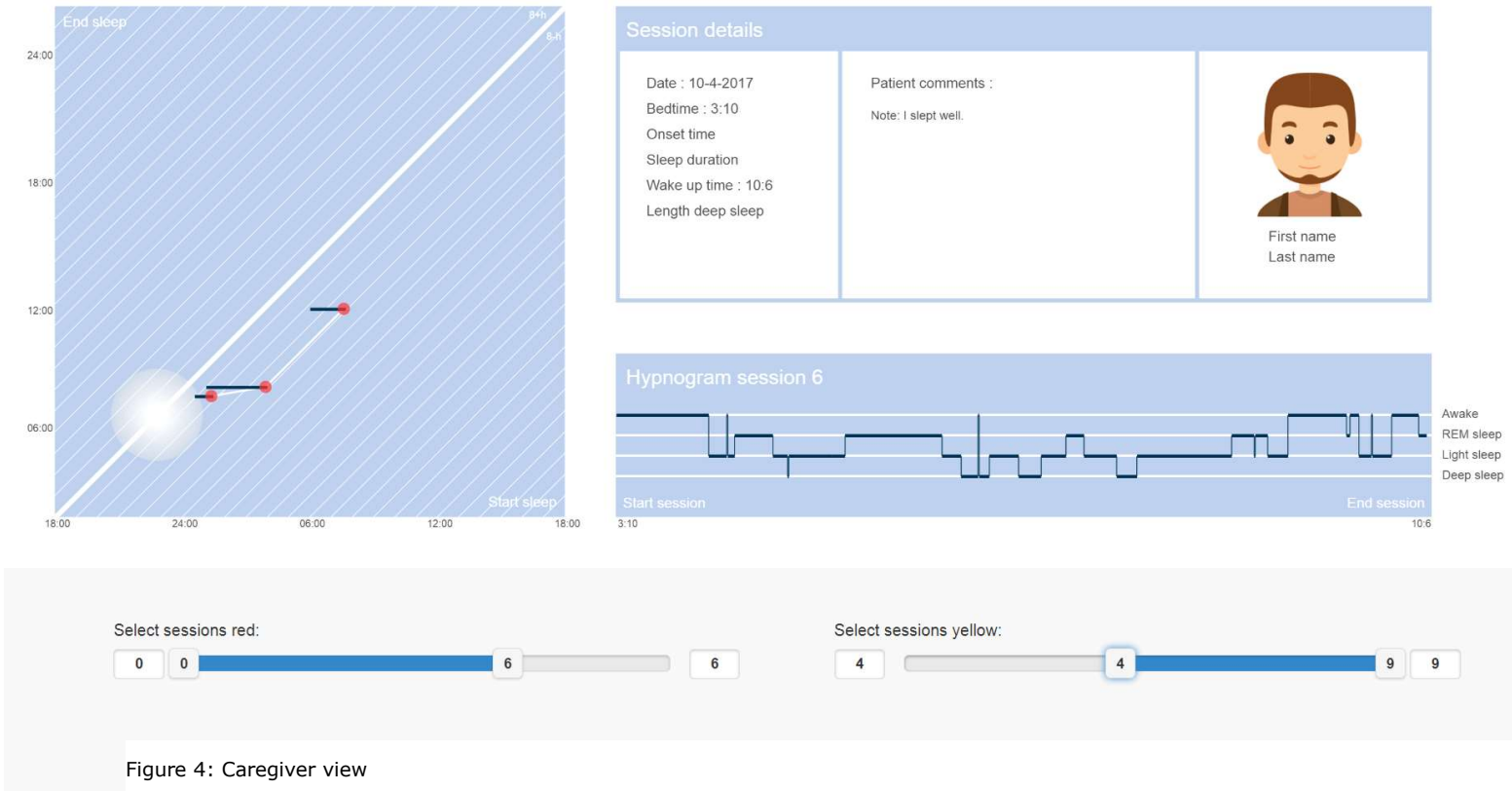


Figure 4: Caregiver view

Clinical Professional View, for example: Family Doctor

What follows is a visualization of sleep cycles on Thursdays. This representation is useful because one of the main perceived roles of the dashboard would be to compare different dates for the same user to make better conclusions and diagnostics. The scatter plot uses color coding to separate the previous events from the ones defined after the latest plan. The sleep cycles visualization uses both position and color (opacity) encoding to illustrate the depth of sleep.

Figure 5: Clinical Professional View

- The main role of the tool is being used as a **diagnosis tool**
- It enables the professional to **see what is normally hidden in conversation** (factual and objective historical data)
- A tailored **plan is created** by putting together the recommended healthy sleeping patterns, the user profile (characteristics, sports, job schedual)
- Subjective data helps in **creating cause-effect reasoning**. It informs the doctor instinct
- Basic **understanding of statistics**, using or disregarding outliers

Data Scientist View, for example: Product management

The perceived use of the Data Scientist visualization is to enable research and hypothesis testing. Another perceived use would be to increase product satisfaction of individual users. A consideration while designing were the principles of privacy, and as you may observe the information regarding notes or goal setting is not available to the researcher. This access may or may not be granted depending on the researcher goals and on the willingness of the user.

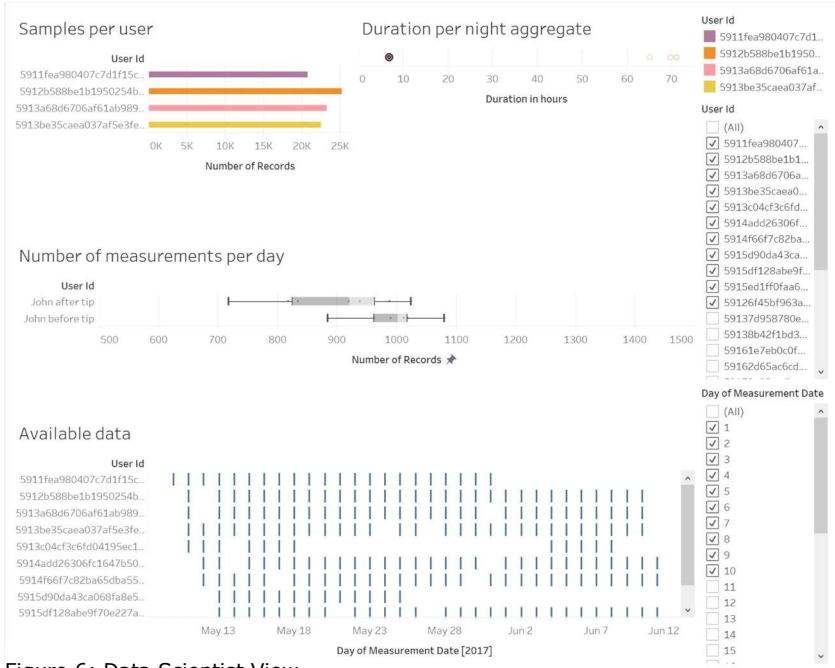


Figure 6: Data Scientist View

- The tool enables more **statistics and analysis (e.g. for**
- Even **more flexibility and variables** than what the clinical professional is displayed
- Shifts the focus from one user to cross-user: **compares between users**
- Used as **Research tool**
- Example roles: Monitoring whether equipment is working well, Increase engagement of users

Putting it together, the design process process started with an explorative approach, which quickly ended in a communicative iteration. The visualization made use of sleep insights in order to inform the average person of the sleep information. The better knowledge of the data and of the user, the better the design is able to present it in a digestible format.

Conclusion

The sleep dataset from Philips was visualized in different ways to accommodate different users. A patient view was designed to record qualitative data, return advice and give a patient insight into their own sleep data to help them achieve their sleeping goals. A professional caregiver view was designed to help the caregiver identify sleeping problems in the patient and define personalized advice. Together the two enable patient and caregiver to collaborate on improving the

patient's sleep, as was the goal of the visualization. Ideas were formulated to expand the information products to the other users home caregiver, clinical professional and sleep researcher.

Discussion

Strong points in the design include the focus on personalizing the views to the different users' needs. Particularly in the patient view care has been taken to visualize the data not only in a way that is informative, but in a way that is aesthetically pleasing to motivate the user to work on their problems and not discourage them. The interactivity in the dashboards lift their functionality beyond a mere infographic, the user is given tools to easily do analytical tasks such as comparing progress over time. Another strong point is the mix of quantitative and qualitative data. This ensures that personal experience of the patient is taken account, since this can vary wildly from how the sensor data of the night looks, as the Philips experts indicated.

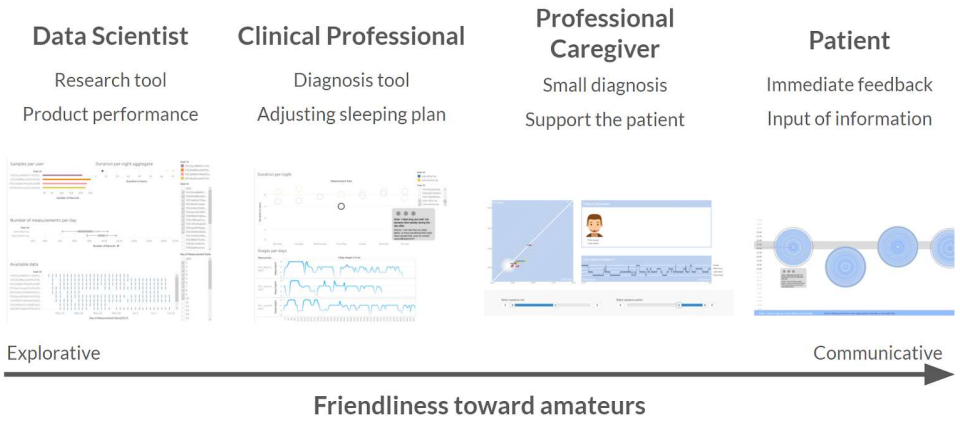


Figure 7: All Views

Areas of the concept could also be improved. For example in the patient view a trade-off was made sacrificing some detail and accuracy in order to present the information in a friendly look. This was considered a priority in order to motivate the patient, but means the visualization may not be optimally intuitive or legible. On the professional view feedback was given that the overview chart on the left may be too cluttered, as it combines many different parameters. This could be improved by splitting the chart up into multiple charts or views. An effort was already made by, when a session is selecting, only displaying that one and the preceding and succeeding one rather than all sessions. Adding different views could also make it possible to display more parameters, such as a heatmap of the quality of sleep experience. Another thing that needs more thought is the dynamics of interaction. The focus of this project lay on the product and what it can do, whereas the interactions around it of when do patients input data and how are they triggered around it are essential to the effect as well.

References

1. Kuppermann, M., Lubeck, D. P., Mazonson, P. D., Patrick, D. L., Stewart, A. L., Buesching, D. P., & Filer, S. K. (1995). Sleep problems and their correlates in a working population. *Journal of General Internal Medicine*, *10*(1), 25-32.