Rank Ordered Design Attributes for Healthcare Dashboards including Artificial Intelligence (AI): Usability Study

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Abstract

Background: A healthcare dashboard is a visual representation of vital healthcare data designed to emphasize key information for individuals and organizations, aiding them to make informed decisions. [5] These dashboards are increasingly utilized worldwide to track and report emerging and widespread diseases, trends, and other information to allow the public to make better healthcare decisions. [6, 7] Some examples include the Johns Hopkins COVID-19 dashboard, the Centers for Disease Control and Prevention FluView Interactive dashboard, the World Health Organization Monkeypox dashboard, and the State of Pennsylvania's Cancer Statistics dashboard.

Objective: This study identifies the top 15 attributes of a healthcare dashboard. The objective of this research is to enhance healthcare dashboards worldwide to benefit the public by making better healthcare information available for more informed decisions by the public and to improve population-level healthcare outcomes.

Methods: The authors evaluated 250 US government and commercial healthcare dashboards and conducted a survey of healthcare dashboards with 218 individuals identifying the best practices to consider when creating a public healthcare dashboard.
The dates of the survey and data collection were from June 2023 to August 2023.
These features ranked in descending order of importance are (1) easy navigation, (2) historical data, (3) simplicity of design, (4) high usability, (5) use of clear descriptions, (6) consistency of data, (7) use of diverse chart types, (8) compliance with Americans with Disabilities Act, (9) incorporated user feedback, (10) mobile compatibility, (11) comparison data with other entities, (12) storytelling, (13) predictive analytics with Artificial Intelligence (AI), (14) adjustable thresholds, and (15) charts with tabulated data. The prior study on COVID dashboards with 118 participants showed similar results.[3] Both studies validated top attributes of healthcare dashboards as easy navigation, simplicity of design, high usability, use of clear descriptions, and use of diverse chart types. Future studies can extend the research to other types of dashboards such as bioinformatics, financial, and managerial dashboards as well as confirm these top 15 best practices with further evidentiary support.

Results: The authors conducted a survey of 218 (n=218) individuals above the age of 18. The survey consisted of 15 questions. Responses of "yes" counted as one point, while responses of "no" counted as 0 points. The authors calculated a total of 3,259 responses - 2,945 responses of "yes" and 314 responses of "no". The Use of Charts with Tabulated Data had the lowest percent agreement of "yes" responses of 83%, whereas Easy Navigation had the highest percent agreement of "yes" responses of 96%, and the use of Predictive Analytics using Artificial Intelligence had "yes" responses of 87%, ranking at the 13th most popular attribute.

Conclusions: As technology evolves, the availability of resources and data has become increasingly easier and better. With a click or a quick search, consumers have access to an abundance of healthcare data and data dashboards which aid in making informed healthcare decisions. However, healthcare dashboards may not be of the highest quality or as easily understood. Through our observational review and multiple surveys, we evaluated the effectiveness of healthcare dashboards in the United States to better understand and improve their design elements. From our analysis, we were able to develop and confirm the top 15 best practices of healthcare dashboard design from the ease of navigation to the use of predictive analytics. These 15 top best

practices were assessed as the most important aspects of a healthcare dashboard's effectiveness. The studies validated and concluded that the top five attributes of healthcare dashboards, such as easy navigation, simplicity of design, high usability, use of clear descriptions, and use of diverse chart types. As identified and analyzed, the best practices can be incorporated in order to design and disseminate effective healthcare dashboards making valuable healthcare information available to the public. Ultimately, the availability of better healthcare dashboards will help consumers make better and more informed healthcare decisions resulting in better healthcare outcomes.

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Rank Ordered Design Attributes for Healthcare Dashboards including Artificial Intelligence (AI): Usability Study

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Abstract

Background

On average, people in the United States visit a doctor four times a year, and many of them have chronic illnesses. Because of the increased use of technology, people frequently rely on the internet to access health information and statistics. People use healthcare information to make better educated decisions for themselves and others. Healthcare dashboards should provide pertinent and easily understood data, such as information on timely cancer screenings, so the public can make better informed decisions. In order to enhance health outcomes, effective dashboards should provide precise data in an accessible and easily digestible manner.

Objectives

This study identifies the top 15 attributes of a healthcare dashboard. The objective of this research is to enhance healthcare dashboards to benefit the public by making better healthcare information available for more informed decisions by the public and to improve population-level healthcare outcomes. [1,2]

Methods

The authors conducted a survey of healthcare dashboards with 218 individuals identifying the best practices to consider when creating a public healthcare dashboard. The data collection was conducted from June 2023 to August 2023.

Results

These features ranked in descending order of importance are easy navigation (1), historical data (2), simplicity of design (3), high usability (4), use of clear descriptions (5), consistency of data (6), use of diverse chart types (7), compliance with the Americans with Disabilities Act (8), incorporated user feedback (9), mobile compatibility (10), comparison data with other entities (11), storytelling (12), predictive analytics with Artificial Intelligence (AI) (13), adjustable thresholds (14), and charts with tabulated data (15). The prior study on COVID dashboards with 118 participants showed comparable results.[3] Both studies validated the top attributes of healthcare dashboards as easy navigation, simplicity of design, high usability, use of clear descriptions, and use of diverse chart types.

From May of 2023 to June of 2023, we collected 3,259 responses in multiple different states around the United States from 218 people who were over the age of 18.

Conclusion

Future studies can extend the research to other types of dashboards such as bioinformatics, financial, and managerial dashboards as well as confirm these top 15 best practices for medical

dashboards with further evidentiary support. The medical informatics community may benefit from standardization to improve efficiency and effectiveness as dashboards can communicate vital information to patients worldwide on critically prominent issues.

Further, healthcare professionals should use these best practices to help increase population healthcare outcomes by informing healthcare consumers to make better decisions with better data. [4]

Introduction

A healthcare dashboard is a visual representation of vital healthcare data designed to emphasize key information for individuals and organizations, aiding them to make informed decisions. [5] These dashboards are increasingly utilized worldwide to track and report emerging and widespread diseases, trends, and other information to allow the public to make better healthcare decisions. [6, 7] Some examples include the Johns Hopkins COVID-19 dashboard, the Centers for Disease Control and Prevention FluView Interactive dashboard, the World Health Organization Monkeypox dashboard, and the State of Pennsylvania's Cancer Statistics dashboard.

Dashboards can effectively communicate health information to allow the public to make better healthcare decisions for themselves. [8,9,10] On the other hand, if healthcare dashboards are presented poorly or without the proper information, they can be ineffective tools for the public. [11]

The research team conducted an observational review and surveys on the effectiveness of healthcare dashboards in the United States to better understand and improve their design elements. As a part of this research, the team reviewed over 250 US city, county, and state healthcare dashboards as an observational assessment of whether their designs were favorable or not. Along with the observational study, the team conducted two surveys with the public about the favorability of the top 15 best practices for both COVID-19 and healthcare dashboards. The COVID-19 dashboard survey had 118 people participate and the healthcare dashboard survey had 218 participants. The latter is the focus of this research article.

From these surveys and subsequent analysis, the authors were able to develop and confirm the top 15 best practices of healthcare dashboard design. These 15 top best practices were assessed as the most important aspects of a healthcare dashboard's effectiveness.

There is a wide range of qualities when it comes to healthcare dashboard design. Some dashboards are confusing and difficult to read while others are clear and easily comprehensible. This study attempts to quantify what makes an effective healthcare dashboard.

With these best practices, practitioners can build upon these key elements to design and disseminate effective healthcare dashboards allowing the public to make better healthcare decisions and in turn, help improve healthcare outcomes.

The aim of this study is to rank and explain the relative importance of aspects of healthcare dashboards so that they can be more easily usable and understandable.

Background

The average person in the United States visits a doctor four times a year, and six in ten adults in the United States have a chronic disease [34]. Sixty-one percent of all US adults have searched for health or medical information on the Internet [35]. Additionally, forty-nine percent have accessed a website that provides information about a specific medical condition or problem [7]. Therefore, it is important that healthcare information utilized by the public is both informative and easily understood, since many people are constantly searching for new healthcare information.

The public makes healthcare decisions based on available information, either sourced from the internet or received in-person. Public health tools such as healthcare dashboards play a key role in the healthcare decision-making process because they can be readily available and provide real-time information instantly. Doctors and patients can benefit from healthcare dashboards, if they are designed with the best interest of the public and healthcare officials.

An effective healthcare dashboard should effectively display relevant and comprehensible information to its users [12,13]. For instance, a healthcare dashboard on cancer that provides data promoting timely screenings for breast and colon cancer can not only contribute to reducing the

prevalence of these cancers, but also may influence patients in the consideration of appropriate therapy, enabling them to make well-informed decisions in a collaborative manner. It is also important that information and data are offered through assorted designs to help all demographics, including minorities and ethnically diverse populations that are more susceptible or at risk of specific public health issues [5]. For example, Hispanics are about fifty percent more likely to die from diabetes or liver disease [36]. Dashboards that prioritize population-specific data for screening and prevention in the Spanish language may enhance usability leading to improved prevention strategies.

Further, broadening the conversation regarding the application of these design features in various healthcare settings, such as managing chronic diseases, tracking epidemics, and incorporating AI and predictive analytics, could further enhance the practical implications and overall impact of this research in the health informatics field.

Role of AI and Predictive Analytics

Further, the use of artificial intelligence (AI) to display dynamic on-demand predictive analytics in a healthcare dashboard can have a significant potential future impact. Its incorporation in dashboard design is especially helpful to analyzing and displaying data, identifying trends, forecasting future health scenarios, and providing personalized recommendations based on historical data and current health indicators.

The integration of AI significantly impacts usability by offering enhanced decision support, improving efficiency, personalizing user experiences, increasing accessibility, and enabling data-driven health interventions. These factors make healthcare dashboards more powerful tools for helping individuals and organizations make informed health decisions, leading to better healthcare outcomes. By addressing the effective integration and potential effects of AI, this research offers important perspectives on the future of dashboard advancement in the healthcare industry.

Methods

We initially examined over 250 public-facing healthcare dashboards from both US government and commercial sources such as the Johns Hopkins COVID-19 dashboard, the Centers for Disease Control and Prevention (CDC) FluView Interactive dashboard, the World Health Organization (WHO) Healthcare Monkeypox dashboard, and the State of Pennsylvania's Cancer Statistics dashboard. After the review of these healthcare dashboards, the authors identified key design elements for healthcare dashboards and then conducted a survey validating the top 15 attributes to produce a rank-ordered list.

The attributes surveyed are as follows: (1) Easy Navigation, (2) High Usability, (3) Use of Diverse Chart Types, (4) Mobile Compatibility, (5) Predictive Analytics with Artificial Intelligence, (6) Incorporated Historical Data, (7) Use of Clear Descriptions, (8) Compliance with Americans with Disabilities Act (ADA), (9) Comparison Data with Other Entities, (10) Adjustable Thresholds, (11) Simplicity of Design, (12) Consistency of Data, (13) Incorporated User Feedback, (14) Storytelling, and (15) Charts with Tabulated Data.

In a prior study, we gathered responses from 118 individuals for 10 key elements on COVID-19 dashboards.[4] For this new and expanded survey, we surveyed 218 participants and introduced five additional attributes not previously explored in our research. These newer attributes are as follows: (a) Storytelling, (b) Predictive Analytics leveraging Artificial Intelligence (AI), (c) Mobile compatibility, (d) Incorporated Historical Data, and (e) Consistency of Data.

This survey was distributed using a combination of online platforms and direct outreach to ensure a wide and diverse demographic representation. Measures were taken to minimize response

biases by ensuring anonymity, randomizing the order of questions, and providing clear and neutral question wording. Additionally, the survey was pre-tested with a small group to identify and rectify any potential sources of bias or confusion.

By incorporating these methodologies, the study aims to provide a reliable assessment of the key attributes that make healthcare dashboards effective tools for public health decision-making to include the use of AI for predictive analytics and other prominent features.

Demographic Information

Demographic data including County, State, and gender were included for all survey participants (See Table below). Survey respondents represented a diverse range of ten US states, including Maryland, Virginia, and Texas. The team aimed to ensure that they included at least five different US states. In accordance, the selection process satisfied the team's candidate attributes, as data was collected from a larger number of states than originally contemplated.

Attributes 1-3	Attributes 4-6	Attributes 7-9	Attributes 10-12	Attributes 13-15
Easy Navigation	High Usability	Use of Diverse Chart Types	**Mobile Compatibility**	**Predictive Analytics with Artificial Intelligence**
Incorporated Historical Data	Use of Clear Descriptions	Compliance with Americans with Disabilities Act (ADA)	Comparison Data with Other Entities	Adjustable Thresholds
Simplicity of Design	**Consistency of Data**	Incorporated User Feedback	**Storytelling**	Charts with Tabulated Data

Table 1: Fifteen (15) Key Design attributes for Public-Facing Healthcare Dashboards including 5 new attributes as bolded in a usability study, 2023 (N=218).

Table 2:

Measure	Item	Frequency	Percent (%)
Gender	Male	82	61.9%
	Female	135	37.6%
	Non-Binary	1	0.5%
Age	18-29	61	28.1%
	30-39	25	11.5%
	40-49	54	24.9%
	50-59	26	12%
	60-69	18	8.3%
	70-79	26	12%
	80-89	6	2.8%
	90+	1	0.5%
State of Residence	Maryland	46	21.2%
	West Virginia	70	32.4%
	Virginia	45	20.8%
	New Jersey	22	10.1%
	Pennsylvania	12	0.056%
	Missouri	8	0.037%
	Iowa	3	0.014%
	Texas	2	0.009%
	Ohio	2	0.009%
	South Carolina	3	0.014%
	Indiana	1	0.005%
	Florida	1	0.005%
	Tennessee	1	0.005%

Demographic Results of the Public Health Dashboard Design Survey, 2023 (N=218)

Results:

The survey aimed to help the impact of online learning through data dashboards on all healthcare information. Previous studies have highlighted how to easily read dashboards instead of the specific dashboard designs that would benefit users. Ethical approval obtained from this study was anonymous and de-identified. All participants provided their informed consent electronically before beginning the survey. The survey was developed using credible questionnaire resources, such as Google Forms and Survey Monkey, and tailored to our study needs. This survey was pretested with a small group of students to receive feedback and improve clarity and flow. The inclusion criteria were that all participants had to be 18 years or older and a total of 3,259 responses were recorded. The response rate was 89%, and participants who did not respond were sent a follow-up email. The authors conducted a survey of 218 (n=218) individuals above the age of 18. The survey consisted of 15 questions. Responses of “yes” counted as one point, while responses of “no” counted as 0 points. The authors calculated a total of 3,259 responses with 2,945 responses of “yes” and 314 responses of “no”. (Cherries Checklist)

The Use of Charts with Tabulated Data had the lowest percent agreement of “yes” responses of 83%, whereas Easy Navigation had the highest percent agreement of “yes” responses of 96%, and the use of Predictive Analytics using Artificial Intelligence had “yes” responses of 87%, ranking at the 13th most popular attribute (Table 1).

Rank	Dashboard Feature	"No" (0)	"Yes" (1)	Total Points	Percent of Agreement
1	Easy Navigation	9	209	218	96%
2	Incorporated Historical Data	10	207	217	95%
3	Simplicity of Design	14	204	218	94%
4	High Usability	14	204	218	94%
5	Use of Clear Descriptions	16	201	217	93%
6	Consistency of Data	16	201	217	93%
7	Use of Diverse Chart Types	23	195	218	91%
8	Compliance with Americans with Disabilities (ADA) Act	20	195	215	91%
9	Incorporated User Feedback	21	195	216	91%
10	Mobile Compatibility	23	194	217	89%
11	Comparison data with other entities	26	192	218	88%
12	Storytelling	24	193	217	88%
13	Predictive Analytics with Artificial Intelligence	29	188	217	87%
14	Adjustable Thresholds	33	185	218	85%
15	Charts with Tabulated Data	36	182	218	83%
Total		314	2,945	3,259	90%

Table 3: Results of Health Dashboard Design Survey, 2023 (N=218)

The descriptive statistics for the survey includes the following:

No (0): Mean: 21 Standard Deviation: 8 Minimum: 9 Maximum: 36

Yes (1): Mean: 197 Standard Deviation: 8 Minimum: 182 Maximum: 209

Total Points: Mean: 217 Standard Deviation: 1 Minimum: 215 Maximum: 218

Percent of Agreement: Mean: 91% Standard Deviation: 4% Minimum: 83% Maximum: 96%

The quartile summary for the survey includes the following:

No (0): 25th Percentile: 15; 50th Percentile (Median): 21 ; 75th Percentile: 25

Yes (1): 25th Percentile: 193; 50th Percentile (Median): 195 ; 75th Percentile: 202

Total Points: 25th Percentile: 217; 50th Percentile (Median): 217 ; 75th Percentile: 218

Percent of Agreement: 25th Percentile: 88%; 50th Percentile (Median): 91% ; 75th Percentile: 94%

Below is a description and discussion for each of the top 15 attributes for a healthcare dashboard.

Easy Navigation:

The ability to navigate through various pages and windows of a healthcare dashboard with ease is an essential and top-rated element of a healthcare dashboard. Users of healthcare dashboards should be able to navigate fully throughout the dashboard regardless of education level or background.[14, 15] While reviewing over 250 different healthcare dashboards, it was noted that many of the dashboards were difficult to navigate due to erroneous navigation features such as unclickable links and no scroll bars. We noted that several modifications could be introduced in some of the dashboards regarding the dimensions and positioning of the navigation elements, aligning them more closely with the more efficient dashboards or data services like those found in Apple or Samsung mobile phones. Additionally, a healthcare dashboard should allow a user to hover over a data element to review additional information regarding that element of data, known as a “focus mode” [22] for a data dashboard or website. Easy navigation can be a major key to the success of healthcare dashboards and should be advanced further in many healthcare dashboards. It ranked as the #1 design attribute out of 15 design attributes based on the 218-person survey.

High Usability:

High usability for healthcare dashboards is a key concept for dashboard design. The attribute of high usability can be achieved through faster loading speeds, consistent labeling, simpler layouts, and optimization for multiple devices. Poor responsiveness of the dashboard can negatively affect the perception of the quality and reliability of your dashboard. Using simple, clear, and consistently labeled data with highly readable fonts and text, effective labeling, and avoiding clutter and distortion helps optimize usability. [18, 19, 20]

A good dashboard should have a simple layout with a logical and coherent structure, with a clear hierarchy, flow, and balance. Using grids, white space, borders, and headings to create visual separation and alignment among elements can help create harmony and proportion on the dashboard, helping the user process the information quickly. Finally, healthcare dashboards with high usability should have accurate, clear, and concise information to increase the adoption and use of the dashboard and its information.

Use of Adjustable Thresholds:

An adjustable threshold customizes the level of specificity that a graph or other charts show and makes the dashboard more interactive. The use of interactive and adjustable thresholds is a principal factor to incorporate in healthcare dashboards. They are advantageous as users can interact with the dashboard and modify its parameters through these adjustable thresholds. For example, a short 10-day period may not be able to capture noticeable fluctuations in Covid-19 or Monkeypox cases. [21, 22] Expanding the view, a 90-day threshold for example brings benefits when assessing the dashboard more comprehensively. Incorporating adjustable thresholds based on percentages offers greater flexibility enabling easier and effective evaluation of the data. Transitioning from daily to monthly statistics or changing data trends over an extended period helps improve insights. This method proves significantly more potent, helping streamline data evaluation.

The interactivity of the dashboards makes the experience more intuitive, responsive, and meaningful, allowing the user to filter, drill down, zoom, highlight, and/or compare data as needed.

Use of Diverse Types of Charts:

In a healthcare dashboard, incorporating a diverse set of chart types offers many advantages. To diversify visualization options and expand the scope of the information presented it is important to offer a variety of chart types such as bar, line, and pie charts. Considering the diverse range of dashboard users, the addition of elements other than line charts, such as heat maps, can add variety, and help with comprehension by different user groups. Studies show that users prefer to review various chart types. Additionally, interactive graphs that allow users to explore data from different perspectives can be valuable additions.

Use of Charts with Tabulated Data:

The use of charts with tabulated data can be immensely helpful because it improves data comprehension, enables the ability to see and track trends in the data, and promotes data exploration. Tables allow a deeper dive into the numbers and help examine exact values instead of focusing on approximations or visualizations. For example, displaying the number of illnesses diagnoses over a specific period may be easier to accomplish with a chart by simply showing numbers and locations. However, a tabulated format is more useful when it is necessary to communicate other additional variables as well such as causes, outcomes, and even specifics about length of the illness, number of relapses, and more.

Incorporated User Feedback:

Healthcare dashboards are powerful tools, but they are not static. As a best practice, they should be constantly updated and improved based on feedback from the user.[14] User satisfaction and feedback are important concepts for the design of healthcare dashboards. While the designers of dashboards try to anticipate the concerns of users, it is vital to have a quick and simple system for users to express their suggestions about the dashboard. With a similar system, designers can incorporate feedback into their dashboards and attract more user activity. By utilizing user feedback, designers of healthcare dashboards can optimize the comprehensibility of their information. User feedback provides designers with valuable insights into user perspectives, helping them identify potential enhancements and rendering data more accessible and comprehensive. Designs that incorporate feedback from the user and continuously monitor and evaluate the feedback data help keep the dashboard updated, relevant, and user-friendly.

Simplicity of Design:

Simplicity of Design is a key factor for creating a well-designed healthcare dashboard. Users should be able to navigate any healthcare dashboard easily and effectively. Based on the authors' survey of 218 adults, the design of healthcare dashboards should not be complex. The amount of text on each page should be kept to a minimum and information should be presented simply and concisely. The most important and urgent information should be shown on the first pages while less relevant information should be displayed later. Users should be able to search for more details as they navigate the dashboard. The simplicity of design allows all users, regardless of their age or background, to easily interpret and analyze data.

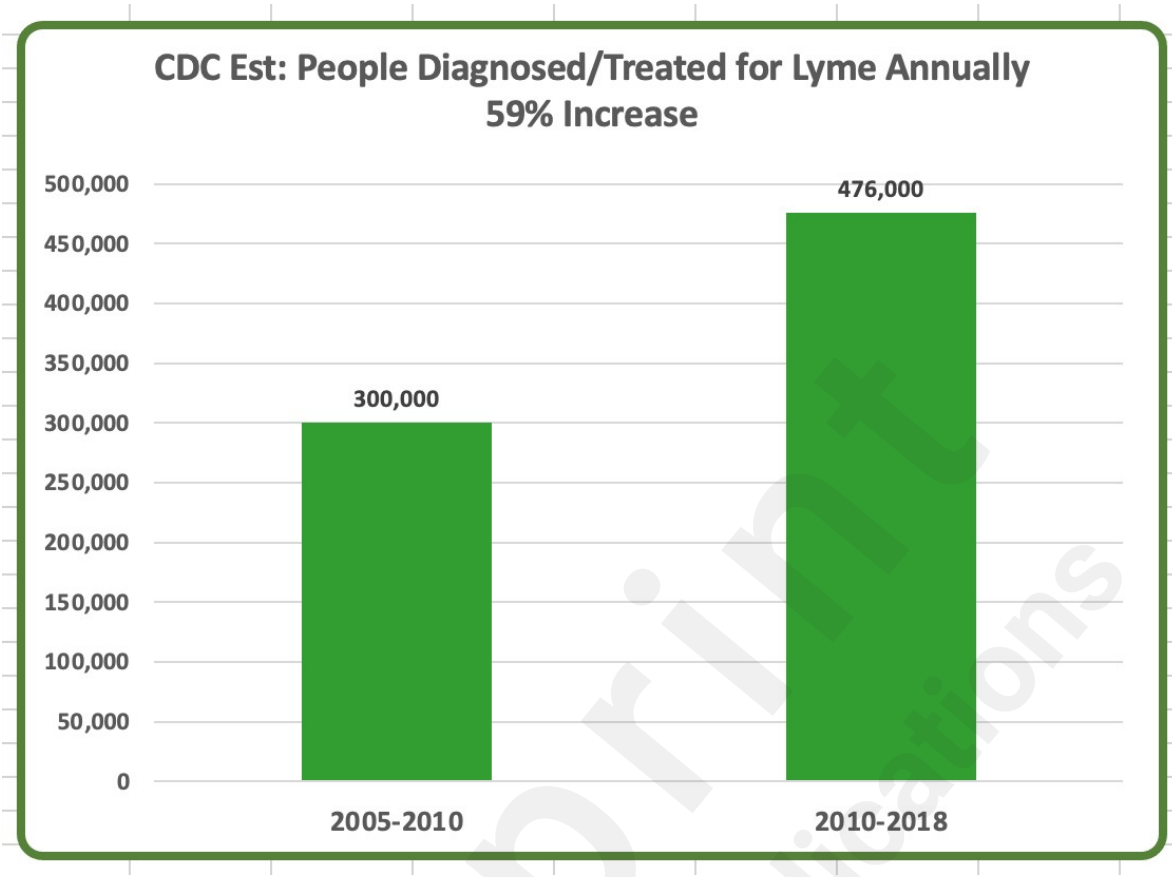

Fig 1: Example for Best Practices for Simplicity of Design [23]

Adding Clear Descriptions for Charts:

Since data displayed in charts can be overwhelming, complicated, or difficult to understand, it is important that there are clear and concise descriptions for charts. Descriptions should be simple, while still getting the information across. With clear axis labels, units, and scales of measure, as well as titles, the users can easily comprehend the data. For example, in Figure 2, there are clear labels for the axes stating what is being compared, as well as obvious differences in scale and a clear title. Through these quick and simple descriptions of the axes, a reader does not waste time trying to interpret the information on their own, as it is displayed in a clear and concise manner.

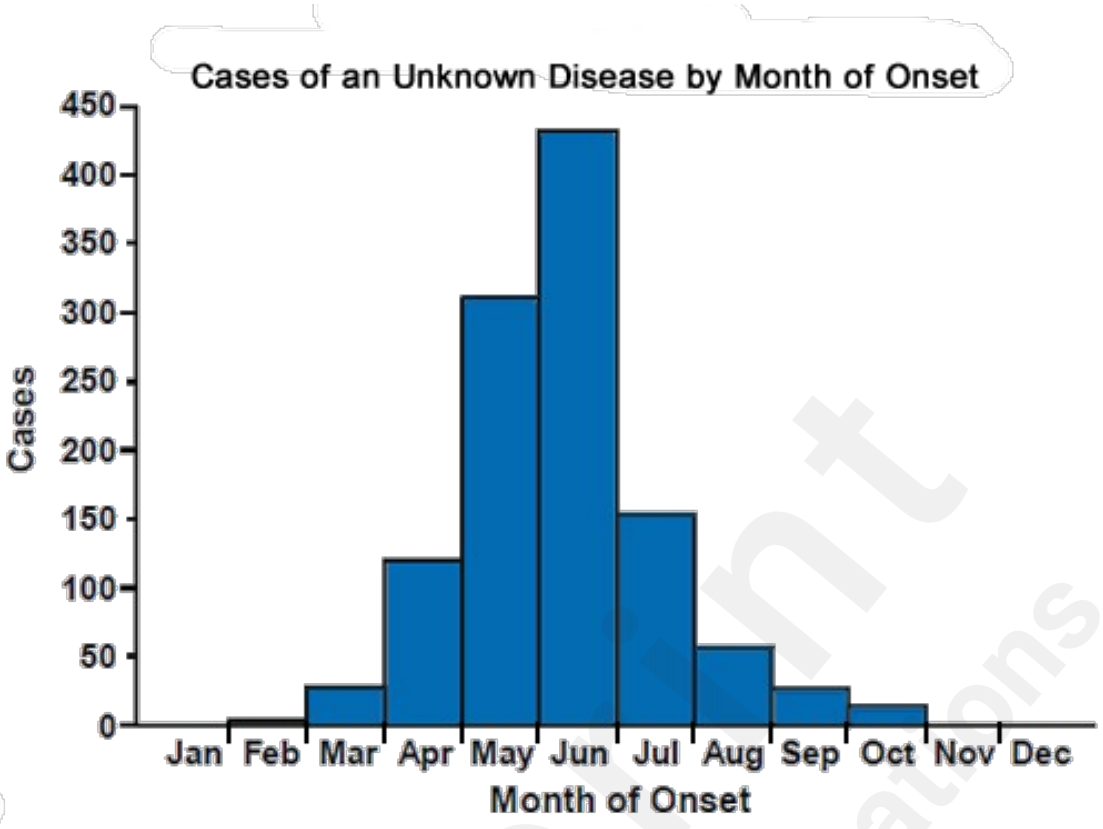

Fig 2: Example for Adding Clear Descriptions for Charts [23]

ADA Compliance:

To ensure equal access to information to all people across the United States, healthcare dashboards should make efforts to abide by the Americans with Disabilities Act (ADA). For example, there are an estimated 300 million people in the world with color vision deficiency and red-green color blindness is the most common form of color blindness [37]. To address this issue, healthcare dashboards should refrain from using red and green colors. The dashboards should make sure that the alerting system is also differentiated in some other way besides color; for example, pairing light and dark colors or light and dark variations of individual colors. Healthcare professional's dashboards should utilize the ADA website to ensure equal access to healthcare dashboards for all people across the United States.

Comparison of data with other entities:

Comparison of data with other reference groups is essential for a healthcare dashboard to be easily read and understood. By comparing and displaying different elements such as demographics users can compare their own experiences with other groups in similar situations, proving a valuable tool towards better comprehension. For example, the number of Monkeypox cases in Canada vs. the United States displayed on a dashboard allows users to understand the prevalence and potential risk of Monkeypox in the context of their own lives and locality. It can also warn or help make educated predictions about what could potentially arise in the future due to the number of cases or deaths in a neighboring area. Dashboards are intended to inform the public about information that should help them make informed decisions not only about the current situation but also the future.

Historical data:

Comparison to historical data on a healthcare dashboard is highly effective because it allows for meaningful comparisons in terms of any changes. Providing historical data on healthcare dashboards will enable users to identify and analyze specific trends and patterns to make their own decisions based on past experiences. Being able to track data throughout the years and using it to make future decisions makes historical data important in a variety of healthcare-related situations.

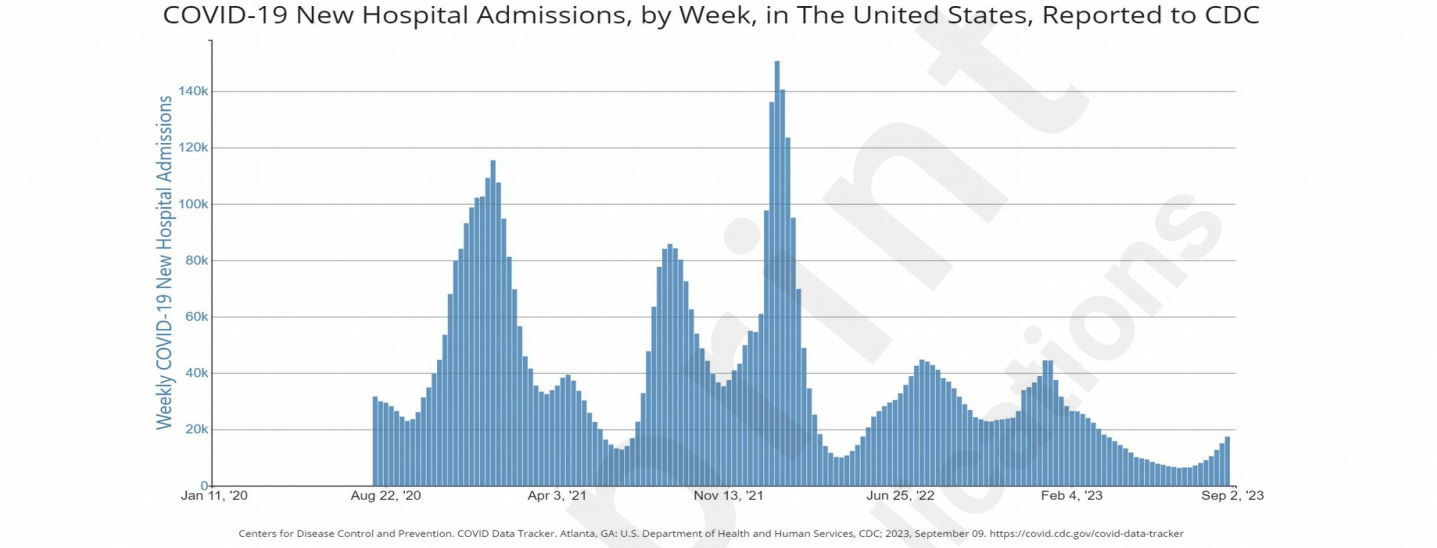

Fig 3: Example for Historical data - comparison to previous data [23]

Storytelling:

When presenting data, storytelling is vital for building relevance and aiding in comprehension. When a person reviews a chart or selection of data in a limited and isolated manner it can lead to a lack of comprehension. Converting the data within the context of the background helps create a narrative helping in relevance and comprehension. For example, a story can be presented through points on the graph, explaining a particular event and why it affected the data, or through creating a section outside of the data to explain all factors that could have created trends that were shown. Through storytelling, a viewer can fully grasp and better understand the information. It also helps create a “timeline” of events, as well as a link to future events or actions that may affect the data in question.

Consistency of Data:

The consistency of data in healthcare dashboards is crucial for accurate and reliable information. Consistency refers to the quality of the data and in reference to data being accurate, uniform, dependable, and up to date throughout. Maintaining consistency ensures that the data presented on the dashboard is trustworthy and can be used for informed decisions. Throughout healthcare dashboards, data is collected from complicated systems and sources, and consistency becomes one of the most crucial factors to help in comprehension. As an example, consistency

should be shown through the different axes of the charts having the same scale of measure. Consistency of data enables healthcare professionals, policymakers, and researchers to analyze trends and make informed decisions based on accurate, comparable, and reasonable data. Most importantly the consistency of data in healthcare dashboards affirms the credibility of the information provided and improves the effectiveness of the data.

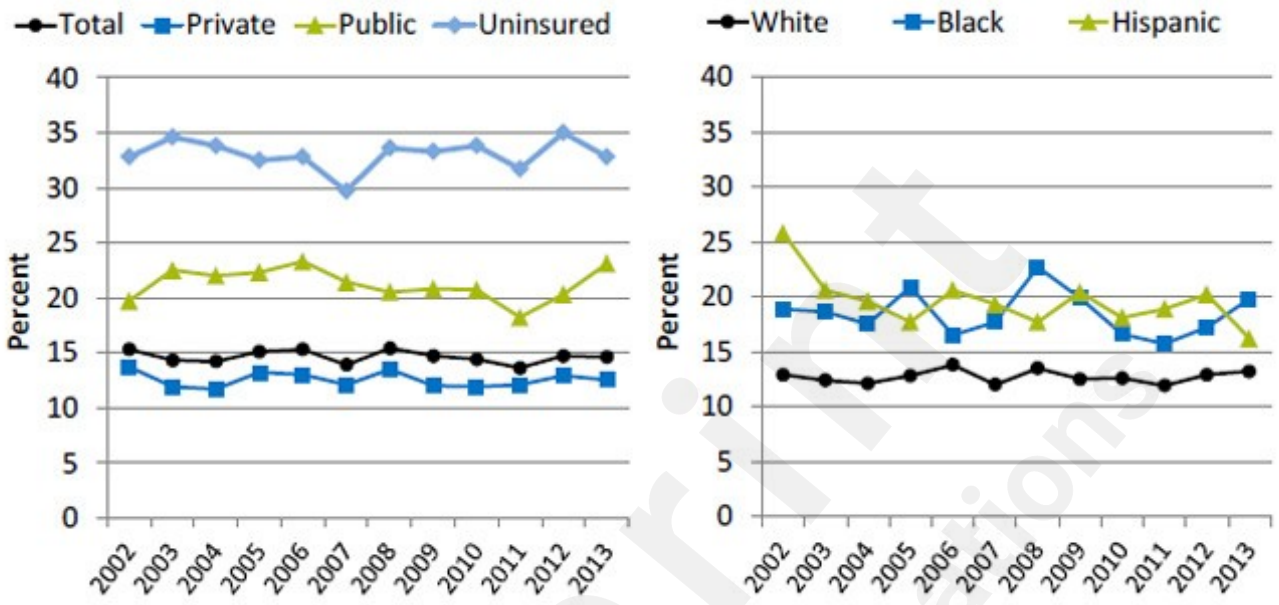

Fig 4: Example for Consistency of Data [24]

Predictive Analytics with Artificial Intelligence:

As our world continues to develop, predictive analytics based on artificial intelligence (AI) technology is increasingly relevant and beneficial. It is only fitting that predictive analytics using AI should be applied to the field of healthcare informatics research. If the user can input certain individual parameters, the dashboards should be able to provide predictive analytics for any parameter or question. Using predictive analytics, analysts can examine how data trends may fare in the future, and a user can review a detailed example of future data.[25] Predictive analytics of potential future trends are important for dashboards and data as they allow users to make decisions for themselves beyond the expectation of a linear trend. When viewing data for even a few past years, consumers assume linear trends and make predictions based on their perception of what data will look like in the future. Performing a similar analysis with predictive analytics with AI will provide more accurate predictions and allow people to make better medical decisions.

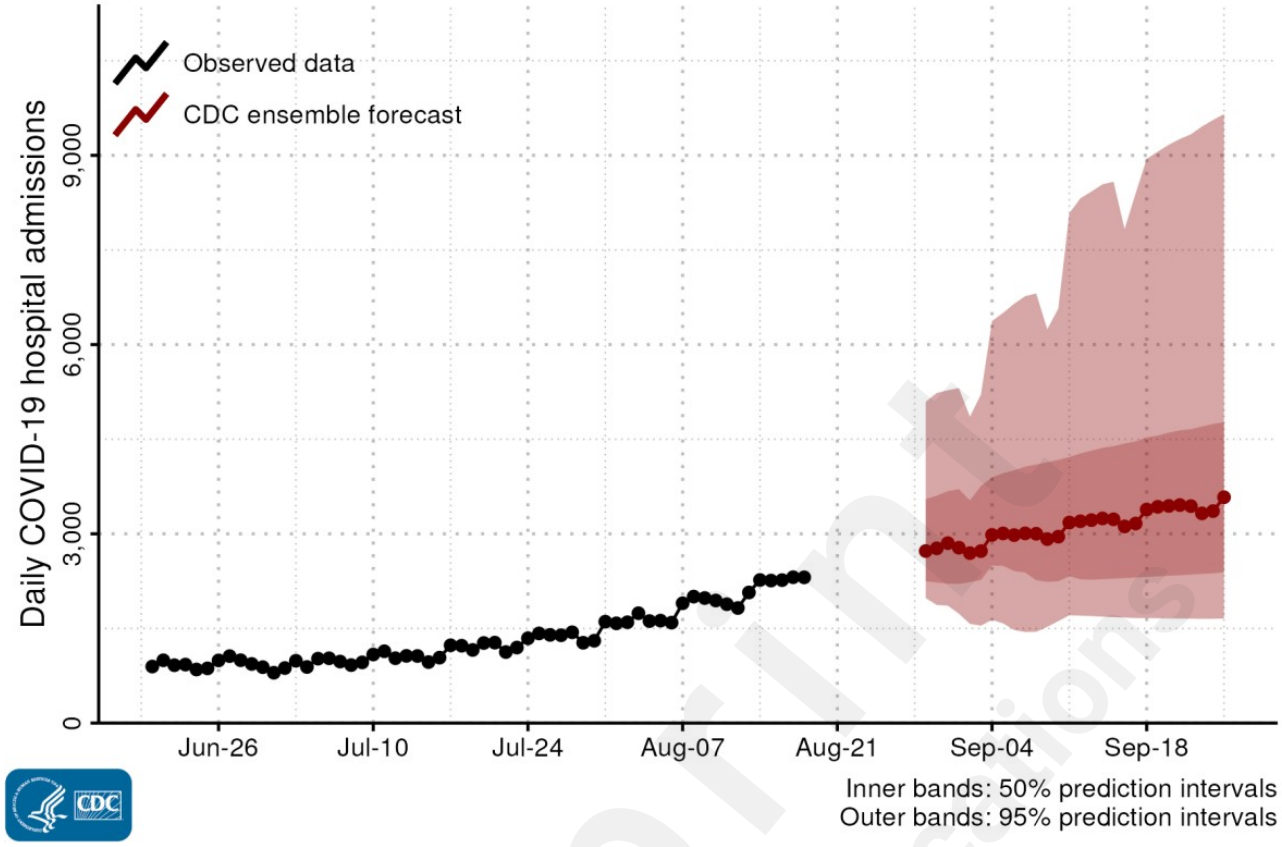

Fig 5: Example for Predictive Analytics with Artificial Intelligence [23]

Mobile compatibility:

The best healthcare dashboards are designed with mobile compatibility. Health informaticians increasingly aim to make healthcare dashboards accessible and usable on diverse types of devices. Mobile compatibility is important given that most users spend a great deal of time viewing and accessing information on their mobile devices. Mobile compatibility is important for three reasons. Foremost, mobile compatibility empowers users with the ability to access critical data anytime and anywhere allowing real-time data tracking, timely updates, and retrieval. Secondly, mobile compatibility ensures that charts and graphs seamlessly adjust to the screen dimensions of the user's device. This adaptation optimizes data visualization and user experience by presenting data in an easily comprehensible format, regardless of the screen size. Lastly, mobile compatibility enables healthcare dashboards to leverage the unique functionalities of different devices. For instance, when data is accessed on a smartphone, these dashboards can employ features like 'push notifications' to provide users with instant updates and keep them informed about the latest healthcare information. Given the widespread use of mobile devices in society, it is imperative to publish healthcare dashboards compatible with a range of devices, from large public displays to compact cell phones, thereby promoting broader accessibility to healthcare data.

Discussion:

Health dashboards are an important part of the health-data world which provides insight into health information through easily accessible images, charts, and representations. We found that the top 5 most important design attributes for an effective healthcare dashboard are easy navigation, simplicity of design, high usability, use of clear descriptions, and use of diverse chart types.

The results from this research produce the top 15 design attributes for an effective healthcare dashboard. As healthcare dashboards are better designed, the idea is that the public will make better informed healthcare decisions which will in turn increase healthcare outcomes.

These specific 15 design attributes have been generally discussed in prior literature for healthcare dashboards, but this is the first time they have been specifically identified for healthcare dashboards. Similar studies have supported this overall research stream but do not compete with or overlap with these results.

AI generated dashboards in specific may have certain ethical biases that would lead to potentially incorrect conclusions by the public. The user of the dashboard should be informed if AI has been utilized in predictive analytics for example and the characteristics of the data (i.e., size, type, kind, location) should be available for the user to access to address the ethical concerns about the use of AI in healthcare.

Limitations:

Over 70% of the study's participants were from the 3 US States including Maryland, West Virginia, and Virginia. The study therefore is limited as far as the generalizability across the entire United States. Further, with only 218 participants the study could have had a greater impact if it were for example over 1,000 participants with at least 5 to 10 participants per State. Beyond the number and location of the participants, this study is limited in scope as it is based on self-reporting by the public for what they consider positive dashboard design. It does not measure whether a better dashboard design, for example, results in a better actual healthcare decision. Beyond these limitations, this study is important as it attempts to quantify the top 15 elements of healthcare dashboard design which is undocumented in this context in prior literature.

Conclusion:

As technology evolves, the availability of resources and data has become increasingly easier and better. With a click or a quick search, consumers have access to an abundance of healthcare data and data dashboards which aid in making informed healthcare decisions. However, healthcare dashboards may not be of the highest quality or as easily understood. Through our observational review and multiple surveys, we evaluated the effectiveness of healthcare dashboards in the United States to better understand and improve their design elements. From our analysis, we were able to develop and confirm the top 15 best practices of healthcare dashboard design from the ease of navigation to the use of predictive analytics. These 15 top best practices were assessed as the most important aspects of a healthcare dashboard's effectiveness. The studies validated and concluded that the top five attributes of healthcare dashboards, such as easy navigation, simplicity of design, high usability, use of clear descriptions, and use of diverse chart types. As identified and analyzed, best practices can be incorporated in order to design and disseminate effective healthcare dashboards making valuable healthcare information available to the public. The availability of better healthcare dashboards will help consumers make better and more informed healthcare decisions resulting in better healthcare outcomes.

Declaration of Interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Generative AI disclosure:

Generative AI was not utilized in any way in the development of this manuscript.

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