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Research Paper

Investigating Graphical User Interfaces for Covid-19 Dashboards

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ABSTRACT: *Web-based public reporting by means of dashboards became an essential tool for governments worldwide to monitor COVID-19 information and communicate it to the public during the pandemic. The purpose of such dashboards was to deliver specific information that individuals needed. There was a significant usability requirement, were the correct information needed to be placed onto the display at the right time and in a manner that could be easily understood. This paper assesses a number of popular dashboards and provides guidelines on improvements for future use.*
KEYWORDS: *Human-Computer Interaction, Usability, COVID-19, Dashboards, Interface*

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I. LITERATURE REVIEW

It is common to think of statistical design and information visualization as relatively modern improvements in statistics. In fact, the realistic representation of quantitative data has profound roots. These roots reach into the histories of the earliest map-making and visual depiction, and later into topical cartography, statistics, statistical design, pharmaceutical, and other areas [1,2]. The perfect example of an early data visualization was John Snow's Cholera Map. John Snow was an English doctor who lived in the 19th century, who is known among the data visualization community for his outline portraying deaths in Soho from the cholera outbreak of 1854. Unlike his contemporaries, John Snow accepted cholera was transmitted through contaminated sources of water instead of through the air and he managed to demonstrate his point through his now-famous map [1]. After the cholera outbreak on Broad Road in 1854, he plotted deaths and found that most of them had happened near an open water pump. Many of the things Snow did when he builds his map were not new, the novelty was the association between the graphic representation and the search for a logical clarification for the cause of the illness. Without visualizing the information on a map, it would have been difficult to realize that most cholera deaths were clustered around a single pump [1,3,4].

1.1 Data Visualization

Over the past decade, data visualization tools have undergone a remarkable transformation, propelled by advancements in technology and the increasing demand for data-driven decision-making. The proliferation of data in various sectors, from business to healthcare, has necessitated more sophisticated and user-friendly tools to analyze and present information effectively. Modern data visualization tools have revolutionized the way data is interpreted, enabling users to transform complex datasets into intuitive and interactive visual representations. These tools not only enhance the clarity and impact of data presentations but also facilitate real-time data exploration, making it easier for stakeholders to uncover insights and trends quickly [5,6].

Data analysis is the process of analyzing data in various formats. Even though data is abundant nowadays, it is often available in different forms and scattered over various sources [7]. Data needs to be cleaned and transformed into a consistent form so it can be effectively studied and analyzed [8].

Comparative analyses are conducted to explain and gain a better understanding of the causal processes involved in the creation of an event. Comparison of two data sets can measure the relationships between factors over two or more detailed periods. Comparison of data acts as a viable and easy-to-use data to higher order of thinking which improves comprehension by highlighting vital details, making theoretical ideas more concrete, and reducing the confusion between related concepts [9].

The exponential growth in data analytics and visualization tools is partially due to the way that they assist operational decision-makers, ensuring they are not overwhelmed by too much information. In the last

decade dashboards have become a valuable interface allowing users to interactively process and analyze their data [5,6].

1.2 Dashboard Interfaces

The COVID-19 pandemic that emerged in 2019 was caused by the infection of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Governments worldwide were forced to take measures that impacted the lives of millions of individuals to protect the health of their citizens. Making the right COVID-19 policy decisions required a balanced trade-off between protecting the population from infection and its consequences and ensuring that non-COVID-19 care needs were met [10].

Web-based public reporting by means of dashboards became an essential tool for monitoring COVID-19 information and communicating it to the public [11]. Many researchers admit that during the pandemic dashboards became the most important tool of health data visualization [12].

Moreover, dashboards were also used to support individuals in informed decision making, for instance to educate citizens on whether they need to adapt their behaviors to minimize individual and population risk. Casual users can quickly check information visualization dashboards, getting a high-level view of key information focuses without having to sort through spreadsheets, graphs, or records for the answers to basic questions. Dashboards became a powerful communication tool, and they were also frequently used by the media as key information sources. If, however, dashboard information is inaccurate, it could produce undesirable effects, such as misleading perceptions, stress, or anxiety [13].

In mid-2020, an international network of performance intelligence researchers carried out a global study to assess the actionability of 158 COVID-19 dashboards at international, national, and regional levels in 53 countries worldwide [14]. The study highlighted how dashboards were updated and modified in response to the evolving pandemic. An international panel of experts evaluated the dashboards and emphasized the importance of having dashboards that are both fit for purpose (meeting specific information needs) and fit for use (placing the right information into the right hands at the right time). They also concluded that data availability and dashboard technology experienced the most improvements. However, no improvements were found in communicative elements [14].

One research study undertook a systemic review of the diverse data visualization methods that can be used on dashboards within the open health division. The study examined data interpretation and showed that color-coding was common though only one-fifth of the dashboards. Few of the dashboards contained content explaining the quality and meaning of the information presented. In total, 20/158 dashboards were evaluated as profoundly lacking as competent interfaces [12,15]. One particularly notable, actionable feature of the interface included reducing the density of the display of numeric information which caused usability issues, where users were unable to access information [12].

Accessibility and usability are essential in dashboard design. There are many guidelines available, such as the Web Content Accessibility Guidelines (WCAG, which are widely used to ensure web interfaces are accessible and usable [16]. A recent study evaluated the usability of the John Hopkins University (JHU) COVID-19 vaccine dashboard, this particular study used the Web Availability Assessment Tool (WAVE) [17]. WAVE distinguishes site openness boundaries, counting deficiently differentiate, alternative text, unlabeled buttons, the total number of errors, and the mistake density. The study highlighted the barriers people with disabilities may experience when trying to access data, and registering for the COVID-19 vaccine. This underscores the inequities in the pandemic reaction to the disability community and the need to prioritize accessibility of open health data [17].

II. EXPERIMENTAL METHODOLOGY

The Bing COVID-19 dashboard[1] and John Hopkins University (JHU) COVID-19 dashboard[2] were launched in early 2020. They were designed to help people stay informed about the pandemic by providing up-to-date information on case locations, infection prevention, and more [18]. These dashboards were continuously evolving, using feedback from expert panels and from surveys among the public, and were widely used throughout the pandemic [15]. This is why these dashboards were chosen as the case studies in this research project.

This study attempts to evaluate how the Bing and JHU COVID-19 dashboards developed from their launch, and to assess their actionability, and to understand what factors guided decisions during each of the dashboard's development. This study identifies design irregularities, usability issues, and key deterrents experiences by users of both the Bing and JHU COVID-19 dashboards.

The overall aim of this study was to improve both dashboard's usability to enhance public understanding of future pandemics. Experiments were undertaken to assess ease with which users can utilize the

[1] The Bing COVID-19 dashboard was developed by Microsoft, and launched in March 2020
[2] The JHU COVID-19 dashboard development was led by the Ministry of Health, Welfare and Sport, and launched in January 2020

native dashboard interfaces to complete basic tasks finding information on COVID-19 cases or vaccination number.

Experimental metrics included determining the different interactions participants had when using the two dashboards to perform activities such as finding individual county cases, listing vaccine data by county, asking questions about testing, checking the Pandemic Data Initiative, and getting the news related to COVID-19 and the virus variants.

A secondary goal of this study involved understanding the baseline user performance, accessibility, and satisfaction levels of users with both COVID-19 dashboards. Finally, a determination was made as to which dashboard had the more usable interface.

These objectives translated into the following research hypothesis:

- How did the Bing and JHU COVID-19 dashboards change over the course of the pandemic ?
- Are there usability issues with the Bing and JHU COVID-19 dashboards ?
- Which COVID-19 dashboard is more convenient for users to find information ?

2.1 Participants

A total of 16 participants were involved in this usability test. Participants were recruited through convenience sampling, carried out among students from the State University of New York (SUNY) at Oswego. Participants were asked if they would like to participate in a usability test and if so, a one hour experimental session was scheduled.

2.2 Experimental Tasks

During each hour-long experimental session, participants were asked to complete five tasks on each of the dashboards (Bing and JHU). These tasks were designed to simulate an average user's dashboard experience. All experimental test sessions were scripted to ensure conformity. Formal experimental guidelines were used to guide participants to successfully complete the tasks, interact with the interface, and provide feedback on their experience. This ensured that participants could not spend longer than twenty minutes on each task.

A range of demographic data was collected in pre-test questionnaires, which were used to assess the participant's familiarity, and previous experience, with the two dashboards. After the participant's completed each task, the evaluator would write down the pathway(s) to complete the task, determine the success rate of the task, count the number of errors made, time on task, and make any other notes and observations. A screen recorder was used to determine the number of errors and pathways for the usability testing. At the end of each experimental session a Likert scale (strongly disagree to strongly agree) post-test questionnaire was completed by the participants.

The five tasks undertaken by the participants on each dashboard were as follows :

1. *Jenny wants to travel Maldives for vacation, so she needs to explore the most vital information about how COVID-19 has affected the Maldives in past 90 days.*
2. *Ralph is currently living in the Boston area, and he wants to know Massachusetts' State vaccination progress for his safety.*
3. *Find resources and expert guidance for tracing the COVID-19 pandemic*
4. *Determine the hospital capacity for Indiana state.*
5. *How to get testing results from the COVID-19 testing tool kit.*

2.3 Experimental Metrics

A range of data was collected in pre-test questionnaires regarding the participant's previous experience with COVID-19 dashboards. This included questions on how long participants had used any dashboards, which dashboards they had used, recent activity, and their thoughts about the current dashboards. The participants were also asked how much they trusted the information presented in the dashboard interfaces.

2.3.1 Task Pathway

A screen recorder was used to determine the pathways taken through each task by each participant. This included recording where the participant clicked on the interface, i.e which menu/tab/link/icon/image the participant selected in which order.

2.3.2 Success Rate

In this experiment, the success rate is defined as the percentage of tasks participants completed successfully. The success rate metric is measured by observing the participants performing each task and accordingly determining if the task was completed. The success rate for each task was rated into three levels :

0- Not Completed,
1- Completed with difficulty or help, and
2- Easily completed.

If the participant could complete the task with ease, then the success rate was rated as 2. However, if the participant struggled to complete the task by asking for help, or randomly clicking on items, then the success rate is 1. If the task was still unfinished after the maximum task completion time (20 minutes), the participants failed to complete the task, and the success rate is 0.

2.3.3 Error Rate

Errors, in the context of this experiment, were defined as any click the participants made while performing the requested task that caused the efficiency to decrease, or the performance and time needed to complete the task to increase. For example, if a participant were trying to find the weekly change of the positive COVID-19 cases. During this task the participant could make many clicks on the interface in unrelated sections of the dashboard. For each erroneous click the participant makes, the error rate for this task is increased by one. The error rate for each task is the summation of the total error clicks divided by the number of participants

2.3.4 Time on Task

Time on task is the amount of time (in seconds) needed for each participant to complete each task. Once the observer had finished explaining the task to the participant and the participant had started interacting with the website, then the start time is recorded. As soon as the participant indicates that they had completed the task, then the observer recorded the end time for this task.

2.3.5 Task Based Efficiency

Task-based efficiency is a measure of the amount of effort a participant expended to complete a task over its time on task. Using the screen recorder, the number of clicks that a participant made to complete a specific task could be recorded. The number of clicks is used in this context as an indication of the effort expended by the participant to complete the task. Therefore, task efficiency is equal to the number of clicks divided by the task completion time. It is important to note that the number of clicks also includes any error clicks made by the participant. Hence, task based efficiency will be calculated using equation 1.

EQUATION 1: TASK EFFICIENCY EQUATION

$$Task\ efficiency = \frac{Total\ number\ of clicks}{Task\ completion\ time}\ X\ 100\%$$

2.3.6 Time Based Efficiency

To calculate the overall efficiency of all tasks over time, time based efficiency will be calculated using equation 2.

EQUATION 2: TIME-BASED EFFICIENCY

$$\mathbf{Time - based\ efficiency} = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N}\frac{nij}{tij}}{NR}\ \mathbf{X\ 100\%}$$

Where:

N = The total number of tasks (goals)
R = The number of users
n_{ij} = The result of task i by user j; if the user completes the task, then N_{ij} = 1; if not, then N_{ij} = 0
t_{ij} = The time spent by user j to complete task i. If the task is not completed, then time is measured till the moment the user quits the task.

2.3.7 Usability Metrics

At the end of each experimental session post-test questionnaire was completed by the participants. The survey used Likert scales to obtain a measure of the some of the main usability metrics : usefulness, ease of use, satisfaction, learnability, feedback, accessibility, and information architecture [19, 20]

Table 1 contains a list of the questions from the experimental post-test questionnaire, and the associated usability metric to which it relates.

Table 1. Likert scale prompts from the post-test questionnaire and associated usability metrics

Lickert Scale Prompts from the Post-Test Questionnaire	Associated Usability Metrics
I think that I would use this dashboard frequently	Usefulness
It was simple to use this dashboard	Ease of Use
I think I would need additional support to use this dashboard	Ease of Use
I am comfortable using this dashboard	Satisfaction
I needed to learn a lot of things before I could get going with this dashboard	Learnability
I would imagine that most people learn to use this dashboard very quickly	Learnability
If I made a mistake, it was easy to fix	Feedback
It is easy to find the information that I need	Accessibility
The information provided on the dashboard helped me complete the tasks	Information Architecture
Overall, I am satisfied with this dashboard	Satisfaction

III. EXPERIMENTAL RESULTS – JHU DASHBOARD

Eight of the participants, half of the participant group, attempted the five experimental tasks on the JHU dashboard. In this section, the results of the following performance metrics: success rate, time-on-task, error rate, and efficiency, are reported and analyzed. A qualitative methodology was used to examine the results with a comparative analysis.

3.1 Success Rate

Table 2 shows the overall success rate for completion of the five tasks by the eight participants on the JHU dashboard. All participants successfully completed all tasks. Therefore, the system is 100% effective, although the participants and tasks varied greatly in efficiency measurements.

Table 2. Success rate data for the eight participants undertaking five tasks on the JHU dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	2	1	1	2	2
2	2	2	1	2	2
3	1	2	2	2	2
4	2	1	1	2	2
5	2	2	1	2	2
6	2	2	2	2	2
7	2	2	1	2	1
8	2	2	2	2	2
Note : 0 = Not Completed; 1 = Completed with Help or Difficulty; 2 = Easily Completed					

The data in Figure 1 clearly shows that the Task 1, Task 4, and Task 5 were easily completed by almost all of the participants. Conversely, Task 3 recorded the highest number of participants who required assistance to complete it (62.5%). Only two of the participants needed help with Task 2 (25%)

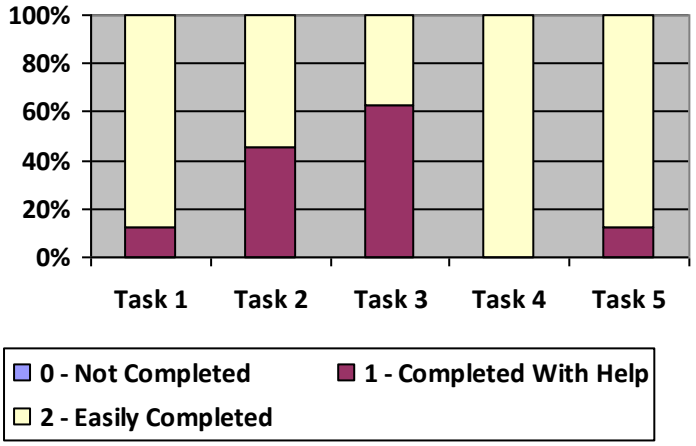

Figure 1. Success rate percentages for the eight participants undertaking five tasks on the JHU dashboard

3.2 Time on Task

Table 3 shows the time on task for completion of the five tasks by the eight participants on the JHU dashboard. All participants successfully completed all tasks.

Table 3. Time on task for the eight participants undertaking five tasks on the JHU dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	60	120	180	30	60
2	30	60	35	5	10
3	84	49	70	3	449
4	60	60	60	7	60
5	67	18	174	14	32
6	16	9	98	3	124
7	120	210	180	30	60
8	90	180	5	10	55
Mean	**65.9**	**88.2**	**100.2**	**12.7**	**106.2**
Note : All times are in seconds					

As can be seen in Figure 2, Task 4 took the shortest time to complete, with an average time on task of 13 seconds. Task 5 took the longest time to complete, with an average time on task of 106 seconds. Therefore, the average time required to complete all five tasks was approximately 6 minutes (360 seconds).

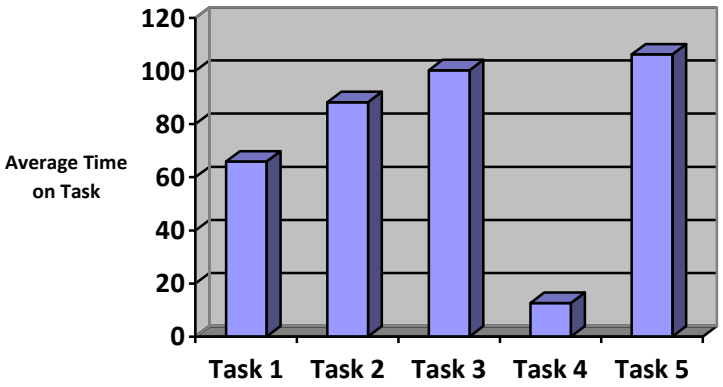

Figure 2. Time on task for the eight participants undertaking five tasks on the JHU dashboard

3.3 Error Rate

Table 4 shows the error rate for completion of the five tasks by the eight participants on the JHU dashboard. All participants successfully completed all tasks.

Table 4. Error Rate for the eight participants undertaking five tasks on the JHU dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	0	0	2	0	0
2	0	0	0	0	0
3	1	1	0	0	7
4	1	0	1	0	1
5	0	0	5	0	0
6	0	0	1	0	6
7	0	0	1	0	0
8	0	0	3	0	0
Error Rate	**25 %**	**12.5 %**	**162.5 %**	**0 %**	**175 %**

The results shown in Figure 3 indicate that Task 3 and Task 5 have the highest error rates of 162.5% and 175% respectively. None of the participants made any errors while performing Task 4. Task 1 and Task 2 also recorded relatively low error rates of less than 30%.

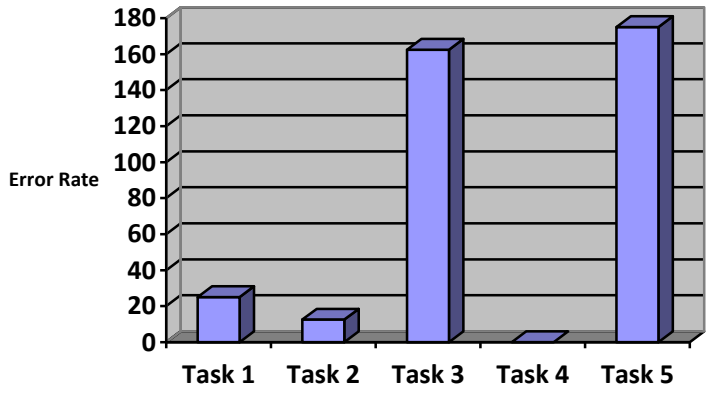

Figure 3. Error rate for the eight participants undertaking five tasks on the JHU dashboard

3.4 Task Efficiency

Table 5 shows the task efficiency for completion of the five tasks by the eight participants on the JHU dashboard. All participants successfully completed all tasks.

Table 5. Task Efficiency for the eight participants undertaking five tasks on the JHU dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	0.22	0.12	0.09	0.07	0.07
2	0.23	0.16	0.20	0.40	0.40
3	0.07	0.14	0.07	1.00	0.09
4	0.08	0.03	0.10	0.14	0.07
5	0.06	0.11	0.06	0.07	0.13
6	0.19	0.12	0.05	0.39	0.08
7	0.03	0.06	0.02	0.06	0.05
8	0.13	0.06	0.05	0.10	0.07
Task Efficiency	**13.6 %**	**10.1 %**	**8.0 %**	**29.0 %**	**12.0 %**

As shown in Figure 4, the task efficiency for all five tasks is under 30%. Task 5 is the most efficient with a 29% efficiency rating, and Task 3 is the least efficient at 8%.

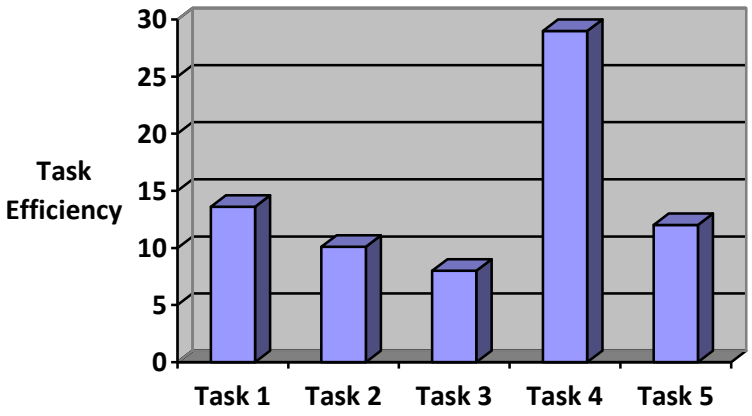

Figure 4. Task efficiency for the eight participants undertaking five tasks on the JHU dashboard

As a further efficiency analysis, time-based efficiency was also calculated using Equation 2 from the methodology section. The time-based efficiency for all tasks is equal to **5.5%**. Hence, the conclusion is that overall task based efficiency metric on the JHU dashboard is very low, i.e. the dashboard is efficient to use.

3.5 Post-Test Data Collection

After the experimental session was completed, participants rated the JHU dashboard on five measures: usefulness, ease of use, satisfaction, learnability, feedback, accessibility, and information architecture. Table 6 shows the ten Likert style questions with their corresponding measurements.

Table 6. Likert scale percentage agreement from the post-test questionnaire (JHU dashboard)

Lickert Scale Prompts from the Post-Test Questionnaire	Percent Agree
I think that I would use this dashboard frequently	87.5 %
It was simple to use this dashboard	87.5 %
I think I would need additional support to use this dashboard	25.0 %
I am comfortable using this dashboard	75.0 %
I needed to learn a lot of things before I could get going with this dashboard	0.0 %
I would imagine that most people learn to use this dashboard very quickly	100.0 %
If I made a mistake, it was easy to fix	63.0 %
It is easy to find the information that I need	63.0 %
The information provided on the dashboard helped me complete the tasks	63.0 %
Overall, I am satisfied with this dashboard	87.5 %

Based on the results displayed in Table 6, most of the participants (87.5 % or higher) agreed (agree or strongly agree) that the JHU dashboard is useful, easy to use, and satisfying. Also, all the participants agreed that they could easily learn how to interact with the dashboard without any prior knowledge. Approximately 60% of the participants stated that the information structure is well organized and highly accessible, and the feedback process made it easier to interact with the JHU dashboard.

IV. EXPERIMENTAL RESULTS – BING DASHBOARD

Eight of the participants, half of the participant group, attempted the five experimental tasks on the Bing dashboard. In this section, the results of the following performance metrics: success rate, time-on-task, error rate, and efficiency, are reported and analyzed. A qualitative methodology was used to examine the results with a comparative analysis.

4.1 Success Rate

Table 7 shows the overall success rate for completion of the five tasks by the eight participants on the Bing dashboard. All participants successfully completed all tasks. Therefore, the system is 100% effective, although the participants and tasks varied greatly in efficiency measurements.

Table 7. Success rate data for the eight participants undertaking five tasks on the Bing dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	2	1	1	2	2
2	2	2	2	2	2
3	2	2	1	1	2
4	2	1	2	2	2
5	2	2	1	2	2
6	2	2	1	1	2
7	2	2	1	1	2
8	1	2	2	2	2
Note : 0 = Not Completed; 1 = Completed with Help or Difficulty; 2 = Easily Completed					

The data in Figure 5 clearly shows that Task 1 and Task 5 were easily completed by almost all of the participants. Conversely, Task 3 recorded the highest number of participants who required assistance to complete it (62.5%). Two of the participants needed help with Task 2 (25%), and three needed help with Task 4 (37.5%).

4.2 Time on Task

Table 8 shows the time on task for completion of the five tasks by the eight participants on the Bing dashboard. All participants successfully completed all tasks.

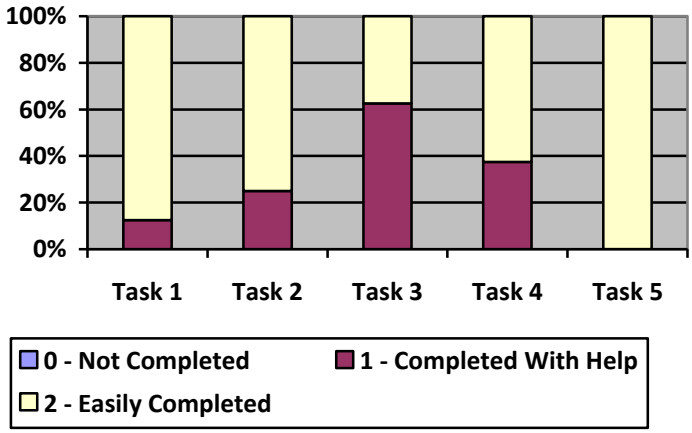

Figure 5. Success rate percentages for the eight participants undertaking five tasks on the Bing dashboard

Table 8. Time on task for the eight participants undertaking five tasks on the Bing dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	60	120	49	70	30
2	30	60	120	132	5
3	75	49	103	98	3
4	60	60	60	106	7
5	67	18	78	150	14
6	16	9	105	83	3
7	70	103	86	145	30
8	97	60	57	140	10
Mean	**59.4**	**59.8**	**82.3**	**115.5**	**12.7**
Note : All times are in seconds					

As can be seen in Figure 2, Task 5 took the shortest time to complete, with an average time on task of 13 seconds. Task 4 took the longest time to complete, with an average time on task of 115 seconds. Therefore, the average time required to complete all five tasks was approximately 4 minutes (240 seconds).

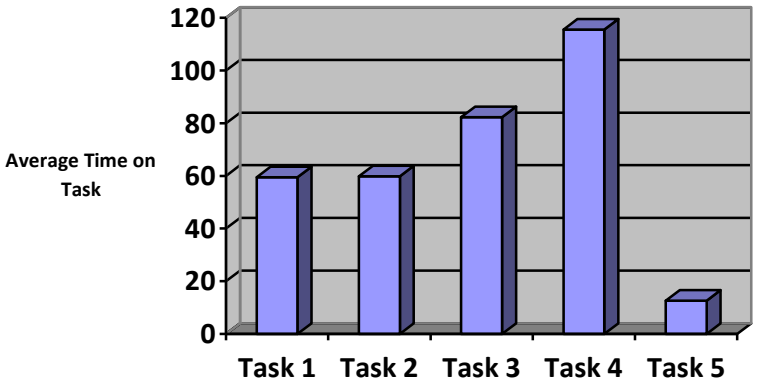

Figure 6. Time on task for the eight participants undertaking five tasks on the Bing dashboard

4.3 Error Rate

Table 9 shows the error rate for completion of the five tasks by the eight participants on the Bing dashboard. All participants successfully completed all tasks.

Table 9. Error Rate for the eight participants undertaking five tasks on the Bing dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	0	2	2	2	0
2	0	0	1	2	0
3	1	1	0	3	0
4	1	0	2	1	0
5	0	0	2	3	0
6	1	0	1	6	0
7	0	1	1	0	0
8	0	0	0	4	0
Error Rate	**37.5 %**	**50.0 %**	**112.5 %**	**262.5 %**	**0.0 %**

The results shown in Figure 7 indicate that Task 3 and Task 4 have the highest error rates of 112.5% and 262.5% respectively. None of the participants made any errors while performing Task 5. Task 1 and Task 2 also recorded relatively low error rates of less than 50%.

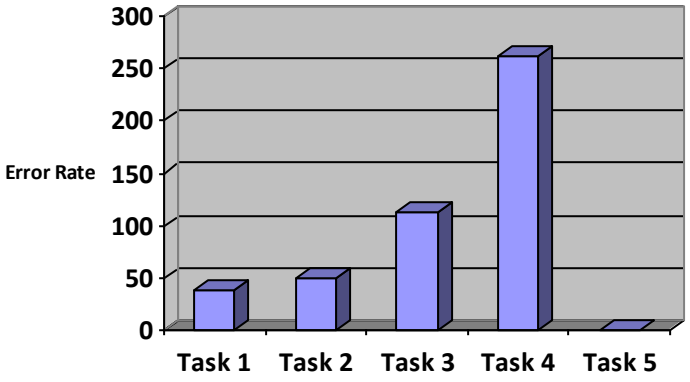

Figure 7. Error Rate for the eight participants undertaking five tasks on the Bing dashboard

4.4 Task Efficiency

Table 10 shows the task efficiency for completion of the five tasks by the eight participants on the Bing dashboard. All participants successfully completed all tasks.

Table 10. Task Efficiency for the eight participants undertaking five tasks on the Bing dashboard

Participant	Task 1	Task 2	Task 3	Task 4	Task 5
1	0.07	0.22	0.12	0.09	0.06
2	0.70	0.23	0.16	0.20	0.40
3	0.07	0.07	0.14	0.07	1.00
4	0.07	0.08	0.05	0.10	0.17
5	0.10	0.07	0.11	0.06	0.07
6	0.08	0.19	0.12	0.05	0.90
7	0.05	0.03	0.06	0.02	0.05
8	0.07	0.13	0.08	0.05	0.10
Task Efficiency	**15.1 %**	**13.0 %**	**10.5 %**	**8.0 %**	**35.0 %**

As shown in Figure 8, the task efficiency for all five tasks is under 35%. Task 5 is the most efficient with a 35% efficiency rating, and Task 4 is the least efficient at 8%.

As a further efficiency analysis, time-based efficiency was also calculated using Equation 2 from the methodology section. The time-based efficiency for all tasks is equal to **4.3%**. Hence, the conclusion is that overall task based efficiency metric on the Bing dashboard is very low, i.e. the dashboard is efficient to use.

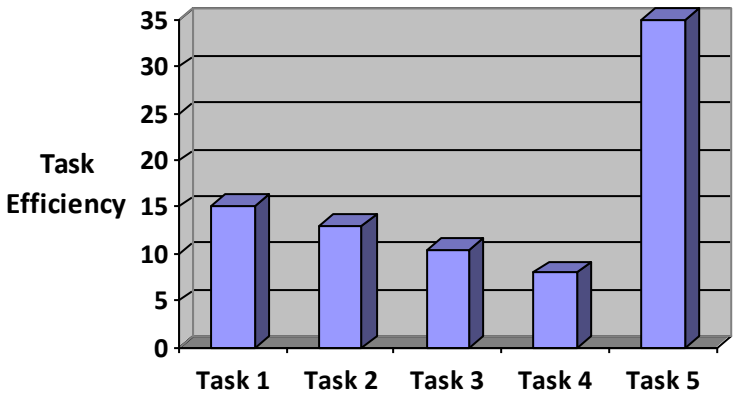

Figure 8. Task efficiency for the eight participants undertaking five tasks on the Bing dashboard

4.5 Post-Test Data Collection

After the experimental session was completed, participants rated the Bing dashboard on five measures: usefulness, ease of use, satisfaction, learnability, feedback, accessibility, and information architecture. Table 11 shows the ten Likert style questions with their corresponding measurements.

Table 11. Likert scale percentage agreement from the post-test questionnaire (Bing dashboard)

Lickert Scale Prompts from the Post-Test Questionnaire	Percent Agree
I think that I would use this dashboard frequently	75.0 %
It was simple to use this dashboard	87.5 %
I think I would need additional support to use this dashboard	63.0 %
I am comfortable using this dashboard	75.0 %
I needed to learn a lot of things before I could get going with this dashboard	0.0 %
I would imagine that most people learn to use this dashboard very quickly	75.0 %
If I made a mistake, it was easy to fix	63.0 %
It is easy to find the information that I need	63.0 %
The information provided on the dashboard helped me complete the tasks	87.5 %
Overall, I am satisfied with this dashboard	75.0 %

Based on the results displayed in Table 11, most of the participants (75 % or higher) agreed (agree or strongly agree) that the Bing dashboard is useful, easy to use, and satisfying. Also, all the participants agreed that they could easily learn how to interact with the dashboard without any prior knowledge. Approximately 60% of the participants stated that the information structure is well organized and highly accessible, and the feedback process made it easier to interact with the Bing dashboard.

V. DATA ANALYSIS

In general, all participants gave feedback that both of the COVID-19 dashboards were relatively easy to use. However, a number of issues were identified.

5.1 JHU Dashboard - Key Findings

All of the experimental participants successfully completed the assigned tasks, though not without some errors and occasionally a need for assistance. Key findings included :

- Tasks relating to finding location specific information on COVID-19 cases or using vaccination guideline services were easily completed by the participants on the JHU dashboard.
- Task 3 (finding resources and expert guidance for tracing the COVID-19 pandemic) recorded the highest number of participants who required assistance to complete it (62.5%).
- Overall, 87.5% of participants easily completed Tasks 1, Task 4, and Task 5, with the remaining participants (12.5%) facing some difficulty or requiring help to complete the task.
- On Task 2 (Massachusetts State Vaccination Progress), 25% of the participants needed assistance to complete the task.
- The most successful task was Task 4 (determining U.S. hospital capacity for Indiana state), which had a 100% of participant's easily completing the task.
- Overall, most of the participants found Task 3 to be the hardest to complete on the JHU dashboard - the efficiency of this task was less as compared to any other task.

5.2 JHU Dashboard - Usability Issues

When using the JHU dashboard, many participants noted the lack of user service functionality. This manifested in confusion when participants were using the dashboard to find specific information they needed. Some participants also had difficulty with the way the information was grouped and categorized, a problem with the basic information architecture. These are significant issues, that needs to be addressed.

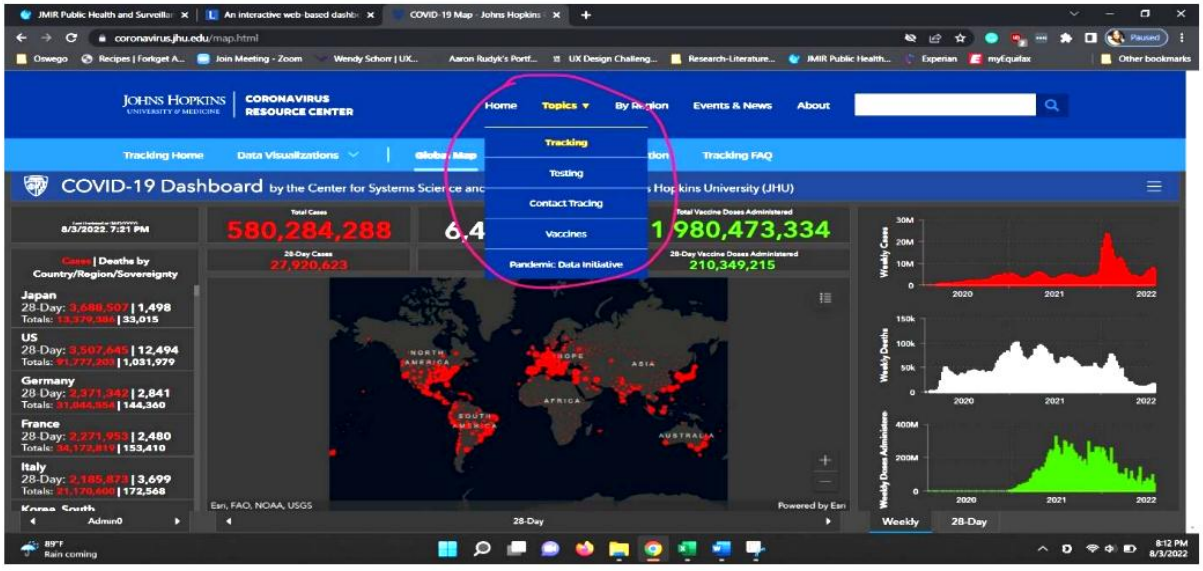

Figure 9. Home page of the JHU dashboard

Figure 9 illustrates a problem identified by a number of participants. Each time a participant opened the home page, they then had to select a tab and navigate through the topic section to reach any of the main content. Users had to perform this action every time they entered any particular page on the JHU dashboard, when they needed to search for the information.

This means that JHU dashboards users need to know exactly which information they are searching for, every time they open a page. This information is difficult to find by casual browsing. This meant that users on the JHU dashboard initially had problems with Task 3 (finding resources and expert guidance for tracing the COVID-19 pandemic) which recorded the highest number of participants who required assistance to complete it. Each participant had to search through the header tabs one by one, to find where the information might be located. This experience caused a lot of frustration among the participants and was pointed out by many as a major concern with the JHU dashboard.

As noted in Table 6, 87% of participants said they would use the JHU dashboard frequently, and said the interface was relatively easy to learn and remember. Analysis of the results for the t-tests that were conducted demonstrated that the type of user and presence of dashboard had an interaction effect, independent of the statistically significant results originally observed in the t-test.

Hence, further testing was performed in order to ensure that results observed in Figure 4 were applicable to the entire population, not just one subgroup of the population. These further statistical tests indicated that all users would benefit from the usage of the JHU dashboard, but that some users might have problems with accessibility.

5.3 Bing Dashboard - Key Findings

All of the experimental participants successfully completed the assigned tasks, though not without some errors and occasionally a need for assistance. Key findings included :

- Tasks relating to finding location specific information on COVID-19 cases or using vaccination guideline services were easily completed by the participants on the Bing dashboard.
- Task 4 (determining U.S. hospital capacity for Indiana state), recorded the highest number of participants who required assistance to complete it (90%).
- Overall, 75% of participants easily completed Tasks 1, Task 2, and Task 5, with the remaining participants (25%) facing some difficulty or requiring help to complete the task.
- On Task 2 (Massachusetts State Vaccination Progress), 25% of the participants needed assistance to complete the task.
- The most successful task was Task 5 (getting testing results from the COVID-19 testing tool kit.), which had a 100% of participant's easily completing the task.
- Overall, most of the participants found Task 4 to be the hardest to complete on the Bing dashboard - the efficiency of this task was less as compared to any other task.

5.4 Bing Dashboard - Usability Issues

A number of usability issues with the Bing dashboard were identified during the experiment :

5.4.1 Accessibility issues

Participants had difficulty finding the information on the Bing dashboard home screen. This issue was caused by participants finding some text and numeric information difficult to read. Figure 10 shows the Bing dashboard home screen. Areas of difficult to read text are highlighted. The text is very light and web accessibility tests showed there are color contrast issues making the text hard to read. This contravenes the Web Content Accessibility Guidelines (WCAG) from the WWW Consortium (W3C) [16].

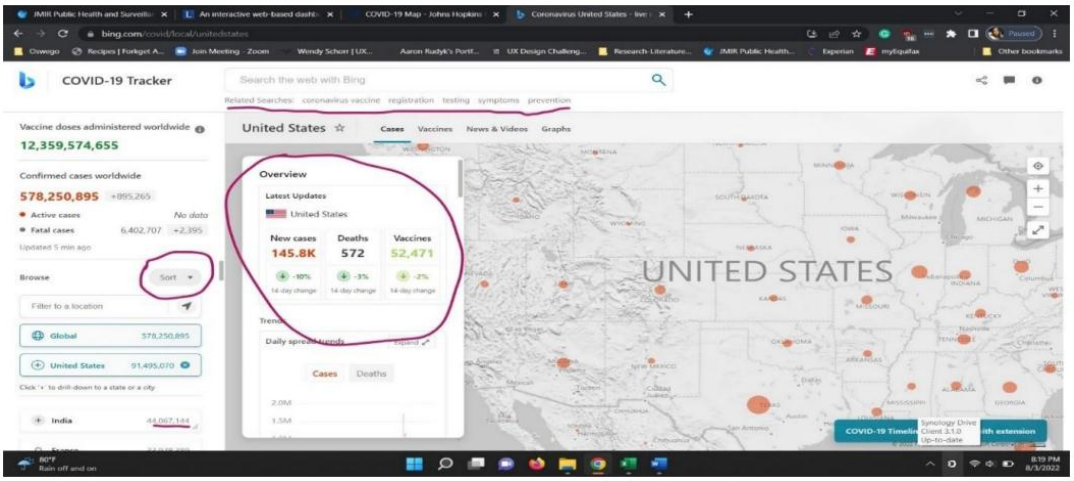

Figure 10. Home page of the Bing dashboard

5.4.2 Navigation bar - grouping

The Bing dashboard also has some information architecture issues relating to information grouping. The navigation bars need to be redesigned to allow students to easily find the relevant information they are searching for. At the moment users need to go through many stages and menus to find one specific piece of content. This was shown in the frustration of the participants with Task 4, when they were searching for information on U.S. hospital capacity for Indiana state.

5.4.3 Structure

The interface design of the Bing dashboard structure has a number of issues. Too much information on displayed on the left side of screen (Figure 10) which often confused the experimental participants. The browse tab, on the left side of the screen was a particular issue, many participants ignored this feature and searched for information using the header tabs.

VI. CONCLUSIONS AND RECOMMENDATIONS

In general, all participants gave feedback that both of the COVID-19 dashboards were relatively easy to use. All participants successfully completed all tasks with both dashboards. Therefore, the two dashboards are 100% effective, although the participants and tasks varied greatly in efficiency measurements. Tasks relating to finding the numbers of COVID-19 cases or using vaccination guideline services were more easily completed by the participants on both dashboards.

This usability study aimed to identify any pain points and interface issues in both the JHU and Bing dashboard user interfaces. Several tasks were designed that would focus participants into both frequent and infrequently used areas of the dashboards. By collecting a range of experimental measurements and following up on the users' experiences using a post-session survey, this research project identified several key areas in which both the JHU and Bing dashboards could improve their user experience.

The issues from the data analysis of both the JHU and Bing dashboards led to some specific and general recommendations.

6.1 JHU Dashboard - Recommendations

A number of improvements were recommended for the JHU dashboard, based on the experimental results :

- The developers need to know their audience and their information needs, and tailor the design to the user's task requirements.
- Information needs to be clearly delineated between the different COVID-19 variants.
- More thought needs to be given to information architecture - the type, volume, and flow of displayed information.
- Some of the information provided needs to be clearly disaggregating into relevant subgroups. Such as, reporting all data clearly categorized by different geographical regions
- There is a need to provide quick access to information on vaccinations, trackers, hospitalizations, and guidelines on a state by state basis.
- The virus trends over time need to be shown relative to policy decisions

6.2 Bing Dashboard - Recommendations

A number of improvements were recommended for the Bing dashboard, based on the experimental results :

- Again, the developers need to know their audience and their information needs, and tailor the design to the user's task requirements.
- More thought needs to be given to information architecture - the type, volume, and flow of displayed information.
- Some of the information provided needs to be clearly disaggregating into relevant subgroups. Such as, reporting all data clearly categorized by different geographical regions
- There is a need to provide quick access to information on vaccinations, trackers, hospitalizations, and guidelines on a state by state basis.
- The virus trends over time need to be shown relative to policy decisions
- Provide data on the homepage of the dashboard which can be compared quickly on a state by state basis.
- Use state specific storytelling visual cues which will be helpful for understand the virus trends.
- Follow the Web Content Accessibility Guidelines (WCAG) from the WWW Consortium (W3C), in particular those relating to font color contrast and typography [16].

6.3 JHU dashboard and Bing Dashboard - Comparison

One of the main outcomes of this experiment was to provide a comparison of the JHU and Bing COVID-19 dashboards.

It was found from the data analysis that the JHU dashboard is more useful and easier to use compared to the Bing dashboard. (Figure 11, shows the results of this comparison, based on the overall satisfaction (user percentage agreeing) on the two dashboards. The JHU dashboard had 87.5% of users reply positively (agree or strongly agree) that they were satisfied with the dashboard. The Bing dashboard scored lower, where 75% of users replied positively (agree or strongly agree) that they were satisfied with the dashboard.

The experimental data (metrics and qualitative) indicated that the Bing dashboard was less accessible and hence less useable. Participants repeatedly reported being 'stuck' on the Bing homepage, and not knowing where to go, or what to do next. These issues were compounded by difficult to read test and contravention of the web accessibility guidelines.

A number of recommended solutions to all of the interface issues discovered during this experiment are given above. Overall, although the JHU dashboard scored higher, in regards to usability, than the Bing dashboard both were recognized as being quite easy to use, and providing useful information, and were both well-liked by the participants.

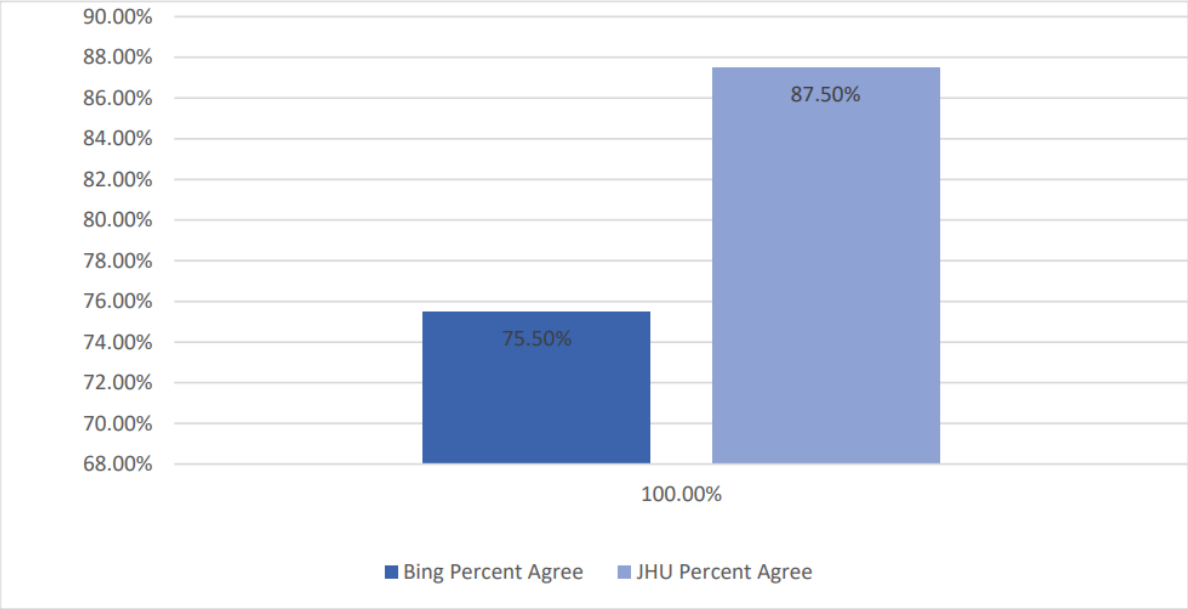

Figure 11. Overall satisfaction (user percentage agreeing) comparing Bing and JHU dashboards

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