All About Sleep

Lucy Chen, Nimisha Devanagondi, Gowri Swamy
INFO 247: Information Visualization, Spring 2023
https://gooseybot.wixsite.com/all-about-sleep

Table of Contents

1. Project Goals 3

2. Discussion of Related Work 5

The Sleep and Technology Use of Americans: Findings from the National Sleep Foundation's 2011 Sleep in America Poll - Link 5

Racial and socioeconomic disparities in sleep and chronic disease: results of a longitudinal investigation - Link 6

Sleep: A Health Imperative - Link 7

Teenage sleep and technology engagement across the week - Link 8

Effects of caffeine on sleep and cognition - Link 8

Impairment of Driving Performance Caused by Sleep Deprivation or Alcohol: A Comparative Study - Link 9

Normal Human Sleep at Different Ages: Infants to Adolescents - Link 10

Sleep Foundation: Alcohol and Sleep - Link 11

Sleep Foundation: Sleep, Athletic Performance, and Recovery - Link 12

3. Visualization Walkthrough 12

Introduction. 13

Stages of Sleep 14

Stages of Sleep in a Night 15

Daytime Factors 16

Sedentary Behavior 17

Exercise 20

Caffeine 22

Alcohol 23

Technology Use 24

Benefits of Sleep 26

Effects of Poor Sleep 27

Chronic Disease 28

Car Crashes 29

Sleep Needs Throughout Life 30

4. Data 31

Caffeine Effects on Sleep Taken 0, 3, or 6 Hours before Going to Bed - Link 31

Caffeine and Sleep - Link 31

5 Surprising Ways A Full Night's Sleep Positively Affects Your Brain - Link 31

Acute Effect of Alcohol Intake on Cardiovascular Autonomic Regulation During the First

Hours of Sleep in a Large Real-World Sample of Finnish Employees: Observational Study - Link 32
Acute Sleep Deprivation and Risk of Motor Vehicle Crash Involvement - Link 32
Stages of Sleep - Link 32
Bedtime Use of Technology and Associated Sleep Problems in Children - Link 32
Sleep and exercise: A reciprocal issue? - Link 33
The association between physical activity, sitting time, sleep duration, and sleep quality as correlates of presenteeism - Link 33
Centers for Disease Control and Prevention: Sleep - Link 33
5. Tools 34
6. Results 34
Context 34
Usability Feedback 35
Changes Made 35
7. Link to Data Repository and Code 36
8. Team Contributions 37
9. References 37

1. Project Goals

Human beings spend a large amount of their life asleep, readying their physical and mental functions for the challenges that lay ahead. While sleep is such a prominent portion of our lives, visualizing the factors that impact sleep quality, and its effects is difficult. Our group used this opportunity to educate people on what goes behind sleeping, the different functions impacted by sleep quality and patterns, and take a deeper look at the complex and intricate process we undergo during our sleep cycles. To accomplish these tasks, we visualized the stages and cycles of sleep in the order they usually occur and understood their purpose, viewed data gathered to assess how we can learn more about the factors that potentially impact sleep, and viewed common sleep disorders and their population-level prevalence. We also spotlighted different factors affecting sleep that people may not even be aware of - sedentary habits, amounts of exercise, technology usage, and caffeine and alcohol intake - that will empower people to understand how what they do during the day affects their nightly rest. We highlighted the benefits of good sleep and the risks of poor sleep to help people prioritize sleep accordingly in their lives. We want people to come away from our visualizations having learned something new about sleep as a key component of our lives, and potentially feel empowered to learn more about or continue improving their sleep quality!

Our goal was to create a story about sleep, featuring a loveable sheep Barry. Barry walks the viewers through the whole website, which includes two “nights” and one “day”. We use our background colors to signify nighttime and daytime and rely on sunset and sunrise colors to signify transitioning between the different sections. During the first night, Barry presumably did not get a good night of rest; however, after learning about sleep, he sleeps well the second night.

Tasks Supported / Targeted Towards:

1. Visualize the stages/cycles of sleep in the order they usually occur, and understand their purpose.
    a. Compare how much time someone spends in a certain stage of sleep, compared to another.
2. Analyze detailed information and statistics about daytime factors that affect sleep, to inform users about how their habits or actions impact their nightly rest. Because some of this information is complex, the more complicated charts include interactivity to support a better user experience; users can select the appropriate amount of cognitive load for themselves.
3. Understand the benefits of good sleep and visualize the drawbacks of poor sleep.

4. Understand how much sleep is recommended throughout their lives.

2. Discussion of Related Work

The Sleep and Technology Use of Americans: Findings from the National Sleep Foundation's 2011 Sleep in America Poll - Link

The paper reports the findings from a large-scale survey on the sleep habits and technology use of Americans. The study found that nine out of 10 Americans used technological devices in the hour before bed, with TVs being the most popular. Young adults' sleep patterns were significantly later than other age groups on both weekdays and weekend nights. The study also found that the more interactive technological devices used in the hour before bed, such as cell phones, video game consoles, and computers/laptops, were most strongly associated with sleep complaints. The study highlights the prevalence of technology use near bedtime and its potential impact on sleep quality, particularly in younger age groups (Figure 1).

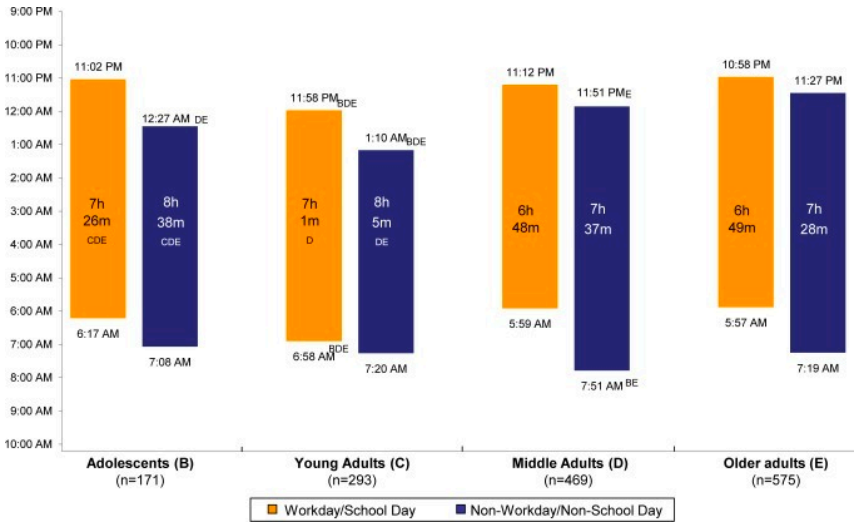


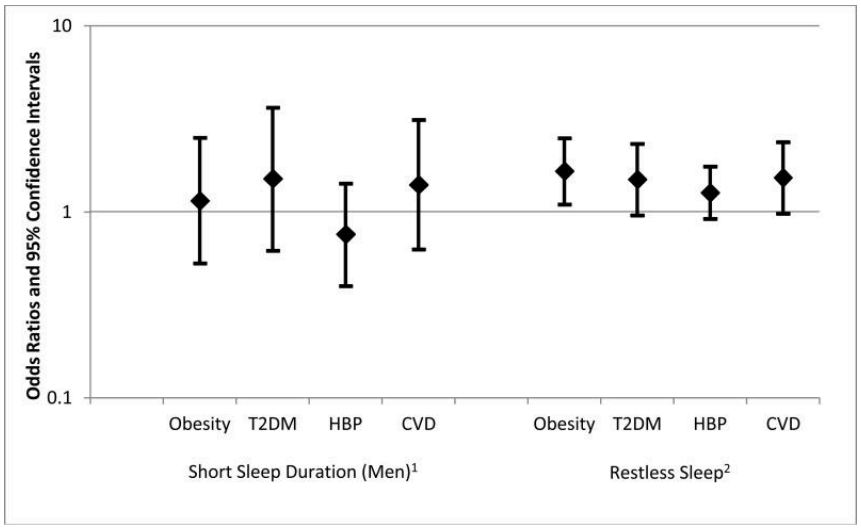
Figure 1

By reading these findings, our team sparked interest in visualizing information related to sleep and technology, such as creating infographics or data visualizations that show the types of technology used by different age groups before bed and how this relates to their sleep quality. By presenting this information in a visually compelling way, it may be

easier for individuals and healthcare professionals to understand the impact of technology on sleep and to make informed decisions about how to optimize sleep hygiene. We also became interested in visualizing how sleep needs change throughout one's life, since different phases of human development are supported by different levels of sleep.

Racial and socioeconomic disparities in sleep and chronic disease: results of a longitudinal investigation - Link

This paper examines the relationship between sleep disparities and the incidence of obesity, type 2 diabetes mellitus (T2DM), hypertension, and/or cardiovascular disease (CVD) in different population subgroups. The study is based on data from the Boston Area Community Health (BACH) Survey, which is a population-based random-sample cohort of 5,502 participants aged 30-79. The results show that there are significant differences in the prevalence of sleep-related problems by both race and socioeconomic status (SES) and that there are significant disparities in the incidence of T2DM, high blood pressure, and CVD at follow-up. Restless sleep was associated with an increased risk of obesity, T2DM, and CVD. However, the study found that sleep does not mediate social disparities in health outcomes. The paper also discusses the downstream health consequences of sleep-related problems and the mechanisms by which sleep disturbances and/or deprivation may contribute to weight gain and incident obesity, T2DM, hypertension, and CVD.



[1] Age and race adjusted models
[2] Age, race, and sex adjusted models

Figure 2

This paper highlights the significant impact that sleep problems can have on an individual's health (Figure 2), including increased risk for obesity, type 2 diabetes, hypertension, coronary heart disease, stroke, and mortality. By demonstrating the link between sleep and health, the paper underscores the importance of studying and addressing sleep-related problems as a crucial component of promoting overall health and reducing health disparities. This paper inspired us to begin thinking more about sleep and how chronic health diseases are impacted by differing sleep patterns within communities. This and the resource below inspired the visualization of how chronic sleep deprivation affects different chronic diseases ("Effects of Poor Sleep" section).

Sleep: A Health Imperative - Link

This paper takes a look at inadequate or mistimed sleep, known as chronic sleep deficiency, which is an increasingly important determinant of health status that is often overlooked. Even in the absence of primary sleep disorders, sleep deprivation can lead to molecular, immune, and neural changes that contribute to the development of cardiovascular and metabolic diseases, as well as a shortened lifespan. Additionally, cognitive and motor performance impairments resulting from sleep deficiency can increase the risk of accidents and injuries. The American Academy of Sleep Medicine and the Sleep Research Society have released a statement to inform national health stakeholders of the crucial link between sufficient sleep and circadian alignment in adults and overall health.

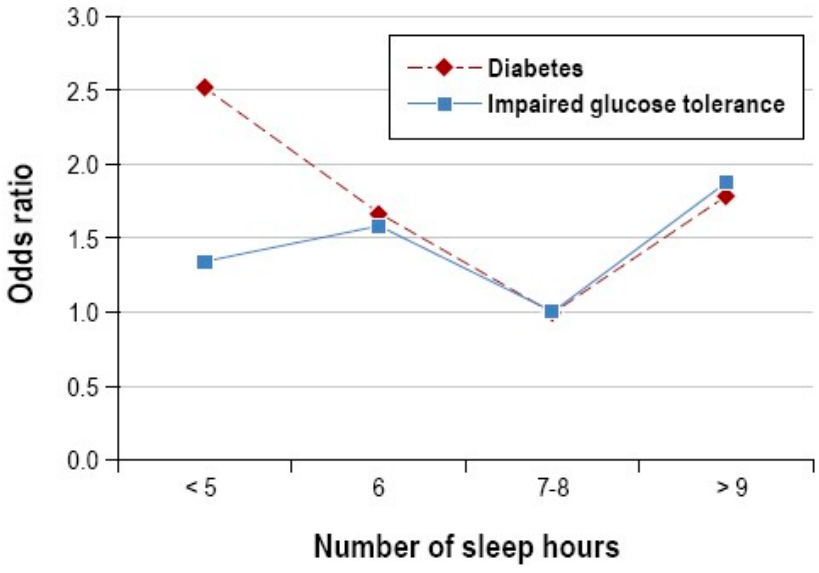


Figure 3

As seen in Figure 3, this paper assisted us in delving deeper into specific chronic health problems and how sleep may impact their diagnosis. It showed us that there were patterns to be looked at and inspired us to broaden our approach and begin looking at a larger number of chronic diseases that may be impacted by sleep patterns.

Teenage sleep and technology engagement across the week - Link

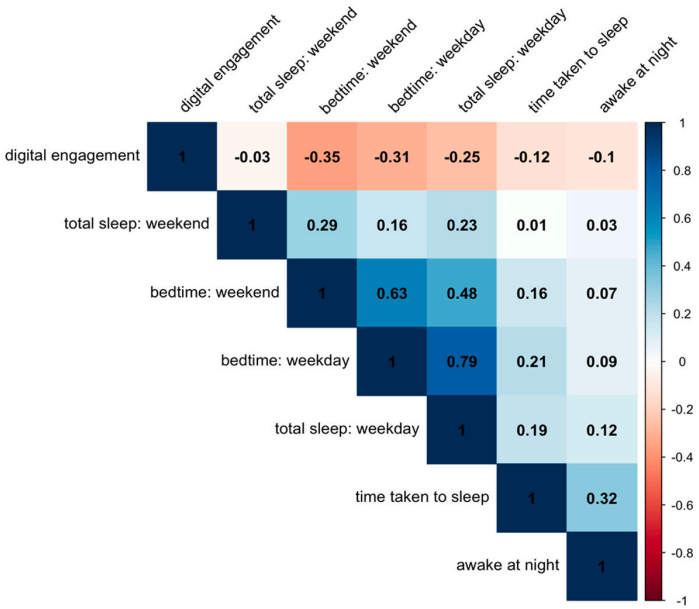


Figure 4

This article demonstrates the need for more accurate and nuanced approaches to studying the association between digital engagement and adolescent sleep. While previous studies have relied mainly on self-report questionnaires, this study uses time-use diary measures to provide a more detailed understanding of the effects of digital engagement on sleep. The study finds a small negative association between digital engagement and adolescent sleep, but the effects are mainly driven by retrospective technology use measures and total time spent on digital devices during the day. The study also suggests that more work is needed to determine how to accurately measure digital screen time before designing interventions to address the issue.

Taking a closer look at this article, particularly Figure 4, motivated us to delve into the patterns between adolescents, sleep, and technology usage. To take a closer look at these patterns, we decided to broaden our study to include different types of technology and not

just the times or types of days the paper was analyzing. By obtaining this initial data, we were on track to digest information related to sleep and technological usage.

Effects of caffeine on sleep and cognition - Link

The article discusses the effects of caffeine on mental and physiological states, particularly concerning sleep-deprived individuals. Caffeine is described as a mild stimulant that antagonizes adenosine receptors, which affect various brain mechanisms involved in sleep, arousal, and cognition. The article also notes that the effects of caffeine vary from person to person, depending on their metabolic rate, tolerance, and genetic makeup. The study also points out that caffeine can have positive effects on wakefulness and cognitive performance, but it can also produce negative effects on subsequent sleep, resulting in daytime sleepiness. Therefore, the risks associated with caffeine consumption in combination with sleep deprivation need to be carefully considered, especially in adolescents. The article emphasizes the importance of careful screening of participants in caffeine research and accurate estimation of habitual caffeine intake.

Because this article demonstrated how caffeine has been shown to affect sleep patterns, we were able to see that by comparing the sleep patterns of individuals who have consumed caffeine to those who haven't, researchers can better understand the effects of caffeine on sleep. These findings can then be used to create visualizations and graphs that help illustrate these effects which is how this research further motivated us on our visualization journey - specifically in the “Caffeine” daytime factor impacting sleep.

Impairment of Driving Performance Caused by Sleep Deprivation or Alcohol: A Comparative Study - Link

This research study was carried out to compare the effects of partial sleep deprivation (limitation to 4 hours of sleep before testing) and full sleep deprivation (no sleep the night before testing) with alcohol consumption (average blood alcohol content of 0.07%) on a simulated driving task lasting 2 hours. The study included 64 male participants who were assessed based on their driving performance, psychophysiology (0.1 Hz heart rate variability), and self-assessment. The results showed that the full sleep deprivation and alcohol group had a significant decline in lane-keeping performance, which was considered a safety-critical issue. On the other hand, the partial sleep deprivation group had only minor alterations in primary task performance, which were not considered critical. Both sleep-deprived groups experienced discomfort and reduced performance, but the alcohol group did not experience any such symptoms. The study's implications were discussed with respect

to developing systems to diagnose driver fatigue online, including performance criteria that could be included in a driver impairment monitoring system.

Participant Group	Age (years)	Driving Experience[a]	Average Duration of Sleep[b]	Average Alcohol Intake[c]
Control	30.63 (20–46)	12.8 (2–25)	7.7 (6.0–8.0)	16 (3–23)
PartSD	30.63 (22–47)	9.94 (2–2)	8.0 (7.0–9.5)	17 (4–28)
FullSD	30.63 (20–50)	11.3 (4–23)	7.7 (6.5–9.0)	14 (3–24)
Alcohol	30.68 (20–50)	12.5 (3–25)	7.8 (7.5–9.0)	16 (3–30)

Note: Minima and maxima given in parentheses.
[a]Number of years participants held a full driving license. [b]Self-assessed to the nearest 30 min. [c]Self-assessed units of alcohol consumed per week.

Figure 5

By taking a look at the dynamic relationship between duration of sleep, alcohol consumption, and driving experience (Figure 5), we realized how important it is for our project to include these variables when thinking through sleep patterns. Taking this research into account helped us delve further into finding creative ways to imagine the intricate relationships between these variables. This research inspired our visualization of the link between car crashes and sleep deprivation ("Effects of Poor Sleep" section), showing that the individual is not the only one suffering consequences of sleep deprivation.

Normal Human Sleep at Different Ages: Infants to Adolescents - Link

Findings from this article demonstrate that children's sleep behavior is influenced by a complex interplay of biological, psychological, and social factors. There is large variability in sleep behavior among children and across cultures. As children develop, their sleep patterns undergo significant changes in physiology, phenomenology, and distribution. The emergence of monophasic sleep in early childhood and the development of a circadian sleep phase preference in school-aged children and adolescents are notable changes. Sleep is regulated by both homeostatic and circadian processes, and sleep plays a crucial role in brain

maturation, development, and learning processes during childhood. The perception of problematic sleep behavior in young children is largely influenced by parental expectations and beliefs. Overall, understanding the biopsychosocial framework of children's sleep behavior is important for promoting healthy sleep habits and developing effective interventions.

Taking a closer look at this data helped us examine the findings to specifically take a look at the different aspects of sleep that change across age groups. Understanding how sleep changes over time is important in developing an understanding of differences in sleep across age groups and we wanted to incorporate this into our visualization process. This resource, along with the first information source, inspired us to visualize how sleep needs change throughout one's life ("Sleep Needs Throughout Life" section).

Sleep Foundation: Alcohol and Sleep - Link

The article on the Sleep Foundation website demonstrates the negative effects of alcohol on sleep. It explains how alcohol consumption can disrupt the different stages of sleep, leading to sleep fragmentation, insomnia, and daytime fatigue. The article also highlights the fact that while alcohol can initially make you feel drowsy and help you fall asleep faster, it can ultimately impair the quality of your sleep, making you feel less rested and more tired when you wake up. The article also discusses how alcohol can worsen sleep apnea and other sleep disorders, and how it can interact with sleep medications and other drugs to further disrupt sleep. Overall, the article emphasizes the importance of avoiding alcohol or limiting consumption to improve the quality of sleep.

Figure 6

The data provided in this visualization (Figure 6) and content through the website demonstrated the power of using data visualizations to evoke emotions pertaining to the impact of sleep on alcohol and vice versa. It seemed critical to delve into this for our visualization process and we wanted to use this information to impact the way people may think of sleep in relation to their consumption of alcohol. The information is reflected in the "Alcohol" daytime factor, under the "Daytime Factors" section.

Sleep Foundation: Sleep, Athletic Performance, and Recovery - Link

The article discusses the important relationship between sleep and athletic performance. It explains that getting enough quality sleep is essential for athletes to achieve peak performance. The article notes that sleep deprivation can negatively affect reaction time, accuracy, and overall athletic ability, while also increasing the risk of injury. It also points out that athletes who get enough sleep have better endurance, improved cognitive function, and faster reaction times. The article provides some practical tips for athletes to improve their sleep, such as establishing a regular sleep schedule, creating a relaxing bedtime routine, and avoiding screens before bedtime. Overall, the article emphasizes the importance of sleep for athletes and encourages them to prioritize it as part of their training regimen.

While it was important and interesting for us to learn more about athletic performance and sleep, we realized our audience will learn more from the overall effects of stationary behavior and exercise rather than going into detail about training regimens. It helped show that we can take a look at this information at a broader level and focus on what is important for our audience members to learn from. We used this article as a starting point to explore information pertaining to the relationship between sleep, exercise, and sedentary behavior, the eventual result of which can be seen in the corresponding sections under the "Daytime Factors" section.

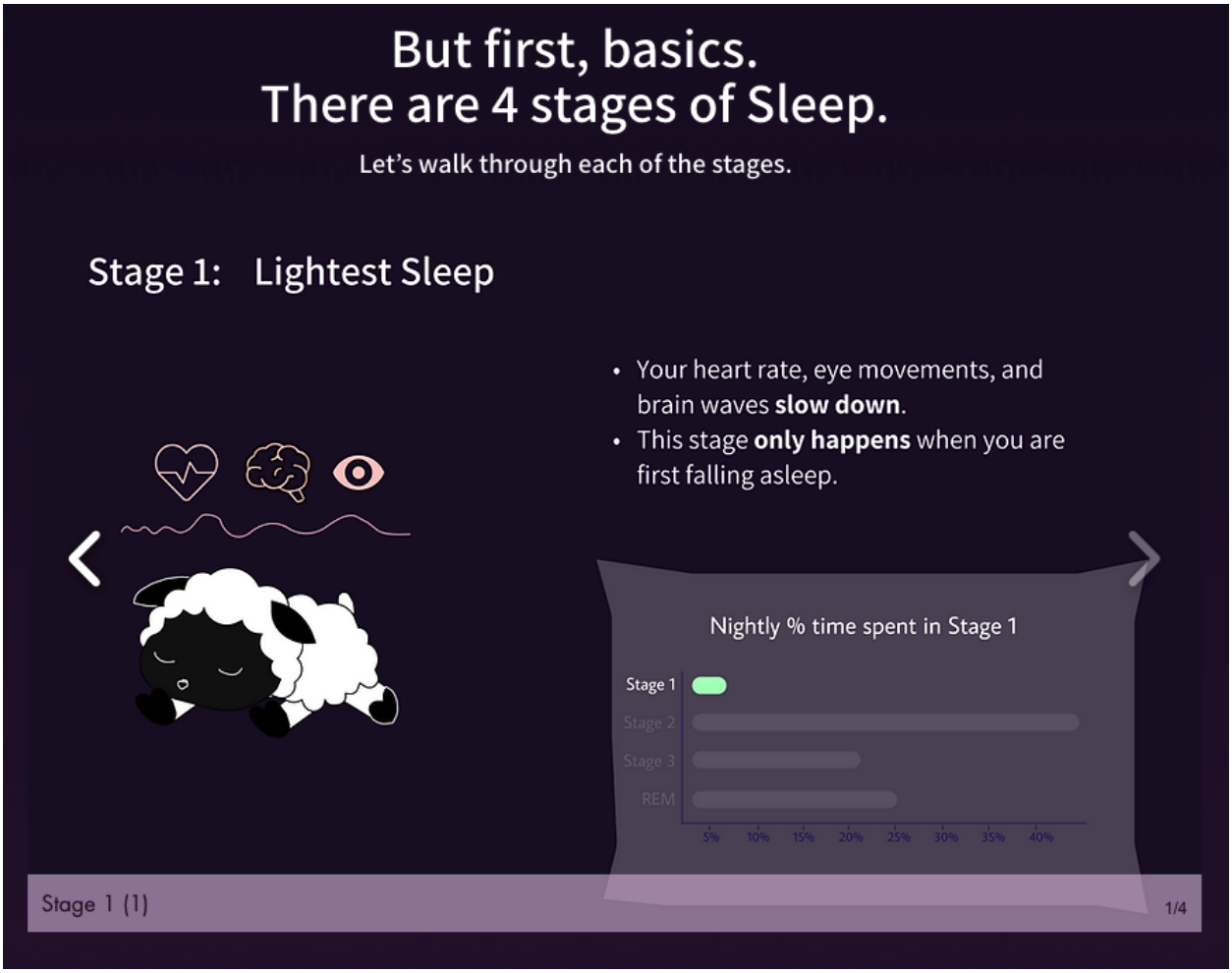
3. Visualization Walkthrough

The following is a section-by-section walkthrough of our website, with titles so the reader can connect the references to different sections based on the names here.

Introduction.

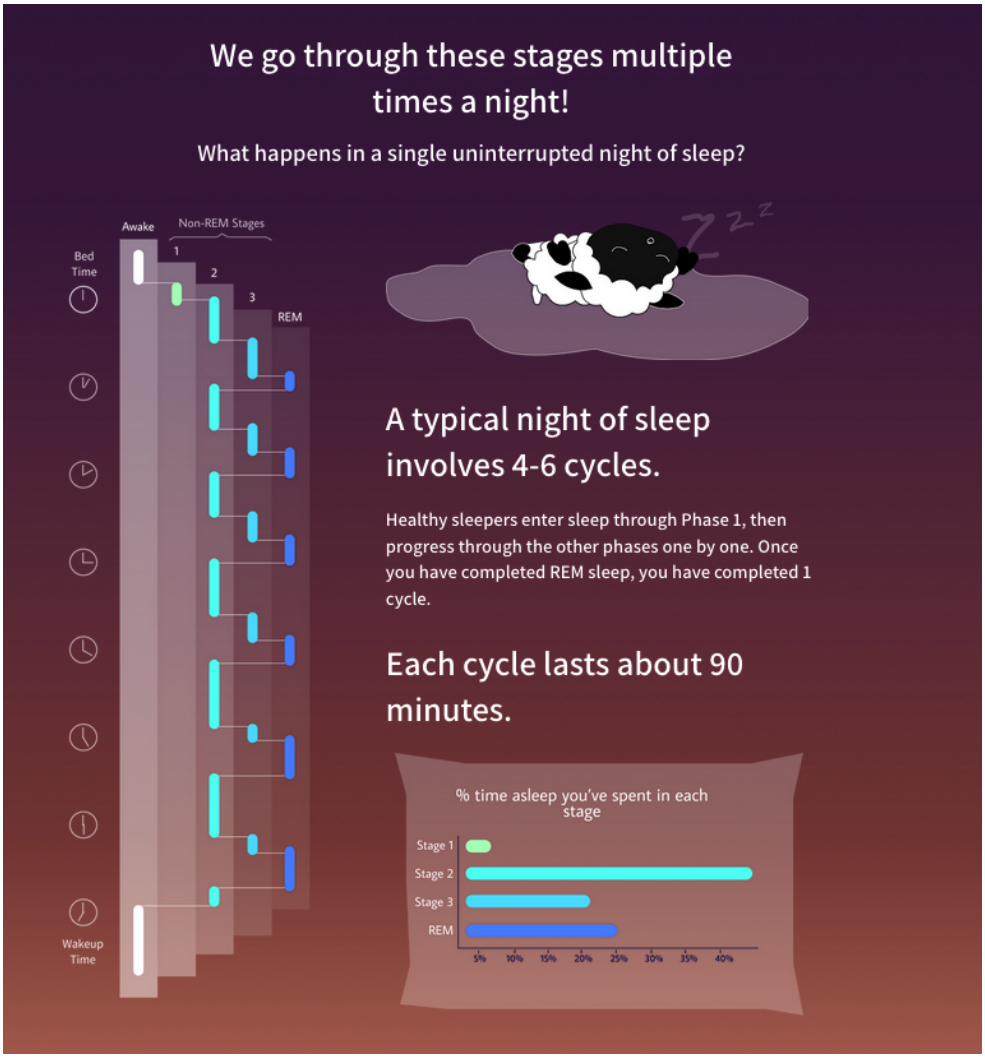
This section introduces the purpose of the visualization (overall), as well as the intended audience. It is important to stress that this website will not help users diagnose sophisticated sleep issues, but rather to cover the baseline of "normal, healthy sleepers," lest the user set inappropriate expectations for the visualization's aims.

Stages of Sleep



Next, the user is introduced to the stages of sleep. The stages are presented in a gallery format, where users can flip through the different stages in the order in which they occur in a normal night of sleep (priming the user for the next section). This has several benefits: readers can enjoy a reduced cognitive load by being presented with the stages one at a time, choosing when to move on rather than having one long section the user must "get through" by scrolling down to read all of them. This also has the benefit of priming the user to engage with the website by clicking through the gallery pages - an easily recognizable way of interacting - rather than having the user's first interaction be in the more complex context of the subsequent data visualizations.

Stages of Sleep in a Night

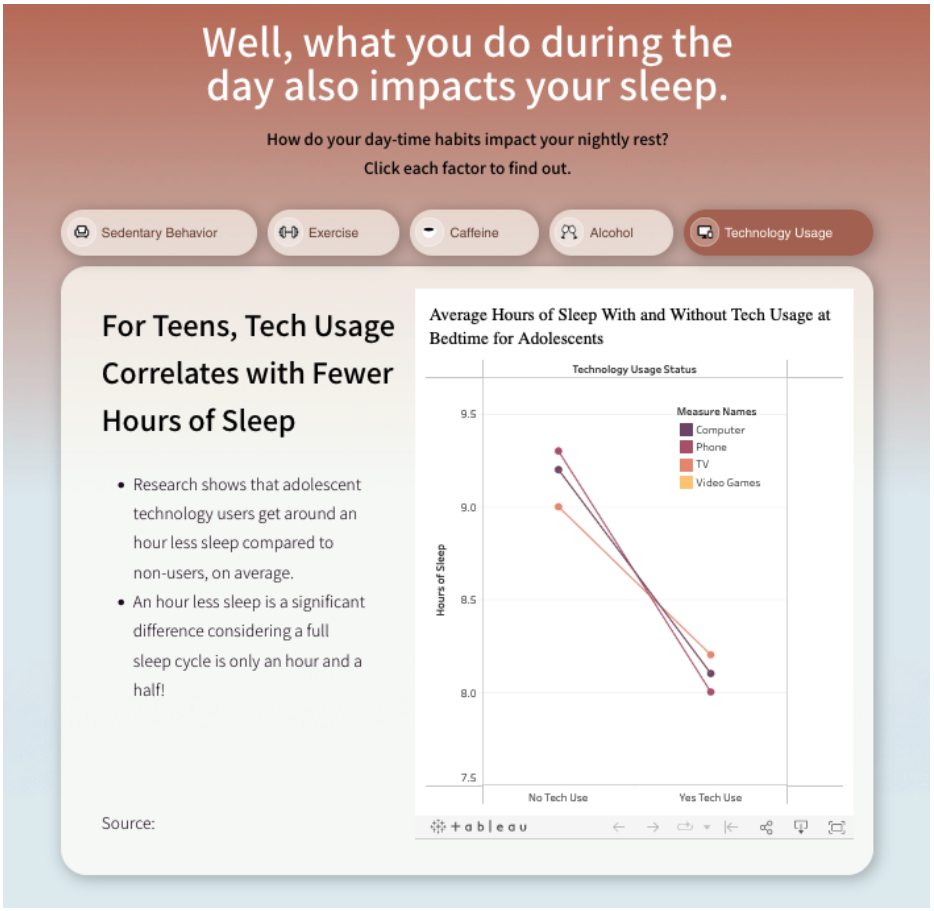


The goal of this visualization is to walk viewers through a full, uninterrupted night of sleep from Bedtime to Wake Up time. Starting with the graph on the left: we broke the visualization into 5 different panels, one for each stage of sleep and 'awake'. We intentionally decided to keep gradient panels as part of the design because it helps visually segregate the stages of sleep by using the Gestalt principle of 'Closure'. Without the panels, it became hard to distinguish between the different sleep stages. We also used the Gestalt principle of continuity to connect all the segments together to create a coherent path that viewers can trace as they go from bedtime to waking time. We chose bright colors that would stand out from our background colors. We also incorporated those colors in the section before this graph to create a sense of visual continuity between the previous section and this graph.

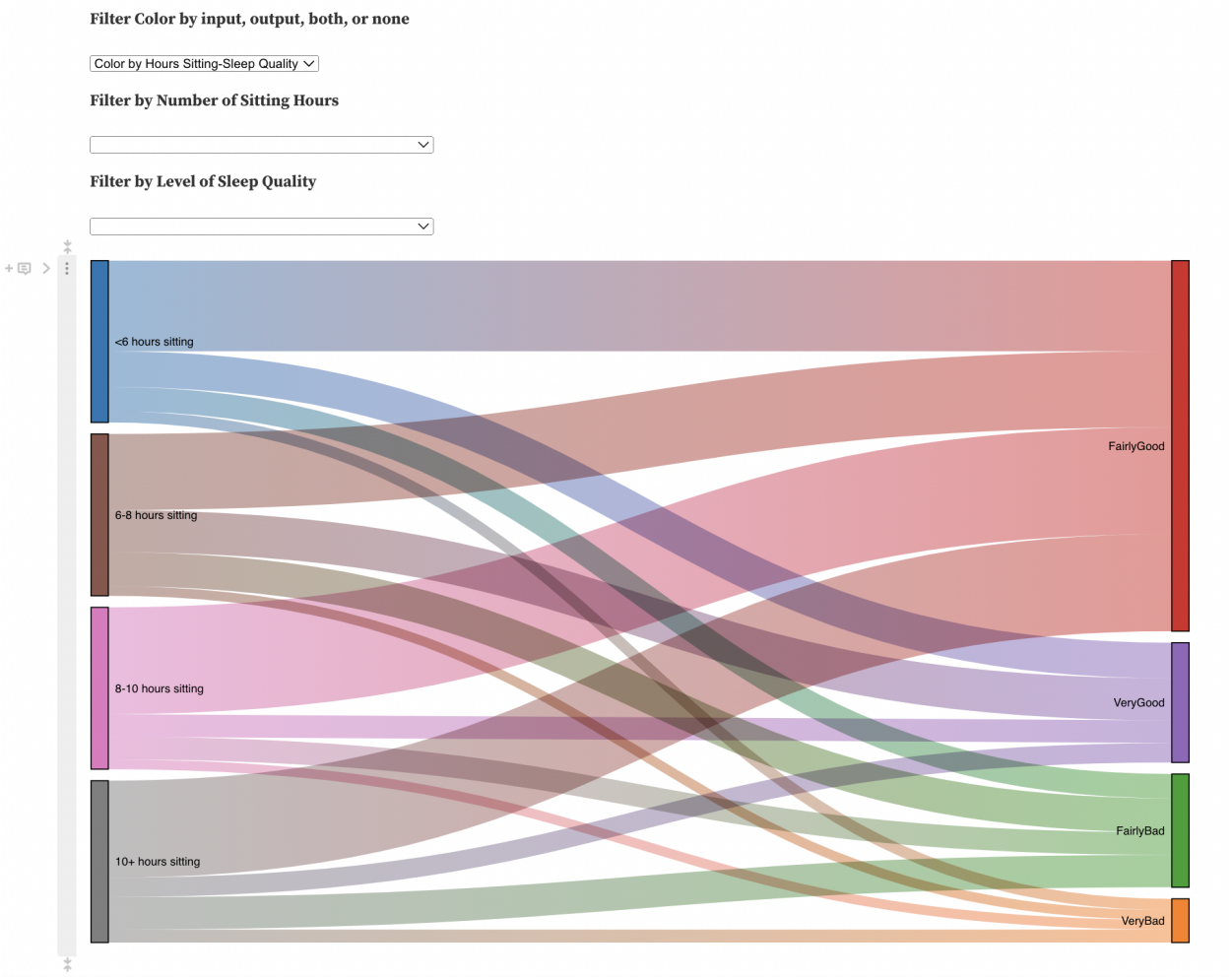
The chart in the lower right-hand corner of the graph, using matching colors as the left-hand graph, is the culmination of the series of charts presented in the previous section, accompanying the different stages of sleep. Now the user can compare the lengths of time they spend in a given night of sleep, a target-supported task. The user can also benefit from the large text “fun facts” to understand their sleep cycle.

Daytime Factors

The following section contains our more complex visualizations, showcasing what we have learned during this course. For this section, we used a frame to encapsulate the different factors and allow users to tab through the different visualizations so they would not feel overwhelmed and suffer high cognitive loading. Below, we will go into more detail regarding each visualization contained in the tab, from left to right.



Sedentary Behavior



In order to better understand the intricate patterns between stationary behavior (in this case, sitting) and quality of sleep (very good, fairly good, fairly bad, and very bad), we took a look at the relationship they both share and the level of variability depending on behavior. The data was highly credible and used detailed research methods to gather information from participants. We started the visualization process with code from a Sankey Diagram function which we found on Observable. By taking an initial look at the code provided, we realized that it provided a great start to visualize the data in the form of a Sankey Diagram and provided some initial filters we could work with.

In order to further augment and make the code our own and tailor it for the data which we were working with, we decided that it would be a good idea to implement unique ways of interacting with the diagram in order to better understand the nuanced patterns which were emerging. We started by replacing the existing data (found on the original function) with the data found in the paper we were using. To do so, we created and uploaded

a CSV file in the same format as the existing file. We then changed the way the colors were coded on the diagram to ensure that unique colors were given to each input and output element of the diagram.

After the initial cleaning process, we added two extra filters which we thought were necessary in order to better understand and visualize the data at hand. We decided that simply using the filter provided (by input, output, both, or none) did not provide the level of detail wanted. Therefore, we enhanced the code to include filters based on the number of hours a person sat as well as the level of sleep quality experienced. Doing this allows the user to select the area they want to hone in on, take a deeper look at the connections being made, and further delve into relationships between and within the categories defined.

We also wanted to make sure that there was a way to see the actual numerical value associated with the lines. In order to do this, we created titles for the connecting bands so that the specific journey being considered is depicted alongside the value of that line. This function can now be seen on hover. When the user hovers, that line is highlighted in color and a tooltip provides the description of that line. For example, hovering over the first line reads that <6 hours sitting → Fairly Good at a value of 56. In order to experience this, the user must hover over the line for a few seconds.

In order to fully understand and enjoy the interactive experience, we added a number of key data visualization elements which are described below:

Filtering color by input, output, both, or none: As a user and researcher of sleep and stationary behavior, we may be interested in taking a look specifically at the input elements (number of sitting hours), output elements (quality of sleep), both (a pattern between the two), or none (no color associations). Having the ability to filter by each one allows the user to obtain the initial view and information that may answer a research question that they have. If I'm specifically interested in the number of sitting hours, we can filter by that category broadly in order to be presented with an overview of the patterns associated with input elements. Furthermore, having the option to remove color presents the option to view an unbiased presentation of the information in order to merely consider the thickness of associated lines.

Filtering by the number of sitting hours: To get into the specific input elements which a user may wish to consider, this filter allows the user to select a range of numbers upon which the view will be focused. Having the ability to concentrate on a specific set of hours allows the user to obtain a narrower view, highlighting the elements of interest. The user can now focus on the more nuanced patterns within a set range that may assist in answering questions within that element.

Filtering by the level of sleep quality: The next filter allows the user to filter by the level of sleep quality and enhances the understanding of patterns and relationships within

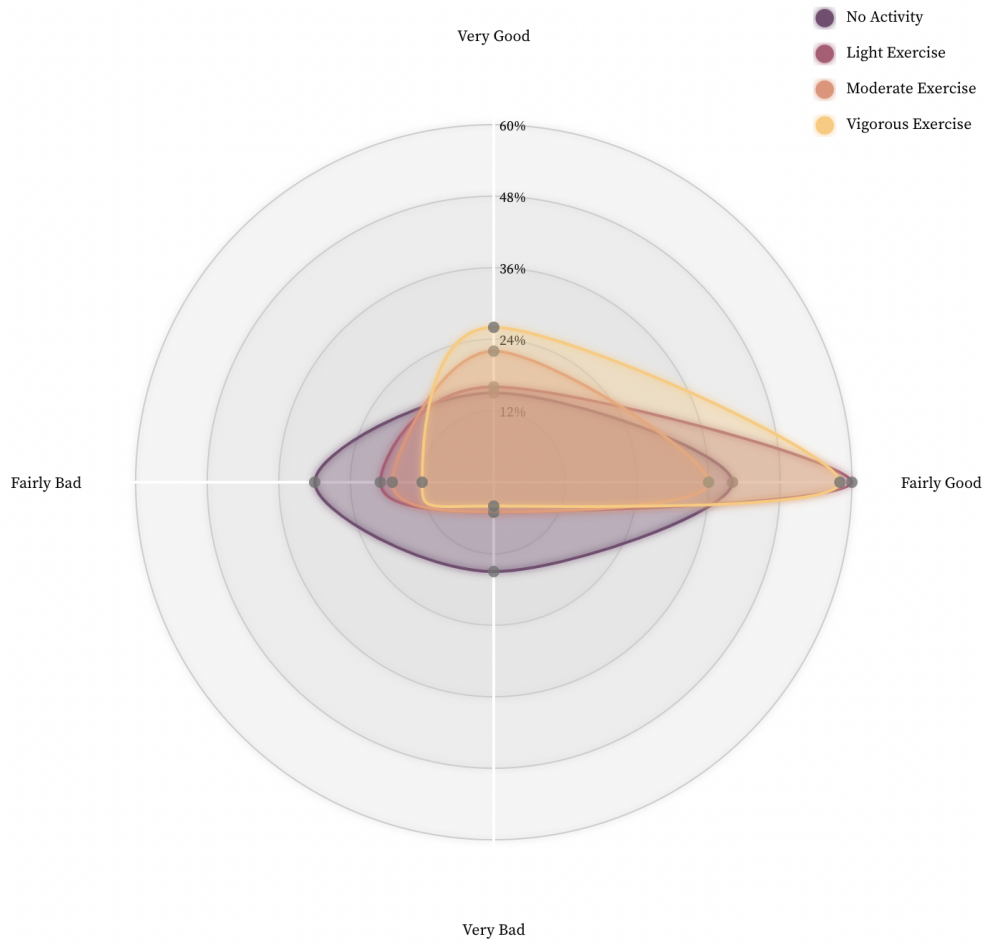
the output area of the Sankey diagram. Similar to the previous filter, this filter allows the user to highlight specific outputs to see how they may relate to and be spread amongst the various number of hours of sitting they may be associated with.

All three of these filters can be used in conjunction with one another in order to provide an increasingly nuanced look into specific questions a person may have. A static view simply does not enable a user to take a detailed look at these qualities in relation to one another. Being able to use these filters alongside one another provides a unique look into specific questions that may arise.

Tooltip seen through hovering over a line: Hovering over a line within the Sankey diagram leads the user to be able to obtain the value of that specific line along with the journey that line is on. For example, hovering over the first line reads that <6 hours sitting → Fairly Good at a value of 56. In order to experience this, the user must hover over the line for a few seconds. This interaction is very important as it provides the user with a detailed and quantitative view of the information being considered. Allowing them to obtain this information when they want gives them the license to conduct key comparisons and monitor the relationships in a numerical manner. It decreases confusion regarding a line as it clearly denotes the input and output points. It also decreases confusion regarding any discrepancies regarding the line widths which is critical when considering the variables in relation to one another.

Highlight when a line is clicked or hovered on: Finally, this interaction provides the functionality to focus on a specific line when it is clicked or hovered on. When interacting with the visualization, this provides the ability for a user to hone in on a specific line and view the connections it holds in a quick and effective manner. This interactive feature allows the user to communicate their area of focus or simply navigate to specific areas of interest.

Exercise



For this graph, we wanted to take a closer look at how levels of exercise impact sleep quality. The research paper that we used to extract and better understand data (See Data) addressed four main levels of exercise, including: Vigorous Exercise, Moderate Exercise, Light Exercise, and No Activity. Based on these levels, the research tracked the quality of sleep obtained by the person who engaged in the specific level of exercise.

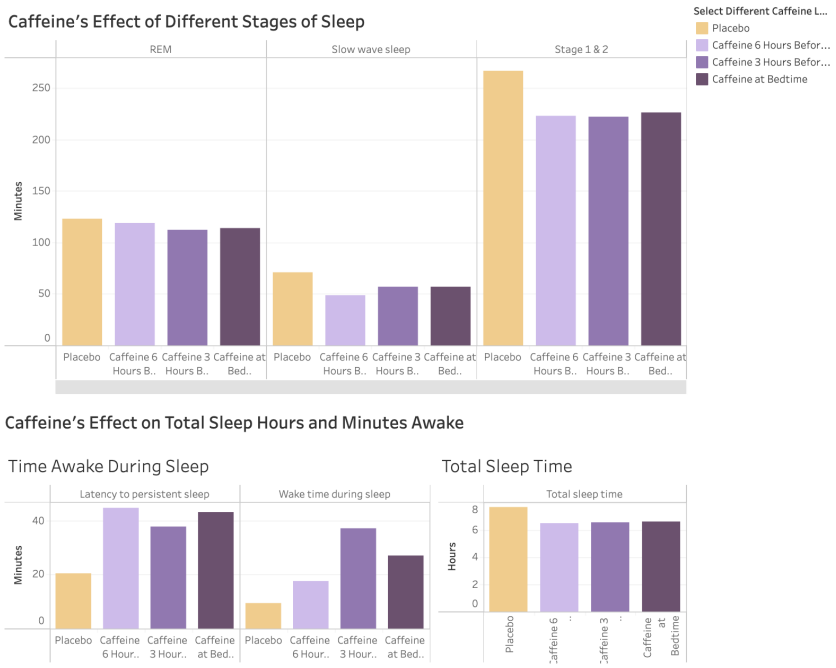
Through this visualization, we wanted to be able to both take a look at the changes in sleep quality based on exercise level within said exercise category as well as within said level of sleep. To do this, we realized that merely creating a static image would not be enough - we wanted to create something that allowed us to conduct detailed comparisons and also interact with the categories the user wishes to compare and consider in more detail. Our

exploration led us to believe that the best possible way to do this is through a radar chart with four endpoints and four categories.

Because our main research questions seek to gain a better understanding of factors that may impact sleep - we decided that sleep quality would be our four main points within the circle. Inside the main circle lie the four categories of exercise which we are taking a closer look at. To begin the visualization process, we labeled each inner circle to represent the amount of that specific type of sleep obtained by participants. We then added blobs connecting each data point for the two variables to establish a clear trajectory between the level of exercise and quality of sleep. We also added unique color codes for each type of sleep covered in the data set to both draw unique distinctions between them as well as aesthetically integrate with our website's design.

Finally, adding interactivity assisted in highlighting the specific blob being considered when a user was interacting with it. Because a radar chart provides multiple (in this case, four) overlapping blobs, it was important to us that users be able to hover and interact with each one as needed. Therefore, we included code that allowed us to focus on one blob at a time and also hovers on each node to take a look at the specific percent being referenced as they explored.

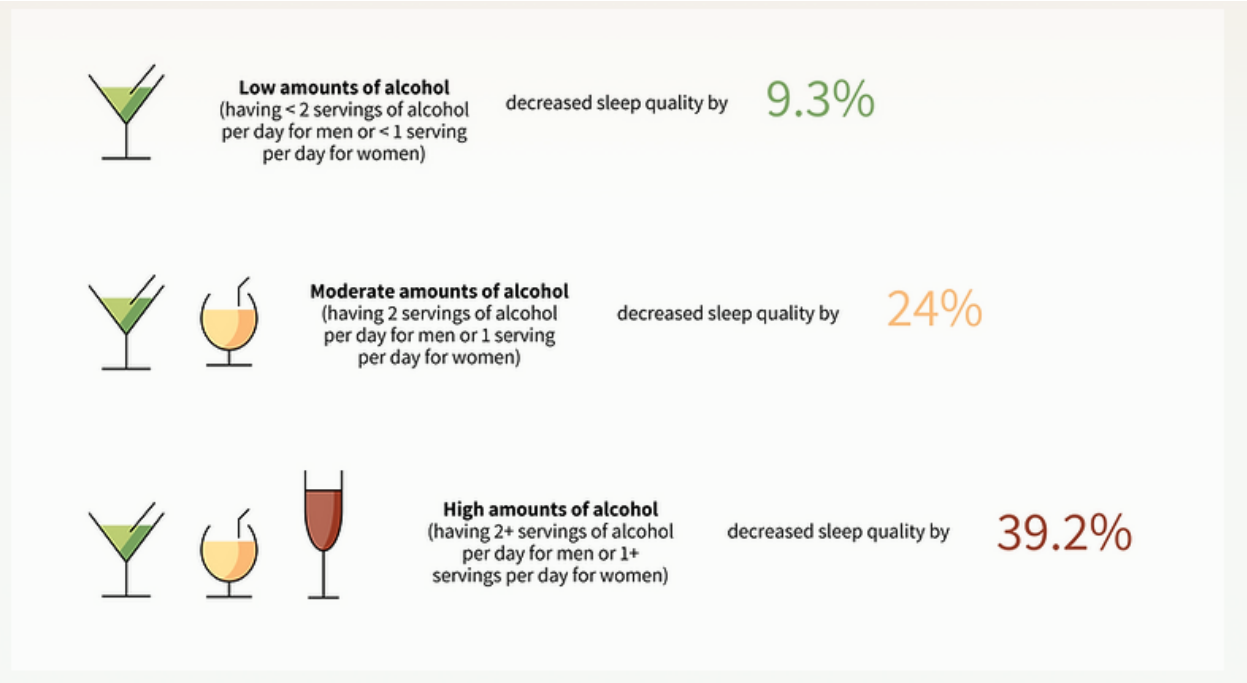
Caffeine



This visualization aims to show the differences between no caffeine(placebo) and consuming sleep, different numbers of hours before bedtime, and their respective effects on sleep. Placebo is intentionally colored in a contrasting color to the data from participants who had caffeine; this makes it stand out more and makes it easier to compare between no caffeine and caffeine groups as a whole. The caffeinated participants are colored different shades of purple, with the darkest purple being participants who had drank caffeine at bedtime. The logic behind this was that the participants who had caffeine 6 hours before bedtime would have had more time for the caffeine to "wear off," thus we associated it with a lighter shade of purple. We zoom in on a few different aspects of sleep here, and related aspects are grouped together in this visualization. The first section talks about the different stages of sleep. The bottom section is split in half. The left side talks about the time awake during sleep, and the right side is the total sleep time. These graphs were put in two separate sections because one set was measured in minutes and the other set was measured in hours. We did intentionally leave out some aspects of sleep that were originally in our data set. The ones that were left out were: the percentage of slow wave sleep, the percentage of REM sleep, the percentage of stage 1 and 2 sleep, and sleep efficiency percentages. We felt that data percentages felt more abstract than data that was in minutes and hours, which is more concrete. Because the data is averaged, percentages do not add up to 100, which would also add to the confusion. Data in minutes and hours is also easier to compare between each other, and because we were working with 4 different groups of participant data, we wanted

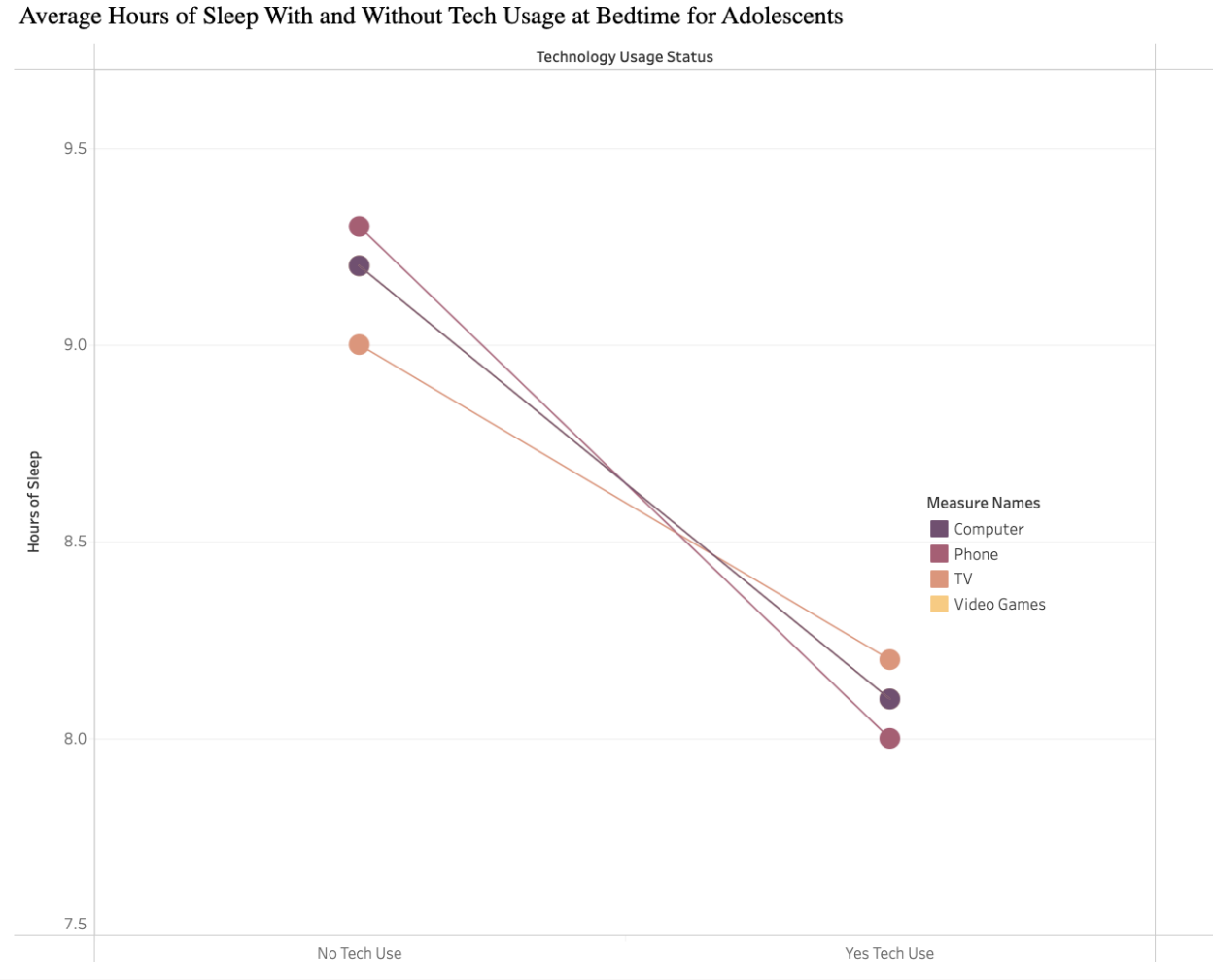
to decrease the mental work viewers had to do to effectively compare the groups. We made sure that this dashboard is aligned in terms of width to make it more aesthetically pleasing.

Alcohol



This visualization is about the effects of alcohol and sleep. For this graph, we wanted to visualize text. We thought that the best way to do this was through the images of drinks on the left which are increasingly based on “low”, “moderate”, and “high” amounts of alcohol. We then use colors that are known for being associated with low (green), moderate (yellow), and high (red) danger. These colors are kept consistent between the drink colors and the percentage colors to make an impact on the viewer and to make the associations very easy to synthesize. We hope the audience will take away the fact that higher amounts of alcohol have a significant impact on sleep quality and that even moderate amounts of alcohol can impact sleep quality as well! We wanted to make the percentages stand out by increasing their size. We also wanted to create a diagonal line on the right side of the graph to visually indicate an increase as you raise the amount of alcohol consumed. No data was left out of this visualization because we were just visualizing the corresponding text.

Technology Use



Our technology and sleep graph aims to make viewers more aware of how their technology habits might impact their sleep duration. We decided to make a dumbbell chart to visualize this to see the clear decline that technology use creates. The colors are chosen to match the sunset/sunrise color scheme of our whole website. We constrained the axis to start at 7.5 and end at 9.5 to zoom in on the data and emphasize the impact. While some may argue that not starting with a 0 axis is misleading and that the change in sleep hours is not as drastic, we would argue that even an hour of lost sleep every night is significant. To put this in perspective, one hour is almost one whole sleep cycle. To emphasize our view on how important this loss of sleep is, we decided to modify our axis and not start at 0.

In addition, you may notice that the line for 'Video Games' is not visible. This data was difficult as the values for 'Video Games' was the same as 'Computer' for both values. Viewers can see the video games line by clicking on it under the "Measure Names" filter we provided. This was a tough decision to make for us, but it was a tradeoff we had to make to

be able to compare each technology and present them together without creating small multiples. We believed that the use of small multiples, in this case, may not create a cohesive impact because viewers will be looking at 4 very similar graphs sharing the same story. Having one graph with all the data creates a better takeaway message, and in doing so, we had to sacrifice creating slight confusion with the video game dumbbell. To slightly reduce this confusion, we gave 'Computers' and 'Video Games' contrasting colors. Since viewers will automatically notice the absence of yellow, it will be more clear to viewers that 'Video Games' is not present without clicking on the text. To increase the clarity, we also had text explaining why 'Video Games' is hidden next to the graph.

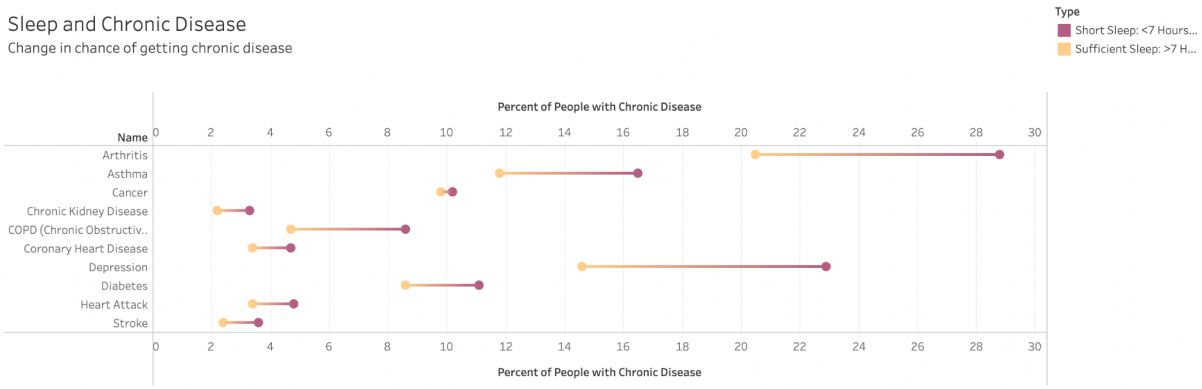
Benefits of Sleep

This section helps cement specific ways in which sleep is good for you. Because users generally understand that sleep is beneficial and because the health effects of sleep are even more complex to visualize than daytime factors (due to the complex nature of sleep and human bodies), they are listed here to give readers a visual and cognitive break from the dense and cognitively intense section above.

Effects of Poor Sleep

This section explains the drawbacks of poor sleep, both individually and collectively. The main charts comprising this section are spotlighted below.

Chronic Disease

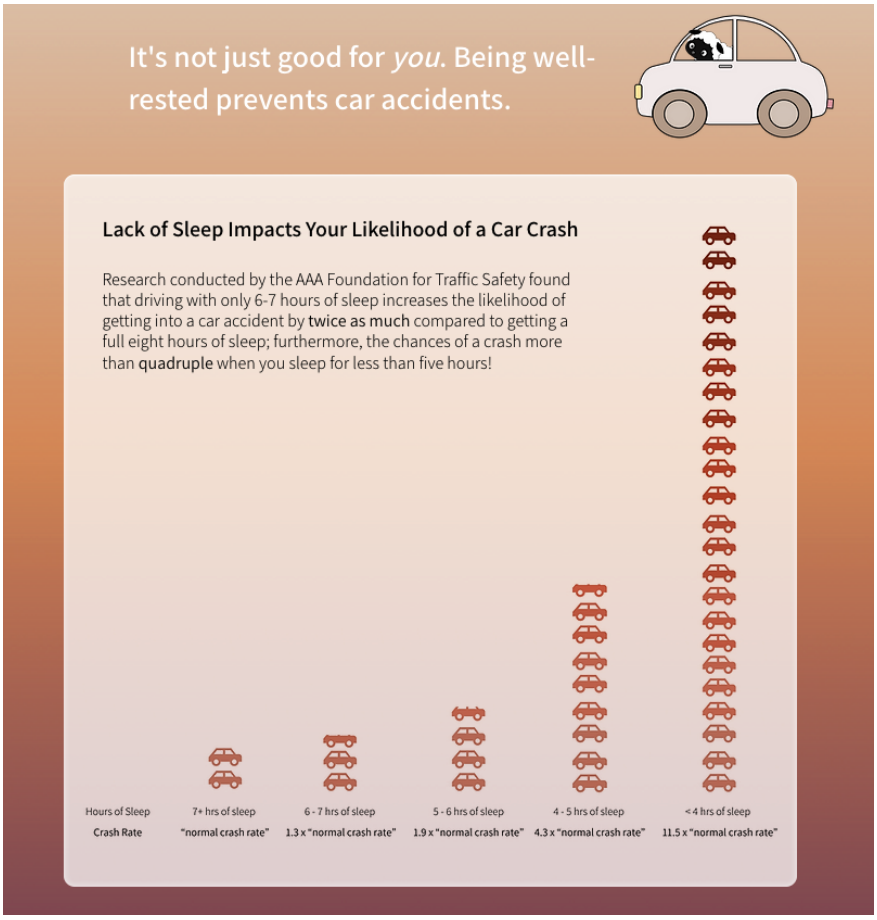


In order to delve further into the impact that sleep has on health, we wanted to consider how varying chronic health diseases can be visualized through the lens of the amount of sleep received. Data we found from research papers assisted us in understanding how a wide range of chronic health diseases may be impacted by the amount of sleep that a person receives. Specifically, we looked at the comparison between short sleep (less than seven hours) or sufficient sleep (seven or more hours) and how the percentage of people with a certain chronic disease changes based on which category of sleep they received.

Visualizing this data meant being able to compare what different amounts of sleep can do to the probability of being diagnosed with a certain disease as well as comparing between diseases to see which ones are most impacted by the amount of sleep received. Being able to conduct this multifaceted comparison process required taking a mode of visualization that allowed us to look within and between chronic diseases that had been identified. We identified a dumbbell chart as the best form of visualization to compare the factors we were considering. Furthermore, connecting variables with a line (as done through dumbbell charts), further enhances the connections we are attempting to demonstrate through the use of the visualization.

The use of two colors (yellow and pink) not only emphasizes the differences in the number of hours of sleep received but aesthetically coordinates with the background that the website uses. The slow change in the colors indicates the variability in the chance of being diagnosed with a certain disease and also demonstrates the uncertainty involved in the process of understanding the connection between sleep and chronic diseases. Interestingly, the chart is able to not only demonstrate the wide-ranging differences in the probabilities of being diagnosed with one of the disorders but also the variability in sleep's role amongst the diseases.

Car Crashes



This graph aims to show how sleep (or a lack of sleep) impacts the likelihood of a car crash. We decided to rely on iconography and isotypes to visualize the data associated with this graph. We intentionally chose 2 cars to be equivalent to the “normal crash rate” baseline. This is to make sure that the graph has a dramatic exponential increase, but is still comprehensible. We decided that creating a larger baseline might make the final column too high to comprehend. Two cars was a good compromise to create emphasis but in a constrained dimension. We decided to create a color gradient with the cars which will gradually increase as the crash rate increases. This emphasizes the increase in crash rate visually.

Sleep Needs Throughout Life

This visualization allows viewers to see how many hours of sleep they need based on their age. This visualization allows viewers to compare the hours of sleep needed in different parts of life. We utilized isotypes and iconography to convey our visualization's message. Zs are often associated with sleeping so we thought it would be clever to use 1 Z to indicate each hour of sleep needed. The data we had for this graph indicated a range of hours for each age group. To visualize this range, we labeled the minimum number of hours as "required" and the maximum number of hours as "recommended." We distinguished between the two groups using opacity, making the "recommended" Zs more transparent to signify them being "optional" though highly recommended. We also created vertical grid lines to help viewers easily determine how many Zs are in the row without individually counting them.

4. Data

We used a wide variety of datasets in order to take a closer look at sleep, its diverse impacts, and the factors which may influence sleep patterns. Datasets were gathered through the investigation of research papers and the exploration of credible national health medical websites. Before using each data source, we assessed its credibility and took a closer look at how we can use the data to create rich visualizations. Below are the data sources we used along with descriptions of what they entailed.

Caffeine Effects on Sleep Taken 0, 3, or 6 Hours before Going to Bed - Link

A study was conducted to compare the sleep-disruptive effects of a fixed dose of caffeine (400 mg) administered at three different time points (0, 3, and 6 hours before habitual bedtime) with placebo on self-reported sleep in the home. Objective sleep disturbance was also monitored using a validated portable sleep monitor. The study results revealed that a moderate dose of caffeine consumed at bedtime, 3 hours prior to bedtime, or 6 hours prior to bedtime significantly disrupted sleep when compared to placebo ($p < 0.05$ for all). The reduction in total sleep time suggests that caffeine consumption 6 hours before bedtime can have significant disruptive effects on sleep.

Caffeine and Sleep - Link

Caffeine affects people's quality of sleep, especially their deep sleep (stage 3). Caffeine also seems to have different effects on different individuals. This data showed that if an individual goes to bed at 10 p.m., it may be beneficial to avoid caffeine consumption after 2 p.m. to reduce the risk of sleep disturbances. It is possible that a more extended period of caffeine abstinence, such as 10 hours or more, may result in improved sleep quality.

5 Surprising Ways A Full Night's Sleep Positively Affects Your Brain - Link

This article outlines five mental benefits to sleep. Sleep deprivation can lead to mood disorders such as anxiety and depression, while on the other hand, a full night's sleep can help regulate emotions. The article also mentions that sleep is essential for memory consolidation and that good-quality sleep can improve decision-making abilities. Additionally, getting enough sleep has been linked to reduced levels of stress hormones and

increased feelings of happiness. The article emphasizes that good sleep hygiene is crucial for maintaining good mental health.

Acute Effect of Alcohol Intake on Cardiovascular Autonomic Regulation During the First Hours of Sleep in a Large Real-World Sample of Finnish Employees: Observational Study - Link

Alcohol consumption is a common behavior that is known to have adverse effects on sleep quality. Previous research has revealed that alcohol disrupts sleep homeostasis in people's bodies. In this study, we learn of the impact alcohol has on sleep as more alcohol is consumed. However, the impact of acute alcohol intake on physiological changes in natural, non-controlled environments has yet to be examined.

Acute Sleep Deprivation and Risk of Motor Vehicle Crash Involvement - Link

This PDF outlines car crash data and safety strategies for drivers. In this PDF, we learn the catastrophic effects lack of sleep can have on the car crash rate. The study analyzed data from over 7000 crashes and found that the risk of crashes was significantly higher for drivers who had slept for less than four hours. The study also found that the risk of crashes was elevated during the early morning hours when individuals are more likely to experience sleep deprivation. The PDF concludes that sleep is essential for safe driving, and individuals should prioritize getting adequate sleep before driving to avoid the risk of crashes.

Stages of Sleep - Link

This data outlines the details of all 4 sleep stages and what a typical night of sleep looks like. We used this data in the first part of our website to introduce all the stages and visualize how many cycles are in one night.

Bedtime Use of Technology and Associated Sleep Problems in Children - Link

The journal article explores the impact of bedtime electronic use on the health of children aged 8 to 17 years. The study surveyed parents of 234 children to determine the number of hours of technology use (including computer, video games, cell phone, and television), hours of sleep, and inattentive behaviors. The findings indicate that using any device at bedtime increased the use of technology at bedtime and in the middle of the night, reduced sleep quantity and quality, and increased the risk of elevated body mass index. The study concludes that clinicians should discuss the impact of technology at bedtime with

parents to prevent the harmful effects of overexposure. The article also discusses the potential relationship between increased technology use and ADHD and BMI.

Sleep and exercise: A reciprocal issue? - Link

The research on sleep and exercise demonstrates that there is a complex, bidirectional relationship between the two. Physical activity is generally considered beneficial for improving sleep, but the effectiveness of exercise on sleep may depend on factors such as age, sex, fitness level, sleep quality, and the characteristics of the exercise. Moreover, sleep disturbances can also negatively impact cognitive performance, and the ability to exercise, and increase the risk of injuries related to exercise or team sports. This review highlights the importance of understanding the fundamental physiology linking sleep and exercise to improve the use of exercise in sleep medicine and prevent sleep disorders in athletes. Ultimately, the research suggests that exercise can be a useful tool for improving sleep and preventing sleep disorders.

The association between physical activity, sitting time, sleep duration, and sleep quality as correlates of presenteeism - Link

This research study demonstrates that poorer sleep quality, suboptimal duration, and lower work sitting time are significantly associated with higher presenteeism, which refers to the phenomenon of employees being present at work but performing poorly due to health issues. The study also found that engaging in three or more risky lifestyle behaviors was associated with higher presenteeism compared to engaging in none or only one risky behavior. The study suggests that interventions should address sleep behavior along with other activity-related behaviors to improve productivity and reduce presenteeism.

Centers for Disease Control and Prevention: Sleep - Link

The data presented on the Centers for Disease Control and Prevention (CDC) website about sleep and chronic diseases provides important information about the relationship between sleep and various health conditions. For example, the data shows that people with certain chronic diseases, such as diabetes or obesity, are more likely to experience sleep disturbances such as sleep apnea or insomnia. This information can help healthcare professionals identify patients who may benefit from sleep evaluations and interventions to improve their sleep and potentially reduce the risk of complications from their chronic disease. The data also provide insights into the prevalence of sleep problems in different populations, such as among different age groups, races and ethnicities, and

socioeconomic status. This data helped improve our understanding of the relationship between sleep and chronic diseases.

5. Tools

The tools we used for our visualizations are Figma, Observable with D3, and Tableau.
The tool we used for our website was Wix.com, which we embedded HTML elements into.

6. Results

Context

We conducted a usability test with three participants. We recruited three participants from the UC Berkeley graduate student population to give us feedback on our visualization, and also due to ease of access. Since our target audience was anyone who is interested in bettering their sleep but who also has a baseline in understanding and interpreting research and complex visualizations, we felt like graduate students at UC Berkeley would fit into our target audience.

Our purpose was to delve further into our design to better understand how we can work towards refining our prototype to ensure that it is increasingly usable and intuitive while maintaining the educational qualities we set out to answer. We wanted to make sure that the research questions that we established at the beginning of the project were being answered and were sparking user interest to learn more about the topic at hand.

In order to ensure that our usability testing process yielded detailed qualitative and quantitative findings regarding the current state of our prototype, we designed multiple stages for the user to engage in. First, we introduced the study to the participants - clearly stating our goals, disclaimers regarding recording, and intention behind the data collection. Next, we proceeded to a quantitative questionnaire that aimed to discover more about the pre-existing knowledge regarding sleep. We then sent them the link to our prototype in order to walk through the design and think aloud as they navigated. For each step, we asked them what was working well and what wasn't to better assess how our design needed to be improved to cater to the user's needs. After they walked through the design, we administered the quantitative questionnaire again to see how much they learned and what information they retained throughout the process. Finally, we asked a series of summative qualitative questions to delve into their overall perceptions of the designs.

Usability Feedback

The overall feedback from the usability test was that it was very informative, but some of the information was difficult to interpret. If these results hold with a larger user population (especially considering our user population was intentionally highly educated), there are a few underlying improvements to be made.

One participant struggled to interpret our radar chart, which is helpful to know since our testing population is probably more educated than our larger target user population. In our final version, we hope to simplify our radar charts.

Overall, our visualization needs to conform better to match the cognitive principles and Gestalt principles we learned in class. We saw the importance of putting key information at the top of the graph/chart since people read top-to-bottom, in order to reduce our users' cognitive load. We also noticed slight participant fatigue because of the wordiness of our captions and copy. Some of the descriptions were too long and detracted from the visualization and its effect.

Changes Made

We made a lot of changes to increase audience engagement and knowledge retention. Our biggest change was to make a more cohesive storyline throughout the whole visualization, which heavily starred Barry the Sheep. We hope our lovable sheep protagonist helps to hold the viewer's attention throughout the whole website. We made more Barry graphics to add throughout the whole website and included Barry asking questions to guide the viewer and pique their curiosity. We added some elements of animation, for example with Barry in the car, to make the website less static.

In order to improve the usability of the radar chart, we realized that it was important to clearly denote which bubble represented which level of exercise. To better incorporate this into our visualization, we included a legend that demonstrated which types of exercise have been included and which colors they are represented by. For the Sankey diagram which represents the impact of stationary behavior on quality of sleep, we wanted to make sure the filters we were using were clear in working towards the goal of answering the research questions previously established. We made sure to add filters for the input and output levels in order for the user to be able to better visualize the patterns which were appearing. In order to further enhance the visualization which represents the connection between chronic diseases and the amount of sleep received, we wanted to color code the levels of sleep to delve deeper into the patterns. Making sure that hovering over each circle presents the

disease, level of sleep, and value of the x-axis better equips users to understand the connections being drawn.

We made changes to our visualizations according to our participant feedback. We improved the captions on visualizations, aiming for them to be concise yet informative. We moved the X-axis title location to the top for the Sleep Through The Ages chart to remove confusion. We changed the color of our graphs to better complement the theme of our website. We also dulled down our background sunset and sunrise colors to make sure the attention stays on our content and visualizations rather than the background. We made sure to link our Barry storyline to our background; for example, Barry wakes up as the background mimics a sunrise.

We also removed any elements that were creating confusion and were unnecessary to the overall storyline. We took out all of the EEG brain wave graphics because we felt like it was out of scope for the general public; people do not need to go into that much depth to understand sleep and its benefits. We also made the difficult decision to remove 'disordered sleep' from the sleep factors section. Our participants found it confusing to have disordered sleep displayed in sleep factors because it felt like it did not belong with the other factors. We did not find a good home for that visualization and felt like it was also slightly tangential to the storyline of our whole website. For those reasons, we chose to remove that visualization so the viewer could spend more time and energy on our other visualizations. We also moved the "car crash" section after sleep benefits, and did not have it combined with the sleep benefits section.

7. Link to Data Repository and Code

https://github.com/goosey-edu/all-about-sleep - before we switched to Wix.
No data repository for Wix, but we can provide edit access if necessary.

8. Team Contributions

Section	Contribution by Team Member
(General) Icons and Images not otherwise attributed	Made by Nimisha (100%) in Figma
(General) Website dev / Wix website creation	Done by Lucy (95%) in Github and Wix, helped by Nimisha (5%) Prototype completed by Gowri (40%), Nimisha (40%), and Lucy (20%) in Figma
Introduction	Equal / collaborative
Stages of Sleep	Nimisha (100%)
Stages of Sleep in A Night	Lucy (100%)
Daytime Factors	Sedentary Behavior - Gowri (100%) Exercise - Gowri (100%) Caffeine - Nimisha (100%) Alcohol - Nimisha (100%) Technology Usage - Nimisha (100%)
Benefits of Sleep	Equal / collaborative
Effects of Poor Sleep	Chronic Disease - Gowri (100%) Car crashes - Nimisha (100%)
Sleep Needs Throughout Life	Nimisha (100%)
Conclusion	Equal / collaborative

9. References

Gradisar M; Wolfson AR; Harvey AG; Hale L; Rosenberg R; Czeisler CA. The sleep and technology use of Americans: findings from the National Sleep Foundation's 2011 Sleep in America Poll. *J Clin Sleep Med* 2013;9(12):1291-1299.

Piccolo RS, Yang M, Bliwise DL, Yaggi HK, Araujo AB. Racial and socioeconomic disparities in sleep and chronic disease: results of a longitudinal investigation. Ethn Dis. 2013 Autumn;23(4):499-507. PMID: 24392615; PMCID: PMC3884220.

Faith S. Luyster, PhD, Patrick J. Strollo, Jr., MD, Phyllis C. Zee, MD, PhD, James K. Walsh, PhD, Sleep: A Health Imperative, *Sleep*, Volume 35, Issue 6, 1 June 2012, Pages 727–734, https://doi.org/10.5665/sleep.1846

Orben A, Przybylski AK. 2020. Teenage sleep and technology engagement across the week. PeerJ 8:e8427 https://doi.org/10.7717/peerj.8427

Snel, Jan, and Monicque M. Lorist. "Effects of caffeine on sleep and cognition." *Progress in brain research* 190 (2011): 105-117.

Fairclough, Stephen H., and Robert Graham. "Impairment of driving performance caused by sleep deprivation or alcohol: a comparative study." *Human factors* 41.1 (1999): 118-128.

Jenni, Oskar G., and Mary A. Carskadon. "Normal human sleep at different ages: Infants to adolescents." *SRS basics of sleep guide* (2005): 11-19.

“Alcohol and Sleep.” Sleep Foundation, 17 Mar. 2023, https://www.sleepfoundation.org/nutrition/alcohol-and-sleep.

“How Sleep Affects Athletic Performance.” Sleep Foundation, 13 Apr. 2022, https://www.sleepfoundation.org/physical-activity/athletic-performance-and-sleep.

Pietilä, Julia et al. “Acute Effect of Alcohol Intake on Cardiovascular Autonomic Regulation During the First Hours of Sleep in a Large Real-World Sample of Finnish Employees: Observational Study.” JMIR mental health vol. 5,1 e23. 16 Mar. 2018, doi:10.2196/mental.9519

Drake C; Roehrs T; Shambroom J; Roth T. Caffeine effects on sleep taken 0, 3, or 6 hours before going to bed. J Clin Sleep Med 2013;9(11):1195-1200.

Pacheco, Danielle. “Caffeine and Sleep.” *Sleep Foundation*, 17 Mar. 2023, https://www.sleepfoundation.org/nutrition/caffeine-and-sleep.

Westbrooks, Emily. “5 Surprising Ways a Full Night's Sleep Positively Effects Your Brain.” *Romper,* Romper, 27 Feb. 2018, https://www.romper.com/p/5-surprising-mental-health-benefits-of-a-full-nights-sleep-according-to-science-8337251.

Tefft, Brian. “Acute Sleep Deprivation and Risk of Motor Vehicle Crash Involvement.” *Foundations for Traffic Safety*, 2016, https://publicaffairsresources.aaa.biz/wp-content/uploads/2016/11/Acute-Sleep-Deprivation-and-Risk-of-Motor-Vehicle-Crash-Involvement.pdf.

Suni, Eric. “Stages of Sleep.” *Sleep Foundation*, 2 Mar. 2023, https://www.sleepfoundation.org/stages-of-sleep.