

# Continuous Positive Airway Pressure (CPAP) Data Visualization Project

HCDE 411 — Winter 2015 — G8 — Final Paper

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*Abstract*— In this paper, we discuss the creation of data visualization tool made for people who suffer from sleep apnea and want to view their sleep data. Using Continuous Positive Airway Pressure (CPAP) machine data as our lens, we offer novel visualizations that present sleep data in such a way that enables users to meaningfully explore and interact with their data.

*Keywords*— CPAP; Continuous Positive Airway Pressure; Data Visualization; Human Centered Design & Engineering; Sleep Apnea; Tableau

## I. Introduction

Just a few decades ago, the extent of personal data we tracked about ourselves was at most, limited to the odometer readings in our steel made cars. Today, we track everything from calories burned to baby's first events. There was a prediction reported by Heer, Bostock, and Ogievetsky that in 2010, society would generate over 1200 exabytes of data- 60 times the size of the Library of Congress [1]. As we wrangle with unfathomable amounts of data, the need for effective visual communication is paramount if we are ever to make sense and good use of it. In turn, this need for effective visualizations inspired how we viewed sleep disorder reporting as a problem domain. In an effort to empower users with autonomy over their sleep data, and to furnish them with more information to discuss with their doctors, we have designed a modest data visualization tool. The lack of effective visualizations for everyday CPAP users inspired how we viewed sleep disorder reporting as a problem domain.

According to the Center for Disease Control and Prevention (CDC), an estimated 50-70 million US adults have sleep disorders [2]. Many say that snoring is a problem for them, but the problem can actually be more serious than just noise. Snoring is often a major indicator of sleep apnea, which is a sleep disorder characterized by the throat muscles relaxing or the brain failing to send signals to the breathing muscles. Sleep apnea sufferers can experience from 5 to 50 events per hours, and are more prone to high blood pressure and heart disease.

Doctors often prescribe CPAP machine therapy to sleep apnea sufferers. A CPAP machine generally consists of a mask that covers the mouth and/or nose, and it increases air pressure in the throat to prevent the airway from collapsing. While regulating breathing, CPAP machines can also record vast amounts of data, which can then be viewed and analyzed during medical visits by physicians. Individual sleep data points can vary by manufacturer, but usually include: AHI (apnea/hypopnea index), Vent Flow Rate (allowed air leak through mask's built in vents), Mask Leak Rate (air leaking from areas around the mask and not the built in vents), Flow Rate (flow of air back and forth from the machine to the mask), and Pressure (air pressure amount required to cause the throat to open and restore/maintain regular air flow rate). These as well as many other data points can be recorded every second of every hour and of every year, so long as a person consistently follows their therapy.

The main problem with CPAP collected data is its limited audience. It typically remains inaccessible to patients, and most of the data requires analysis and interpretation by trained medical professionals. It is not recommended that patients attempt to interpret their own results. Despite our agreement with this sentiment, we believe there is information in the collected data that requires little medical training to comprehend and highly beneficial to users. However, we have found where the data has been made available to CPAP users, the visualizations are cluttered and have been laden with technical jargon. For this reason, we've designed a data visualization tool that centers on CPAP users. It is our contention that people would be helped by gaining a better understanding of what happens while they sleep, enabling them to become better educated about their sleep history, and finally, to empower patients to have informed discussions about their sleep experiences with their physicians.

## II. Previous Work

CPAP manufacturers are the primary designers and providers of sleep visualization tools. For example, the Philips Corporation manufactures the Respireonics CPAP machine and it includes web and mobile versions of its application for users to view their sleep data. Philips' SleepMapper tool provides slightly interactive visualizations, and we determined its primary goal is to communicate. As seen in figure 1, SleepMapper provides length of therapy, mask fit percentage, and AHI measurement. Users are limited to a 90-day maximum view of these three dimensions and does not include information about mask leaks, snoring events, nor the ability to compare the dimensions against an average. Also, SleepMapper's details-on-demand fails to offer clear explanations about what the dimensions actually mean. To improve on these issues, we strove to create an effective visualization with more data points that promotes the user's comprehension of their data.

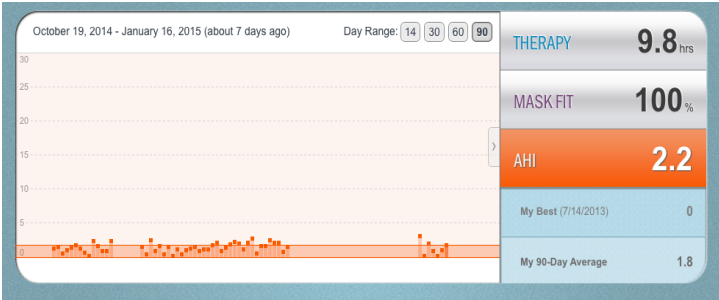


Figure 1: Example of Philips SleepMapper Web interface - AHI is an undefined term for the user.

In contrast to the proprietary SleepMapper tool, SleepyHead is an open source tool and works with several manufacturer CPAP machines. SleepyHead, supports a greater number of data dimensions, which affords users the opportunity to educate themselves about their sleep. However, this opportunity comes at a great cost of usability. Figure 2a shows SleepyHead's primary interface for communicating sleep data. Overall, it offers a lot of information, but unless the user has experience interpreting the graphs, much of the visualization is confusing and meaningless.

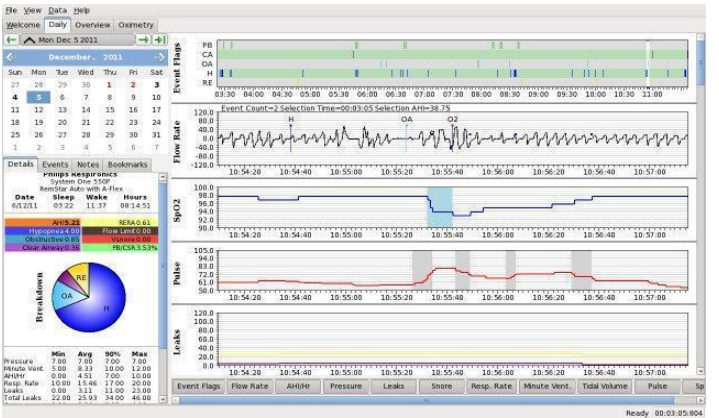


Figure 2a: SleepyHead overview screen with multiple data points

Although SleepyHead also offers details-on-demand, it still does not meet our criteria for being useful to CPAP users. It uses excessive medical jargon and fails to address the needs of users by providing simple explanations of the details it presents. SleepyHead's greatest downfall is that the overview is busy, with no clear visual hierarchy. And while users may interact with the data visualizations by clicking on line graphs

and zooming in for even more granular views, the data remains unusable (See figure 2b). As we see it, details-on-demand should reveal insights about the data and lead to greater discovery. Figure 2c offers a close up of the details-on-demand that appears once a user mouses over data points. These are great details, but if the user is not given clear descriptions within the details, the additional information is meaningless.



Figure 2b: Screen shot of SleepyHead software offering details-on-demand amongst several months' worth of data.

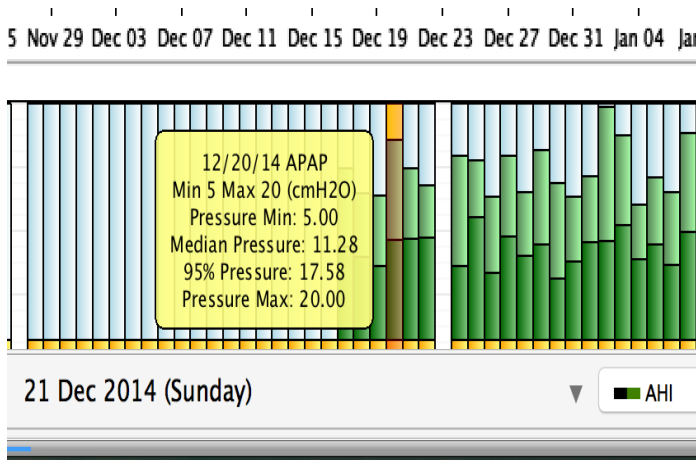


Figure 2c: Close up screenshot of SleepyHead visualization revealing details-on-demand

Overall, the SleepyHead tool illustrates the challenge of complexity when creating interactive multi-dimensional data visualizations for the purpose of analysis. In comparison, SleepMapper provides greater clarity of the data results by focusing on communication rather than analysis. Using both tools as inspirations, our goal is to create an intuitive interactive visualization tool that communicates users' results while affording the opportunity for deeper analysis. We believe users should be able to answer questions such as, "Did my mask leak? How

severe has my apnea been? and How was my snoring rate last night?"

### III. Data Collection & Implementation

The data collection process was difficult because national medical privacy acts have strict limitations on the use of individual records and rarely make them publicly available. Originally, we hoped to use a public data set from sleepdata.org to include a data comparison tool for users. Unfortunately, we discovered access to this data required IRB review and approval and the process could take up to 4 weeks. As a result, we were constrained to the raw data we collected from family and friends who regularly use CPAP machines.

Multiple steps were required to clean and convert the data into a usable format. All sleep and medical time-series data is formatted in "European Data Format" (EDF), which is used to compress massive amounts of captured data such as CPAP data. The conversion process took more than two weeks, involving painstaking tasks which required intimate familiarity with the raw data. Upon exploration of the data, we discovered three distinct EDF files types used by CPAP machines. Each recorded unique sleep attributes and stored them differently. Using the only available third party EDF conversion program (EDFbrowser) we were able to slowly convert the various EDF's into an XML format which allowed us to run a quick Python script to turn the 70 or so files we collected into CSV files.

With our data finally in a somewhat usable format, we copy and pasted the data into two separate excel worksheets (one that contained AHI and event data, the other which contained hundreds of thousands of time series measurements data) to import into Tableau. Unfortunately, the time series format outputted by the EDF converter was unrecognizable in Tableau, so we created a calculated field from the recording date and length of recording. This created a continuous time series format that Tableau recognized instead of recording the data as a series of null values. Finally, once we could actually use the data in Tableau, we linked both underlying excel data sets

together using Time & Date as a common attribute so both files could be used interchangeably and begin making our first data visualizations.

#### IV. Design Process

We planned to use an iterative approach consisting of a four-step process of ideation, research, design, and testing for three distinct cycles. The three cycles were supposed to be investigative, design effectiveness, and design refinement. Unfortunately the complicated data processing restricted our process, reducing the number of iterations and depth of user testing. Due to the time constraints we eliminated the design refinement cycle. A representation of our actual design process is depicted in figure 3.

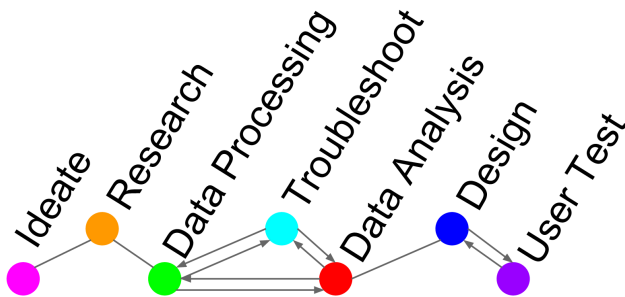


Figure 3: Detail of revised design process

*User Research:* We conducted three semi-structured interviews with males who identify as regular CPAP users. The first interviewee was a 54-year-old who has been using his machine for two years. He is aware that his CPAP data may be uploaded onto a sleep tracking website, and used this feature for two months after getting his machine. He is tech savvy, able to navigate the sleep data website, and understands the data being presented to him. However, he is unsatisfied with the amount of viewable information. He stopped using the website after his sleep patterns appeared to stabilize and he felt confident the machine was working well. The second interviewee was a tech savvy 41-year-old, who has been using his machine for one year. He has a lot of data available for him to view on his sleep application, but he does not understand all of the information presented. The third interviewee was a 39

year-old who has been using his machine for approximately two years. While he is aware that he can view his data, but he is not interested in viewing it.

We discovered some interesting similarities amongst the three users, such as a heavy reliance upon their doctors to interpret their results and to inform them of any irregularities. When we conducted web research to investigate CPAP machine user statistics, we discovered that most people who are diagnosed with sleep apnea are male, overweight, and over the age of 40, another similarity shared between our participants. Although sleep apnea can affect anyone at any age, even children [3], our interviewees happened to be typical users of CPAP therapy. Based on our user research, we created a provisional persona named Bruce shown in figure 4 so that we could test our system and build functionality into our product that users will actually use, which is crucial according to experts of user research, Courage and Baxter [4].

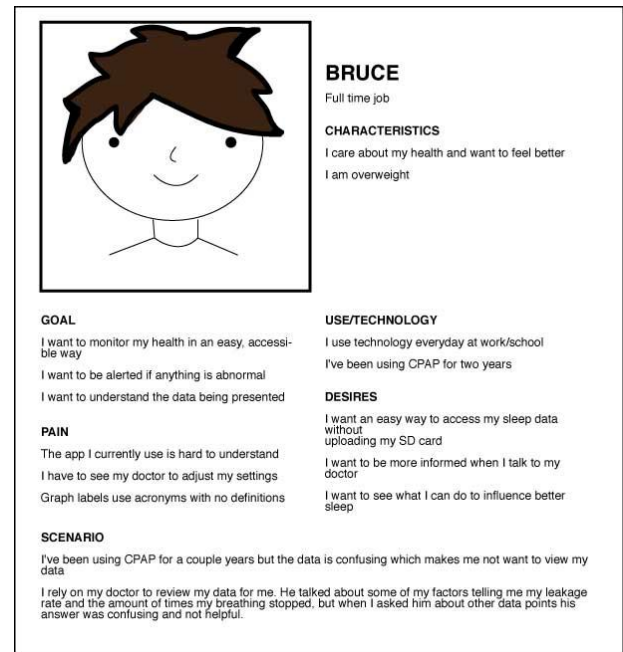


Figure 4: Detail of our provisional persona

*Sketches:* We began to sketch visualization ideas using our persona as a guideline for our target user. We focused on visualizing relationships between the measures in an interesting and usable way. Knowing that we were going to build our final visualization in

Tableau, we included features and tools that are native within Tableau. Our sketches show tooltip features, brushing and linking, average trend lines, and dashboard views. A few of our early sketches can be seen in figures 5a through 5c.

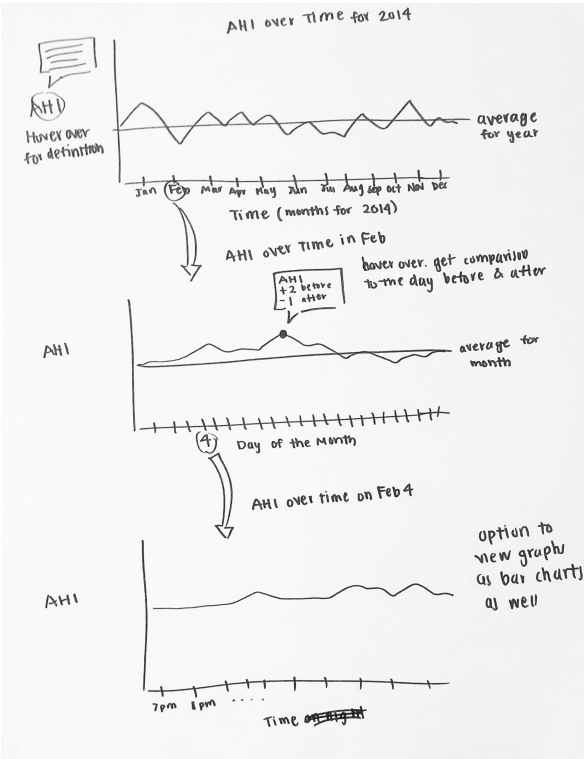


Figure 5a: Early design sketches 1

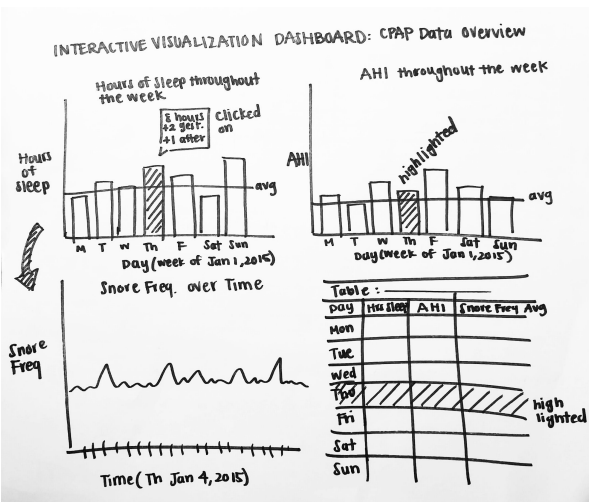


Figure 5b: Early design sketches 2

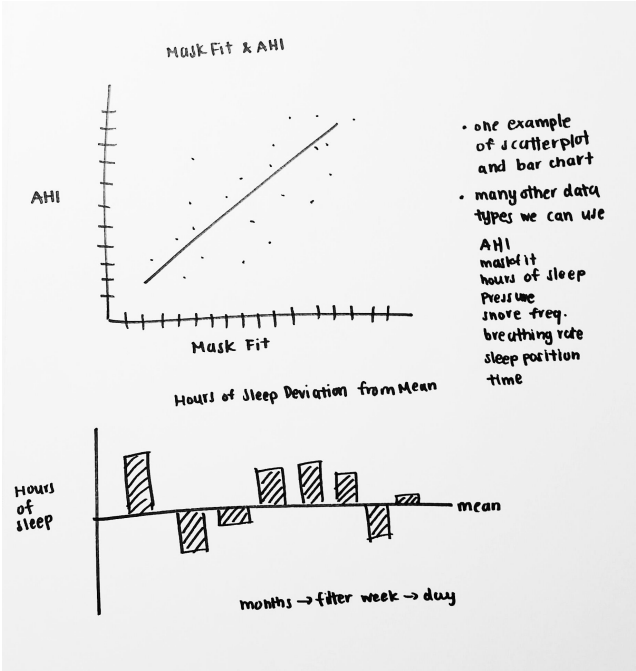


Figure 5c: Early design sketches 3

**Surveys:** We deployed a Google Form survey and recruited participants on our personal Facebook walls, public Facebook CPAP user groups, and dedicated online CPAP forums such as Apneaboard.com and CPAPTalk.com. We received a total of 74 responses: 44% female, 50% male, and 4% prefer not to say. The ages reported were 18 and up, with 33% between 56 and 65 years old. While 71% of respondents independently view their own data, only 33% strongly agree with feeling comfortable interpreting it. Respondents who do not view their data on their own said they either do not have a tool that enables them to do so, their machine does not support viewing capabilities, or they just prefer to rely on their doctors. When asked if they would like to view their data, the majority of respondents overwhelmingly said yes. Based on the responses of the surveys, it was confirmed that there is a need for an accessible tool to view CPAP data and for the information to be conveyed in a meaningful way.

Of all the data measures available, respondents expressed highest interest in *AHI* (67%), *apnea* (61%), *leak* (60%), *average AHI* (54%), and *pressure* (51%). Based on this feedback, we then focused on those data points deemed most significant and



extractable from our users’ SD cards. Then we utilized them in our next step: The Card Sort.

**Card Sort:** We conducted a card sorting exercise via OptimalSort, an online card sorting tool, and used terms that we identified from our interviews and surveys. In this round of research we had three CPAP user participants who helped us by sorting the terms into three categories: *Important*, *Somewhat Important*, and *Not Important*. Amongst their results we found that they all agreed that important terms included: *AHI*, *Apnea*, and *Average Hours of Use*. The popularity of the terms also coincided with our findings from the earlier survey. The results of our card sort can be seen in figure 6.

	Very Importa...	Somewhat L...	Not Important	unsorted
AHI	3			
Apnea	3			
Average AHI	1	2		
Average Hours of Use	3			
Average Time in Large Leak P...	2		1	
BPM	1		2	
Compliance		1	2	
Daily Events Per Hour	1	1	1	
Desaturation		2	1	
Exhaled Tidal Volume	1		2	
FL		1	2	
Hours of Usage		2	1	
Hypopnea	1	2		
Hypopnea Index		3		
Leak	2		1	
MaP	1		2	
Mean Pressure		1	2	
Obstructive Apnea Index	2	1		
Patient-Triggered Breaths	1	1	1	
Pressure	1	1	1	
Pressure Pulses		1	2	
Ramp	1		2	
RR	1	1	1	
Session		1	2	
Snore	1	1	1	
Tidal Volume		1	2	
Total AHI		2	1	

Figure 6: OptimalSort results

**Tableau Visualizations:** Based on the results of the surveys and card sorting exercises, we incorporated participant and respondent preferences within our visualizations. We began with ideation as each team member experimented in Tableau to develop visualizations that incorporated user feedback. Afterwards, we collectively critiqued all visualization concepts and identified the designs with the most promise. We then began the task of relating visualizations to one another in a way that would introduce context to the dashboard stories. These dashboards were then tested by potential users by having them attempt a series of tasks. Finally, we

refined our dashboards once more and arrived at our final versions.

## V. User Evaluations

We conducted two rounds of testing with users. The initial phase of user testing consisted of interviews and card sorts with three CPAP users, and a survey of over 74 CPAP users. The purpose and results of these evaluations were discussed in the previous section. The goal of the second round was to evaluate the designs for efficiency and effectiveness.

**Method:** We created a usability test for our two initial dashboards; see figure 7. We administered the tests to two CPAP users, and one Non-CPAP user. The tests consisted of four tasks for each dashboard and a questionnaire administered at the end. The first task used a “think aloud” protocol to acquire users first impressions of the data visualization. The remaining tasks were designed to evaluate how easy it was for users to answer questions about the data. The difficulty of the tasks increased as users moved through each. The results of all user tests were analyzed in a team review session. We discussed initial “aha” moments, reviewed the responses for each task, and noted any consistencies and discrepancies that were discovered.

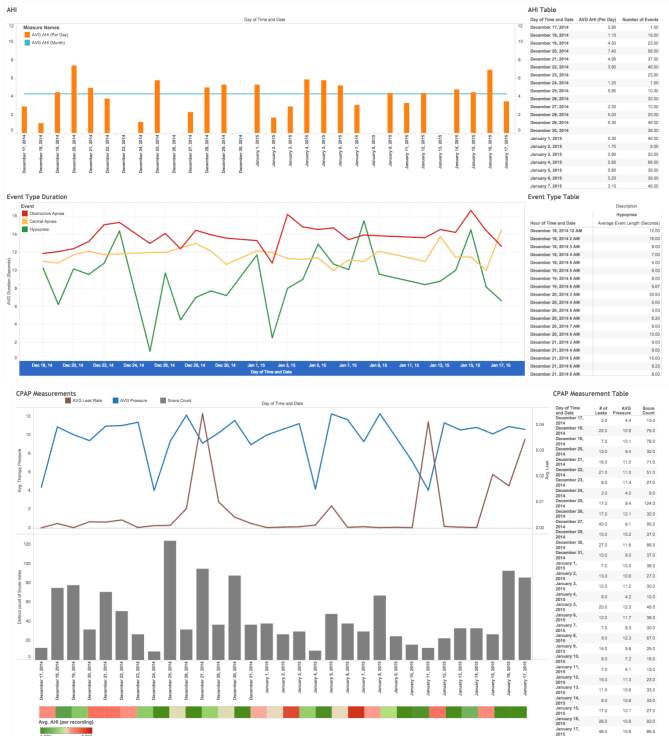


Figure 7: Images of initial Dashboards used in Usability Testing

**Results:** Overall users' first impressions were underwhelming. Users did not like the colors, and one of them was color-blind which made distinguishing the differences between some of the lines impossible. Upon hearing this news, we immediately reflected on Stephen Few's warning that 10% of males and 1% of females suffer from the most common form of color blindness [5]. We found that we needed more consistency between the two dashboards with the colors and legends. We failed to use descriptive titles for the dashboards, which made it difficult for users to quickly determine the meaning and purpose of the visualization.

Overall we obtained some compelling insights from our users. We found that users relied heavily on the graphs to complete tasks and rarely noticed the brushing and linking feature in the table. This insight made the details-on-demand feature more important than anticipated. We discovered that the definitions and terms we used in the details-on-demand feature were vague and not helpful, the names of measures were confusing, and the number of decimals on the data was inconsistent.

Our Post-test Questionnaire provided additional insights, however the results are not very scientific as the test was administered to only three users. We received conflicting feedback on the visual design, two of three users said they liked it. However, when asked whether the visual design was attractive on a scale of 1 to 5 (1 agree - 5 disagree) we scored a 2.3. On a positive note, the users did not find the dashboards to be cluttered, and this was one of our main objectives.

The next questions addressed users likes and dislikes of the visualization. Users liked that the dashboard fit within the screen and they were not required to scroll to find additional information. They disliked colors and the red and green AHI visualization at the bottom of the second dashboard. The dates did not line up to the graphs and they had no idea what the visualization was communicating. When asked about the improvements they would make, one suggestion was to increase the font size to improve clarity. The overall effectiveness score for both dashboard designs was extremely low. We scored 1.7 out of 5 on the question of usefulness. While these results were not ideal, we gained some valuable insights to address in our final iteration.

We decided to implement the following list of changes within our final designs.

- Revise colors
- Add titles for the dashboards
- Clarify names of the data points
- Improve definitions
- Edit the names in the x and y axes to be more descriptive
- Increase size of the font for the axes
- Eliminate AHI from dashboard 2
- Match Y-axis on dashboard 2
- Fix legends
- Disable clickable legends if they don't filter and sort
- Include a help button with definitions in one consistent location

We determined that these were ten actionable items that could be resolved prior to due date of the final deliverable.

*Discussion:* As we discovered, it is easier to evaluate designs for effectiveness than it is to create them. For this reason, good data visualizations require significant time and effort to create. Our greatest challenge was converting the data for use in Tableau. This delay wreaked havoc on our project schedule and significantly reduced the time we had to create and test the initial designs. This delay also contributed to the lower quality and effectiveness of the initial design itself. That said, we found our usability testing to be incredibly valuable because it provided many opportunities to improve the visualization.

Another issue we discovered related to the limitations of Tableau, the software tool we used to create the dashboards. We made a few assumptions about the helpfulness of their features and were surprised to witness users' difficulty finding them. An example of this was the sorting feature. Tableau allows users to sort the bars on a graph or data in the table by ascending or descending order. This feature is hidden until you hover in a certain location, near the y-axis on the bar chart or the top of the table. All of our users struggled with this task, which is not only a flaw of Tableau, but may also have been a poorly designed task.

## VI. Redesigns & Iterations

Based on the results of our usability research and evaluations we improved definition clarity and legend consistency, making the dashboards easier to interpret and minimize confusion. We adjusted the color palette of our design after users commented on the lack of contrast between the colors and one user disclosed he was color-blind. After this experience we chose a color palette from Tableau that was specifically created to address this need, and used a blue and orange color scheme since they are color-blind safe according to color expert, Maureen Stone [6]. We adjusted the colors of each dashboard to

follow a consistent color palette to show that they relate to each other.

As part of the final deliverable, we created a website to host our visualizations. On this website we created a "help" button that opened a popup screen of definitions of the terminology used so that users have one location for such resources that is not intrusive. Our previous visualizations had the definitions appear on-hover on the graphs. This was a problem because once users know what the definitions are, they will no longer need this information to keep showing up. Another problem was identified in our initial tool tips: Regardless which line the user hovered over in a graph, the same tooltips would appear. Instead it should only be showing the user the relevant information. By deleting these tooltips and congregating them in the help page popup, we were able to eliminate these problems. Furthermore, we were able to avoid the problem SleepMapper had, which was leaving the data to get to the definitions on a separate page.

For first time Tableau users we created a Tutorial tab, which shows users how to use the zoom and sort features. These features are extremely important according to Tufte [7], however Tableau does not make these features obvious to users in the visualizations. Currently, to zoom into the data users must press on the small plus symbol. This symbol is so hard to find that no one was properly able to use it during our usability tests. By creating a tutorial, we were able to solve this problem as a work-around of Tableau's limitations.



## VII. Final Visualizations



Figure 8a: Final Visualization 1

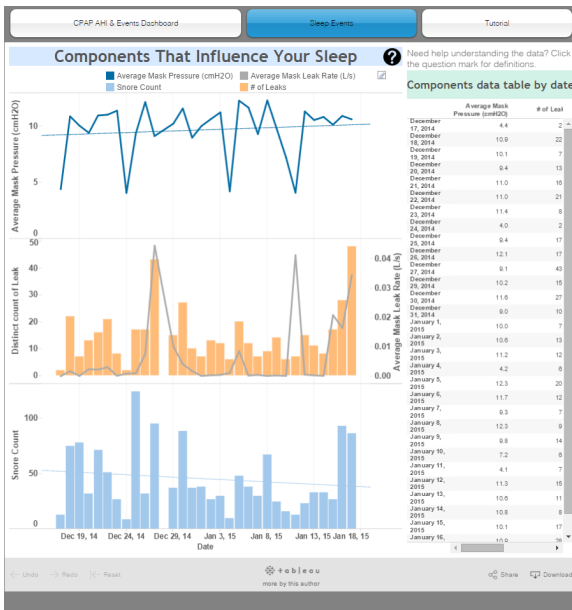


Figure 8b: Final Visualization 2

Our two final dashboards. The first shows an overview of sleep apnea events and the second shows measurements collected by the CPAP machine over time. Full versions can be found in the appendix.

Link : <http://hcde411cpap.wix.com/infovisualization>

## VIII. Evaluation

To evaluate the success of our dashboards, we followed principles from data visualization experts Edward Tufte and Ben Shneiderman. We based these

evaluations on how well our target users could accomplish their goals and complete their tasks. Our goals for these visualizations were to provide CPAP users with access to their data, to make their visuals meaningful, and empower them to have informed conversations with their healthcare providers. Our primary user group was current CPAP users, and our secondary user groups were healthcare providers. Using interviews and a card sort, we identified that the most important tasks for users to accomplish were evaluating AHI, number of Apnea and Hypopnea events, mask leak and pressure rates, and average hours of use.

Based on these criteria we believe we have made an effective data visualization tool for CPAP users. Using Edward Tufte's principle of graphical excellence [7], we successfully presented the greatest number of ideas in the shortest time with the least ink in the smallest space using multivariate data. We addressed the most important tasks for users to accomplish with two interactive visualizations that users can quickly scan to answer their most urgent questions. Our visuals are not cluttered with excessive dark gridlines; we utilize them sparingly to improve users ability to analyze their data. According to Tufte, "A gray grid works well and, with a delicate line, may promote more accurate data reconstruction than a dark grid" [6]. Tableau already minimizes line usage and the darkness of the lines, however we reduced them even further by getting rid of unnecessary lines. As you can see in figure 8 compared to figure 7, the finalized version of the first dashboard has fewer lines. The choice was made to add lines in the second dashboard however, in order to communicate that the three graphs share the same x-axis. Additional areas that improve the excellence of our visualization and address the specific needs of our target users are the color selection and the implementation of a help button that we will address in the details-on-demand section.

There were two areas that reducing the amount of ink on the page was difficult. The first was a limitation of Tableau that we were unable to overcome, and the second would have compromised the usability of the visualization. Tableau did not allow us to eliminate

the name of the month from the daily dates on the x-axis. This created a redundancy that was unnecessary and caused some frustration with our users. Second, our users claimed that the size of the text on the axes and in the legends was difficult to read, so we increased the font size from 10pt to 12pt to improve the readability. While this increased the amount of ink on the page, we felt that it was justified and improved it's effectiveness for our users.

Next we evaluate our design utilizing Ben Shneiderman's principles of overview first, zoom and filter, then details-on-demand [8]. The first dashboard supports overview, where both visualizations communicate the most important user measures. Zoom and filter was more difficult to implement. Both dashboards support zooming, however you can only zoom in and not zoom out. We have been unable to determine if this is a limitation of Tableau, or our implementation of the tool.

Filtering is supported on the "Event type and duration" visual on the Sleep Events Overview dashboard. When one clicks on any of the three variables in the legend, the data in the table filters to the selected measure and the other two measures fade into the background. The details-on-demand principle has been important throughout the process, which we have implemented on two instances. The first is when the user hovers and clicks on any point on the graphic, a pop-up box appears with the details for the specific point clicked. The second is a help button on the website, that provides definitions and a tutorial for users to learn the sort and zoom features when needed.

Our Tableau visualizations supported as many features as possible in accordance to Ben Shneiderman's mantra, "overview first, zoom and filter, then details-on-demand," and other suggested visual interactions, based on some of the qualitative data we collected from various CPAP users [8].

Our final visualizations are completely interactive and you are able to click or hover on any of the graphics. This allows users to interact with the data and extract

results. We started with what Shneiderman would call an "overview of selected dimensions" to allow users to look at our various data points and begin their interactions [8]. The most prominent interaction of our visualization allows for users to click on a point, bar, or line on any of our graphics which will then filter and extract the data by displaying the it in a corresponding table adjacent to the graphic being looked at. Users are able to filter the data by clicking and dragging a box to select a portion of the graphic. Since we are using a multi-view to display a variety of data points, we decided to filter the data through brushing and linking to a table as a way for users to quickly look at a data point and make sense of it. As Schneiderman states, linking the data enables "rich multidimensional reasoning" across views to better assess the data and find patterns, so we made sure to emphasize this task especially in our final visualization [8].

Tableau also naturally supports a few of Shneiderman's tasks such as details-on-demand by hovering over a portion of a graphic or table, "interaction histories" that allows a user to undo or redo an action as they are interacting with a graphic, and the ability to zoom by hovering over a certain section of the graphic and clicking a plus ( [+ ] ) symbol. See figure 9 as an example. Focusing on two of these three implemented interactions, the details-on-demand and zoom features have some limitations (as noted previously), and in the case of the zoom feature we were unable to effectively make it usable for our users without the use of a tutorial.

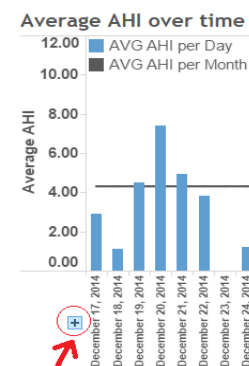


Figure 9: Example of zoom feature included in tutorial

Overall, our final visualizations are highly interactive and support Shneiderman’s task. However, to make our visuals more interactive and usable we would have to somehow make the zoom feature more intuitive for our users instead of just using a tutorial.

IX. Future Work

Limitations of time and tools hindered us from implementing several features that would have enhanced our visualizations. First, the zoom and sort features could be improved to make them more obvious. As discovered in our usability tests, participants were not aware that they could zoom in to get a more detailed views or sort the bar charts in ascending or descending order. Participants pointed out that if we had not given them specific tasks, they would not have known these features existed. While our tutorial helps address this issue, a more elegant solution could be designed. Next, we would like to incorporate a calendar view for users to choose ranges of dates, but this would require larger datasets. This would enable users to view trending events and make more complex comparisons in their sleep. Users could compare their data from when they first started using the machine, to their current data. Implementing this feature would allow users to evaluate their progress and really see the effect of the machine on their sleeping patterns.

While brainstorming ideas for visualizations during class, we consulted our mentor, Taylor Scott, who proposed a graphic idea that would be helpful in visualizing CPAP machine data. However, this graph unique and too customized to create using Tableau. Instead, we rendered a mockup of the visualization in Illustrator. Shown in figure 10, the graph has two small multiples and would be used to compare two different days, months, years, or even a day and a year, etc., which divides the graph into a left and right section. The x-axis is the time of night in hours, repeated for both the left and right section and the y-axis is the duration of the event in seconds. The data points are color-coded to indicate the different types of events: obstructive apnea, central apnea, and hypopnea. By splitting this graph in half horizontally we can focus on the points above the line, which are

more problematic than the ones below the line since their durations are longer than normal. We can easily spot clusters and select them as shown in the graph, which brush and link to the tables on the right. Here, you can see the points in more detail and you can also find out the calculated AHI values.

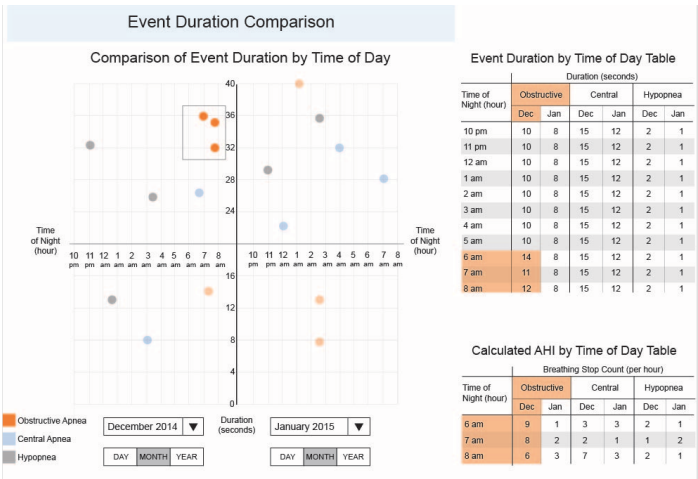


Figure 10: Illustrator Mockup Data Visualization

We would prefer to make our revised Tableau dashboards and our Illustrator mockup visualization using D3. This would allow more flexibility in our design and also allow us to incorporate animations to draw attention to the most important values and trends. After completing these changes, we would like to conduct a second round of usability testing with new participants to focus on design refinement. Ideally, our end goal would be a visualization tool for any CPAP user to view their own data.

X.Acknowledgments

We would like to thank our family and friends who have generously supported us while we focused on our research. We also thank our mentors Taylor Scott & Monica Caraway who inspired us with new avenues of design thinking and consistently challenged us to refine our approach.

## XI. References

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XII. Appendices



Appendix 1

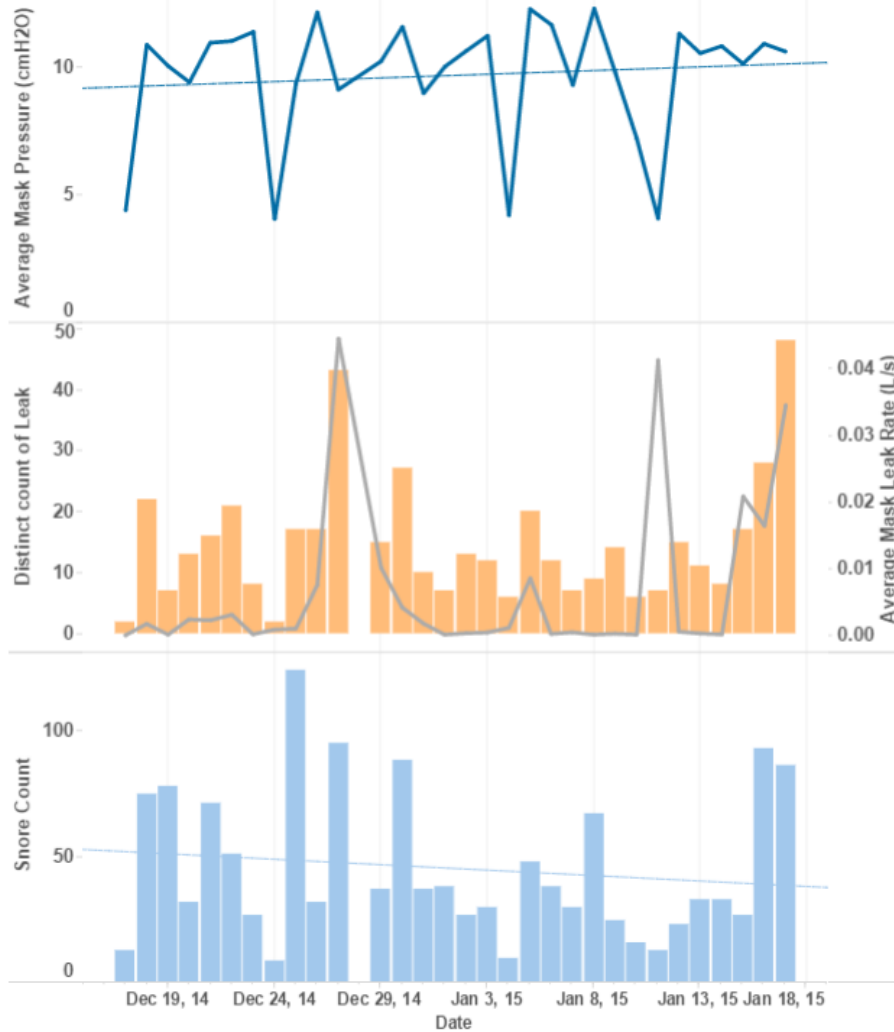


## Components That Influence Your Sleep



Need help understanding the data? Click the question mark for definitions.

■ Average Mask Pressure (cmH2O)
 ■ Average Mask Leak Rate (L/s)
 ■ Snore Count
 ■ # of Leaks



### Components data table by date

	Average Mask Pressure (cmH2O)	# of Leak
December 17, 2014	4.4	2
December 18, 2014	10.9	22
December 19, 2014	10.1	7
December 20, 2014	9.4	13
December 21, 2014	11.0	16
December 22, 2014	11.0	21
December 23, 2014	11.4	8
December 24, 2014	4.0	2
December 25, 2014	9.4	17
December 26, 2014	12.1	17
December 27, 2014	9.1	43
December 29, 2014	10.2	15
December 30, 2014	11.6	27
December 31, 2014	9.0	10
January 1, 2015	10.0	7
January 2, 2015	10.6	13
January 3, 2015	11.2	12
January 4, 2015	4.2	6
January 5, 2015	12.3	20
January 6, 2015	11.7	12
January 7, 2015	9.3	7
January 8, 2015	12.3	9
January 9, 2015	9.8	14
January 10, 2015	7.2	6
January 11, 2015	4.1	7
January 12, 2015	11.3	15
January 13, 2015	10.6	11
January 14, 2015	10.8	8
January 15, 2015	10.1	17
January 16, 2015	10.0	28

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