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# COMP3736 Information Visualization Coursework 2: Evaluation Exercise

## Introduction

The aim of our experiment is to compare the effectiveness of bar charts against maps for the visualisation of plastic pollution. The data for each visualisation will be randomly generated. This includes producing different data for each question, regardless of whether that specific question has been shown for a different chart type.

We are going to measure the effectiveness of both chart types by measuring how quickly and accurately participants can comprehend the data presented to them. Our experiment is designed to ask a question related to each visualisation and to measure two metrics. Firstly, we measure if the answer is correct, to quantify accuracy, and then we measure response time to quantify comprehension speed. These metrics will be collated from all participants to determine how effective each chart type is.

The task will be executed by gathering a group of 10 participants and displaying 10 maps and 10 bar charts to each participant. Each visualisation will be displayed one by one, with the participant having to answer a multiple-choice question in a graphical user interface about the current visualisation. Both the correctness and response time of the participant's answer will be recorded. Each participant will perform this action for all 20 charts. The experiment should take each participant no longer than 15 minutes to complete, as there is only one question per visualisation and the questions themselves are straightforward to answer.

## Method

### Participants

For this evaluation, we had a total of 10 participants. Each of the participants were given a participant information sheet that outlined the experiment, and were informed that by participating in the experiment, they are giving informed consent. All participants were voluntary in the process, at no stage were there any incentives offered or provided to them.

### Materials

To create the visualisations, the *Matplotlib* library for Python was used for all bar charts produced. For the maps, the *geopandas* library was used. Python's *dateTime* library was also used to utilise timestamps to record response times of the participants to each question. To provide the user interface, the Tkinter library in Python was used.

Python's *random* library was used to create all the random data used for the visualisations. A static random seed value was also used to ensure the reproducibility of the random data. There was also an initial terminal before the GUI was loaded that explained the procedure and details of the experiment to participants was also made in Python 3.

When the question is first displayed to the user, the timestamp is stored as a variable. Upon the user answering the question, the overall time in milliseconds is calculated, based on the difference between the earlier stored timestamp and the current timestamp.

The users' response time and whether their answers were correct or not is then stored within a .csv file.

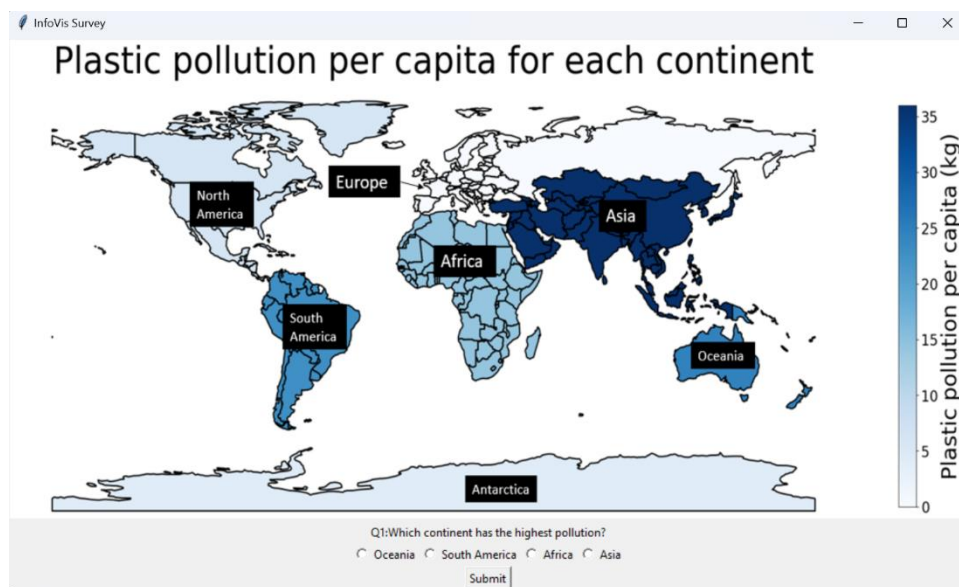
## Procedure

The experiment will start by running the Python application on a laptop. Once it starts running, a message appears on the terminal informing the participant about what the experiment will entail, what metrics are being recorded, and instructions for how to answer the questions.

The user presses the “Enter” key in the terminal to ensure they understand the procedure. This helps ensure that response times for the first few questions won’t be unnecessarily long if the user is confused about what to do.

Each participant will then be presented with 20 visualisations and multiple-choice question regarding that data, which will be shown one by one. There is a short one second delay in between displaying each visualisation.

To answer each question, the user will have to comprehend what information the visualisation is showing, and then answer a question based on the visualisation in question. The GUI provided shows the visualisation, 4 options and an ‘Submit’ button. An example is shown in Figure 1.



**Figure 1:** A sample question from the experiment

To answer the question, the participant must press an option, then press the ‘Submit’ button in the GUI. Both the data and related question for each visualisation will remain constant for every participant, in order to achieve fairer results.

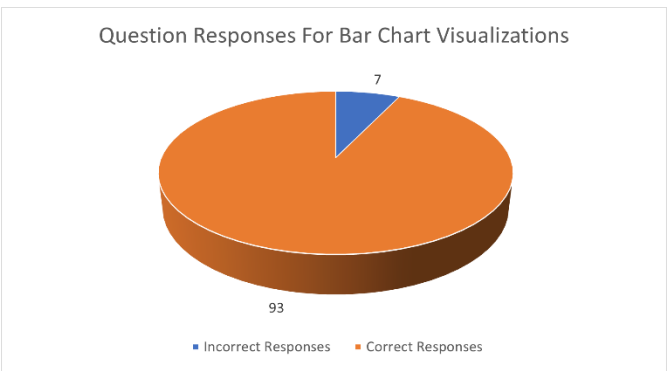
After a participant completes all these questions, we will store the metrics (the correctness and response time). After we have repeated this procedure to collect metrics from 10 participants, the metrics will be loaded into Excel for data analysis.

Given that every participant was answering the same question, the experiment took place within participants.

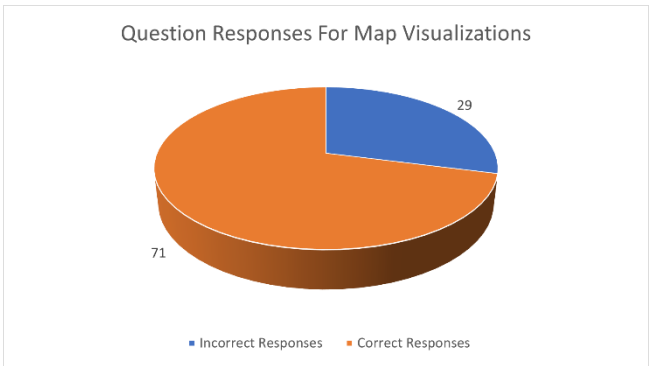
## Results

A quick note that questions 1-10 are based on maps of the world, UK, Europe, and the US. Questions 11-20 are bar maps displaying the same types of data as in questions 11-20 (e.g., the same countries) but

the data itself has been randomised again. Data has been randomised again to eliminate any sort of participant recall which could lead to the response times for bar chart being quicker than they would be otherwise.

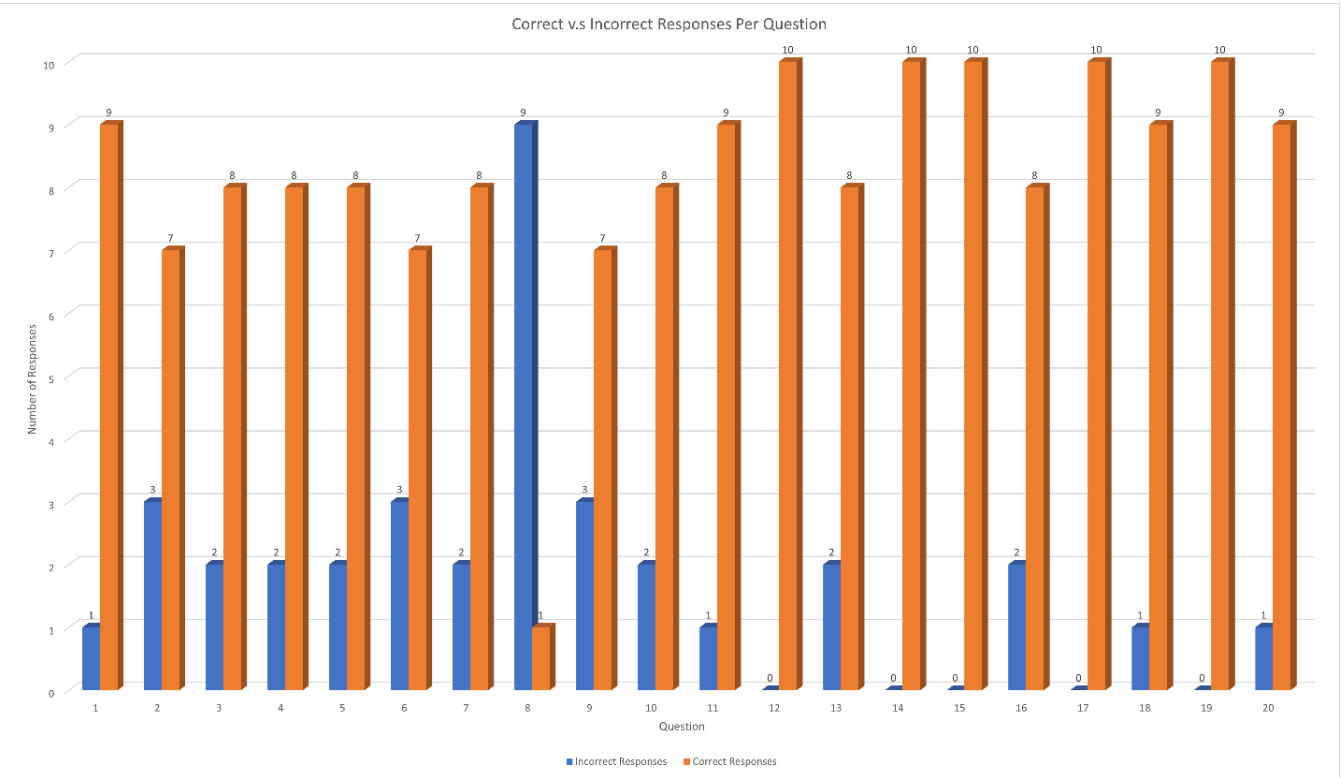


**Figure 2a:** The correctness of responses to each individual question on bar charts



**Figure 2b:** The correctness of responses to each individual question on maps

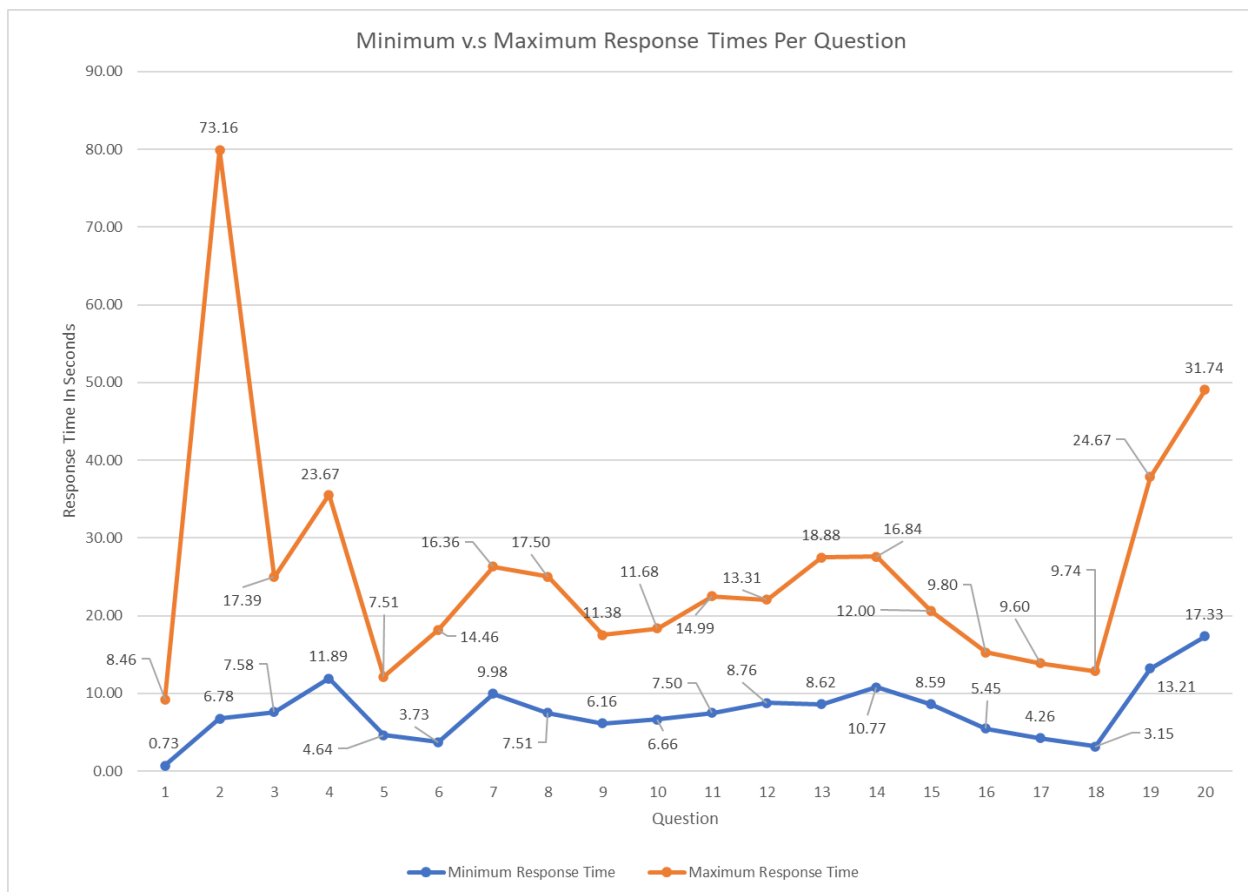
If we look at both visualizations of Figure 2, it clearly shows that bar charts are superior to maps when answering questions about a certain visualisation correctly, producing over 20% more correct responses in our results. This is likely down to bar charts showing the exact values for each data point, where maps only show the hue. Therefore, data differentiation for small differences is far less straightforward for maps, leading to more errors in answers. Whilst both chart types are still effective in accomplishing this task, there is a significant increase in error for maps.



**Figure 3:** The correctness of responses of all participants for each individual question

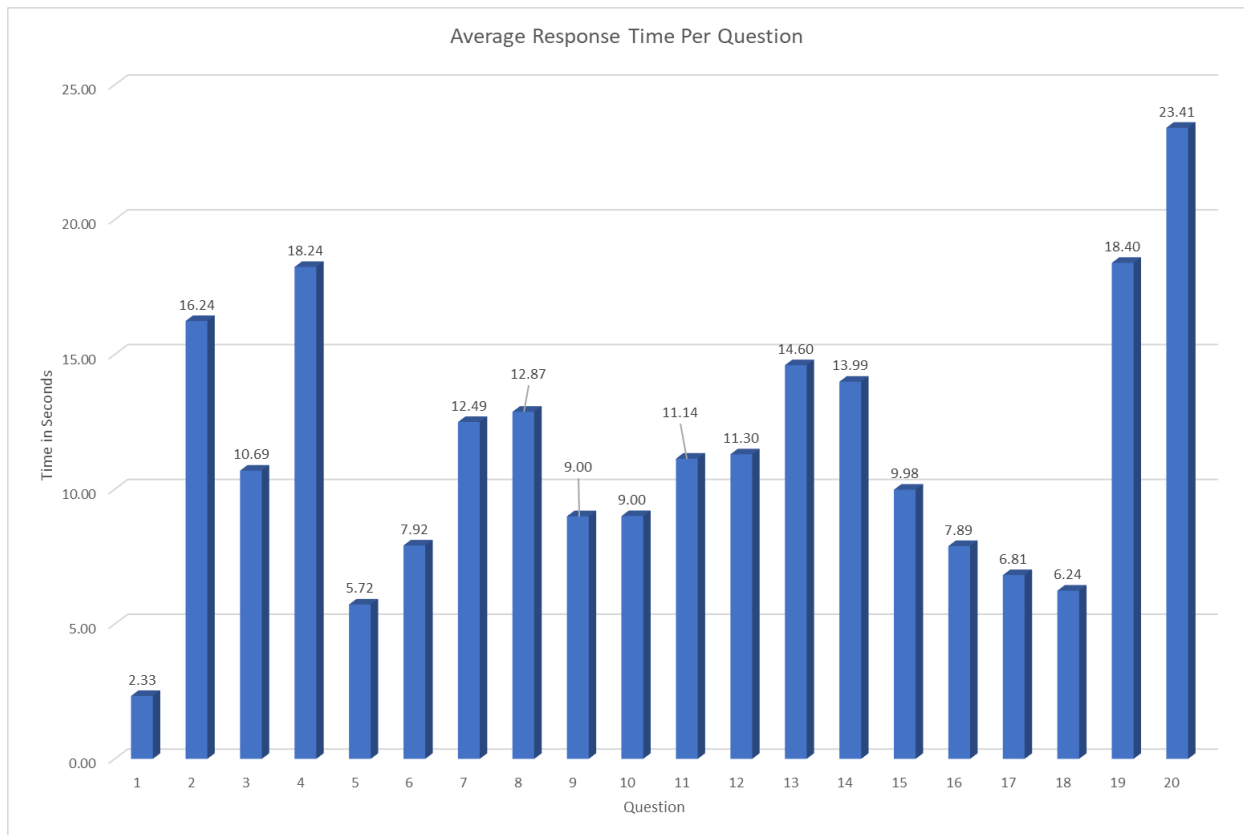
The majority of answers given to questions were correct, as shown in Figure 3, except for the outlier of Q8. This outlier is caused by the hues on the maps being extremely similar, which has resulted in many respondents getting the question incorrect. This shows that hue is often not as discriminable as other visual encoding methods, as in this instance the majority of participants were unable to correctly read the chart. In addition to this, the regions asking to be compared shared no borders, which made direct comparisons between the hues of these regions more difficult.

The percentage of answers that were correct is also significantly higher for questions 11-20, as these questions are all bar charts. From this we can show that responses are more accurate for bar charts than for the maps. From these results we can conclude that the length of bars is easier to compare than the hues of regions on a map, particularly when data is similar.



**Figure 4:** The highest and lowest individual response time for each question.

We can see that there is a large disparity between the maximum and minimum response time for Q2, shown in Figure 4. This is due to a single outlying value, which is shown by the average response time for Q2 (see Figure 5) not being an outlier, whilst its standard deviation (see Figure 6.) is significantly higher than all other values. This shows that maps can have a significantly wider disparity in response time, due to factors such as some users struggling to discern hue and the users' geographical knowledge varying.

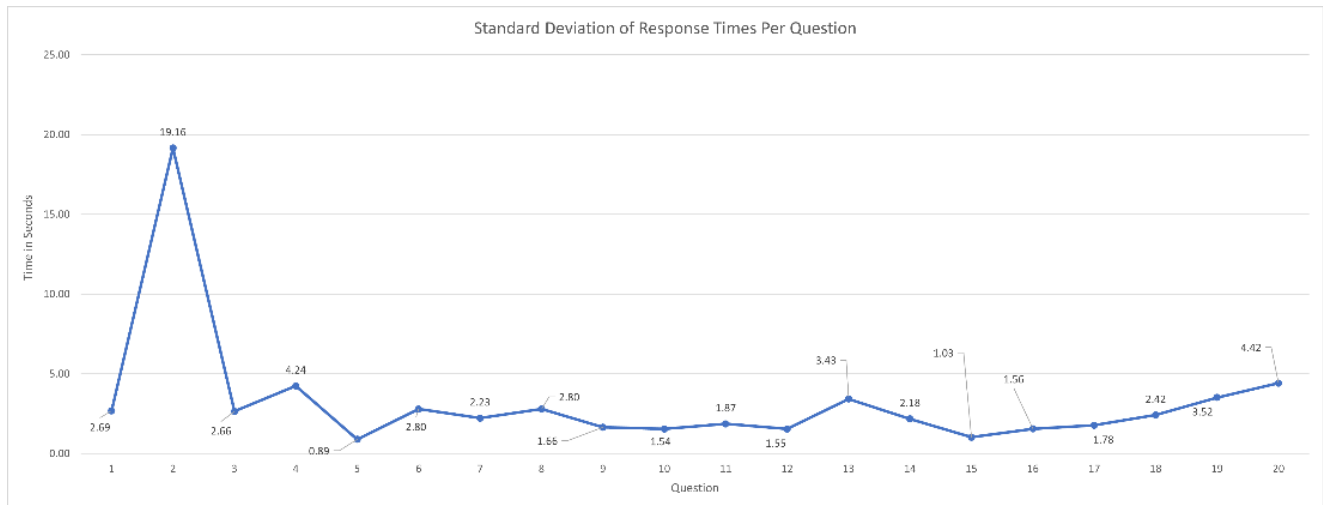


**Figure 5:** The average response time of each individual questions from all participants.

Generally, we can see from Figure 5 that the response time for bar charts is slower than the response time for maps. This suggests that it may be easier to quickly comprehend a map in comparison to a bar. It's worth noting that the previously discussed outlier is heavily skewing Q2, and without this outlier it would likely have a similar response time to Q1 due to them both being questions about continents. As continents are large, well known geographic groups they can be comprehended quickly. This result for Q1 illustrates that maps are more suited for areas with fewer and clearer regions/groups (in this case, continents).

The much longer response times for Q19 and Q20 can be explained by the fact that these questions had a very large number of bars, as they were for each US state. This takes a lot longer to comprehend than less populated bar charts in Q16, Q17 and Q18. This explains the large jump in response time.

However, it's important to note that Q18's bars are ordered by weight. This made it much easier to spot the highest value and thus was a factor in the very quick response time for this question.



**Figure 6:** The standard deviation of the response time for each individual question

Aside from the previously mentioned outlying value influencing Q2, we can see in Figure 6 that the next highest standard deviation is Q4. Q4 displayed a colour map of Europe, therefore meaning that some countries being shown were significantly smaller in area than others. This means that users with a poorer knowledge of Europe took far longer in responding than those who had a good geographical knowledge of Europe. This accounts for the standard deviation for Q4 being so generally high, due to a disparity in users' knowledge.

A general trend that we can see for our bar charts (Q11-20) is that questions which have significantly more columns, such as questions 19 and 20, also have larger standard deviations. This shows that bar charts' readability becomes increasingly inconsistent when there are more columns within them.

## Conclusions

From this experiment, we've discovered that maps are very useful for getting a good general overview of the data quickly, as shown by their quick response times. However, they aren't as effective for answering specific questions about a visualization. This is because the hue is not very suitable for showing minute differences in values, especially if the two countries in question aren't bordering each other.

Bar charts are far more effective if you want to answer specific questions about a plastic pollution visualisation, as shown by their far superior accuracy rate for question correctness. This is because it's much easier to spot small differences in values, due to bar length being a more obvious visual encoding method. However, this comes at the expense of taking more time to comprehend and understand the data being shown, which is backed up by the slower question response times in comparison to maps. This is especially true for bar charts with a greater number of columns.

Overall, this report finds that maps are more suited for quicker comprehension, especially for a large number of different variables. However, they struggle to deliver the accuracy that bar charts can provide. This is particularly true for when users have poor geographical knowledge of the areas they're being presented with, and when the values of variables are similar.

## Appendix

### Participant Information Sheet

#### **Participant Information Sheet: Coursework 2 Evaluation Experiment – COMP3736 Information Visualization**

Participating Student:

Address: School of Computing, University of Leeds

We are a group of 4 students in the module COMP3736 Information Visualization here at the University of Leeds. We are interested in how a group of participants evaluate a series of different chart visualizations. If you volunteer for this experiment, you will answer 20 questions in regards to 20 different visualizations. Each question will display either a bar chart or a map visualization, and your task is to answer a question that will test your interpretation of the data that the visualization is presenting.

The experiment will take approximately 15 minutes. Your responses will be recorded, but you will remain anonymous. The research will be reported in our deliverables for the coursework, but no-one should be able to identify you and at no point will your identity be divulged.

By taking part in the experiment, you are indicating informed consent. You are free to withdraw from the experiment at any time.

Finally, please let me know if you have any questions or would like to discuss anything with me.