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Human Factors Visualization and Storytelling Design Questionnaire: Validity and Reliability Tests

Muhammad Faris Basheer Mohd Zanan*, Madihah Sheikh Abdul Aziz

Department of Information Systems, International Islamic University Malaysia, 53100, Gombak, Selangor, Malaysia
E-mail: farisbasheer.z@live.iium.edu.my, madihahs@iium.edu.my

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Abstract: In the era of data and the quest for data-driven decision-making, the capacity to tell stories from data is proving to be increasingly valuable. Storytelling is not only a great method displaying facts, but also an effective approach to package knowledge and information so that everyone can understand it. While numerous tools are available to produce a strong storytelling visualization at the moment, the tools' ability to be personalized by the user is almost non-exist. To determine the connection between personality and user preferences toward different visual designs, this study employs the user preferences on visual design related to the data visualization questionnaire that was used in the previous research. In this research, the data storytelling element was added; hence the questionnaire needs to be evaluated based on validity and reliability test. In this paper, the validity and reliability tests of the questionnaire will be explained thoroughly. The outcome of this test will help in producing a questionnaire that is valid and reliable for upcoming research related to the field.

Keywords: *Information Visualization, Data Storytelling, Visual Design, Personality, Questionnaire, Survey Design, Validity Test, Reliability Test*

1. Introduction

Due to the ever-increasing volume of digital information, users are exploring information visualization to efficiently communicate that information. In order to transform vast amounts of data into information and knowledge, information visualization strives to assist people in exploring, navigating, and understanding them [1]. This research attempts to close the gap between how user personalities can influence their decisions on visual storytelling elements by modifying the questionnaire. Understanding the impact of personality and user preferences on information visualization and storytelling is very important and useful. While there are numerous information visualization tools available on the market today to perform visual tasks efficiently, these tools themselves are constrained by their universal nature, neglecting the diversity in user personalities [2].

Among these limitation is the fact that consumers can only make limited customizations, the possibility of receiving services they do not think they require, and the possibility of missing out on profitable prospects for bespoke design. The gap between users and designers may result from designers' general approach, which also downplays the value of uniqueness in information visualization and storytelling reporting. In order for the developers of business intelligence software like Microsoft Power BI or Tableau to be able to adapt their services to the user's personality by making their services more flexible and catering to different types of people, this research may help in understanding the personalities differences, and the preferences toward different visual design elements [3].

This questionnaire aimed to examine how personality influences user preferences in relation to the visual design style. Personality is a special trait that makes each user different, and it has the potential to improve usability and the

Corresponding Author: Muhammad Faris Basheer Mohd Zanan, Department of Information Systems, International Islamic University Malaysia, 53100, Gombak, Selangor, Malaysia. E-mail: farisbasheer.z@live.iium.edu.my

user experience. However, it is important to keep in mind that the human species is exceptionally differentiated by biological factors like gender, age, neurochemistry, body type, and many others [4]. This research includes the various options for a graph, such as hierarchy, evolution through time, and comparison contexts; also other visual elements such as font style, font size, information density, navigation bar position, and visual storytelling styles, as these have all been used regularly in cutting-edge research. To this end, this research employ the questionnaire from a previous research on the effect of user preferences regarding idioms used for hierarchy, evolution over time, and comparison contexts [2]. The questionnaire was selected because it already establishes a good question structure appropriate to the current research. It also provides good references, especially regarding user preferences toward specific visual design elements. Storytelling elements were added to this questionnaire as a new section.

In order to effectively use information visualization, data storytelling has emerged as a powerful technique [5]. In the research field, storytelling has recently attracted a lot of attention, particularly when engaging audiences. It can be challenging to communicate with viewers who lack advanced analytical abilities when working with extensive data and complicated mathematical, graphic, and interactive tools [6]. Each visualization's visual examples were included in the survey, which was divided into 10 sections. The participants will first read the corresponding questions before selecting their favorite visual designs on a 7-point Likert scale, with 1 being the least favorite and 7 being the most. With the addition of data storytelling into this questionnaire, validity and reliability tests are required before they can be used in new research to ensure that it is both valid and reliable for the modified questionnaire.

2. Materials and Methods

2.1. Related Work

One of the most popular methods for gathering data, is the questionnaire. The primary goal of a questionnaire in research is to gather pertinent data in the most accurate and legitimate way possible [7]. As a result, validity, and reliability—other terms for the correctness and consistency of surveys and questionnaires—form an important part of the research technique

Validity is defined as the extent to which a concept is accurately measured in a quantitative study. For example, a survey designed to explore depression but anxiety would not be considered valid [8]. Reliability refers to the degree to which a measurement of a phenomenon yields a stable and consistent result [7]. Validity is fundamental in developing measurement tool so that it is valid to use in research [9]. Repeatability is another aspect of reliability. For instance, a scale or test is considered dependable if it consistently produces the same result when repeated measurements are conducted using it [10]. In this research, 7 experts in visualization and data analytics were invited to revise the item pools of the enhanced questionnaire. The enhanced questionnaire will help in determining out the relationship between the user preferences and visual design elements.

Information visualization and visual storytelling elements were the two sorts of categories used to create the questionnaire for user preferences in visual design. Information visualization is a graphical representation of information and data [11]. Due to its capacity to enable the human eye to "see" things that are difficult or impossible to interpret in vast datasets and abstract text-based information, information visualization is crucial. Information visualization is able to describe situations, detect patterns, adjust the level of abstraction of the database, and match the mental model [12]. Information visualization has been around for a while, and it effectively conveys data to the audience; however, the visualization needs to suit the audience to prevent the audience from information overload or misinformation because of a bad visual design [13]

Storytelling is "a narration of the events in a person's life or the existence of a thing, or such events as a subject for narration," according to one definition [14]. Using actors, events, and actions to analyze data with the purpose of enhancing information cognition. By identifying pertinent information and improving its cognition, storytelling gives information visualization a purpose [15]. Data storytelling exists in many different forms, like a poster for earth day with information on how to reduce the combustion of the ozone layer, a slide presentation from lecturers, and a budget meeting in a corporate sector. Recently, there has been a great deal of interest in the visualization field as it is an effective way to apply information visualization [5].

2.2. Method

In order to investigate the relationship between personality traits and user preferences, the visual design toward meaningful, effective, and efficient visualization and storytelling reporting for users to make informed decisions, the original questionnaire from Gonc’s[2]was enhanced, and summarized in Figure 1.

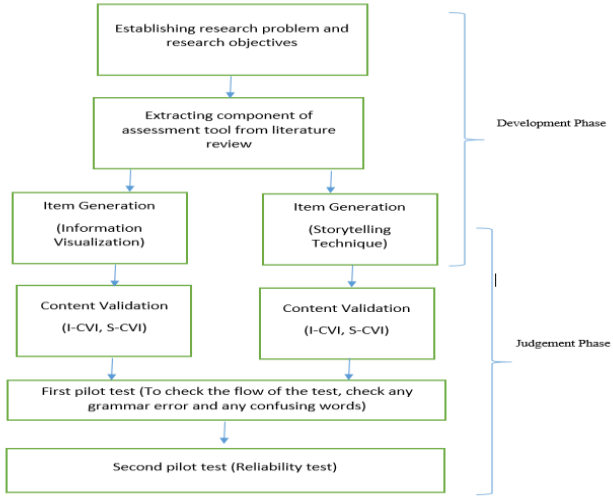


Figure 1. The flowchart of development and validation of the enhanced questionnaire.

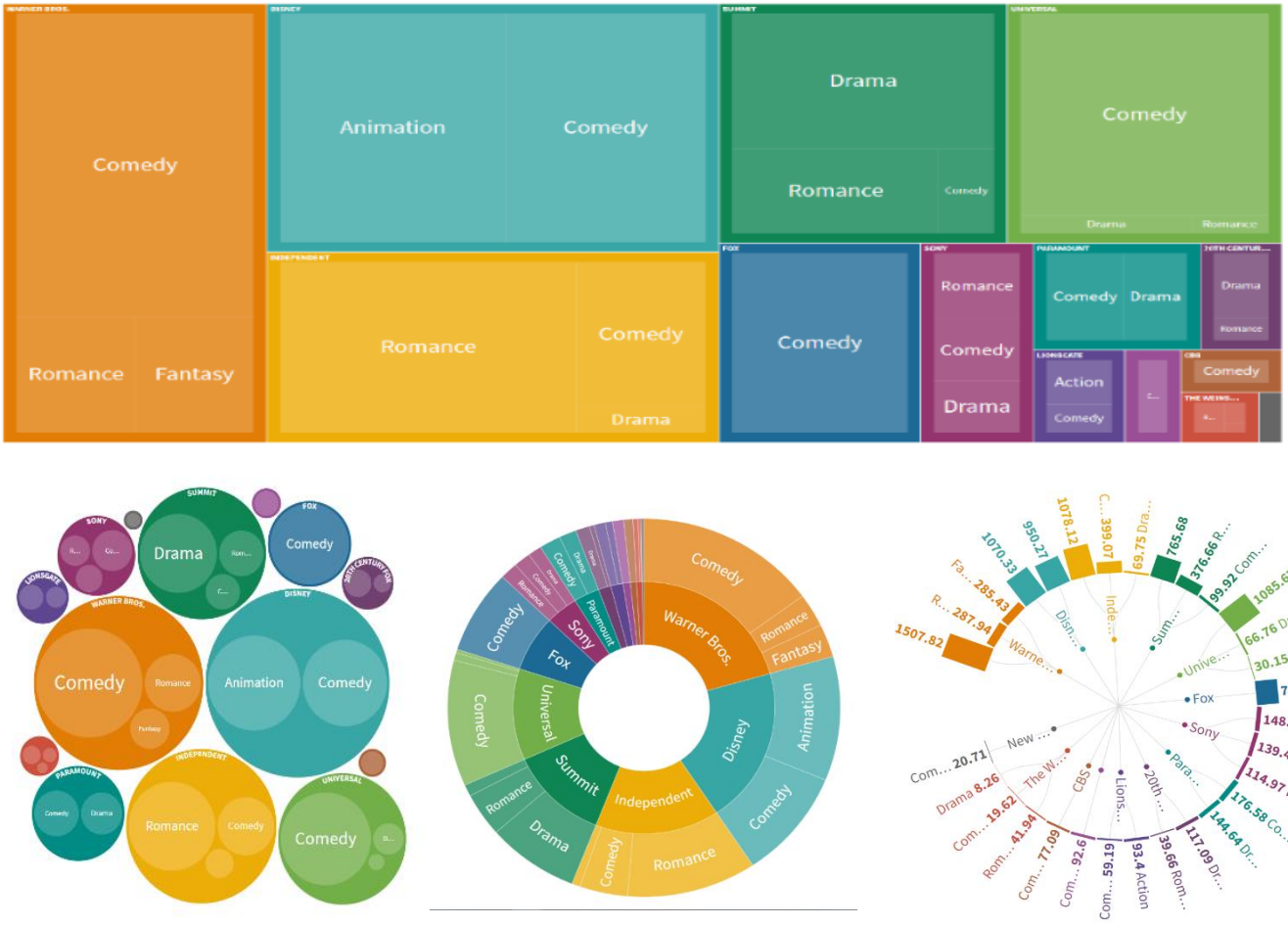


Figure 2. From top to bottom right; Tree map, circular packing, sunburst and radial diagram. The visuals were design and drawn by the author

User context, font, buttons and Icons, information density, navigation bar position, visual hierarchy, change over time, and comparison was the 9 sections of the original questionnaire, and the enhanced version will include visual storytelling elements as the 10th section. The participants select the groups to which each of the primary 5 personality attributes their score belongs based on user context (Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to experience). A person with a

score of 45 on the extraversion scale, for instance, falls in the 40–59 range. The user context also includes two additional questions from the original questionnaire on the participants' devices and color blindness. The participants selected their desired font style and size under the section on fonts.

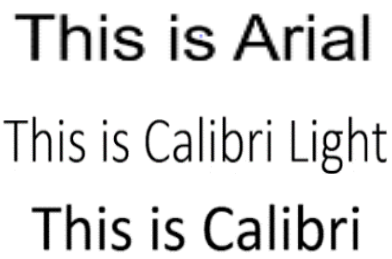


Figure 3. From top to bottom; font style for Arial, Calibri Light, and Calibri

The participants selected their preferred type of information button for the button and icon categories. Participants will rate the information density section according to their preferences for the density of information in proportion to the size of each interface's screen. Participants can select their preferred position for the navigation bar in the section under "Navigation bar position".

Figure 4. From top left to bottom; Button with icon, button with text, and button with icon and text

A hierarchy visual is a set of information from a domain that adheres to a certain hierarchical organizational [16]. For the hierarchy visualization section, the participants will choose which type of visual design graph they prefer to represent movie studios based on their genres

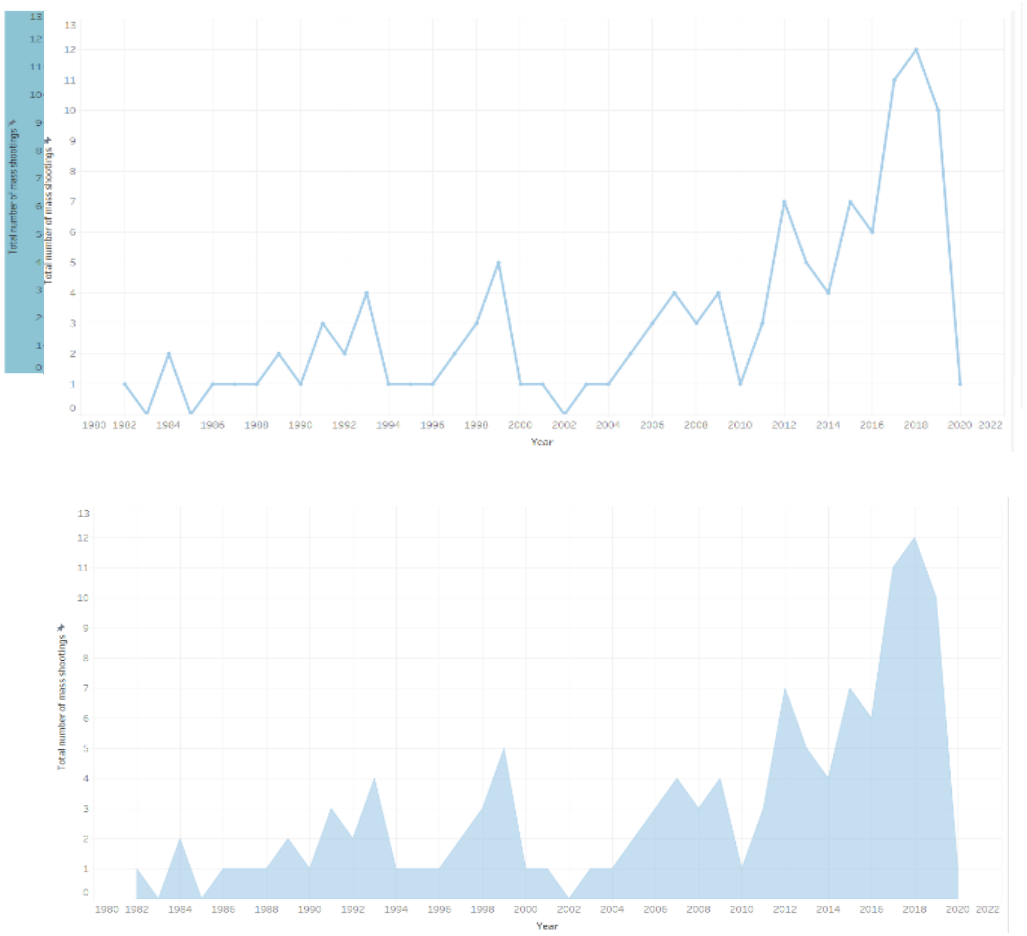


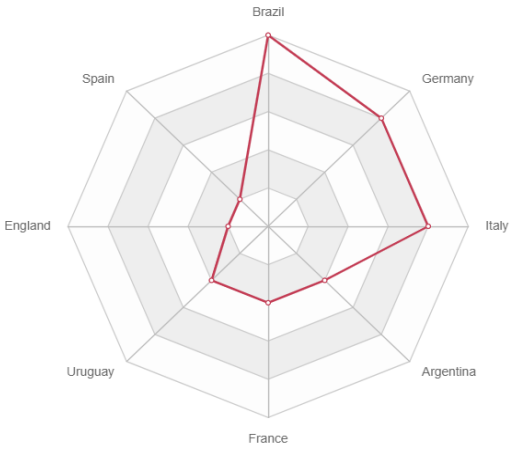
Figure 5. From top left to bottom; a line chart, line chart with point and area chart. The charts were designed by the author

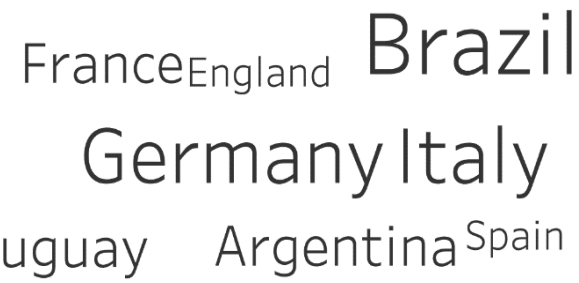
The data of the movie studios and their movies were collected from various websites such as RottenTomato.com.

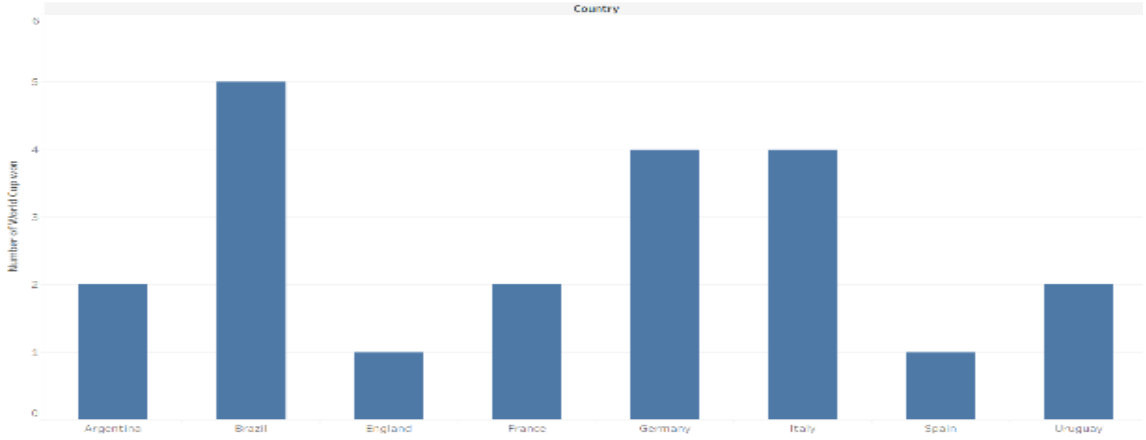
For the change-over-time visualization section, a movement in data attributes and states over time, as well as the instances at which data states change abruptly, are represented through changes over time visualization [17]. Some visual designs that represent the change over time are the line chart, line chart with points and area chart. The visualization was represented by the data of the number on the mass shooting in the USA from 1980 to 2021. The information was taken from the Statista.com website.

Comparison visualization best displays differences or correlations between variables at a particular level of detail [2]. Data of the football World Cup victories between eight different countries were used to create the visualizations (England, Italy, France, Brazil, Argentina, Germany, Spain, and Uruguay).

For the storytelling styles preferences section, participants selected the type of visual storytelling design styles they preferred. Magazine style is the most popular for static visualization, which introduces data graphics with descriptions set in a fluid prose consistent with the journal form of media [18]. Magazine style mainly uses in author-intended data stories [19]. The magazine style in this research was created using Canva site and was designed by the author. The information was taken from World Health Organization (WHO) website, and the issues were about the recent pandemic that occurred around the world, COVID-19.







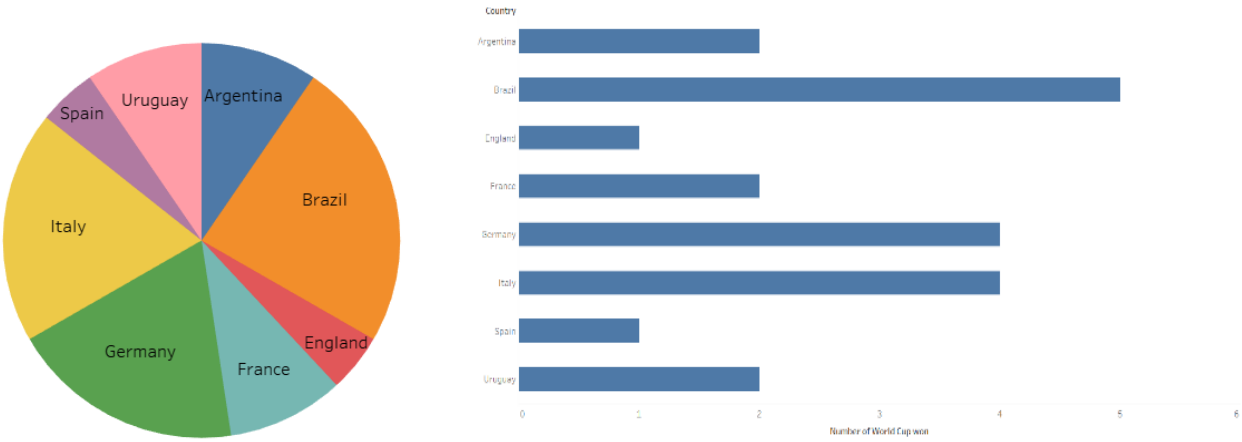


Figure 6. From top left to bottom; radar chart, word cloud, vertical bar chart, horizontal bar chart and pie chart. The figures were designed by the author

Flowchart-Infographic is the combination of both flowchart and infographic. By integrating the story elements connected with boxes and arrows, a flowchart enables one to show information about a system or machine schematically while, infographics are graphic visual representations of data or figures that aim to communicate the information succinctly, accurately, and effectively [18]. In this research, the information was taken from the Star Wars: Return of Jedi movie from 1983. The flowchart-infographic showed the characters' relationship with each other and was designed by the author. Using endnotes and summary boxes, annotated charts that empower and clarify the information shown in graphs are created [18]. Annotations encourage viewers to focus on specific elements of the charts, while endnotes let presenters explain and highlight the key significance or information [20]. The information was taken from Statista.com about the US unemployment rate from 2000-2020.

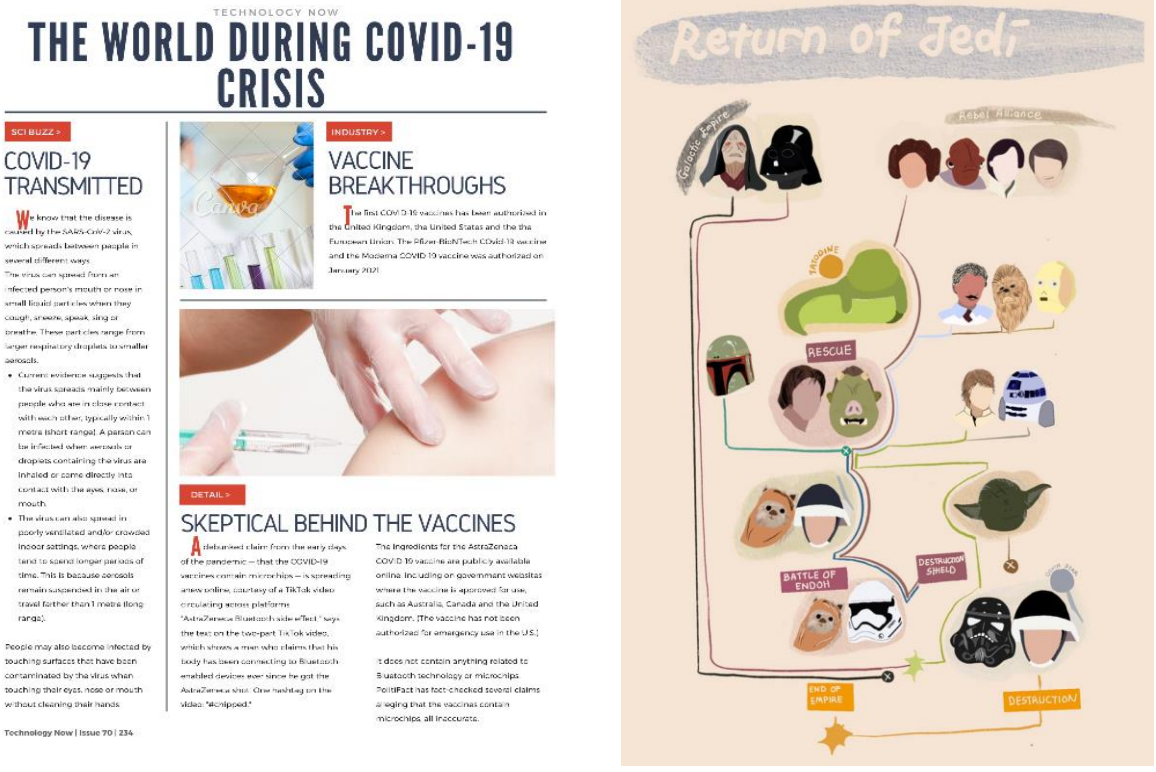


Figure 7. From top to bottom; magazine style and flowchart-infographic. The images were designed and drawn by the author.

A partitioned posters is a form of an infographic that can have several frames to visualize disparate yet connected groups of data [18]. Posters with a segmented message network were created as a series of design frames, with the design space divided into at least two frames and the data connection between them [21]. For this research, the information in the partitioned poster is the simplified illustration of the equilibrium concept made by using drawing software by the author.

Then there are animation, cartoons, and comics. This visual medium also includes scene changes that resemble those between panels of a fictional movie or comic strip [22]. Comics allow for the production of tales utilising cartoon representations of situations involving both photography and live animation. They also allow for the hierarchical expression of the final narrative through images and text [23]. The information used in this research for the comic and animation is about China's investment in India through the years. The illustration was done using drawing software and designed by the author.

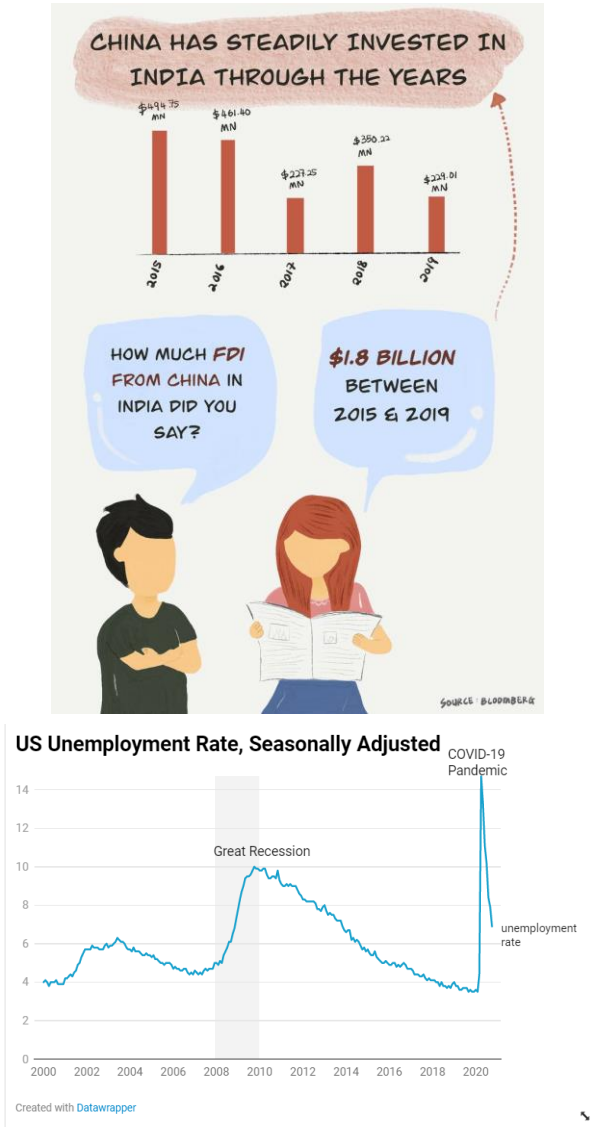


Figure 8. Comic and Animation and Annotated chart. The figures were designed and drawn by the author

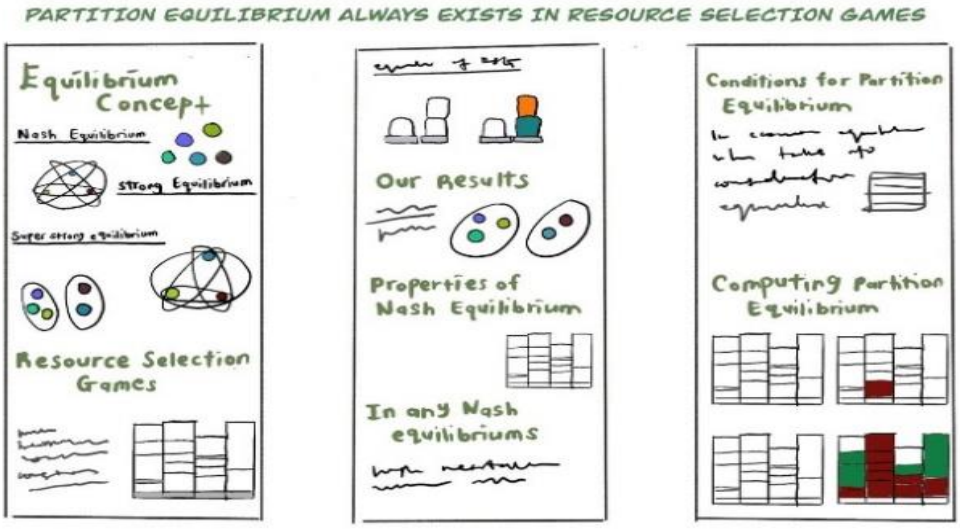


Figure 9. Partitioned Poster, designed and drawn by the author

3. Discussion

3.1. Validity Test

The testing for both inter-rater reliability and content validity (CVI) was performed on each item. How well a measuring tool covers a representative sample of the domain of the aspect being assessed is known as content validity [24]. The CVI expert panel assessed each item's applicability and representativeness to a particular issue [25]. Seven panels of data analysis and data visualization specialists were put together from academia and business. Each issue was evaluated using a Likert scale, ranging from 0 (not relevant) to 4 (very relevant). Items were altered after the initial meeting in accordance with the panel's suggestions. During the last meeting, the raw panel ratings were collected and entered into Microsoft Excel. Manual calculations were used to determine the content validity indices at the item and scale levels, as well as the universal agreement calculation method and averaging calculation method.

There are two categories of CVI: CVI for the item (I-CVI) and CVI for scale (S-CVI). The average of the I-CVI scores for each item on the scale (S-CVI/Ave) and the percentage of items on the scale that receive a relevance rating of 3 or 4 from all experts (S-CVI/UA) are the two techniques used to compute S-CVI [26]. The relevance rating must be recorded as 1 (on a relevance scale of 3 or 4) or 0 (no relevance) (on a relevance scale of 1 or 2) before CVI is calculated [27]. During the data presentation, each item's average and individual item evaluation will be considered. The measurement of inter-rater dependability would be made easier by the added universal agreement. S-CVI/Ave was determined using the two following formulas:

I-CVI = (agreed item) / (number of raters)

S-CVI/Ave = (summation all I-CVI) / (number of items)

The first method was multiplying the total I-CVI values by the number of items. The second method involved figuring out the average rating for each rater. The S-CVI/UA was then calculated by dividing the total number of items in that domain by the number of items with 100% agreement. For the instrument to be regarded as having acceptable content validity, it must achieve 80% agreement or greater. Testing for content validity was done on the questionnaire. During the period of July 5 through July 14, 2021, seven experts were hired. Although fifteen experts were initially sought, only seven accepted the invitation. Four of the seven experts work in the data analysis and visualization industries, and the remaining three are professors. The content validation method employed a non-face-to-face approach. When using a non-face-to-face method, the experts are frequently given a content validation form to complete online along with detailed instructions. The non-face-to-face strategy is very effective if a methodical follow-up is in place to raise the response rate and time. There were 39 items in the questions. The validation form was created with instructions and a rating scale to guarantee that the target respondents' panel has clear expectations and understands the questionnaire. The experts gave a score on each item individually using the corresponding scale after examining the domain and items. The experts were required to submit their responses to the researcher once they had finished assigning grades to each question. The outcomes are displayed below.

Item/Expert	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7		Expert in Agreement	I-CVI	UA
Q1	1	1	1	1	0	1	1		6	0.86	0
Q2	1	1	1	1	1	1	1		7	1	1
Q3	1	1	1	1	1	1	1		7	1	1
Q4	1	1	1	1	0	1	1		6	0.86	0
Q5	1	1	1	1	0	1	1		6	0.86	0
Q6	1	1	1	1	1	1	1		7	1	1
Q7	0	1	1	0	1	0	0		3	0.43	0
Q8	1	0	1	0	0	1	0		3	0.43	0
Q9	0	1	0	1	0	0	0		2	0.29	0
Q10	1	1	1	1	1	0	0		5	0.71	0
Q11	1	1	0	1	0	1	1		5	0.71	0
Q12	1	1	0	1	0	1	1		5	0.71	0
Q13	1	1	1	1	0	1	1		6	0.86	0
Q14	1	1	1	1	1	1	1		7	1	1
Q15	1	1	1	1	0	0	1		5	0.71	0
Q16	1	1	0	1	1	1	1		6	0.86	0
Q17	1	1	1	1	0	1	1		6	0.86	0
Q18	1	1	1	0	0	0	1		4	0.57	0
Q19	1	1	1	0	0	0	1		4	0.57	0
Q20	1	1	1	1	0	0	1		5	0.71	0
Q21	1	1	1	1	0	1	1		6	0.86	0
Q22	1	1	1	1	0	1	1		6	0.86	0
Q23	1	1	1	1	1	0	1		6	0.86	0
Q24	1	1	0	1	0	1	1		5	0.71	0
Q25	1	1	0	1	1	1	1		6	0.86	0
Q26	1	0	1	1	1	1	1		6	0.86	0
Q27	1	1	1	1	1	1	1		7	1	1
Q28	1	1	1	1	0	1	1		6	0.86	0
Q29	1	1	1	1	1	1	1		7	1	1
Q30	1	1	1	1	1	1	1		7	1	1
Q31	1	1	1	1	1	1	1		7	1	1
Q32	1	0	1	1	1	1	1		6	0.86	0
Q33	0	1	0	0	0	1	1		3	0.43	0
Q34	1	1	0	1	0	0	1		4	0.57	0
Q35	1	1	1	1	0	1	1		6	0.86	0
Q36	1	1	1	1	1	1	1		7	1	1
Q37	1	1	1	1	0	0	0		4	0.57	0
Q38	1	1	1	1	0	0	1		5	0.71	0
Q39	1	1	1	1	0	1	1		6	0.86	0
Propotion Relevance	0.92	0.92	0.79	0.87	0.41	0.72	0.87		S-CVI/Ave	0.79	
Sum of Proportion	5.5								S-CVI/UA	0.230769	
S-CVI/Ave	0.79										

Figure 8. The original questionnaire validation data

The results from the data up top indicate that the questionnaire is invalid. S-CVI-Ave, as displayed, is 0.79. For six to eight experts, a CVI score of at least 0.83 is appropriate [25]. The researcher must update the questionnaire by deleting the parts with the fewest CVI values in order to raise the CVI values to acceptable levels. The researchers identify some of the items in both the storytelling techniques and colors section (items 32 - 34) and (items 7-9) respectively, have low I-CVI value. The colors section I-CVI value are 0.43, 0.43 and 0.29 while the storytelling technique I-CVI value are 0.86, 0.43, 0.57 and 0.86. Both portions were eliminated, raising the content validity to 0.84. Storytelling techniques are the technique to showcase information to the viewers. One example is using horizontal logic. The concept behind horizontal logic is that the audience may read each slide's title, and when combined, these snippets can convey the user's intended narrative [3]. The colors section shows a selection of colors that the user can choose and different shading. Both sections have fewer CVI values may be due to the confusing nature of the storytelling technique, which takes a considerable amount of knowledge to understand the color; people with colorblind may have a problem with this section due to their disabilities in identifying certain colors.

3.2. Reliability Test

Reliability is the ability of a test to be repeated and yield the same results each time it is used. In other words, the degree to which a score accurately reflects a person's abilities is related to reliability. Consider the situation when students are being taught the subject of English. Over the course of a school term, the instructor administers two tests in an English language class. The students regularly do well on the exams, demonstrating the validity of the test items. Since it deals with the constancy of a measurement instrument's component parts, reliability testing is essential. A scale is said to have strong internal consistency reliability if the items "hang together" and measure the same concept. The internal consistency statistic with the highest usage is the Cronbach Alpha coefficient. It is regarded as the most acceptable reliability metric when employing a Likert scale. In this test, the average of all correlations in each pair of split-halves is

calculated. Instruments with multiple-choice questions may be used during this test. The range of Cronbach's alpha is 0 to 1. A reliable score of 0.7 or higher is regarded as acceptable. Twelve target users who responded to an email with a URL link to an online survey were used for the reliability testing. Most target audience consists of university students who have earned at least a bachelor's degree.

Item/Expert	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7		Expert in Agreement	I-CVI	UA
Q1	1	1	1	1	0	1	1		6	0.86	0
Q2	1	1	1	1	1	1	1		7	1	1
Q3	1	1	1	1	1	1	1		7	1	1
Q4	1	1	1	1	0	1	1		6	0.86	0
Q5	1	1	1	1	0	1	1		6	0.86	0
Q6	1	1	1	1	1	1	1		7	1	1
Q10	1	1	1	1	1	0	0		5	0.71	0
Q11	1	1	0	1	0	1	1		5	0.71	0
Q12	1	1	0	1	0	1	1		5	0.71	0
Q13	1	1	1	1	0	1	1		6	0.86	0
Q14	1	1	1	1	1	1	1		7	1	1
Q15	1	1	1	1	0	0	1		5	0.71	0
Q16	1	1	0	1	1	1	1		6	0.86	0
Q17	1	1	1	1	0	1	1		6	0.86	0
Q18	1	1	1	0	0	0	1		4	0.57	0
Q19	1	1	1	0	0	0	1		4	0.57	0
Q20	1	1	1	1	0	0	1		5	0.71	0
Q21	1	1	1	1	0	1	1		6	0.86	0
Q22	1	1	1	1	0	1	1		6	0.86	0
Q23	1	1	1	1	1	0	1		6	0.86	0
Q24	1	1	0	1	0	1	1		5	0.71	0
Q25	1	1	0	1	1	1	1		6	0.86	0
Q26	1	0	1	1	1	1	1		6	0.86	0
Q27	1	1	1	1	1	1	1		7	1	1
Q28	1	1	1	1	0	1	1		6	0.86	0
Q29	1	1	1	1	1	1	1		7	1	1
Q30	1	1	1	1	1	1	1		7	1	1
Q31	1	1	1	1	1	1	1		7	1	1
Q35	1	1	1	1	0	1	1		6	0.86	0
Q36	1	1	1	1	1	1	1		7	1	1
Q37	1	1	1	1	0	0	0		4	0.57	0
Q38	1	1	1	1	0	0	1		5	0.71	0
Q39	1	1	1	1	0	1	1		6	0.86	0
Propotion Relevance	1	0.97	0.85	0.94	0.42	0.76	0.94		S-CVI/Ave	0.84	
Sum of Proportion	5.88								S-CVI/UA	0.272727	
S-CVI/Ave	0.84										

Figure 9. The updated version of the questionnaire

Table 1: List wise deletion based on all variables in the procedure.

An example of a column heading		N	%
Cases	Valid	12	100.0
	Excluded[a]	0	.0
	Total	12	100.0

Table 2: Cronbach's Alpha value

Cronbach's Alpha	N of items
.910	33

The IBM SPSS Software tool was used to conduct the reliability analysis. Table 1 demonstrates the reliability of the survey. For 33 items, the Cronbach alpha value is 0.91, exceeding the minimal or acceptable value of 0.7. In conclusion, Cronbach Alpha is used to measure reliability and content validity to validate the questionnaire. The questionnaire is legitimate with a CVI value of 0.84, equal to the acceptable CVI value of 0.83, according to the findings displayed after modifying the content. The survey is also trustworthy. Cronbach alpha is 0.91, which is higher than the allowed value of 0.7.

3.3. Pilot Test

On June 7, 2021, a pilot test using the WhatsApp application was carried out. A scaled-down version of the entire survey was used for the pilot test. The study includes 8 persons (25 and older) from various socioeconomic, educational, and gender backgrounds. In order to clarify the project's goals and protocol and to estimate the required number of participants for the study, the researcher shared the survey link with a WhatsApp group.

The subjects were given enough time to decide if they wanted to participate before being requested to participate in the study. They were then given a questionnaire, about user preferences and personality differences in visual design for information visualization and storytelling reporting.

Participants must fill out a questionnaire as part of the measurement process. The questionnaire's comprehension and appropriateness, as well as the questions' definition, comprehension, and presentation, were all tested throughout the pilot.

The survey was broken into three sections: (1) user context, (2) information visualization, and (3) storytelling. The questionnaire was completed by participants in an average of 10-15 minutes. One person completed the survey in 20 minutes. Errors were corrected after considering all comments.

Some of the participant responses and suggestions were made to enhance the questionnaire. Four out of eight participants voiced their dissatisfaction with the personality test's tick boxes due to their size. The questionnaire now includes advice on top of the first page for individuals to complete the personality test on a PC rather than a mobile device for a simpler experience. All participants agreed that the instructions for filling out the score were too complicated. The researcher fixes this issue by switching the format from selecting the personality score range to inputting the score. The participants will select the categories to which their test results for each personality traits and facet belong after receiving their overall personality test scores. One participant complains that there are too many questions on the surveys (personality test and user preferences). However, the personality test was already an established indicator; the author refrained from reducing the number of items, as it may affect the quality of the indicator.

4. Conclusion

This paper discussed on the validity and reliability of the questionnaire on user preferences on visual design related to data visualization questionnaire. With an additional topic; data storytelling, the questionnaire will undergo validity and reliability testing. The questionnaire is valid with CVI values of 0.84, more than the acceptable CVI value. The Cronbach alpha value of the questionnaire is 0.91, indicates that the questionnaire is reliable to use. In summary, this questionnaire can be utilized in future studies to explore the connection between individuals' preferences and visual design. The next phase of the research will involve collecting and analyzing the data, and the results will be published in a separate paper.

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