ISSN 2409-2665
Journal of Logistics, Informatics and Service Science
Vol. 9 (2022) No.3, pp.243-257
DOI:10.33168/LISS.2022.0317

Assessment Model for Information Visualization of Human-Computer Interface in the COVID-19 Pandemic

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Abstract. The purpose of this study is to investigate and describe an example of COVID-19 pandemic information visualization in human-computer interface to serve as a reference for future pandemic information visualization performance improvements. The relevant local and international literature was investigated and studied, as well as the visualization projects of pandemic information from each stage released by major media outlets in the mid-term outbreak of COVID-19. Thereby, the assessment model of information charts, color evaluation, and interaction model for pandemic information visualization of human-computer interface design was obtained. To make the assessment model more effective, an evaluation system was introduced which contributes to the popularization of information, narrows the gap between truth and public cognition, and arouses public attention and vigilance. In the future, pandemic prevention and control will be supported by the assessment model for the design of information visualization of human-computer interface in different scenarios by systematization, standardization and real-time.

Keywords: information visualization, human-computer interface, COVID-19, assessment model.

1. Introduction

COVID-19 has been assessed as a global pandemic by the World Health Organization, and the global risk level is the highest, which means that it has a terrible transmission rate and infection rate. The form of information visualization of human-computer interface greatly improves the readability of pandemic information that can be more easily accepted by users after being reasonably interpreted and expressed (Comba 2020). People are no longer limited to observing and analyzing information through relational information tables, but can also realize the information and its structural relationships in a more intuitive way (Ad et al., 2020). With the development of the pandemic situation, the media or institutions have presented the development trend of the pandemic situation to relevant government departments and society in different visual ways every day, accompanied by constantly optimizing the content and mode of visual presentation. This is also relevant to the visual management trend in a recent lean manufacturing and lean 4.0 concepts. In fact, visual information has been investigated to be one of the seven main dimensions in measuring leanness (Wahab et al., 2013). The information visualization needs to use intuitive approach to reveal the related data and operation to make government and users to see information progress with the eyes clearly and quickly, and to find out proper methods and countermeasures (el Abbadi et al., 2020).

Information Visualization method has been employed and evaluated to display the Personal History Data of patients for nutritionists within counseling sessions (Noah et al., 2009). Considering the examination of a visual measurement pattern of the Human Capital and ICT dimensions, it create a skeleton of a Knowledge-based Society for Malaysia regarding an Innovative Digital Economy (Badioze Zaman et al., 2011). According to the method of visual perception, information visualization application has been designed to assist a specific comprehension of the visual accordance with the information of the hadith environment (Fabil et al., 2012). Besides, some studies also introduced the importance of user experience in information visualization interface system (Ali et al., 2012).

In a sudden public crisis, the psychology of anxiety and panic is a common and normal phenomenon across national boundaries for the general population, who are more likely to believe rumors, conspiracy theories, and exaggerated digital assertions (Nicomedes et al., 2020). Information visualization, as a means of design and presentation, can effectively transform the original monotonous statistics into readable information so that the public can understand the rule of the development of pandemic situations and hopefully "see" the pandemic trend. As a component of information visualization, color provides the most interactive visualization experience for people. Color not only has a huge impact on the aesthetics of an interface but also evokes a range of emotions in users. The first one is an instinctual sensation, which is the first reaction to color that occurs without cognition or intervention from other elements for the viewer. The other one is an indirect sensation derived from the visual connection and experience of the viewer for color (Xiao 2016).

This study establishes an assessment model for information visualization of human-computer interface in the COVID-19 pandemic, consisting of information charts, color evaluation, and interaction modes. In the information chart, we collected the information visualization design scheme of the pandemic situation and analyzed the types of visual presentation charts of pandemic information created by major media. Based on the principle of human cognitive processing, the capacity of the user to perceive and react to color is stronger than other aspects such as form and text (Shepherd 1992). We identified and analytically described the three-color evaluation features of information visualization in the human-computer interface. Considering the development of interaction technologies, this study presented three multimodal categories (static, dynamic, and interactive information visualization) to efficiently interact with the public. Finally, the evaluation system was introduced for designers to test validation for the schemes of pandemic information visualization (Jo et al., 2008). This model can effectively accelerate the design process of human-computer interaction interface and enable more people to obtain information related to the COVID-19 situation in a timely manner.

2. Related Literature

Information structure is essential for the framework of pandemic information visualization of human-machine interfaces, which involves listing and arranging information in combination with the characteristics of visual perception and logic for users to obtain information and avoid cognitive impairment (Robbins et al., 2021). The Washington Post utilized a variety of graphical forms for comparing experimental instances and fatalities across nations (Taylor et al., 2020). The Financial Times designed an information visualization interface using a set of line graphs to track everyday fatalities (Bern-Murdoch et al., 2020). A few visualization interfaces permitted user interactivity, like moving the cursor across bars and spots in line charts (Stevens 2020). The theory of visual communication has already been applied to the information visualization of human-computer interface, improving people's awareness of prevention, reducing fear and anxiety, and giving people warm feelings through color, illustration, information charts, material design and so on (Wei 2018). Considering the correlation of emotions and color, the correspondence analysis method was used for the association between the hue circle and the circumplex model of emotion/affect (Hanada 2018). An intelligence algorithm has been used to accomplish a multi-dimension evaluation of color design for color harmony and emotional satisfaction Guo, et al. (2020).

Based on the development of information technology, static or dynamic interaction visualizations would enable end-users to achieve their essential requirements for an efficient means of delivering and accessing information through a multimodal information visualization interface (Jorge et al., 2013). As a result, there are some empirical intelligent methods that have been referenced from the aforementioned content in the assessment model for information visualization of human–computer interaction interface.

3. Assessment Model

Information visualization of human-computer interface plays a significant role in scientific studies. Starting with John Snow's study of the cholera pandemic in 1854 until today, a perfect visualization interface may highlight fundamental tendencies of the information that may not otherwise be obvious from raw statistics. Different demonstrations of information visualization can provide distinct psychological sentiments to users according to the results of investigating user cognitive psychology for public health situations (Jin et al., 2021). The main interface schemes of COVID-19 visualization information are compared and analyzed in this study, which mainly include three objects: information charts, color evaluation, and interaction modes.

3.1. Information Charts

The visual presentation of pandemic information determines whether users find it easy to understand and acceptable. Reasonable information charts can also improve users' reading and viewing experiences to a certain extent. Massive and complex pandemic information can be transmitted to users efficiently and clearly by visual design. Based on hierarchical rules of visual processing in the human brain (Robbins et al., 2021), information charts objectively describe data by graphic elements to improve the readability and understandability of information. For example, the case of information visualization was shown in Fig. 1 (Zastrow 2020).

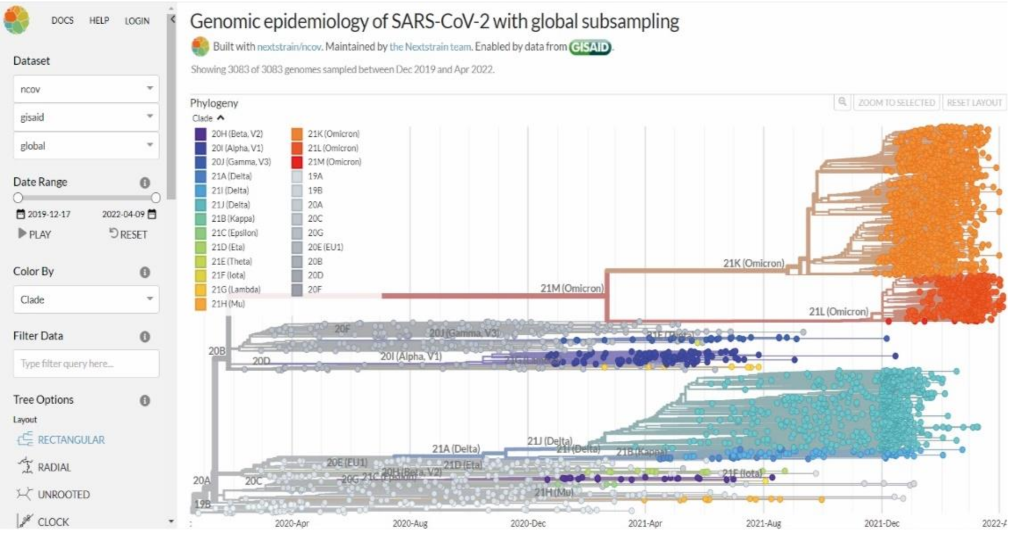

Fig. 1: Cases of information visualization of pandemic COVID-19.
(Source: websites of Nextstrain (Hadfield et al., 2018))

Table 1: Type analysis of pandemic information visualization chart.

Type	Explanation	Application
Column diagram	Shows the information changes and comparison	The pandemic situation in key countries/regions
Curve diagram	Shows the trend of information fluctuation	Pandemic trend; Cure rate / fatality rate / severe disease rate
Map	Shows the value size of the area range	Zero growth map; National entry control measures
Scatter diagram	Shows relationship between variables	Media attention analysis
Circle chart	Shows logical relationship of administrative areas	Pandemic flow: cases and places
Flow diagram	The width reflects the quantity	New daily cases of COVID-19
Barometer	Shows the macro trend of pandemic development	The number of newly diagnosed cases
Square diagram	Shows the development trend of the pandemic situation	Pandemic area (domestic/international version)

The information visualization of human-computer interfaces can show information about an epidemic, but it lacks interaction with users and emotional considerations. A summary and comparison of the chart types was made to understand how the information is presented in the process of visualization of various pandemic information as shown in Table 1. The analysis results of the chart types include eight classic charts, such as column diagram, curve diagram, map, scatter diagram, circle chart, flow diagram, barometer, and square diagram. The item of explanation and applications are used to longitudinally compare and analyze the regular characteristics of charts in the information presentation process. For instance, the map uses the depth of color to display the quantitative score of the regional range and intuitively show the spatial uptrend of pandemics, which can be utilized to evaluate the spatial spreading of the pandemic and control the source of the pandemic. A variety of chart types were focusing on incremental information and cumulative information was used comprehensively to show the macro development trend of the pandemic situation (Xiang et al., 2020). It was shown that various types of chart applications provide various forms and methods for the presentation of information by comparison, they each have different application scenarios and have various limitations. Designers need to compare and choose the best chart types to show information in conjunction with their designs. Color evaluation

As a visual element, the color in the information visualization of the human-computer interface can make the interface achieve visual consistency with a strong visual effect which can effectively enhance the user's perception of stimulation and affect the user's experience of the entire interface. Color may be split into three fundamental dimensions: hue, value, and chroma, also known as the three fundamental properties of color. In the information visualization of human-computer interfaces, the visual impression that the interface color ultimately provides to the viewer is the cumulative consequence of the three-color qualities acting in concert. If any of these three characteristics changes, the perceived impact of color on the sense of sight due to light scattering will change as well. Additionally, various color arrangements have a profound effect on how individuals perceive the pandemic information. This work reviews and presents three color-characteristic (color difference, color distribution, color harmony) calculating formulae according to previous research (Yuan et al., 2015; Hsiao et al., 2017).

3.1.1. Color difference

According to Munsell color theory (Judd 1940), the greatest hue difference in color matching was determined to be 144 (Fig. 2) in the hue ring, which exhibits strong visual identification. The following formula may be used to calculate the huge difference among primary variants:

$$H_d = \frac{\beta_k}{144°} \tag{1}$$

where β_k is the degree of the spacing angle between primary variants.

$$C_d = \frac{(\frac{C_x}{C_{xmax}} - \frac{C_y}{C_{ymax}})}{50} * 100 \tag{2}$$

where C_x denotes the chroma of color x, and $C_x$max is the highest degree of the actual state of individual x in the coloring theory.

$$V_d = \frac{(V_x - V_y)}{45} * 10 \tag{3}$$

where V_x is the coloring value of item x.

$$C_f = \frac{H_d + V_d + C_d}{3} \tag{4}$$

Then C_f (color difference) is eventually obtained.

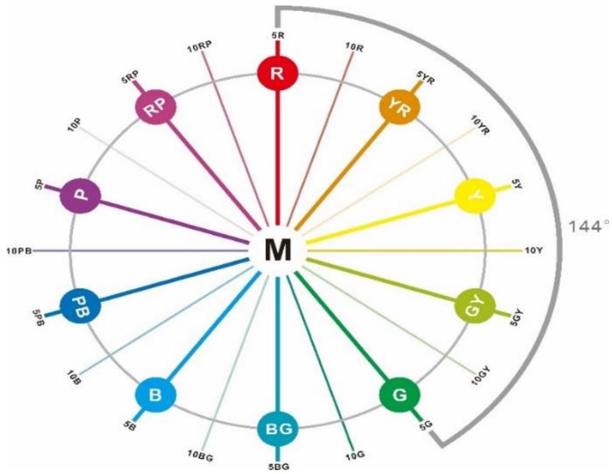

Fig. 2: Munsell hue ring.

3.1.2. Color distribution

Information entropy is a quantity utilized in information theory to quantify the extent of chaos in a system (Martinas and Kaitlin1997), which was employed to quantify the homogeneity of color distribution in a human-computer interface in this study. The human-computer interface was split into four parts by the X and Y axes based on the center point, the first quadrant (X1Y1), the second quadrant (X2Y1), the third quadrant (X2Y2), and the fourth quadrant (X1Y2). The entropy reaches its greatest value in the area that corresponds to the pixel degree of a particular color in each of the four zones [24].

$$E_x = -\frac{1}{ln\,4}\sum_{y=1}^{4} F_{xy} \cdot ln(F_{xy}) \tag{5}$$

$$F_{xy} = \frac{A_{xy}}{\sum_{y=1}^{4} A_{xy}} \quad (x=1, 2, 3, \ldots, n;\ y=X_1Y_1, X_2Y_1, X_2Y_2, X_1Y_2) \tag{6}$$

where A_{xy} is the region in section y of the interface that is dominated by a definite color x.

$$C_d = \frac{\sum_{x=1}^{n} E_x}{n} \tag{7}$$

Then C_d (color distribution) is eventually obtained.

3.1.3. Color harmony

To evaluate color harmony Birkhoff and David (1933), the aesthetic degree formula can be introduced to assess formal beauty, which has also been referenced by Moon–Spencer's supposition, with the artistic grade principle being obtained (Moon 1944).

$$O_r = \begin{cases} \sum O_g & (Achromatic\ color) \\ \sum O_h + O_v + O_c & (Chromatic\ color) \end{cases} \tag{8}$$

where O_g is the component of order for only having achromatic color. O_h, O_v, O_c are the components of order defined by the hue, value, or chroma discrepancy respectively, while monochromatic color is engaged in normalizing (Jing 2012).

$$C_h = \frac{O_r}{C_n + C_h + C_v + C_c} \tag{9}$$

where C_n is the quantity of corresponding colors. C_h, C_v and C_c are the color pairs in all possible pairwise associations with hue, value, and chroma discrepancy respectively. Then C_h (color harmony) is eventually obtained.

The color of information visualization of human-computer interface can be calculated according to the equations from (1) to (9) in the assessment model.

3.2. Interaction modes

Multimodality is the fusion of multiple senses. The concept of multimodality first appeared in the field of linguistics. People realized that semantics was not only in the language itself, but also reflected in a variety of nonverbal modes, such as expression and body movement (Gottlieb 2005). The traditional single-mode and static displays have been unable to meet users' requirements for information exploration. The multimodal display of information has optimized and expanded the visual design form, providing users with a rich and colorful sensory experience and transmitting information dynamically. The interactive modes of information visualization of human-computer interfaces can be mainly divided into three categories: static, dynamic, and interactive information visualization.

3.2.1. Static information visualization

The forms of static information visualization include illustrations, charts, icons, and text, but lack user interaction experience. As shown in Fig. 3, the visualized map of pandemic information created by teachers of Sichuan Fine Art Institute is a typical static information visualization case. Although single-modal information visualization lacks interaction with users, the design of charts can enhance the user experience and greatly enhance user understanding.

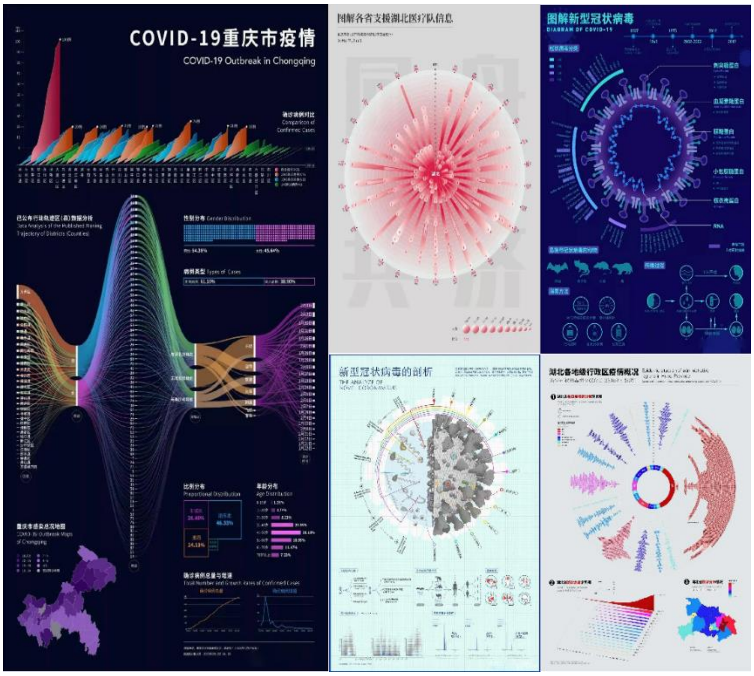

Fig. 3: Visualized information interface case.
(Source: Sichuan Fine Art Institute)

3.2.2. Dynamic information visualization

Dynamic information visualization refers to dynamic changes of information in time and space dimensions and the dynamic changes brought by user interaction. The traditional static information presentation may not meet the multi-sensory needs of users. According to the experiment results, dynamic visual media were better suited for clarifying information transformation or characterizing a process [29]. whereas static visual media were better suited for explaining invariant physical phenomena. Dynamic information visualization can show the change process of information through dynamic videos, animations, operable interfaces, and other forms of interaction. Users intuitively feel the development of the pandemic situation. For example, the "clip-on COVID-19" commentary video, which was created by the "clips" team, gives information to users in the form of dynamic information visualization. Tencent News, today's headlines, Alibaba Health, and other clients have also added information dynamic interaction to the visual design. Users can click the screen to select different information interfaces.

Dynamic information visualization pays more attention to the dynamic changes of information and the interactive experience of users than static information visualization. The dynamic effect combines the benefits of the visual mode with human brain perception, hypothesis, and reasoning. It can help people lessen their cognitive load, improve information understanding and recognition, and make sure they don't forget important information.

3.2.3. Interactive information visualization

Multimodal interaction refers to communication interaction, which is a series of dialogues between people and products, services, or systems (Lucignano et al., 2013). The interactive interface of user operation is a multi-modal information display platform, including multimedia, dynamic elements, and interactive experiences. A more comprehensive classification of interaction methods can be divided into dynamic selection, dynamic navigation, dynamic reconfiguration, dynamic coding, abstract/concrete, and dynamic filtering. Interactive information visualization of human-computer interfaces adds interactive forms such as buttons, progress bars, and navigation based on dynamic information visualization to promote interaction between users and information.

The "Ncov-2019 Tracker" developed by Michael Diben, XR strategic analyst, intuitively shows the spatial changes of the pandemic through sliding buttons. At the same time, combined with AR technology, it provides an interactive schedule related to the pandemic, including the number of infections reported in each country. It contains a 3D globe that allows users to walk around, as well as an auxiliary 2D chart. Users can view it on their smartphones or PCs.

4. Evaluation system

If the information visualization interface of human-computer interaction based on the assessment model had been created by designers, the application effectiveness will be validated according to this evaluation system. Fig. 4 shows the framework of the evaluation system.

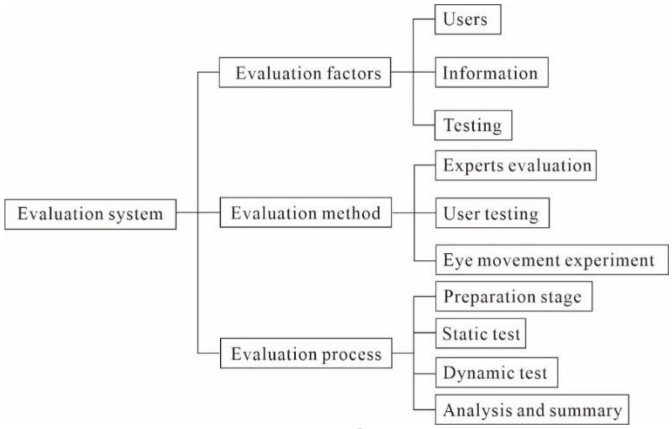

Fig. 4: Evaluation system.

4.1. Interaction factors

It is significant to effectively assess the design scheme of pandemic information visualization requirements. The usability of information visualization can be studied by reasonably controlling variables to guide the optimization direction of information visualization in the future. The factors that affect the results in the process of visualization evaluation will be discussed which mainly include users, information, and testing.

4.1.1. Users

Usability evaluation of data visualization plays a key role for users. It will influence the visual evaluation for the type of users, the level of understanding of data visualization, the level of understanding of visual interaction, and the level of understanding of visual evaluation experiments. To evaluate the visual design more scientifically, it is necessary to consider the personalized acquisition requirements of users as participants with different professional backgrounds.

4.1.2. Information

In information visualization, it will affect the choice of visualization methods for the density and size of information. High-quality original information should have two characteristics: the information should be suitable for visual expression, and the information should be representative and cover all information types in visual presentation (Yu 2016). The selection of useful information data and interactive presentation methods affect the readability and visualization. Furthermore, it will influence the readability of visualization for different information types, the amount of information, and the dimensions of information.

4.1.3. Testing

Usability testing mainly involves four aspects: designing test tasks, determining test users, testing, and quickly analysing usability problems after completing the test. The design task needs to consider factors such as user interface component design and interactive operation design. The current optimization direction is analysed from the results of the evaluation content of task test completion time, task accuracy, and user satisfaction score.

4.2. Evaluation methods

4.2.1. Expert evaluation

Experts in the field of information visualization of the human-computer interface can be invited to evaluate the visualization system. As evaluators who can judge the extent to which some technologies can be applied to such data and tasks at a professional level, they can make a more accurate judgment. If there are multiple experts, the scores can be scored and combined to offset personal bias.

4.2.2. User testing

User testing is the process of observing users using a human-computer interface for information visualization in the actual environment to evaluate the visualization cases (Chen et al., 2020). This type of test should take care to avoid interfering with users to obtain evaluation results that are as close to the actual situation as possible. Therefore, unlike the usability test, there is no host role in this method. The evaluation personnel can observe and record during the experiment, but cannot provide guidance and suggestions. Users are allowed to actively raise questions and suggestions. All feedback from users was used to improve and optimize the information visualization in the human-computer interface.

4.2.3. Eye movement experiment

The human-computer interaction mode based on eye movement information is to record and recognize different eye movement modes as input command signals, which enables the control operation of some instruments and equipment. Eye movement information can be applied to the usability analysis and testing in software and websites to help researchers understand user behavior and usability problems. Compared with the traditional usability testing methods, eye movement technology can provide additional information, such as insight into the user's first gaze position and search method. Eye movement technology can show the user's immediate response and the distribution of concerns and help researchers understand what attracts the user's attention to think about the layout of important content (Chen et al., 2020).

4.3. Evaluation process

4.3.1. Preparation stage

In the preparation stage, it is necessary to analyze the framework of the visual chart and set the specific task process. The organizer will write the experimental plan, recruit the test subjects, and divide the participants to make them familiar with the experimental instruments before the experiment.

4.3.2. Static test

After setting the presentation time of each picture and starting the eye movement experiment, the participants watch the information visualization chart on the screen and save the data to the specified folder. The organizer can view the eye movement results and export the test chart after experiment completion.

4.3.3. Dynamic test

After calibrating the eye tracker for the tested personnel, the organizer lets the tested personnel operate the chart and set four main participants. The first one is responsible for prompting the tested object for the next task and resetting the operation page to ensure the tested state; the second one is responsible for monitoring the real-time picture and recording the completion time of each task; the third one is responsible for recording the operation and response of the tested object, and the fourth one is responsible for shooting and recording. During the operation, the organizer can ask the participants to operate while saying what they want and observe whether the user is dissatisfied during or after the operation to judge the efficiency and satisfaction of the interface. The organizer records the measured testing conditions and questions in real-time. After the operation, the organizer will save the test results for analysis.

4.3.4. Analysis and summary

After the experiment, the static page layout test results are analysed qualitatively and the dynamic test results are analysed quantitatively. The organizer observes the experimental videos and records, analyses the behavior and psychology of the testers, and reaches a conclusion, which may be helpful in further improving the interactive operation and reduce cognitive impairment.

5. Conclusion

The main purpose of information visualization is to enable groups with different cognitive levels to obtain information clearly and also to ensure that pandemic information can be recognized, understood, and applied by more users, and to provide information mining and decision-making services for more users groups in the human-computer interface. By summarizing the information visualization that appeared during COVID-19, the information chart, colors, and interaction modes of the human-computer interface design were analysed. In the mid-term outbreak of COVID-19, the application of information visualization in human-computer interfaces contributed to the popularization of information, shortened the gap between truth and public cognition, and aroused public attention and vigilance, which were helpful to limit the spread of the pandemic. Finally, to test the validation of information visualization schemes, this study introduced an evaluation system. In the future, pandemic prevention and control will be supported by the design of information visualization of human-computer interface in different scenarios by systematization, standardization and real-time.

Acknowledgments

The authors would like to thank Universiti Kebangsaan Malaysia for supporting this research work through the GGPM-2019-065 and TAP-K006873 research grant.

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