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An Emprirical Study of Data Visualisation

SUBTITLE PLACEHOLDER

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Chapter 1

Data collection

1.1 Background on survey design

As explained by Wiley-Interscience (2004), a survey is a means of obtaining quantitative information regarding opinions and experiences of the respondents in order to explore the views of the target population as a whole. In this book, a survey is noted as a "systematic" method of collecting data, where the author states that the word "systematic" is deliberately used in order to separate surveys from other methods of information collection. "systematic" is defined by the Collins English Dictionary as something that *"is done according to a fixed plan, in a thorough and efficient way"* (Collins n.d.), and this reflects the manner in which surveys are created in accordance with a given system, where methods for distribution, implementation and analysis are defined under a pre-determined structure. The survey will be delivered to potential respondents in the target population, who will then be asked to complete a series of standardised questions, or questions for which the question ordering and wording is identical for every respondent, unless different formats are to be used to research purposes. It is once again discussed by Wiley-Interscience (2004) that standardised questioning was not always the norm; most interviewers would more likely have a list of objectives, and each interviewer would formulate and word questions based around these. It was discovered that question wording can have a drastic effect on respondents' answers.

Whether or not the survey is 'thorough' and 'efficient' depends heavily on the survey structure and design. Designing an effective, systematic survey involves balancing efficiency with completeness, creating a survey that can obtain as much information as possible whilst not boring or fatiguing participants, which can lead to non-response and measurement errors due to participants skipping questions or selecting answers at random. A well-designed systematic survey has the capacity to yield large amounts of both qualitative and quantitative information regarding the research topic while minimising these errors.

There exist a variety of methods for delivering a survey, such as self-completed questionnaires and interviewer-administered interviews. Depending on the aims of the study, there will be advantages and disadvantages to each method. There may also be times when a combined approach is helpful in gathering the necessary information. The first method of surveying, a questionnaire, may consist of either physical paper forms that are mailed or handed out to people within the target population, or in an online format. As discussed by Brace (2004), this form of surveying constitutes a method of indirect communication between the respondent and researcher, in effect a non-verbal conversation in which the respondent is replying to the researcher's questions. The non-face-to-face aspect of this method can be beneficial in terms of anonymity; an anonymous respondent is more likely to be honest in their answers than a respondent for whom the identity is known. As a result, an anonymous questionnaire can mitigate errors that may be caused by respondents fearing judgment of their answers. It is also possible to administer a large number of these questionnaires in a short period of time since they are self-administered, and thus constraints such as the number of interviewers or time taken to administer the survey has less effect on the amount of information obtained.

There are, however negatives to this questionnaire method. In his book, Brace discusses the way in which question wording must be very carefully thought about when using this method of indirect conversation, for reasons such as there being no way to correct participant misunderstanding of questions. Additionally, the fact that the researcher and participant never come into contact may allow the researcher to write questions without considering the human nature of the participants; it is easy to become absorbed in attempting to gather information and fall into forgetting that long-winded or complicated questions may bore or confuse respondents, leading to poorer quality responses. Similarly including too many questions in the questionnaire may lead to response errors for the same reasons. It is then crucial to be as clear and concise as possible in question wording, leaving little room for interpretation. This type of survey is also a very static medium; it does not allow for much expansion on participants' answers, with reasoning behind answers unknown unless specifically requested, which again could add to respondent fatigue and affect quality of response.

We can attempt to implement some dynamic discussion into a questionnaire in the form of 'open-ended questions', mentioned above as specifically requesting reasoning behind answers. A questionnaire is composed of two types of questions; closed-ended questions, for which the respondent selects their answer from a given set of potential responses, and open-ended questions, in which the participants are able to write their answers in a free-form format. Closed-ended questions are very good for obtaining quantitative data that may be easily categorised and counted, which is useful for gathering empirical evidence in order to form objective conclusions regarding the sample population.

Open-ended questions are generally used where more expansion may be required in addition to the closed-form answer, or if using a closed-form question would limit the answer range. The Leibniz

Institute for the Social Sciences (Züll 2016) provides guidance on open-ended questions, in which the occasions for using open-ended questions are outlined as:

- "knowledge measurement"; with with multiple choice, respondents would have a chance of guessing the correct answer, and thus this would be a sub-optimal way to measure raw knowledge
- "Unknown range of possible answers"; multiple choice may be limiting for certain questions, and may cause the researcher to miss important information
- "Avoidance of excessively long lists of response options"; if there is a known range of answers, but this range is very large, it may overwhelm respondents to see all of these as options
- "Avoidance of directive questions"; certain questions may have options based on the researcher's own opinions, and thus have the potential to direct the participant in a certain direction, and may not reflect the participants' true views. This links to "unknown range of answers" in that the researcher may incorrectly assume the potential range of answers and thus the given options may not cover the respondents' true opinions.
- "Cognitive pretesting", which covers instances such as ensuring the question was understood correctly.

To summarise, open-ended questions are useful when either there is not enough information to set a standardised range of potential responses or if more information is needed after a closed-ended response.

A method of surveying that is, by design, more dynamic is an interview. An interview may be structured, semi-structured or structured and each of these have a different set of features that distinguish them from one another. Structured interviews, as by the name, are rigid in nature and comprise of a vocal conversation in which the interviewer has a specific set of questions from which the discussion does not deviate. The slightly less rigid semi-structured interview is similar, but slight deviation from the plan is allowed in order to explore new avenues and ideas that might not be found with a structured interview, but the interviewer will still have a set of specific questions for which to obtain responses. For the most flexible of the three, the unstructured interview, the interviewer will tend to follow a loose plan of what they wish to explore rather than a strict question schedule, with the discussion led by the respondent's answers.

Phone calls and other forms of interview-based survey allow the interviewer to form a personal connection with the survey participant, which can be especially helpful for a company's image if the interviewer is particularly professional or charismatic. Additionally, while the interviewer will still be limited to asking the pre-set questions, the format of such a survey can be considered semi-structured

and with much more room for interpretation. This can lend itself to gaining additional insights that may not have otherwise been gathered from a more closed-form paper or online survey. Additionally, the more open format can negate any error as a result of participants misinterpreting questions due to the interviewer's ability to immediately clarify on any misunderstandings. This type of survey also provides an instant response, which is beneficial if there is only a short time frame available in which to gather information.

However, there are also shortfalls to an interview-based survey method. For instance, although a charismatic interviewer can positively impact the image of whoever is conducting the survey, this could also lead to biases, such as the respondent answering in a way they feel will please the interviewer. Additionally, the image of the organisation could potentially be tainted if the interviewer appears rude or unprofessional, alongside potentially providing bias in the opposite direction. As well as this, telephone surveys are likely to be interpreted as a telemarketing scheme, and thus potentially have a negative impact on the number of willing respondents. The reduced anonymity of this type of survey may also create bias in the way of participants avoiding making statements that could be deemed socially unacceptable, or that they feel they may be judged for, and therefore may not provide answers accurate to their true line of thought.

The UK Household Longitudinal Study ("Understanding Society - the Uk Household Longitudinal Study," n.d.) is an ongoing study and an example of implementation of a combined use of the above mentioned surveying methods. Initially, in 'wave 1' of the study, a sample of 40,000 households in the UK were selected to be surveyed on a yearly basis. The survey involves all members of each selected household, overall comprising of around 100,000 individuals, and asks them a range of questions regarding areas such as family life, income, employment and health. The study consists of a self-administered youth paper questionnaire given to respondents ages 10-15, and an interview for those aged 16 and up. This split in age demographic allows some questions to be omitted from the youth survey, such as those about income and employment, and some to be added such as about pocket money habits and 'future intentions', as the website states. Giving the youth respondents a paper questionnaire may help obtain more useful or relevant answers, as the respondent may be more comfortable with this than being interviewed by an adult. The youth questionnaire is also shorter, which could perhaps just be a result of many questions not being relevant to this demographic, or it could be a conscious decision, but either way this with help to ensure the young respondent doesn't lose interest and potentially incur bias in their answers due to either rushing to finish the survey or not paying attention. The adult survey also includes a section specific to 16-21 year olds. The surveys contain a standardised set of core questions asked each year alongside a set asked every other year. The reasoning behind this is given to be that this study has a very large scope, asking about many aspects of each respondents' life, and so it becomes inefficient and counterproductive to include all questions every year since, as mentioned previously, the longer a survey is, the more likely a respondent is to get bored or mentally fatigued. The fact that the adult

survey is administered in an interview also means that there may be limits on the amount of time the survey can take, as interviewers may have to get through a certain number of respondents in a day, additionally to the interviewer potentially also becoming fatigued. If the interviewer is fatigued, their tone and how they hold themselves may change, and potentially cause a subconscious bias in how the respondent answers the questions.

1.2 Specific goals of survey tool for this study

While visualisations can be a very useful tool for understanding data, they also have the potential to be highly misleading. This section of the study will explore how modifying certain aesthetic features of visualisations can impact perception and interpretation of data, and how these modifications can be exploited in order to mislead the observer. Misleading visualisations may be created in an effort to deliberately influence the viewers' perceptions, or accidentally as a result of poor practice and knowledge surrounding data visualisation. In either case, visualisations have the ability to communicate different messages and stories depending on how they present the data to the observer.

The specific aim of the survey is to test whether altering y-axis scaling, bar width, bar grouping method and colouring will have an impact on single data value interpretation and subjective interpretation of differences in data values.

1.3 Survey Design

The survey design will be inspired by the papers discussed in the previous literature review, all of which investigate how different aesthetic and design choices have the potential to mislead the observer or alter perception.

Following this, questions included in part 1 the survey will focus on gauging whether altering the y-scale to be truncated or logarithmic has an effect on user perception of difference in data point values, for both bar and line plots. The respondents will be asked to gauge both individual values and differences in values, with the former providing an open answer box in which the may type their answer to allow for maximum freedom and obtain their true observation, unimpeded by the bias of having a specific set of numbers to pick from when their true observation may lie outside this range. The question for gauging difference perception follows Lauer and O'Brien (2020) and Yang et al. (2021) in using a numbered scale with numbers representing a range from not much difference up to a large difference. The Yang et al. (2021) method of a 7-point scale was employed here. From these papers, it is hypothesised that the truncated scale will cause respondents to overestimate differences between data values, and the logarithmic scale will be hypothesised to result in underestimation.

Additionally, stacked bar charts will be investigated, showing a comparison between using the

stacking method as opposed to a grouped bar plot. Based on reviewing the literature, part 3 of the survey will include questions with the objective of testing standard stacked against grouped bar charts, alongside questions relating to the colour palettes used in depicting the different groups. We aim to test which colour palette is preferred in terms of aesthetics as well as ease of interpretation and reading.

The last two parts of the survey, noted henceforth as 'Sales - part 1' and 'Sales - part 2', explore the different y-axis scalings with respect to line plots, but for these, as opposed to the bar plots, the default was a truncated axis. The three plots investigated will consist of line plots relating to time series data for two fictitious companies. One will display each of the two lines on separate plots with the default axis, one will show both on the same plot with the default axis, and finally one with both on the same plot but with a zeroed axis. It is hypothesised that a difference in value for two time points will be perceived as smaller fopr the zeroed axis, and larger for the separated plots.

As discussed in Peytchev and Peytcheva (2017), too long a survey can result in higher measurement error due to factors such as waning interest or mental fatigue of respondents, resulting in careless responding and non-response. This is also further explored in Brower (2018), whereby a study is carried out to determine causes of careless responding, and specifically looks at questionnaire length and participant disinterest. The study performed in this work provides evidence that longer survey length can have a detrimental affect on careless responding; a long survey may make participants more likely to respond carelessly, and this must be considered when designing an effective and efficient survey. An additional conclusion states that participant interest in the survey content could have an effect, but also that evidence is less supported for this claim. There is significant enough evidence, however, to say that this should also be considered when designing the survey.

The Peytchev and Peytcheva (2017) paper explains that a 'split survey' design, where each respondent is only asked to answer a selection of questions from the whole set, is effective in reducing error while gathering large amount of information, however this will not be employed here. The reasoning for this is that there will already be a set of 12 different surveys being sent, and creating further splits could potentially lead to much too small sample sizes and thus inconclusive results. Additionally to this, the paper investigates how placement of questions in the survey can affect responses, concluding that questions asked later in the survey are more susceptible to bias, which tracks with the conclusion of survey length being a cause of careless responding; the longer a participant is taking a survey for, the more likely they are to start being careless with responding.

Due to this, the survey was designed to last in the range of approximately 15-20 minutes, as suggested in Revilla and Ochoa (2017). One paper (Crawford, Couper, and Lamias 2001) explores the pecieved burden of a survey on the participant, and performs a study whereby respondents were assigned a questionnaire, but given one of two different time estimates, for which the true length of the survey lay between. It was found that more people started the survey with the lower estimated

completion time, but more also dropped out. However, the time at which respondents dropped out did not significantly differ in the two groups. In order to obtain maximum response, it is wise to as accurately as possible disclose the true survey length, and even slightly over-estimate in the disclosure.

With regard to the interest factor, the survey was designed with engaging respondents. The topic of the majority of the survey was chosen to be data relating to the television show *American Ninja Warrior*, as this could be subjectively viewed as a 'more interesting' topic than seemingly meaningless numbers. The survey was administered to a test subject, who commented that they found this topic interesting, with the additional comment that perhaps some pictures of the Ninja Warrior obstacles would be nice, however was not employed. The survey also took this respondent about 20 minutes to complete.

Although the content of the surveys for this study is not likely to be controversial or highly personal, anonymity is still important as the participants could otherwise potentially feel pressure to give a 'correct' answer, given the mathematical nature of the questions. As mentioned prior, anonymity here means that this pressure is potentially reduced and thus the relevant measurement bias may be mitigated. Additionally to the more technical visualisation questions, respondents were asked a series of demographic questions such as age, degree subject (if applicable), and whether they are colourblind or have any disorders that my affect visual processing. Additionally, three Likert scaled questions relating to well they would rate their spatial, observational and numerical skills. The Yang et al. (2021) paper, which explores the truncation effect of barplots, looks at graph literacy and its relation to perception, and hypothesises that those undertaking quantitative subjects at PhD level would be less impacted by the truncation effect as compared to humanities PhD students. It was found that the truncation effect did impact both groups, but those in quantitative fields had their perception marginally less affected. Thus the degree subject question was included to explore if this has an effect here. In relation to the visual processing and colorblindness questions, these are again included to test whether they have any significant impact on perception, as it may be important to consider these factors when creating visualisations to ensure they are accessible to all, and the study will examine the potential impact of such disorders.

The set will consist of two groups if surveys, which will be identical up to the visualisation package used. Particularly, one group will contain visualisations made with R's ggplot2, the next with matplotlib from Python. These surveys will be distributed to the general public by sharing links on social media platforms such as Facebook. The reasoning behind creating two separate surveys in different languages is to ascertain whether the language used influences the interpretation. Within the groups there are 6 surveys, with each altering the order of visualisations shown in part 1 to assess the perception of each plot type without reference or comparison to another, and the same with part 2. in Part 3, each of the 6 used one of 3 colour palettes as the main colour, and another

as a comparitor to test which the preferred colour palette is and which respondents find easier to read and interpret.

1.4 Creating the Visualisations

See appendix for the code and figures of the visualisations. The R visualisations were created using R version 4.0.2 (R Core Team 2017) using ggplot2 version 3.3.3 (Wickham 2009). The Python visualisations were made using Python version 3.7.4 (Van Rossum and Drake Jr 1995) with pyplot from matplotlib version 3.3.3 (Hunter 2007).

1.4.1 The Data

The visualisations for the survey were created with inspiration from the papers discussed above. The bar plots were created using a data set regarding the history of obstacles used over 10 seasons of *'American Ninja Warrior'* (LAESSIG, n.d.). Each row of the data represents a single instance of an obstacle being used, and each instance has variables as specified in the below table.

Variable Name	Explanation
season	Season in which instance occured
location	Location of use
round_stage	Stage of competition in which instance occured
obstacle_name	Name of the obstacle
obstacle_order	Order in which the obstacle was placed in the course

This data was manipulated in R to produce a data frame containing the count of the number of times each obstacle was used over the course of the whole ten seasons. For the stacked and grouped bar plots, a data frame was produced, once again in R, containing columns 'obstacle' and 'stage', where 'obstacle' is a vector containing the name of each obstacle repeated the number of times it was used, and 'stage' similarly contains the names of all the stages of the competition, with each repeated the number of times it appeared. For example, Salmon Ladder was used 41 times, and thus is also repeated this many times, and there are 41 entries in the 'stage' vector corresponding to this. For the python version, the frequency tables were created manually.

The data for the time series plots was taken from the data set `BJsales` in the base R package `datasets` (R Core Team 2017). This data consists of a single vector of values with 150 entries, where each entry corresponds to a measurement taken at some arbitrary time point. Four subsets were taken from this data such that a start index was selected, and then this entry and the 11 following consecutive entries were extracted. The vectors were put into a data frame with the time steps set as months, giving a year of sales data for four fictional companies. This again was used to manually create a data frame in Python. To select the starting index, several seeds were tested for

random selection, and four seeds were selected that would create plots to best test the hypotheses.

1.4.2 The Bar Plots

As explained before, the bar plots for part 1 were made such that one uses the default axis scaling, one uses a truncated axis, and one uses a logarithmically-scaled axis. It is worth noting that in R attempting to truncate the bar plot itself does not work; the bar must start at the zero tick mark otherwise the bars do not show up. To get around this issue, the data itself was truncated before applying to a bar plot with the tick labels then altered to fit the truncation, using intervals of 10 as in the default plot. Python, on the other had, will perform the truncation without this issue and defaults to steps of 2.5, which could affect the reading of values. For the logarithmically scaled plots, R by default starts at 1 and uses a non-standard form notation with tick labels of 1, 3, 20, 30. Python does use standard form and has labels 0, 10^0 and 10^1, starting at zero. The Python scale starting at zero was before mentioned as potentially misrepresenting the data. The height gauging of the R plot could maybe be impacted by the scale starting at 1. The default for the Python control plot scaling was more granular than the R, with steps on 5 as opposed to 10. The control scales for both languages have a range [0, 40], and [20, 40] for the truncated plots. There were 4 bars corresponding to 4 of the most used obstacles, arranged in descending order.

The next part plays with the aspect ratio of the plots. In order to keep this accurate, the plots were saved within the code as opposed to saving from the viewing window. The default aspect ratio for the ggplot is 1/1 for height to width, and using pyplot.gca() and comparing to the default we see that the default for Python using this method is 0.1. For the 'wide' plot, the aspect ratios are halved to 0.5/1 and 0.05, respectively. For the narrow, the aspect ratios were doubled to 2/1 and 0.2. Note that the aspect ratios include the entire plotting area, including labels and titles. These plots contained 7 bars as opposed to the 4, but were still arranged in decending order.

The plots in the third part of the survey were the stacked and grouped plots. The three colour schemes were the package default, a greyscale, and the colurblind-friendly Viridis palette (Garnier 2018). The obstacles here were the same 4 as displayed in part 1, but with the added colours for the competition rounds. The default axis ratios here mean that the R plots appear taller in comparison to their width than the Python plots, due to the legends.

1.4.3 The Line Plots

The plots for part 1 of this show the false sales data in the form of time series line plots, where the x-axis displays the months and y-axis shows number of sales. In the R version, the x-axis displays the 12 months in words, whereas the x-axis of Python version numbers the months and plots them in intervals of 2 months. This was an unintentional error on the part of the designer, however could be used to draw conclusions regarding how the two systems differ; monthly ticks in words or

bi-monthly numbers. The plots in sales- part 2 were created very similarly, just with two different start indices.

1.5 The Survey

This section will discuss the specific survey questions and explain the differences in plot ordering and colour schemes between survey versions. Google forms was chosen as the medium for delivering the survey, as it is a free service and provides easy way to send out survey links and automatically compiles responses in a Google sheet along with time stamps, which can be exported to csv for analysis. To randomly assign each participant a survey, a javascript code was created to link to a landing page, which redirected the participant randomly to one of the 12 surveys. As time progressed it was possible to see how many respondents were taking each survey, and it was possibly to alter the Javascript accordingly to ensure each survey had an approximately even number of respondents. The survey was set such that each page contained a single question with a set of related sub-questions and only the plots relevant to these sub-questions, to prevent participants scrolling through the survey and seeing other figures which may alter their perception. This can also be used to analyse the effect of seeing other plots on perception of the plots following.

1.5.1 Demographic Questions

As discussed, the questions below are used to assess whether these factors have an impact on graph literacy and graph perception.

- Please enter your age (Open)
- If you are a university student or past university graduate please specify your area of study. (Drop down box: Science, Technology, Engineering, Maths, Arts, Social Sciences, Humanities, Business, N/A, Other (please specify))
- How strongly do you agree with each of the following statements? (Linear scale with 1 - 5, 1=strongly disagree, 5=strongly agree)
- - I have good spatial awareness skills
- - I have good observational skills
- - I have good numerical skills
- Are you colourblind? (Checkbox: Yes, No, Prefer not to answer)
- Do you have any disorders that may affect visual processing? (this could be a general visual processing disorder or dyslexia, dyscalculia, ADHD etc) ((Checkbox: Yes, No, Prefer not to

answer))

1.5.2 American Ninja Warrior - Part 1

The questions regarding each of the three bar plots were as follows:

- Approximately many times would you say the 'Salmon Ladder' was used? (Open)
- Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used? (1-7 scale)
- Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used? (1-7 scale)
- In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used? (Open)

Here, the two questions with the difference rating scale are used to assess whether having the bars next to each other vs on opposite ends of the plot has an effect on the difference in rating when comparing the responses for each of the plots.

The table below shows all the permutations of the three plot types, and which questionnaire version they appear in.

	Q1	Q2	Q3
V1	Control	Log	Truncated
V2	Control	Truncated	Log
V3	Log	Control	Truncated
V4	Log	Truncated	Control
V5	Truncated	Control	Log
V6	Truncated	Log	Control

The table shows that, for example, in version 1, the control plot was shown in question 1, the log-scaled in question 2 and the truncated in question 3.

1.5.3 American Ninja Warrior - Part 2

The questions regarding each of the three bar plots were as follows:

- How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is? (1-7 scale)
- How large would you say the difference between 'Log Grip' and 'Floating Steps' is? (1-7 scale)

- How many times would you say 'Floating Steps' were used? (Open)

Similar to part 1, the below table gives all permutations of the three plot types.

	Q1	Q2	Q3
V1	Default	Narrow	Wide
V2	Default	Wide	Narrow
V3	Narrow	Default	Wide
V4	Narrow	Wide	Default
V5	Wide	Default	Narrow
V6	Wide	Narrow	Default

Questions regarding comparisons between the plots were then administered as follows, while showing respondents all of the three plots on a single page.

- Which of the three bar charts do you find most aesthetically pleasing? (Multiple choice with options "A", "B" or "C")
- Which bar chart do you feel is easiest to read and interpret? (Multiple choice with options "A", "B" or "C")
- Which bar chart do you find hardest to read and interpret? (Multiple choice with options "A", "B" or "C")

1.5.4 American Ninja Warrior - Part 3

This part explored the differences in perception for stacked and grouped bar charts, alongside colour preferences. This part had 4 questions, with the first two asking about the stacked and grouped bar plots, with either the stacked first or grouped first.

The first two sub-questions are given below.

- How many times would you say 'Floating Steps' were used in the Finals (Regional/City) rounds? (Open)
- How many times would you say 'Log Grip' was used in the Finals (Regional/City) rounds? (Open)

The next question is "Please select the statement you feel applies to the bar chart above." and consists of a multiple choice answer with the following options:

- 'Log Grip' was used MORE in Finals (Regional/City) rounds than in Qualifying (Regional/City) rounds.

- 'Log Grip' was used Less in Finals (Regional/City) rounds than in Qualifying (Regional/City) rounds.
- 'Log Grip' was used an EQUAL number of times in Finals (Regional/City) rounds and Qualifying (Regional/City) rounds.")

This is followed by another mulitple choice question, given as Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?, with the following options:

- 'Log Grip'
- 'Floating Steps'
- They were used the same amount of times

After answering these questions for both plot types, the respondents were shown both on the same page and asked to select which of the two they found easier to read and interpret, and were then shown the stacked bar plot in two different colour palettes; the one used for the questions so far and a comparitor, with the questions below.

For the stacked vs grouped comparison:

- Which bar chart do you feel is easiest to read and interpret? (Multiple choice with options "A", "B", "C")

For the colours comparison:

- Which colour scheme do you find most aesthetically pleasing? (Multiple choice with options "A", "B", "C")
- Do you feel that one of the colour schemes makes it easier to read and interpret the data than the other? If so, please select which one. (Multiple choice with options "No", "Yes, A is easier", "Yes, B is easier")

For this part, survey versions 1, 2 and 4 showed the stacked bars first, followed by the grouped, and versions 3, 5 and 6 displayed the grouped first. It is shown in the below table which colour schemes were used in each survey.

Version	Main colours	Comparitor
V1	Viridis	Default
V2	Default	Viridis
V3	Default	Greyscale
V4	Greyscale	Default
V5	Viridis	Greyscale
V6	Greyscale	Viridis

1.5.5 Sales - Part 1

The respondents then moved onto part 1 of the sales section of the survey, in which they are asked to once again give subjective opinions regarding the y-axis scaling, but this time relating to time series line plots.

Once again, the same set of questions is asked for each plot which consist of, firstly, a two-row multiple choice grid, with each row relating to one of the companies. Respondents were asked the question "How much would you say sales of each company increased between January and December?" and were to give a response on the 7-point scale.

The ordering of the plots for each version number are given below.

	Q1	Q2	Q3
V1	Separated	Truncated	Zeroed
V2	Separated	Zeroed	Truncated
V3	Truncated	Separated	Zeroed
V4	Truncated	Zeroed	Separated
V5	Zeroed	Separated	Truncated
V6	Zeroed	Truncated	Separated

The second question was "How large would you say the drop in sales between April and July of Company A is?", which once again was rated based on the 7-point scale.

1.5.6 Sales - Part 2

The final part of the survey showed zeroed and truncated plots once again, for two different fictitious companies, this time with the intention of gaining an overall view. For each of the two, each respondent was asked a single 7-point scale rating question; "Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?".

Chapter 2

Univariate Analysis

This chapter will discuss basic univariate analysis of the survey results, including summary statistics and univariate testing for the whole population as well as the subsetting for the programming language used and degree type. Additionally, subsets will be created considering only the first plot shown for each question, drawing comparisons between responses for these plots themselves without influence of the others. The analysis will be performed in R version R version 4.0.2 (R Core Team 2017).

In terms of testing, Shapiro-Wilk tests will be applied with the `shapiro.test()` function to gauge whether the data sets can be considered normally distributed and thus whether parametric T-Tests are suitable for either one-sample or paired comparisons, for the Shapiro-Wilk test, the alternative hypothesis is that the data is not normally distributed. Failing he normality condition, a symmetry test will be administered via the `symmetry.test()` function from the package `lawstat` (Gastwirth et al. 2020), and providing there is insufficient evidence to reject the null hypothesis that the data is symmetric, a Mann-Whitney-Wilcoxon (MWW) test will be used. If there is sufficient evidence that data proves neither symmetric nor normally distributed, sign tests will be applied. MWW will also be used for two sample testing where perhaps a sign test would be most appropriate, but cannot be used as the samples are of different sizes.

The sample sizes are 70, 38 and 32 for the whole population, R subgroup and Python subgroup, respectively before removing NA of invalid values. The sample means and medians will be notated as $\bar{x}$ and $\tilde{x}$, respectively.

2.1 American Ninja Warrior - Part 1

This part of the survey assess the effect of truncated and logarithmic scaling on bar plots perception and interpretation.

The final question in part 1 of the survey, *'In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?'* will not be considered as it is similar to the previous questions, and responses ranged in form, between percentages and decimals, and it can not just be assumed that all the decimals can be converted to percentages; for example a value of 0.5 could be the decimal value for 50%, or the respondent could have meant this as 0.5%.

2.1.1 Effect of Y-Axis Truncation

In general, truncating the y-axis had less of an effect than anticipated. In question 1, *"Approximately many times would you say the 'Salmon Ladder' was used?"*, for which the true value was 41, the distribution of responses for the truncated plot ($\bar{x} = 41.35$) as compared to that of the control plot responses ($\bar{x} = 41.21$) shows a small difference, with the mean perceived value of the bar being slightly higher for the truncated plot. The median for both of these is 41, showing that both distributions are centered around the true value of 41. The control and truncated plots have contextually fairly small variances of 0.752 and 0.753 respectively, depicting both that there is limited variation in the responses and most of the observations lie fairly close to the respective means. The variances are also quite similar, showing that the distributions appear fairly similar, as emphasised by observing the below density plot.

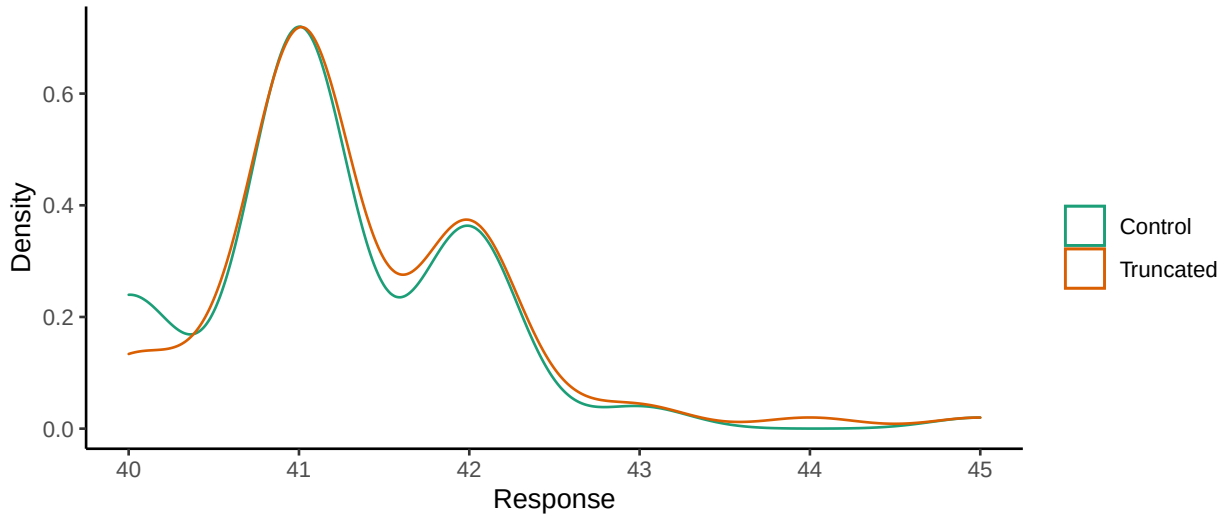


Figure 2.1: Density plot showing distributions of responses regarding the control and truncated plots for the question 1

Performing a dependent-samples sign test comparing these two sets of responses confirms that there is no significant difference ($p = 0.1877$) in the response distributions. However, the one sample sign tests show that there is not sufficient evidence to suggest the control plot responses differ from the

true value of 41 ($p = 0.1214$), but there is evidence to accept the hypothesis that the truncated plot responses differ from the true value ($p = 0.0026$). This shows that, while there is insufficient evidence from sign testing to suggest a statistically difference in the responses for the two plots, the location of the truncated plot responses may be slightly further from the true value than the control, and it is confirmed by a one sided sign test with an alternative hypothesis that the true median of truncated responses is greater than 41 ($p = 0.0002$). This gives evidence that the truncated plot results in a slight overestimation in reading of the bar height as compared to the true value of 41. Note that in the responses for the control plot for question 1, there was a response of "41/41", which was taken to be 41.5.

In question 2, *'Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was was used?'*, the set of responses for the truncated plot ($\bar{x} = 5.87$, $\tilde{x} = 6$) is considered significantly different by a dependent-samples sign test from the control plot responses ($\bar{x} = 5.36$, $\tilde{x} = 5$). By eye, the average values do not seem too different between the two plot types, although the p-value of the sign test ($p = 0.00019$) shows that there is in fact a statistically significant difference. The perceived difference for the truncated plot being rated higher on average than for the control plot provides evidence to accept the hypothesis that using a truncated scale can cause differences in bar height to appear larger, once again this is confirmed by a one-sided sign test ($p = 9.554e - 05$), with the alternative hypothesis that the true median of truncated responses is greater than that of the control responses.

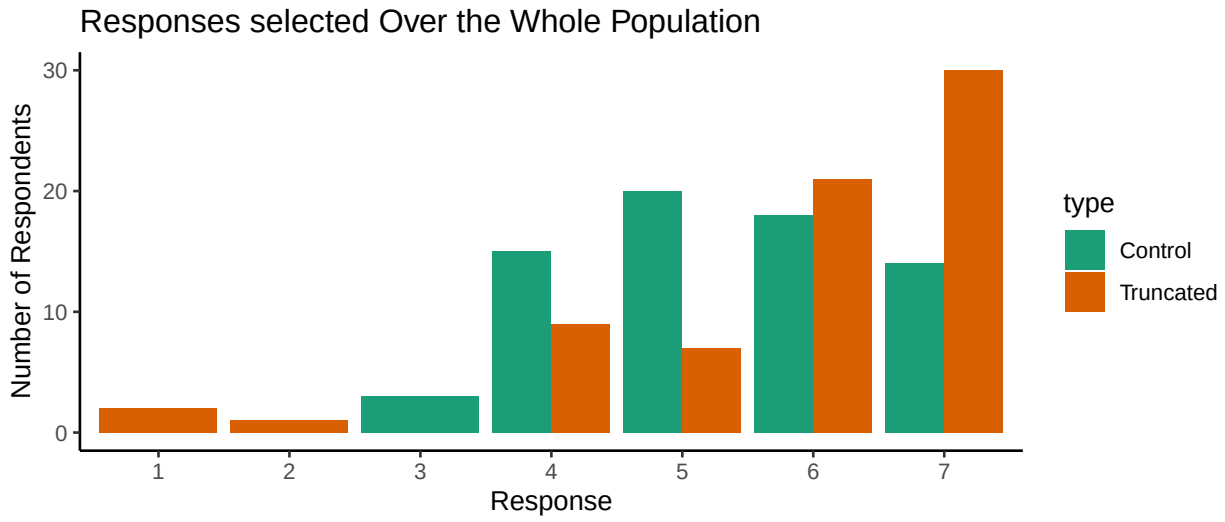
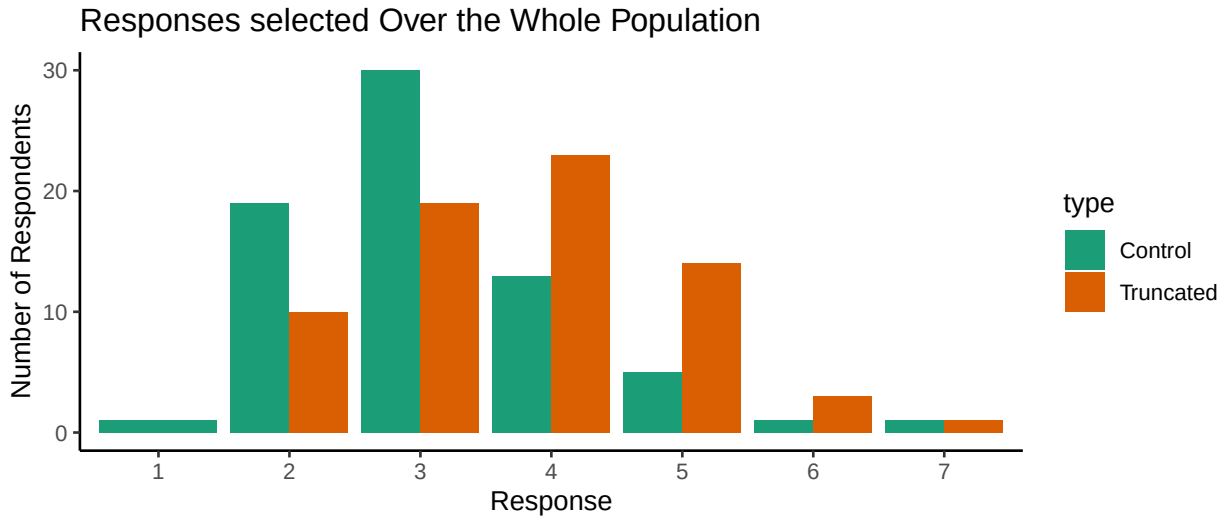


Figure 2.2: Bar plot showing distributions of responses regarding the control and truncated plots for question 2

The spread for the truncated and control plot responses are slightly skewed to the right, depicting that the subjective view on the difference between the bar heights was that it was in general on the

larger side. Looking at the bar heights, for the responses of 4 and 5 the control plot bars are higher, and vice versa for the truncated plot response bars. This again emphasises the evidence to support the hypothesis that truncation leads to larger perceived difference.

Question 3 of part 1, *'Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?'*, asks a similar question to question 2, but asks respondents to judge the difference for bars on opposite ends of the plot as opposed to next to each. Again, the by eye comparison shows not a massive difference between distributions of responses for the control ($\bar{x} = 3.12$, $\tilde{x} = 3$) and truncated ($\bar{x} = 3.12$, $\tilde{x} = 3$) plots, although the sign test shows that the there is evidence to suggest that the truncated plot responses are in fact on average greater than for the control plot ($p = 4.624e - 06$). figure[?] shows the distribution of responses.



The response distributions, conversely to question 2, now seem skewed more to the left. However there is a similarity in the way that for the lower ratings of 2 and 3, the control plot response bars dominate, and for the responses of 4 and 5 the opposite is true.

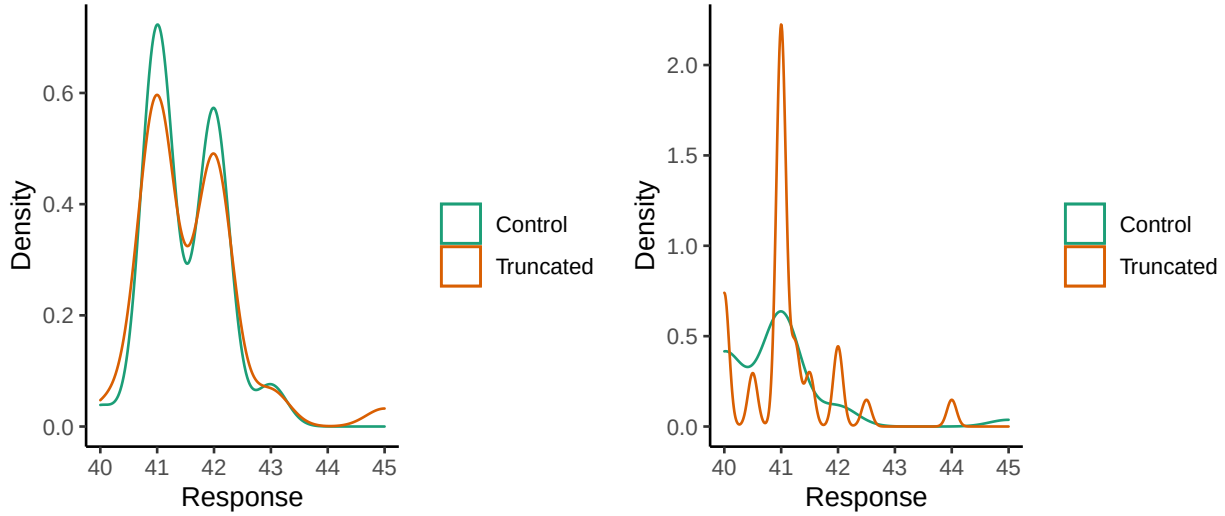
Overall, it seems that the use of truncation has a small but statistically significant effect on perception of height difference between bars, with respondents tending to judge the difference as slightly larger than for the control plot, although this effect is smaller than initially anticipated, and larger for bars that are further apart. In terms of reading values from bars, the truncation did not have a statistically significant effect when comparing the two distributions, however in one sample testing the truncated plot responses did differ significantly from the true value.

When considering the language subgroups, note that there is a discrepancy here between languages in terms of the axis tick breaks and labeling, with the R plot being incremented in steps of 10 for both the control and truncated plots and the Python being more granular in steps of 5 for the control and steps of 2.5 for the truncated.

Consider question 1. Comparing the two language subgroups for the truncated plot, the distributions for both the R ($\bar{x} = 41.56$, $\tilde{x} = 41$) and Python ($\bar{x} = 41.01$, $\tilde{x} = 41$) responses to question 1 appear similar in location to those of both each other and the whole population ($\bar{x} = 41.35$, $\tilde{x} = 41$).

Comparisons via MWW testing show that the responses related to the control plot differ statistically significantly between the two language cohorts ($p = 0.00012$), and similar for the truncated plot responses ($p = 0.02163$), where the tests were performed comparing first the R and Python responses for the control plot, and then for the truncated.

A sign test shows sufficient evidence that the R subgroup responses relating to the truncated plot differ from the true value ($p = 0.0004$), whereas there is insufficient evidence when applying a MWW test to the Python responses ($p = 0.718$). Similarly, the R subgroup's responses in relation to the control plot statistically significantly differ from the true value ($p = 7.629e - 05$), but the Python subgroup's do not ($p = 0.1185$). This could potentially be a result of the less granulated R plot scaling, due to the reduced precision.



The distributions for the control and truncated plot responses for the R subgroup are fairly similar to the whole population, although the peaks for the logarithmic plot responses are marginally lower. The distribution of the truncated plots is unexpected from lokking at the numbers, and more 'chaotic'. This shows potentially more variation in the responses.

For question 2 it is similarly seen that the language used does not have a statistically significant impact on the response for the truncated plot, with means 5.500 and 5.187, and medians 6 and 5 respectively for R and Python for the control plot, and means 5.98 and 5.84 both with median 6 for the truncated. Comparative testing with MWW gives $p = 0.2199$ for the control plot and 0.9105 for the truncated. Thus, the scale granulation or any other differing aspect of the plots does not seem to have a significant effect. See figure[?] for the distributions.

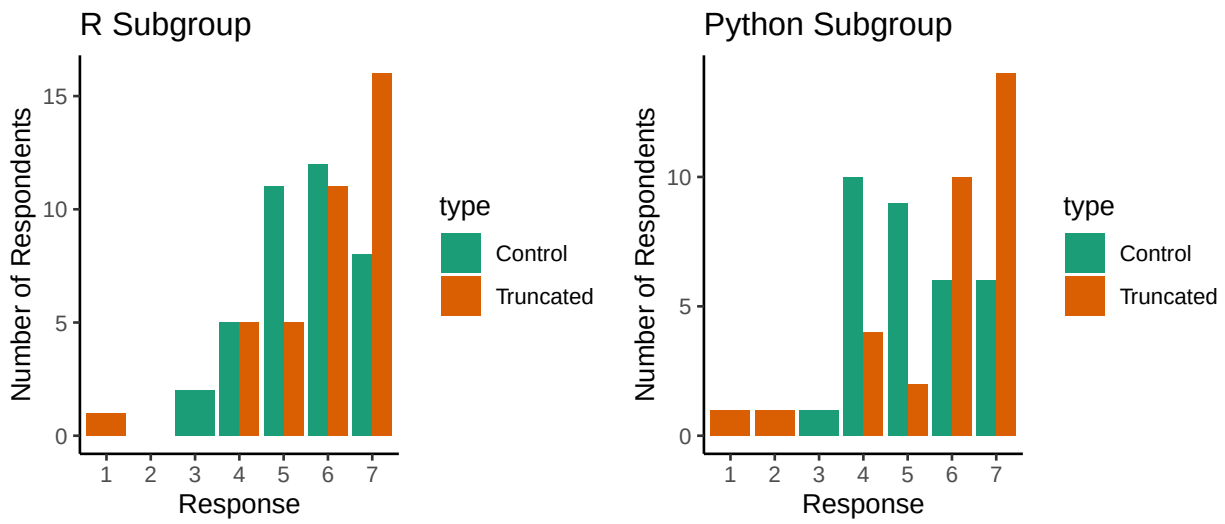
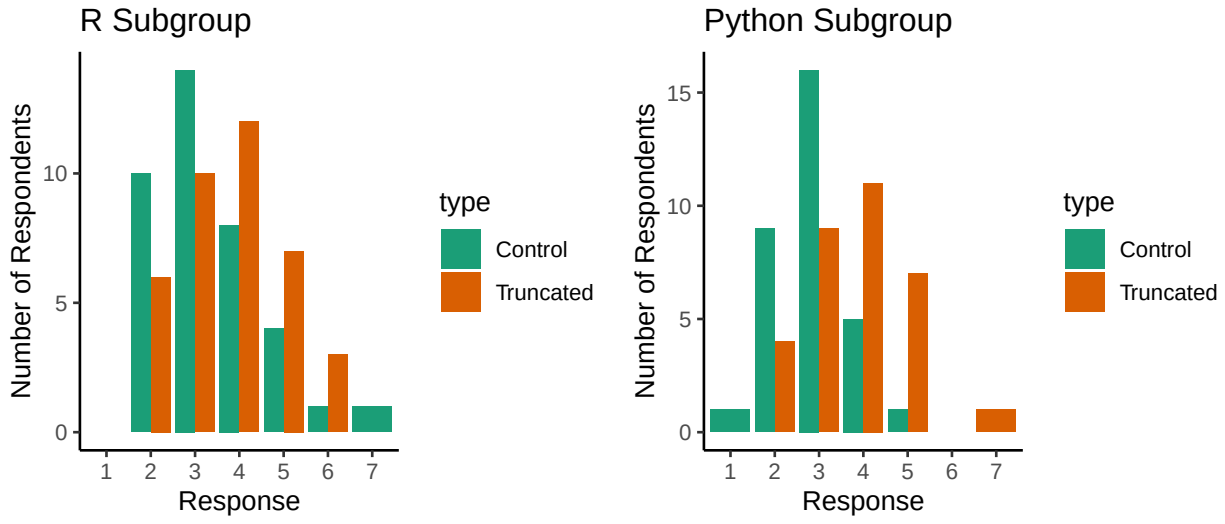


Figure 2.3: Bar plot showing distributions of responses regarding the control and truncated plots for question 2, for the R and Python subgroups

For question 3 (see figure [?]), it is again seen that the responses in relation to the R version of truncated plot ($\bar{x} = 3.76$, $\tilde{x} = 4$) do not differ significantly to those related to the Python version ($\bar{x} = 3.78$, $\tilde{x} = 4$), with a two sample MWW p-value of 0.9708. Similarly the control plot, there is little difference between the R ($\bar{x} = 3.342$, $\tilde{x} = 3$) and the Python ($\bar{x} = 2.87$, $\tilde{x} = 3$) versions of the plot, again with am MWW p-value 0f 0.1465.



Figure[?] shows both distributions, with the R appearing more positively skewed and the python looking fairly symmetric for both plot types, which was also found when performing symmetry tests. For the Python it can also easily be seen that the bars for the truncated plot responses seems 'shifted' to the right slightly as compared to the control.

Now considering subsetting for the respondents that saw the truncated plot first out of the three. Note that 25 saw the control plot first and 23 saw the truncated plot first.

The distribution of responses for the truncated plot in question 1 shows a slightly higher mean (41.696) and median (41.25) than for the whole population, but a MWW test shows that the difference is not significant ($p = 0.1379$). Similarly for questions 2 and 3, performing tests on the truncated plot for respondents who saw this first as compared to the truncated plot responses for the whole population result in p-values of 0.2614 and 0.3145, providing evidence that the plot order doesn't have much of an impact on perception for the truncated plot.

The conclusions appear to be consistent with results from the Yang et al. (2021) paper, in which the researchers, similar to this survey, showed participants a series of control bar plots alongside those with a truncated axis, and concluded that the difference in values for the truncated axis were perceived to be larger than those of the control plots.

2.1.2 Effect of Logarithmic Scaling

Within the logarithmic responses, there were two invalid responses, given as 'Don't know' and 'Next to none.'. These will be considered as 'NA' responses and discounted from the quantitative analysis, however they do provide useful qualitative insights into how the respondents reacted to the plots, particularly as both were entered for the logarithmically scaled plot made in Python.

The mean of the responses for the logarithmically-scaled plot, on the other hand, was magnitudes higher than the true value at 1.493e+13, although with a median of 35; lower than the median response of the control and truncated plots responses. The high magnitude is the result of two answers of '10^15' and '10^9', both again for the python version of the plot.

The default logarithmic scaling in Python uses standard form notation, which perhaps the two participants who entered the high magnitude answers were less exposed to and not as familiar with. Looking at the degree subjects for these respondents, it is observed that they study Social Sciences and Psychology, respectively. This could add to the idea that they are less familiar with this notation as it is more commonly used in mathematical and physical science disciplines. One of the respondents also rated their numerical skills at 1/5, showing they feel that numerical skill is not their specialty. The other rated their numeric skills at 4/5, showing that even with a good self-perceived level of numerical skill, standard form could be considered misleading.

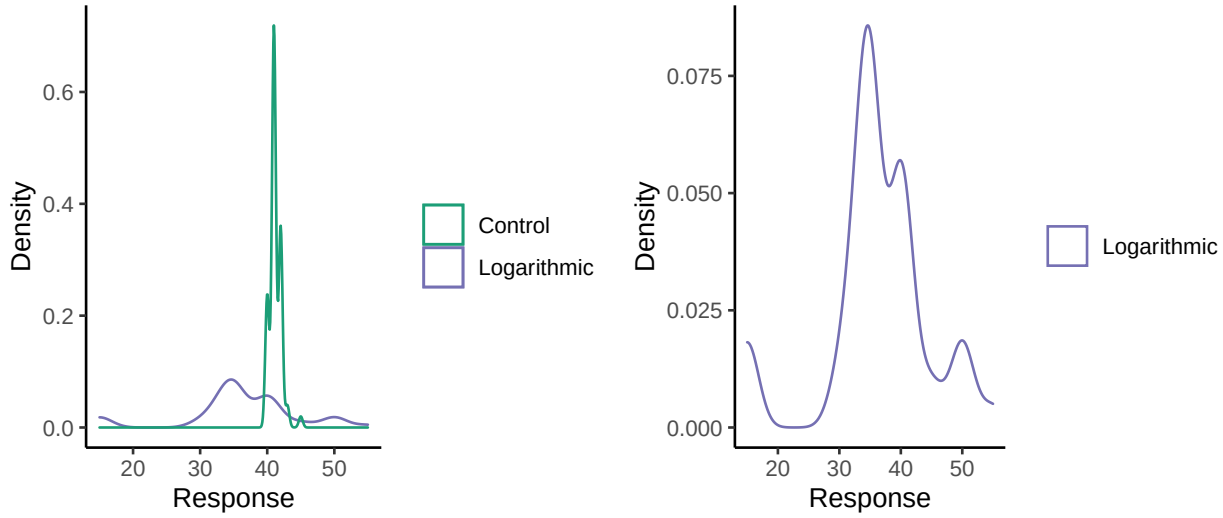
This should perhaps be considered when designing visualisations; the creator of the visualisations may find the logarithmic scale or standard form more effective in showing the data, but they should consider the target audience. Are the audience going to be familiar with this? If, for example, visualisations are being published in a paper targeted at academics in a subject likely to use such scalings often and understand them, this may be a good way to depict the data. However, using

this in something such as an advertising campaign could mislead the public, causing them to either over or under estimate values. As previously discussed, however, this is often done deliberately in order to push the message the creator wishes to sell.

The variance in the responses for the logarithmic plot is also high, with value 1.492×10^{28}, showing that a large amount of the observations differ from the very high mean, and considering this alongside the lower median may point towards many of the respondents either giving an accurate response or even underestimating. Furthering this point, the IQR for the logarithmic responses is the interval $[30, 40.5]$, which sits below the true value, displaying that over 50% of the observations in the total population actually underestimate the value.

The distribution of responses in the R subgroup also shows on average a slight underestimation ($\bar{x} = 39.73$, $\tilde{x} = 35$) and, as expected, vast overestimation for the Python version ($\bar{x} = 39.73$, $\tilde{x} = 35$). This shows that, with a linearly notated logarithmic scale, the scale may cause underestimation, but this is counteracted by using a standard form notation.

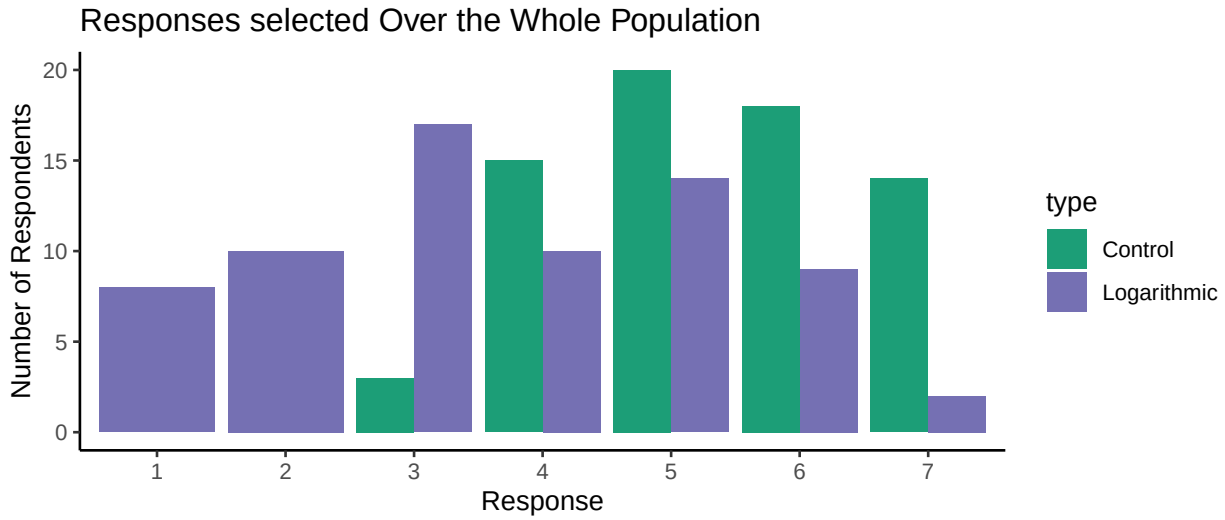
It can be considered to follow the convention of values that have value outside the range $[Q1 - 1.5 \times IQR, Q3 + 1.5 \times IQR]$, where $Q1$ and $Q3$ are the first and third quartiles, which here would be the range $[14.25, 60.75]$ and results in a sample size of 59. Consider now the response distribution for the logarithmically-scaled plot, after removing these responses, for which figure[?] gives the density plot. Both plots show the response distribution of the outlier-removed set of responses, with the providing a comparison with the distribution of responses relating to the control plot.



The Python default of standard form notation appears to have confused certain respondents, who are perhaps not as used to seeing this notation, and there was a large range in the responses along with one person not even entering a number, but rather stating that they “Don’t know”, and another stating they believed the value was “Next to none”. The “Next to none” entry is subjective, but could potentially be be assumed as a value close to 0, once again maybe as a result of standard

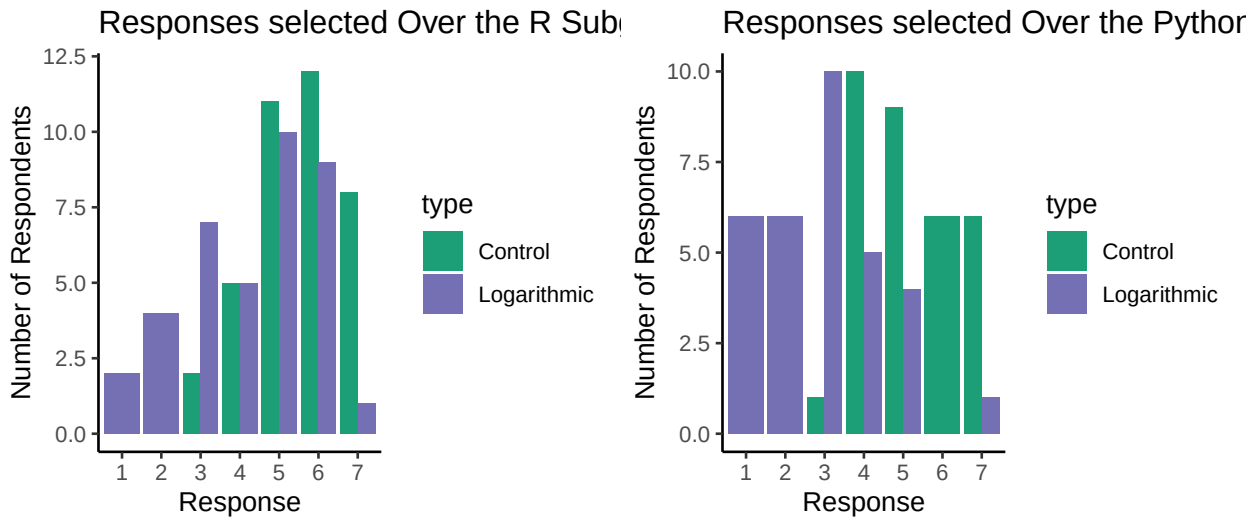
form being less well known to this respondent.

The distribution of responses for question 2 is displayed in figure[?].

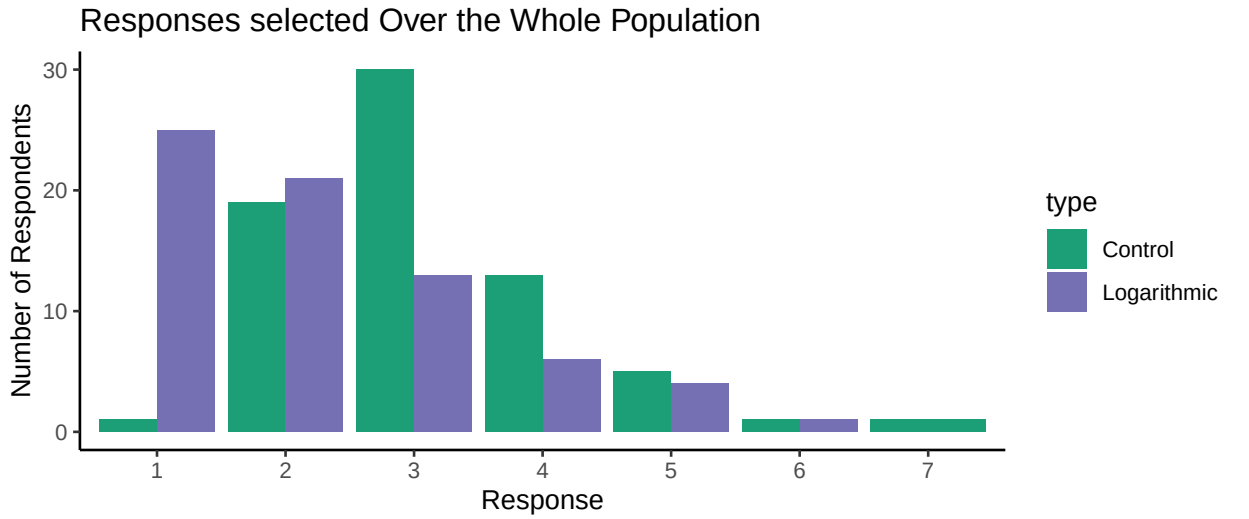


The spread of logarithmic plot values is fairly wide, with at least one response for each option, and the control is the same as stated before. The plot depicts how there is a wide spread of values, with some respondents having very different subjective views of the size of the difference to others. On average, the subjective perceived difference in bar heights was significantly lower for the logarithmic plot responses ($\bar{x} = 3.67$, $\tilde{x} = 3.5$) than for the control ($\bar{x} = 3.35$, $\tilde{x} = 5$). This is evidenced by a one-sided sign test with the alternative hypothesis that the logarithmic plot responses are on average lower than the control plot responses.

There is evidence to show that the difference between the R and Python versions of the logarithmic plot is significant ($p = 0.00096$, $\bar{x}_R = 4.263$, $\bar{x}_{Py} = 2.969$). The distributions for the two language subsets are shown in figure[?].

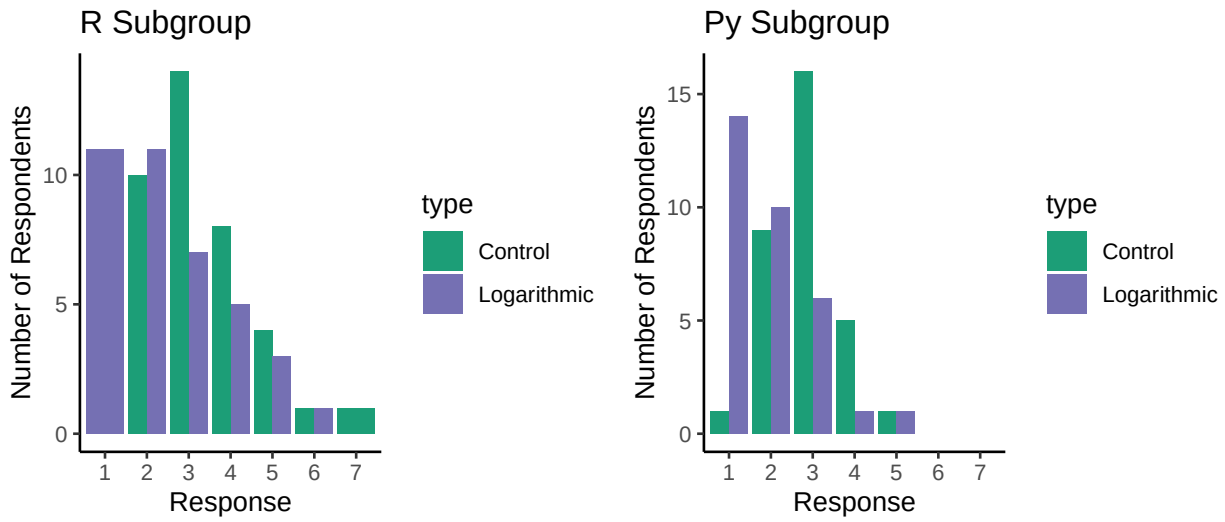


In regard to question 3, see again figure[?] for the plotted distributions.



The responses for the logarithmically scaled plot are skewed towards the lower end of the scale, similar to the control and truncated responses, and there does not appear to be much difference between distributions of the two populations. Looking at the numbers, however, the averages for the logarithmic plot ($\bar{x} = 2.22$, $\tilde{x} = 2$) seem lower than that of the control plot ($\bar{x} = 3.77$, $\tilde{x} = 4$). Indeed, a one sided MWW test comparing the logarithmic and control plot responses elicits a p-value of $1.317e - 06$, showing evidence that the logarithmic scale resulted in lower rating in difference of bar height.

Figure [?] shows the distributions for R and Python subgroups.



The distributions of the logarithmic plot responses for the R ($\bar{x} = 2.5$, $\tilde{x} = 2$) and Python ($\bar{x} = 1.9$, $\tilde{x} = 2$) subgroups appear fairly similar, with the same median albeit with the mean for the R subgroup being slightly higher. The plots to appear to show the R subgroup responses being slightly positively skewed and the Python responses more centered around 3. A two sample, one sided MWW test provides sufficient evidence that the R responses appear in average greater than the Python ($p = 0.03689$).

Looking at the responses from the respondents who saw the logarithmic plot first of the three, the average responses from this group for question 1 ($\bar{x} = 40$, $\tilde{x} = 40$) were closer to the true value of 41 than for the whole population ($\bar{x} = 36.277$, $\tilde{x} = 35$), although the former still differs significantly from the true value ($p = 6.104e - 05$), and there is not significant evidence to state that the two distributions differ ($p = 0.1705$). Comparing the response statistics for the whole population and for those who saw the logarithmic plot first, the log first group perhaps show the bar height difference being perceived slightly higher than for the whole population ($\bar{x}_{overall} = 3.67$, $\bar{x}_{logfirst} = 4.13$), however a two-sample MWW test gives an insignificant p-value of 0.2614 when comparing them. Similarly, the difference between the responses for the whole population and for those who saw the logarithmic plot first for question 3 is also statistically insignificant, with means of 3.08 and 2.68 for and a p-value of 0.1889.

2.1.3 Differences Between Question 2 and 3 Responses

Now take $\bar{x}_{control} - \bar{x}_{truncated}$ and $\bar{x}_{control} - \bar{x}_{logarithmic}$ for each of questions 2 and 3, which is shown in figure[?].

This again shows that the responses for the truncated plot were in general rated higher than the control plot responses, and also that the effect was more significant for the bars on opposite ends of the plot as compared to the bars next to each other. The opposite is true for the logarithmic

Table 2.1: Table showing difference in the percieved difference for the logarithmic-scaled and truncated plots as compared to the control, for questions 2 and 3

	Con - Trnc	Con - Log
Q2	-0.5142857	1.685714
Q3	-0.6428571	0.900000

plot responses; on average they were rated lower than the control plot, but this was greatly more significant for the bars next to each other, as opposed to the truncated plot. Figure[?] shows this visually.

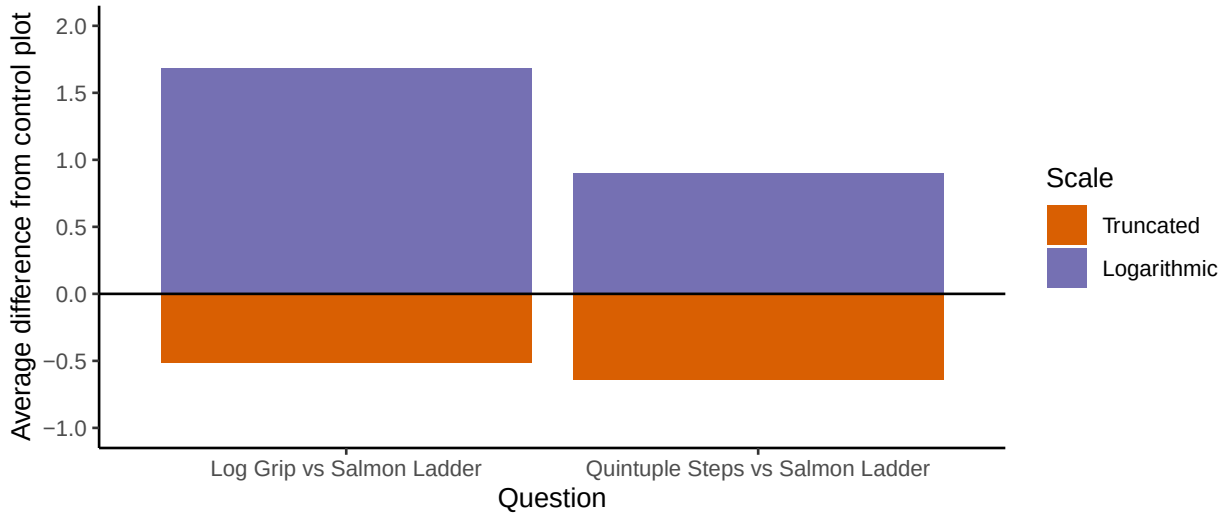


Figure 2.4: Bar plot giving a visual representation of the table

On average, truncating the scale had a similar effect for both questions, albeit with slightly more effect for when comparing 'Salmon Ladder' with 'Quintuple Steps' as opposed to 'Log Grip'. For the logarithmically scaled plots, however, the re-scaling appears to have had a significantly greater effect when considering the bars directly next to each other, with respondents on average judging the difference in bar height to be greater by 1.68 on the 7-point scale, whereas this is 0.9 for the bars further apart. It can be concluded from this that truncating the scale had more of an impact when bars were on opposite ends of the plot as opposed to next to each other, and the way round for the bars close to each other; the logarithmic scaling had more of an impact.

2.1.4 Ninja Warrior - Part 2

This part of the survey assessed whether different aspect ratios would have an impact on perception of bar height differences as well as reading of true values. This part will be analysed question by

question.

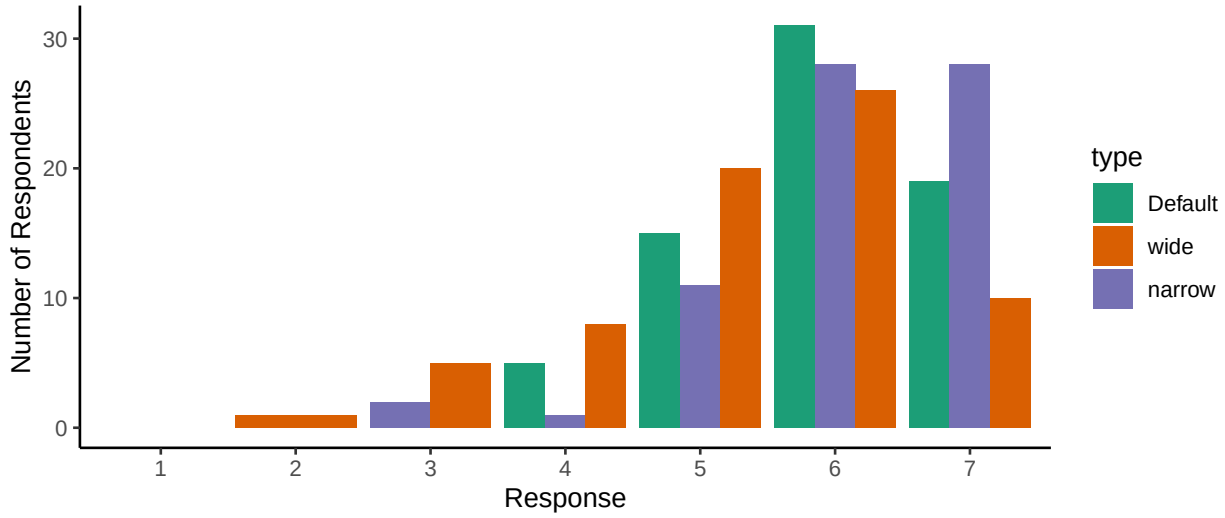
Question 1 asked *'How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?'*. This question once again uses the 7-point scale to gain a subjective view on the degree to which respondents felt the heights between the two bars corresponding to 'Jumping Spider' and 'Salmon Ladder' differed for three bar plots of 7 obstacles, where 'Salmon Ladder' is furthest to the left, and 'Jumping Spider' furthest to the right.

Looking at the means and medians here, it doesn't seem like there is that much of a difference in perception of the differences between the three aspect ratios, as displayed in table[?].

	Default	Narrow	Wide
Mean	5.914	6.129	5.357
Median	6.000	6.000	6.000

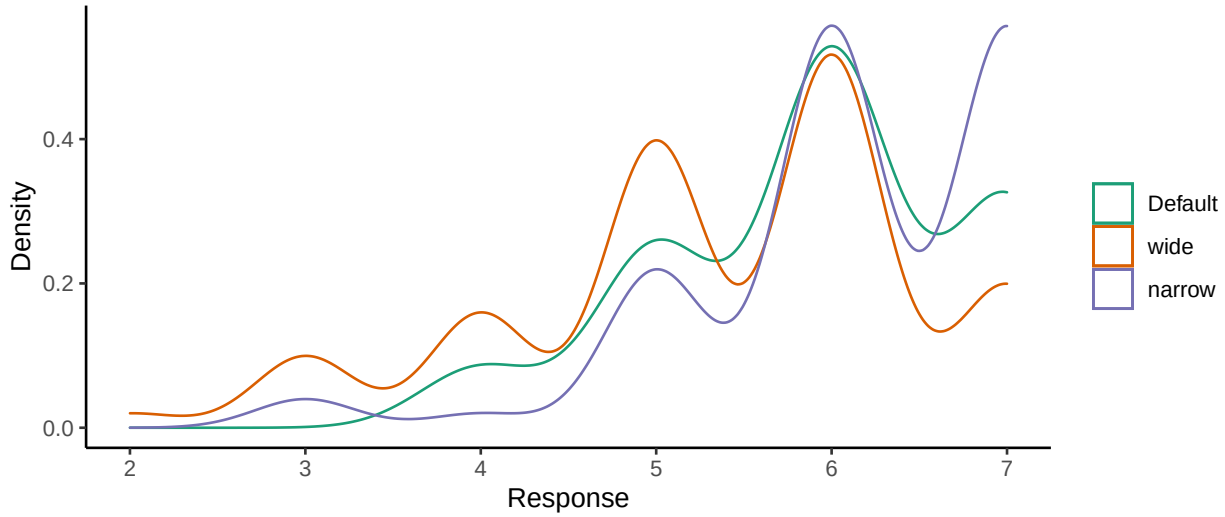
Note that 'narrow' is defined as the plot with the aspect ratio of smaller width to greater height, and vice versa for the 'wide' plot. The means show marginal differences, whereby the default plot mean is the middle-valued mean of the three, with the mean perceived difference for the wide plot being slightly smaller than this and the mean perceived difference for the narrow plot is slightly larger. This result, although at first glance marginal, follows the hypothesis that the wide plot would cause differences to be perceived as smaller and narrow bars to cause differences to be perceived to be greater.

Now looking at figure[?], showing the three distributions. There isn't an immediately obvious difference in distributions, but on closer inspection it can be seen that the orange "Wide" bars dominate over the three for the range [2, 5], and the purple "Narrow" dominated for the response of 7, following the above analysis of summary statistics. There was a fairly strong consensus that in general that a rating of 6 was applicable to all three plots.



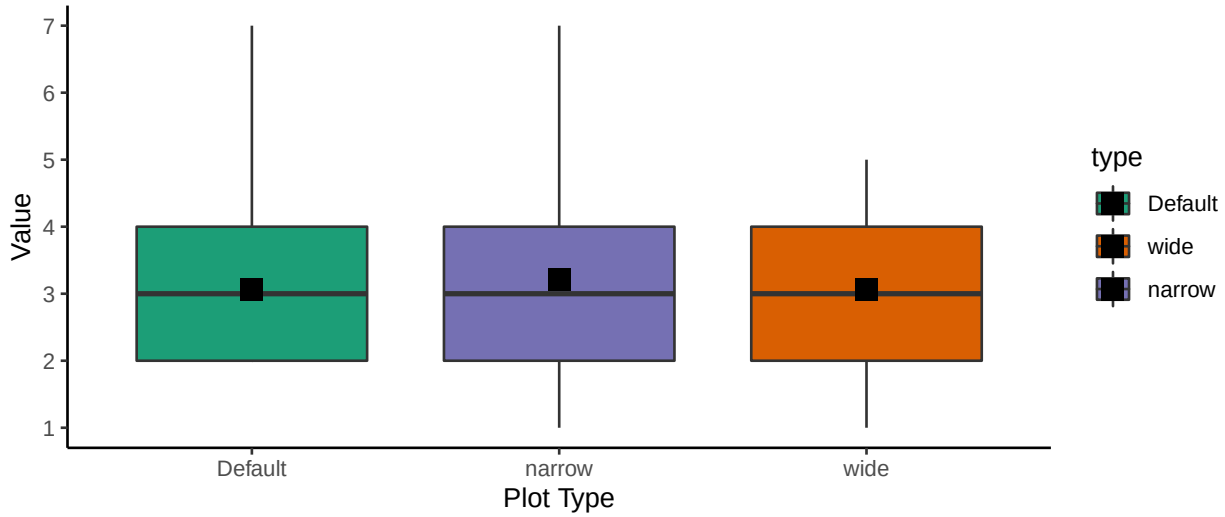

```
    Dependent-samples Sign-Test

data:  default and wide
S = 31, p-value = 6.457e-06
alternative hypothesis: true median difference is greater than 0
95 percent confidence interval:
   0 Inf
sample estimates:
median of x-y
            0

Achieved and Interpolated Confidence Intervals:

                  Conf.Level L.E.pt U.E.pt
Lower Achieved CI     0.9402      0    Inf
Interpolated CI       0.9500      0    Inf
Upper Achieved CI     0.9639      0    Inf
```

Running a one-sided MWW test to compare the responses for default plot to the narrow plot, it is confirmed that there is evidence to suggest that using a 'narrow' aspect ratio causes the perceived difference to be greater ($p = 0.0468$). Then applying a one-sided sign test to compare the default to the wide plot, the perceived difference is shown to be smaller ($p = 6.457e - 06$).

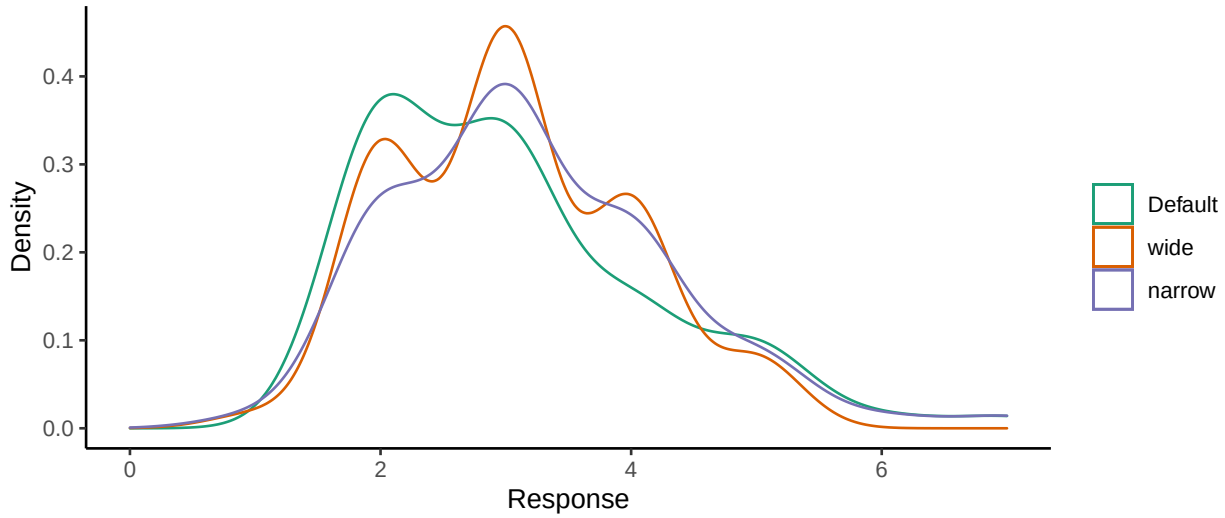


Question 2 then went on to ask *'How large would you say the difference between 'Log Grip' and 'Floating Steps' is?'*. Similar to part 1, there are two questions for gauging differences between bars, for which one asks about bars far away from each other, and one about bars next to each other. In the case of this section, the first question contained bars on opposite ends of the x-axis, and this question asks about two bars that sit adjacent to one another.

The analysis results here show that altering the axis ratio appears to have even less of an effect than in the first question, with the means of the responses for the default and wide plots being identical at 3.057, with the mean of the narrow plot responses only 0.157 greater at3.214. The median for all three is 3, and the IQRs are all $[2, 7]$. The variances, however, do differ from one another, with values 1.301, 0.866 and 1.214 for the default, wide and narrow bars, respectively. The distribution of values are shown in figure[?]. The results of two-sided MWW tests show that neither aspect ratio appears to have a significant effect on the rating of the perceived difference ($p = 0.2446$ and $p = 0.5688$).



At least 50/ of respondents placed the difference in the range $[2, 4]$ for all three plots, showing that they believed the difference was small to moderate, and this didn't change depending on the plot type, and thus for the bars further apart from each other, changing the aspect ratio does not appear to make much of a difference. The overall distributions are shown in the figure[?]



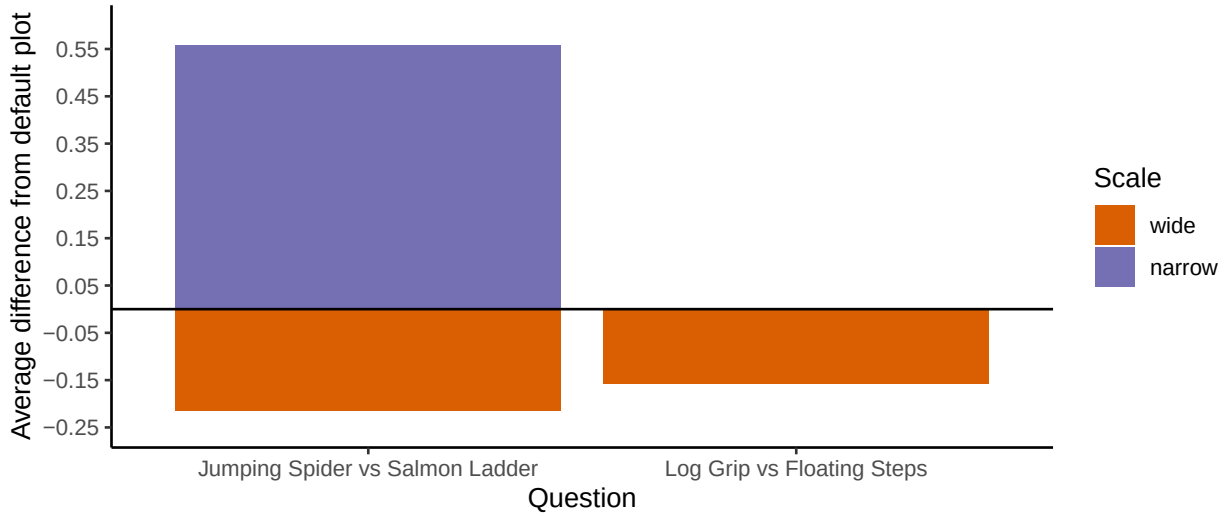
All three distributions are very similar, and almost appear to form bell curve shaped distributions, albeit with some irregularities and very slight negative skew.

As in part 1, the two height difference perception questions will be compared, calculating $\bar{x}_{default} - \bar{x}_{narrow}$ and $\bar{x}_{default} - \bar{x}_{wide}$.

As before, the table below gives a visual representation.

Table 2.2: Table showing difference in the percieved difference for plots with narrow and wide bars as compared to the default, for questions 1 and 2

	Def - Narrow	Def - Wide
Q1	-0.2142857	0.5571429
Q2	-0.1571429	0.0000000

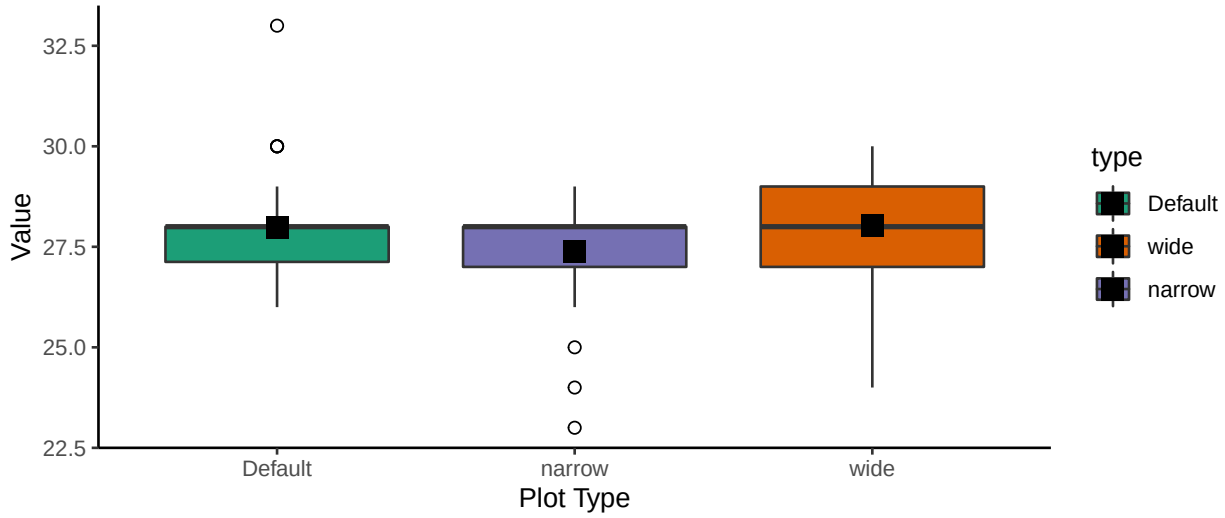


Both by eye comparisons of values and statistical testing show that the language used has negligible effect on the perceived difference, as does the order in which the plots were shown. See tables 51 - 61 in the appendix for more details.

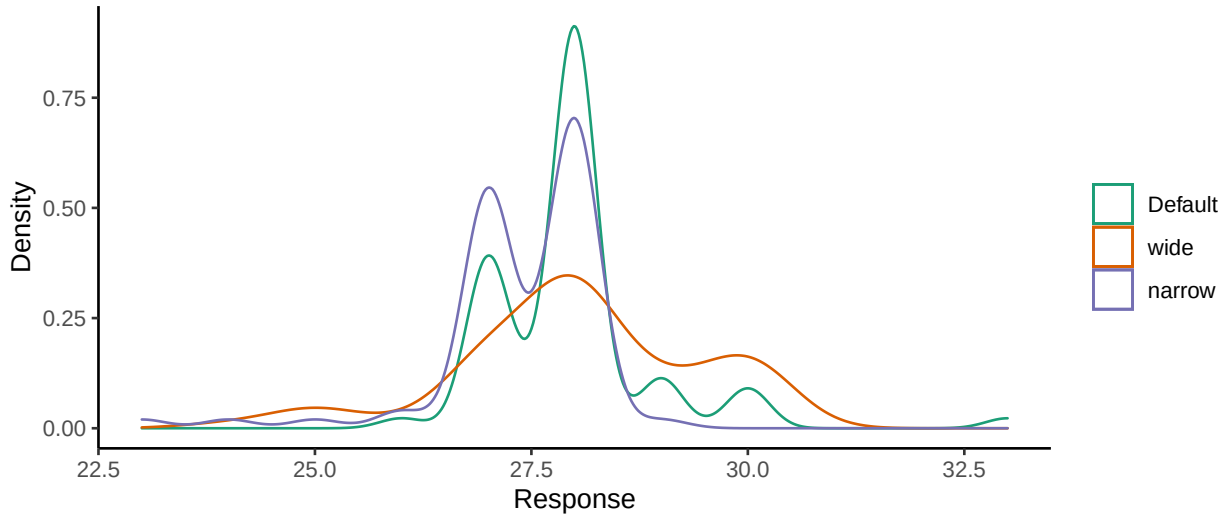
2.1.5 How many times would you say 'Floating Steps' were used?

This is again similar to question 1 of part 1, where participants were asked to state what they believed to be the height of the bar for 'Salmon Ladder', however this time the third bar from the axis is chosen. This is to ascertain whether the distance of the bar from the axis may have an effect alongside any potential perceived distortion of values. Note that the true value was 28.

The means of each of the three sets of responses were very close to the true value, at 27.97, 28.04 and 27.39, respectively for the default, wide and narrow, and the medians are exactly equal to the true value. Based on the means and medians it appears that, once again, altering the aspect ratio had minimal, if any, effect on interpretation of the data value. The value for the default plot also appears to be closer to the true value than the control plot in part 1, question 1.



Looking at the box plots, there are very small ranges in the values, signifying that there was a large consensus between respondents in terms of what they perceived the height to be. It can also be seen that there are three outliers below the box plot for the narrow plot responses, and two above for the default plot responses. There is very little overlap between the boxes, and it appears again that there altering the aspect ratio of the bar plot has little to no impact on reading the height of the bar. Additionally, there was less agreement between respondents for the wide plot than for the other two, although this doesn't seem to be too significant.



The distributions for the default and narrow plot responses are similar, both seeming to be fairly centred on the mean with a steep decrease in density on either side of the mean to shallow tails within the range $[25, 30]$. The responses for the wide plot appear to be more spread with lower density function values, with a slight negative skew.

After removing the outliers the medians have stayed the same, and the mean has obviously decreased

for the default and increased for the narrow, however, these means are all still fairly similar to each other and at a first glance prior to testing it again seems that changing the aspect ratio, at least to the degree tested here, is inconsequential to interpretation of the actual value. As expected as well, the variances for the outlier-removed sets have decreased.

However, statistical tests do actually show that while the default responses did not differ significantly from the true value of 28 ($p = 0.5667$), the responses for the narrow plot did ($p = 2.0955e - 09$), but the wide didn't ($p = 0.5067$).

Changing the language and plot order was once again inconsequential here.

2.1.6 Differences Between Question 1 and 2 Responses

The last set of questions in part 2 show respondents all three of the bar plots presented in this section and ask them to select which they find most aesthetically pleasing, and which they find easiest and hardest to interpret. Table[?] gives the number of respondents that selected each plot for each of the three questions.

	Default	Narrow	Wide
Most aesthetically pleasing?	37	14	18
Easiest to read and interpret?	36	15	19
Hardest to read and interpret?	20	20	30

For the first question, relating to how aesthetically pleasing respondents found each plot, just over half of the respondents chose the default aspect ratio as the most aesthetically pleasing, with 37 out of the 69 who responded selecting this.

Similarly, 37 out of the 70 that responded to the second question found the plot with the default aspect ratio easiest to read and interpret. Perhaps the people that preferred this aspect ratio aesthetically did so because they found it easiest to interpret. Investigating this, 27 respondents who chose the default for question 1 also chose this for question 2.

The plot judged hardest to read and interpret by the most respondents was the one with the wide bars, with 30 selecting this and 20 selecting each of the other two. While a significant number chose the default and narrow bars, the slightly higher amount selecting the plot with wide bars matches the previously stated hypothesis formulated from following the Stephen Few paper, which discusses that an ratio of greater width to length could suffer from perceptual imbalance. While this imbalance isn't seen in the numbers from the previous questions, the result here does give some indication that the aspect ratio producing wide bars may impact on ease of interpretation.

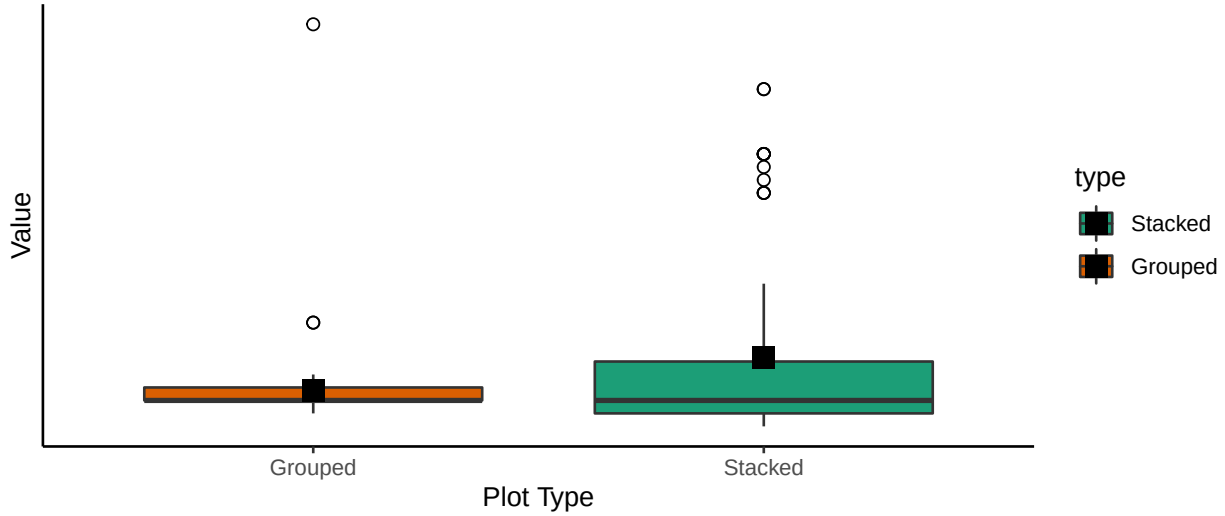
2.1.7 Ninja Warrior - Part 3

The third and final part of the questions about the American Ninja Warrior data discusses stacked bars and colour schemes. The questions asked in this part are used to decipher how data with multiple categories may be best represented in a bar plot. The plots presented use the same bars as in part 1, but this time the number of times each obstacle was used in each stage of the competition for each bar is highlighted. Each participant was shown both a stacked and a grouped bar plot in one of three colour schemes; the default for the language, viridis, and greyscale. For three versions of the survey, the stacked bars were shown first, and for the other three versions the first shown was the grouped bars. The final question of this part also asked respondents to compare two colour schemes, and through the 6 surveys there are comparisons of every colour scheme against every other colour scheme.

The question *"How many times would you say 'Floating Steps' were used in the Finals (Regional/City) round?"* is the first here, and is regarding the reading of a numerical value off the axis. In this question respondents were asked about 'Floating Steps', which is the bar third along from the y-axis. The question asks respondents to view the bar plot, where the bars will either be grouped of stacked, and decipher how many times this obstacle was used in the specified round of the competition. The true value for this was 11. The hypothesis for this question is that the respondents will more accurately gauge the value for the grouped bar than the stacked, which as seen below appears to be the case.

The mean for the values estimated by respondents using the stacked bars is 14.32, a fair bit larger than the true value of 11, and the mean estimated value for the grouped bars was closer to the true value, at 11.8. The IQR for the grouped bars is also smaller than for the stacked, and comprises of the range $[11, 12]$, insinuating that the estimated values tended to be fairly accurate but with some respondents perhaps slightly overestimating. The IQR for the stacked bars on the other hand covers the interval $[10, 14]$, which does contain the true value, but shows a tendency for both over and underestimation of respondents. Additionally to this, there is a large variance in the responses to this question, at 54.8 compared to the variance of 13.1 for the responses regarding the grouped bar plots. This adds to the picture that there was much less agreement between respondents, with many straying away from the mean of 14.3. It is seen however that the median for both the stacked and grouped bars is 11, showing that the higher mean of the stacked bars may be a result of an influential value at the upper end of the distribution, and that many observations do actually sit around 11. The fact that many values actually sit around 11 could be contributing to the higher variance, as variance is simply the sum of the squared distances from the mean, and so will be elevated if there are many values that sit some distance away from the mean. The higher mean could be reflected in the maximum of the stacked responses being 35, although the maximum of the grouped responses is 40, so there may be more than one influential point in the stacked responses.

Outliers can be checked for by looking at the box plots for this data.



It can in fact be seen that the box for the grouped responses is short and centered around 11. The box for the stacked responses shows many high valued outliers that could be causing the mean to be higher, although the IQR is still a fair bit larger than that of the responses for the grouped bars. The mean for this also sits above the IQR, and thus the outliers may be having a significant influence. Now the outliers will be removed, assuming, from the box plot, that outliers are any values above or equal to 25 for the stacked responses and above or equal to 20 for the grouped.

Removing the outliers as specified by the box plot, the mean of the stacked responses is now just above 11, and actually closer to the true value than the mean of the other set of responses, and the median has decreased to 10. From this one could infer that there is no difference between each type of bar plot in terms of gauging the size of the bars. However, there are 12 outliers in the stacked responses, which leads to the idea that these are not in fact all outliers and may be valid responses that just sit on the upper end of the distribution. However, it seems the cause of the high values could be respondents taking the whole height of the bar, which has an actual height of 28, rather than the section of interest. Many of the potentially influential values fall around the range $[25, 30]$, with all but 2 of the 12 potential outliers sitting in this interval, with the remaining two both being 35. Looking below at the summary statistics for only the values picked up as outliers, there is a mean of 29.83, which is higher than the true value of 28, and interestingly goes against the analysis from part 1, question 2 whereby respondents were asked to judge the height of this bar and on average underestimated. The fact that so many participants misinterpreted this plot and signify that stacked bar plots may not be the best way to present data to general public, as there may be the potential to misread the height of the whole bar as the size of the top category.

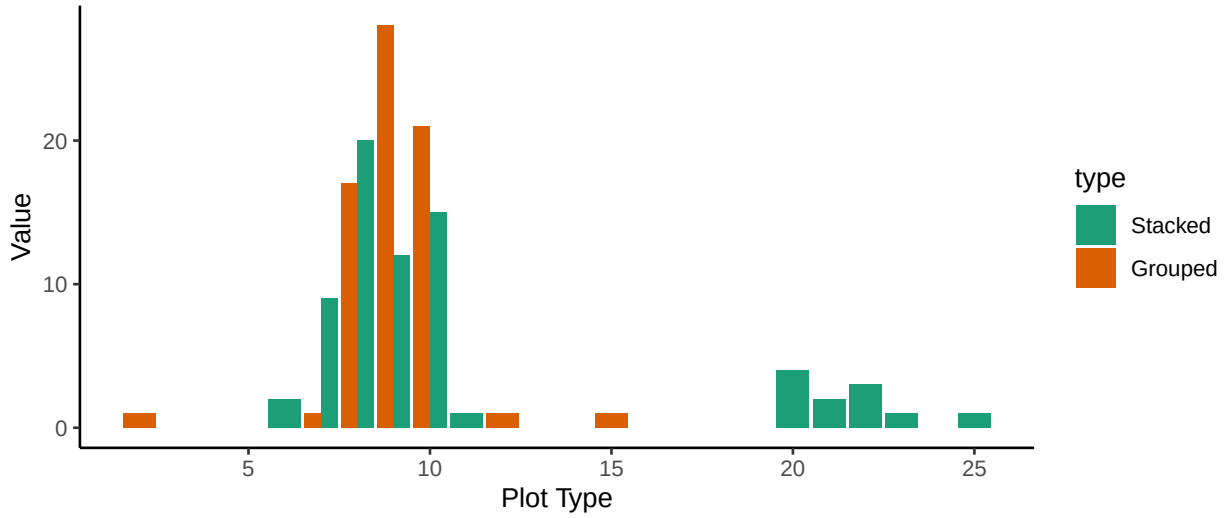
As a result of this, this set of 12 values will be discounted from the analysis, and thus come to the conclusion that, for the respondents that appear to have judged the height of the correct section,

there was little to no impact when using stacked vs grouped bar charts, and most of the difference comes from misinterpretation of the plot itself, as opposed to a poorer judgment of size.

To see if either of these values are significantly far from the true value, tests are once again run. A sign test on the stacked bar plot responses gives a high p-value of 0.5258, showing that for the stacked bar plot responses (after removing the values as priorly specified), the participant estimated values do not differ significantly from the true value. For the grouped bar plot the obtained p-value is $0.009 < 0.05$, and thus these responses are statistically significantly different from the true value. Running t-tests on the means, however, sees both sets of responses differing statistically significantly from the true value.

The next question, *'How many times would you say 'Log Grip' was used in the Finals (Regional/City) round?'*, is similar the above, but for the next bar to the right. The purpose of this question was to test the same hypothesis as the previous question, and also to lead into the following question, where respondents were asked to compare the 'Floating Steps' and 'Log Grip'. Additionally, the bar in the previous question had only two categories, of which the respondents were asked to judge the size of the category on the top of the bar in the stacked plot, whereas the bar for 'Log Grip' has 5 categories, of which the category of interest sits above 4. The true value of this was 9.

Similarly to the previous question, the mean response for the stacked bar plots are higher than that of the grouped, and the mean of the stacked also slightly overestimates the value. Once again however, a selection of respondents appeared to judge the full height of the bar rather than the category as asked.



Indeed, the distributions of values for each of the two response sets appear to be almost identical

After removing the outlying values, there tended to be a slight underestimation in the value for the stacked bar plot, however this is approximately 0.46 away from the true value, and unlikely to be

significant.

Once again the response sets are non-normally distributed and asymmetric, and so sign tests are applicable. The response set for the stacked bar plots produces a p-value of around 0.04, which shows a statistically significant difference in the responses from the true value of 9 at the 0.05 level of significance. However, this would easily become insignificant by slightly lowering the significance level to, say, 0.035. The p-value for the grouped bar responses, however, is » 0.05, as expected given that the median of the data sits at the true value.

The t-tests show that the differences in the means from the true value are statistically significant, although not considering the tests it can be seen by eye that the means are relatively close to 9.

The respondents were then asked to *'How many times would you say 'Log Grip' was used in the Finals (Regional/City) round?'*. This question asked respondents to judge whether log grip was used more, less, or an equal amount in the Finals (Regional/City) and Qualifying(Regional/City) rounds. This was to see how well differences between sizes of categories are judged when relating to the same variable, and are in the same bar. The results for this are given in the table below.

The table shows overwhelmingly that significantly more people accurately judged that the two values were the same for the grouped bars than for the stacked bars. This was the hypothesised result, and has presented to an even greater extent than previously anticipated. All but 7 of the respondents who responded to this question correctly judged from the grouped bars that the obstacle was used an equal number of times in each of the two rounds, whereas the responses for the grouped bar seemed fairly well split between the three options. It may be interesting in the multivariate analysis section to compare responses depending on whether respondents were shown the stacked or grouped bars first. Perhaps a reason for the incorrect judging with the stacked

Respondents were then asked *'Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?'*Similar to the previous question, this asks for a comparison between the size of two categories, but this time about how many times two different obstacles were used in the round Finals (Regional/City), where these two obstacles are those discussed at the start of this part of the survey.

This was a potentially poorly formulated question, as the respondents had already been asked to specify how many times each of these obstacle was used in this round and respondents mostly judged this accurately with regard to both plots, but this could have been impacted by the previous questions. However, this does follow from the results from the past questions showing that respondents mostly accurately judged the values correctly, aside from those who instead judged the height of the whole bar.

The aim of the question *'Which bar chart do you feel is easiest to read and interpret?'* was to assess

the perceived ease of interpretation of both bar plots. This is to gain an understanding in how data may best be presented in an easily understandable, easily readable manner. This is an important factor in visualisation, as a main aim in creating visuals is to provide an aid for the viewer to simply and quickly see the message. The opposite may be beneficial in certain applications however; based on the misreadings in the question regarding judging the number of times 'Log Grip' was used in the specific round, viewers of the visualisations could be easily mislead by incorrectly interpreting the plot. The people being shown the plot in, for example, an advert, may only take a fleeting look and not go beyond to analyse the plot to see accurate differences between values, and thus it is important to produce a plot that gives the easiest interpretation.

Var1	Freq
Grouped	59
Stacked	11

The large majority of participants found the grouped bar chart easier to read and interpret, as predicted.

The questions *'Which bar chart do you feel is easiest to read and interpret?'* and the one following *'Do you feel that one of the colour schemes makes it easier to read and interpret? If so, please select which one.'* are asked with the purpose of assessing the colour scheme that gives the greatest aesthetic pleasure, or effectively which colour palette the respondents feel is subjectively the 'prettiest' or 'nicest'. It is important to note here that aesthetics and readability do not always go hand-in-hand; a plot that is made to look very aesthetically pleasing may sacrifice readability, and vice versa. For each of the two languages, six pairings of three different colour palettes were created, whereby the first colour was the one displayed for the main questions, and the second used only for the comparison questions. As previously discussed, the three colour schemes considered are viridis, greyscale, and each language's default plotting colour palette. The colour palette pairings are outlined below, where each set of two colours is assigned a 'Pairing ID' from A to F.

Pairing ID	Main Palette	Secondary Pallette
A	Viridis	Default
B	Default	Viridis
C	Default	Greyscale
D	Greyscale	Default
E	Viridis	Greyscale
F	Greyscale	Viridis

This table shows that when it came to the default/viridis pairings, displayed in the first two rows, the respondents tended to have no preference overall, although this may differ between languages, which will be explored later on. Comparing this to the bottom two rows, in which viridis is put against

	A	B
Set A	7	6
Set B	6	6
Set C	9	1
Set D	3	9
Set E	11	0
Set F	1	11

greyscale, only 1 respondent out of the 23, a proportion of 0.04, found the grey more aesthetically pleasing, as hypothesised. When considering greyscale/default, there was still a majority preferring the non-greyscale palette, but a higher proportion preferred this as compared to the viridis/greyscale, with 4 out of the 22, or a proportion of 0.18, preferring the grey.

Complementing the aesthetic preferences, the second question assesses the colour preference with regard to readability and ease of interpretation. As mentioned before, this will be used to test both the colour palette preference itself alongside whether this preference matches up with aesthetic preference.

Var1	Freq
A	42
B	20
None	8

Interestingly here, the top two rows appear to give opposing results; the respondents who were presented with viridis for the main questions and the default as a secondary palette stated that they found either viridis easier to interpret or had no preference, whereas those presented with the default first and viridis second tended to find the default easier. Once again looking at the comparisons with the greyscale, there were some respondents that found this easier to read, but the majority chose the alternative, whether this is viridis or the default.

2.1.8 Sales - Part 1

Now consider the sales part of the survey. In this section data was taken from a the `BJsales` data set in R, which is a time series data set containing 150 observations. This data set constitutes a single vector of values with no specified timings, and the visualisation data was formed by taking subsets of size 12 this and setting a month between each point to give a year of fictional sales data.

2.1.9 How much would you say sales of each company increased between January and December? [Company A]

This question was included for the purpose of testing whether, again, axis scaling impacts the perceived differences between values, but this time with time series line plots as opposed to bar plots. Respondents were asked to assess how much the sales of company A increased over the course of the year, or in other words to look at and compare each end of the line.

The plot for which the respondents, on average, found the difference to be smallest was the zeroed, followed by the truncated, and then the separated, with means of 1.371, 2.414 and 3.043 respectively. These differences are found to be statistically significant, as outlined in table[?].

Table 2.3: Table of p-values for this question

Alternatve Hypothesis	P-value
Truncated > Zeroed	8.870681966755e-14
Truncated < Separated	0.00654175643803223
Separated > Zeroed	3.48079934270661e-13

The differences between languages and plot ordering were shown to be inconsequential (see table [?])

2.1.10 How much would you say sales of each company increased between January and December? [Company B]

The zeroed was once again perceived to have the smallest difference ($\bar{x} = 1.371$), but this time with the separated in the middle ($\bar{x} = 4.1304$) and truncated with the largest difference ($\bar{x} = 4.1304$). See table [?] for p-values. The p-values show sufficient evidence that the truncated responses were on average greater than the zeroed, as were the responses for the separated plots. However, the difference between the ratings for the truncated and separated plot responses was inconsequential, along with the language comparisons and plot order.

Table 2.4: Table of p-values for this question

Hypothesis	P-value
Truncated > Zeroed	8.95254768631571e-23
Truncated not equal to Separated	0.2162
Separated not equal to Zeroed	12.46327564235365e-23

2.1.11 How large would you say the drop in sales between April and July of Company A is?

The means for this question appear very significantly different by eye, once again with the zeroed plot eliciting the lowest average rating ($\bar{x} = 1.371429$), followed by the truncated ($\bar{x} = 2.814286$) and then the separated ($\bar{x} = 4.028571$). The p-values confirm the significance of the differences between all three variables.

Table 2.5: Table of p-values for this question

Hypothesis	P-value
Truncated not equal to Zeroed	1.03832498155043e-11
Truncated not equal to Separated	0.00012743463393642
Separated not equal to Zeroed	1.1261341031207e-16

2.2 Sales - Part 2

2.2.1 Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?

The final question of the survey compares just two plots, for which the difference in the ratings is shown to be significant, with the mean for the truncated plot ratings at $\bar{x} = 4.271$ and for the zeroed $\bar{x} = 2.7$ and a one-sided p-value of $p = 4.44089209850063e - 15$ showing the difference in the truncated was on average rated as larger than for the zeroed.

Chapter 3

Appendices

3.1 Apendix 1 - The Survey

The following shows a pdf paper format of the first versions of the surveys, for R and Python.

3.1.1 R

An Empirical Study of Data Visualisation

Thank you for considering taking part in this study, it will take around 25 minutes to complete.

Information for participants:
This study, 'An Empirical Study of Data Visualisation' aims to explore the use and implementation of data visualisation as a tool for understanding data. The survey will ask you subjective questions regarding a series of data visualisations to assess how various factors may impact interpretation of the underlying data.

The survey involves reading charts and giving brief interpretations of them, in the form of multiple choice, ranking or a giving a single number. It is NOT designed to be treated as a test; all answers should be fully subjective and there are no 'correct' answers.

This survey may also investigate the impact of different visualisations on people with disorders in which visual and/or numerical processing may be inhibited. The purpose of this would be to investigate how to create visualisations more accessible to people with such disorders. However, if you feel distressed or overwhelmed by the style of questions presented, please do not hesitate to exit the survey at any point.

The data presented is not expected to involve controversial or distressing information;
- Section 1 will contain data relating to 'American Ninja Warrior'
- Section 2 will involve sales data for some fictional companies.

Important:
1) Participation is voluntary and you may exit the survey at any time. If you decide to cease participation your responses will not be recorded.

2) Post submission, your responses will be saved anonymously in a google sheet <https://www.google.co.uk/forms/about/> and used for analysis, which may be published.

3) If you have any questions please do not hesitate to contact me at murphyka1@cardiff.ac.uk.

*Required

1. If you have read and fully understood the above information and wish to voluntarily participate in the survey, please select 'I agree' below. *

Tick all that apply.

- [ ] I agree

Demographic Information (Optional)

2. Please enter your age

_____

3. If you are a university student or past university graduate please specify your area of study.

Mark only one oval.

- ◯ Science
- ◯ Technology
- ◯ Engineering
- ◯ Maths
- ◯ Arts
- ◯ Social Sciences
- ◯ Humanities
- ◯ Business
- ◯ N/A
- ◯ Other: _____

How strongly do you agree with each of the three following statements?

4. I have good spatial awareness skills

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

5. I have good observational skills

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

6. I have good numerical skills

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

7. Are you colourblind?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Prefer not to answer
- ◯ Other: _____

8. Do you have any disorders that may affect visual processing? (this could be a general visual processing disorder or dyslexia, dyscalculia, ADHD etc)

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Prefer not to answer
- ◯ Other: _____

American Ninja Warrior

The first sets of questions will show you a series of bar charts presenting information regarding how many times some obstacles were used over the course of 10 seasons of the TV show 'American Ninja Warrior'.

For each question you will be asked to look at a bar chart and answer the corresponding questions, where the height of each bar shows how many times the obstacle was used.

Please note that the answers to these questions are meant to be subjective, and that there are no correct answers.

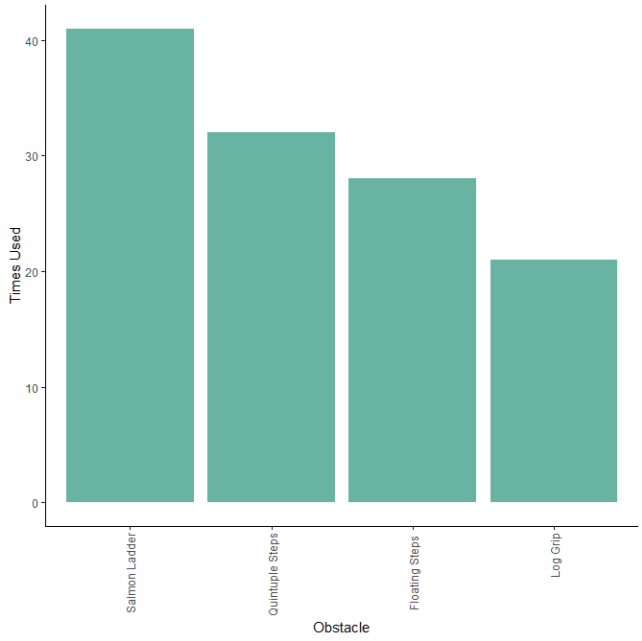
American Ninja Warrior - Part 1

The following bar charts present data for 4 of the most frequently used obstacles. Please look at the following charts and answer the corresponding questions.

American Ninja Warrior - Part 1, Question 1

Please refer to bar chart A, below.

Bar chart A



In relation to bar chart A:

9. Approximately many times would you say the 'Salmon Ladder' was used?

10. Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

11. Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

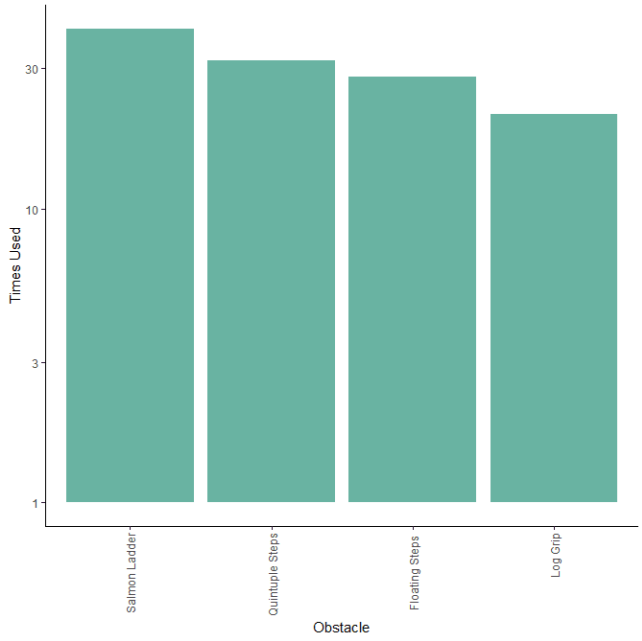
12. In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?

For example, if you think 'Log Grip' was used half as much as 'Salmon Ladder', enter 50%. If you think 'Log Grip' was used a quarter as much as 'Salmon Ladder', enter 25%, and so on.

American Ninja Warrior - Part 1, Question 2

Now consider the below bar chart, B.

Bar chart B



In relation to bar chart B:

13. Approximately many times would you say the 'Salmon Ladder' was used?

14. Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

15. Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

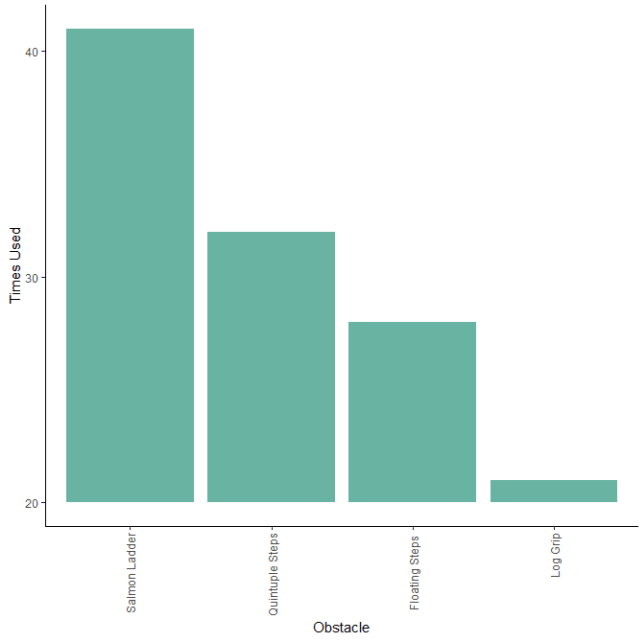
16. In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?

For example, if you think 'Log Grip' was used half as much as 'Salmon Ladder', enter 50%. If you think 'Log Grip' was used a quarter as much as 'Salmon Ladder', enter 25%, and so on.

American Ninja Warrior - Part 1, Question 3

Now consider bar chart C, below.

Bar chart C



In relation to bar chart C:

17. Approximately many times would you say the 'Salmon Ladder' was used?

18. Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

19. Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

20. In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?

For example, if you think 'Log Grip' was used half as much as 'Salmon Ladder', enter 50%. If you think 'Log Grip' was used a quarter as much as 'Salmon Ladder', enter 25%, and so on.

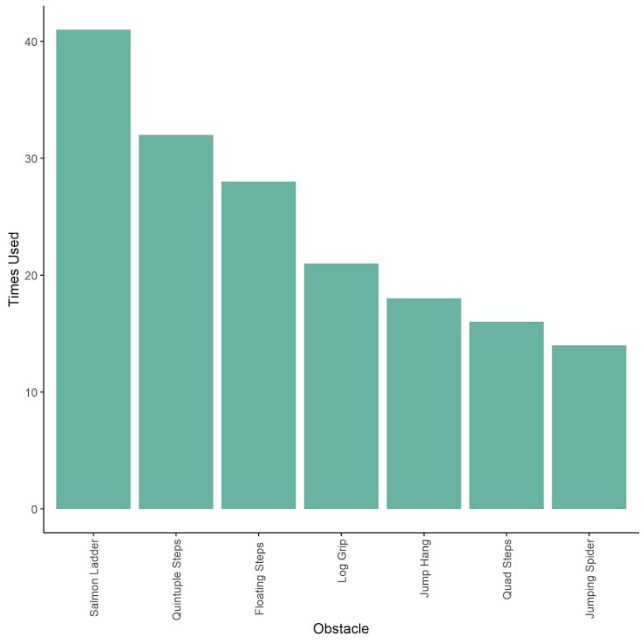
American Ninja Warrior - Part 2

You will now see bar charts regarding 7 of the most frequently used obstacles. Once again, for each question you will be asked to consider the bar chart and answer the corresponding questions. Again note that the answers to these questions are meant to be subjective, and that there are no correct answers.

American Ninja Warrior - Part 2, Question 1

Please see bar chart A, below.

Bar Chart A



In relation to bar chart A:

21. How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

22. How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Mark only one oval.

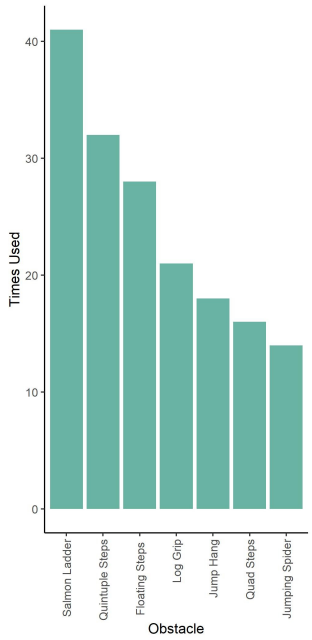
	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

23. How many times would you say 'Floating Steps' were used?

American Ninja Warrior - Part 2, Question 2

Now please see bar chart B.

Bar Chart B



In relation to bar chart B:

24. How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

25. How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Mark only one oval.

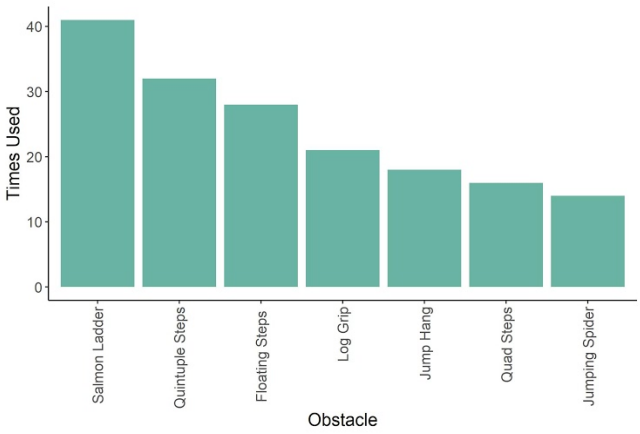
	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

26. How many times would you say 'Floating Steps' were used?

American Ninja Warrior - Part 2, Question 3

Consider bar chart C, below.

Bar Chart C



In relation to bar chart C:

27. How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

28. How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Mark only one oval.

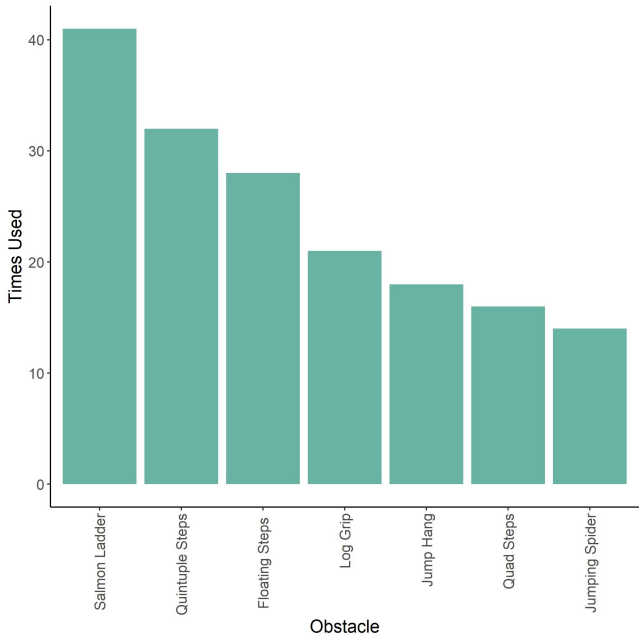
	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

29. How many times would you say 'Floating Steps' were used?

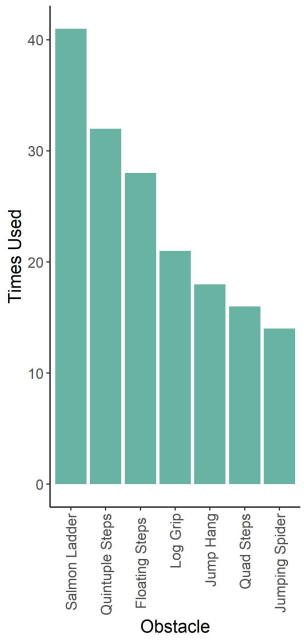
American Ninja Warrior - Part 2, Question 4

You will now see the bar charts A, B and C from part 2 again. Please answer the corresponding questions.

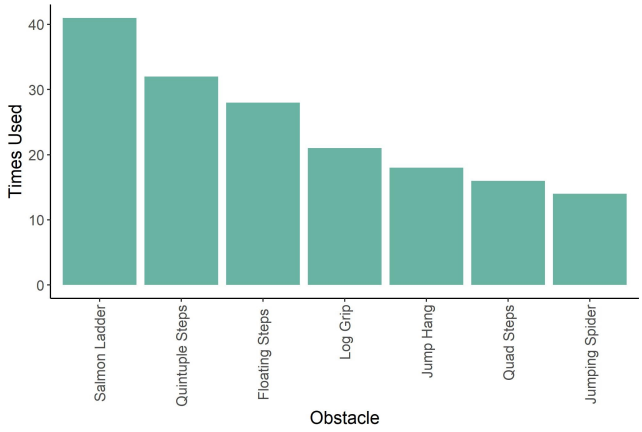
Bar chart A



Bar chart B



Bar chart C



30. Which of the three bar charts do you find most aesthetically pleasing?

Mark only one oval.

- A
- B
- C

31. Which bar chart do you feel is easiest to read and interpret?

This includes ease in reading labels, ease of reading the value of each bar, and ease in seeing the relative differences in values of the bars.

Mark only one oval.

- A
- B
- C

32. Which bar chart do you find hardest to read and interpret?

Mark only one oval.

- A
- B
- C

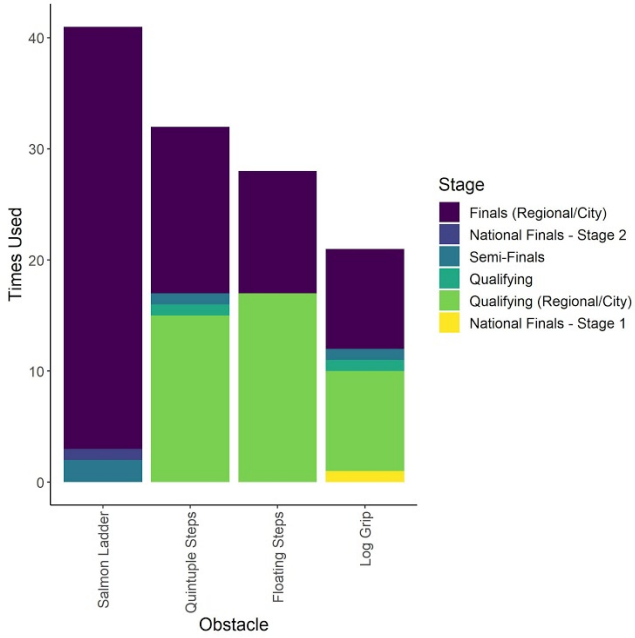
American Ninja Warrior - Part 3

The below plots show the same data as part 1, but are additionally coloured to show how many times each obstacle was used in each stage of the competition.

American Ninja Warrior - Part 3, Question 1

Please answer the questions below, for bar chart A.

Bar chart A



In relation to bar chart A:

33. How many times would you say 'Floating Steps' were used in the Finals (Regional/City) rounds?

_____

34. How many times would you say 'Log Grip' was used in the Finals (Regional/City) rounds?

_____

35. Please select the statement you feel applies to the bar chart above.

Mark only one oval.

- ◯ 'Log Grip' was used MORE in Finals (Regional/City) rounds than in Qualifying (Regional/City) rounds.
- ◯ 'Log Grip' was used LESS in Finals (Regional/City) rounds than in Qualifying (Regional/City) rounds.
- ◯ 'Log Grip' was used an EQUAL number of times in Finals (Regional/City) rounds and Qualifying (Regional/City) rounds.

36. Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?

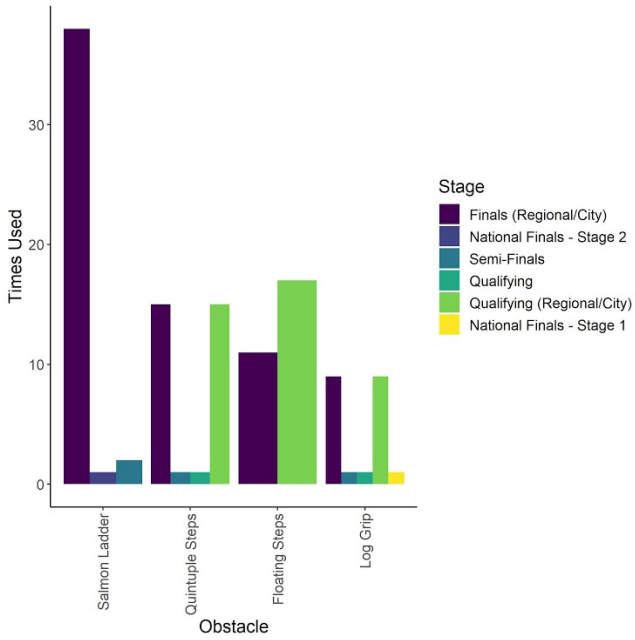
Mark only one oval.

- ◯ 'Log Grip'
- ◯ 'Floating Steps'
- ◯ They were used the same amount of times

American Ninja Warrior - Part 3, Question 2

Now please answer the questions again, for bar chart B.

Bar chart B



In relation to bar chart B:

37. How many times would you say 'Floating Steps' were used in the Finals (Regional/City) rounds?

_____

38. How many times would you say 'Log Grip' was used in the Finals (Regional/City) rounds?

_____

_____

_____

_____

_____

39. Please select the statement you feel applies to the bar chart above.

Mark only one oval.

- ◯ 'Log Grip' was used MORE in Finals (Regional/City) than in Qualifying (Regional/City).
- ◯ 'Log Grip' was used LESS in Finals (Regional/City) than in Qualifying (Regional/City).
- ◯ 'Log Grip' was used an EQUAL number of times in Finals (Regional/City) and Qualifying (Regional/City).

40. Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?

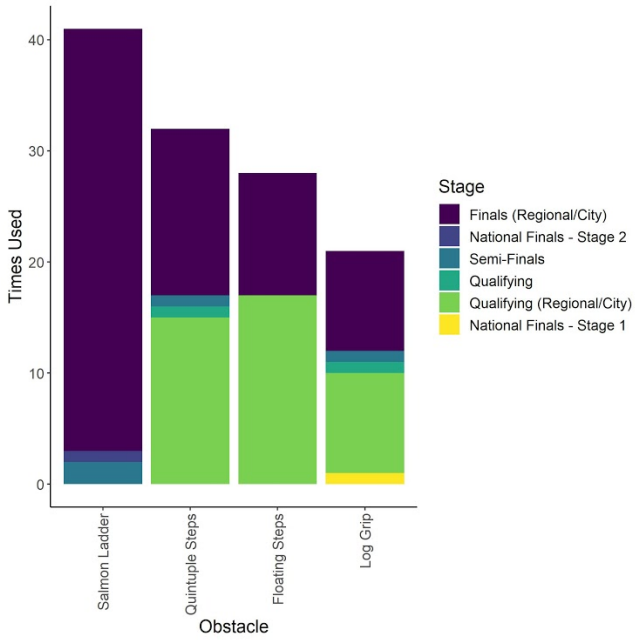
Mark only one oval.

- ◯ 'Log Grip'
- ◯ 'Floating Steps'
- ◯ They were used the same amount of times

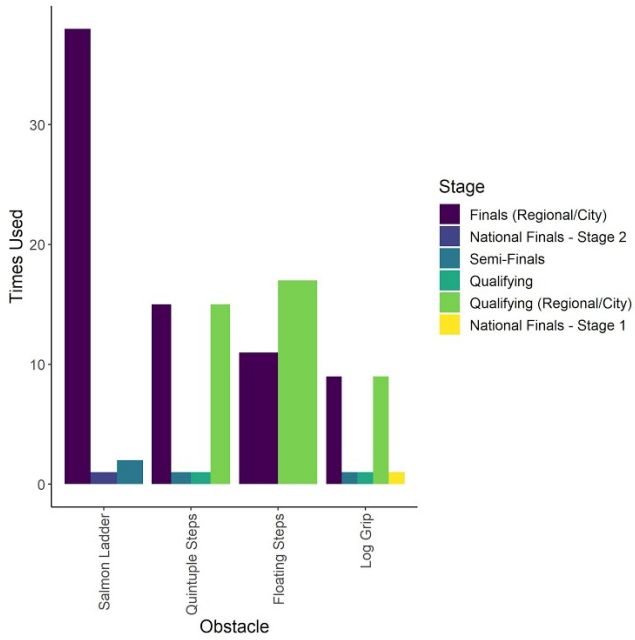
American Ninja Warrior - Part 3, Question 3

You will now see the two bar charts again. Please answer the question below.

Bar Chart A



Bar chart B



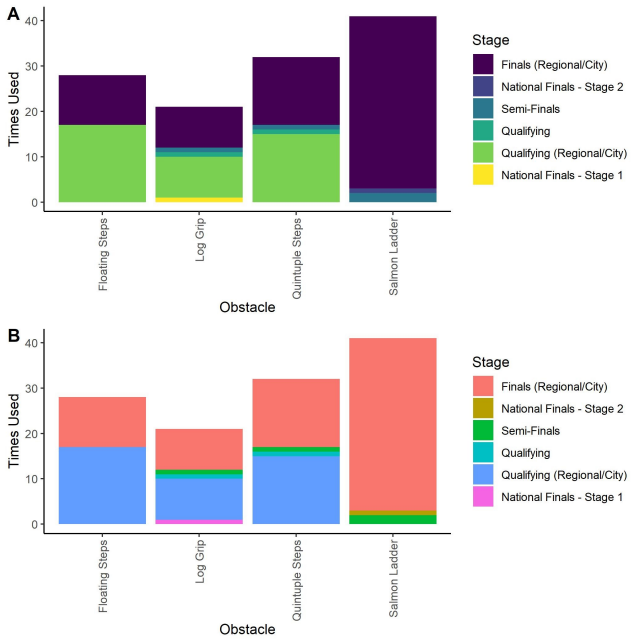
41. Which bar chart do you feel is easiest to read and interpret?

Mark only one oval.

- A
- B

American Ninja Warrior - Part 3, Question 4

Below compares the color scheme of the charts above, colour scheme A with another colour scheme, B.



42. Which colour scheme do you find most aesthetically pleasing?

Mark only one oval.

- A
- B

43. Do you feel that one of the colour schemes makes it easier to read and interpret the data than the other? If so, please select which one.

Mark only one oval.

- No
- Yes, A is easier
- Yes, B is easier

Sales

Thank you for completing the first section of this survey. The second, and final, section is shorter and will show you a series of line graphs relating to monthly sales data from four companies over the course of a year.

Once again, please refer to the following charts and answer the questions.

Please note that the answers to these questions are meant to be subjective, and that there are no correct answers.

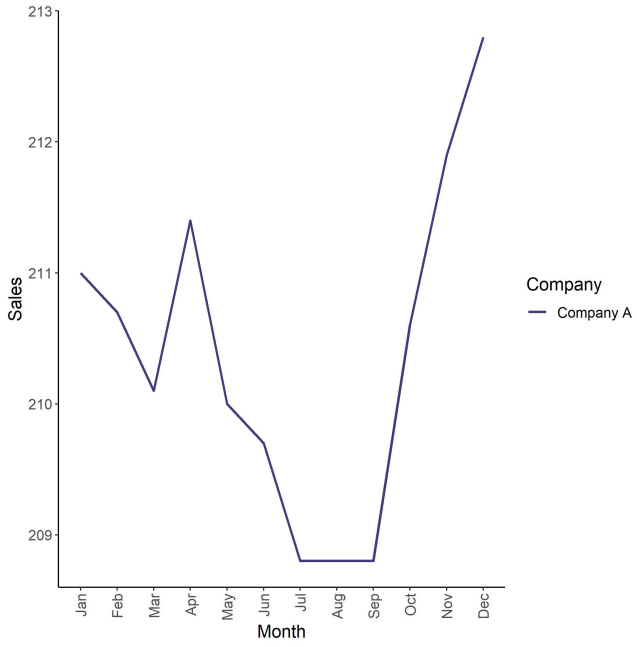
Sales - Part 1

The following section will present graphs showing monthly sales data of two competing companies over the course of a year, and ask you questions relating to the graphs.

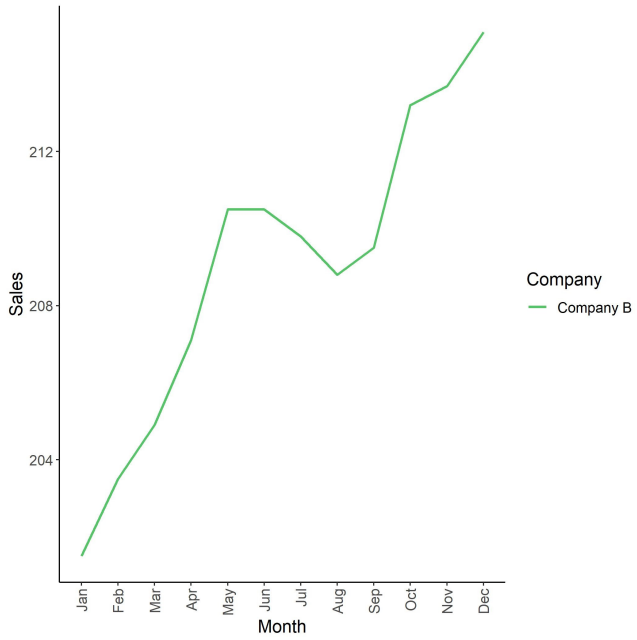
Sales - Part 1, Question 1

Please refer to the two charts below

Sales data for Company A



Sales data for Company B



44. How much would you say sales of each company increased between January and December?

Mark only one oval per row.

	1 (A little)	2	3	4	5	6	7 (A lot)
Company A	◯	◯	◯	◯	◯	◯	◯
Company B	◯	◯	◯	◯	◯	◯	◯

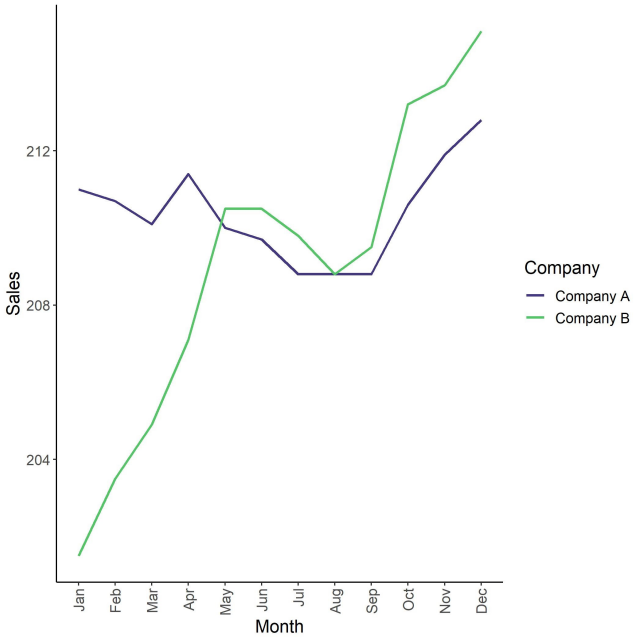
45. How large would you say the drop in sales between April and July of Company A is?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Consider the chart below

Sales - Part 1, Question 2



46. How much would you say sales of each company increased between January and December?

Mark only one oval per row.

	1 (A little)	2	3	4	5	6	7 (A lot)
Company A	◯	◯	◯	◯	◯	◯	◯
Company B	◯	◯	◯	◯	◯	◯	◯

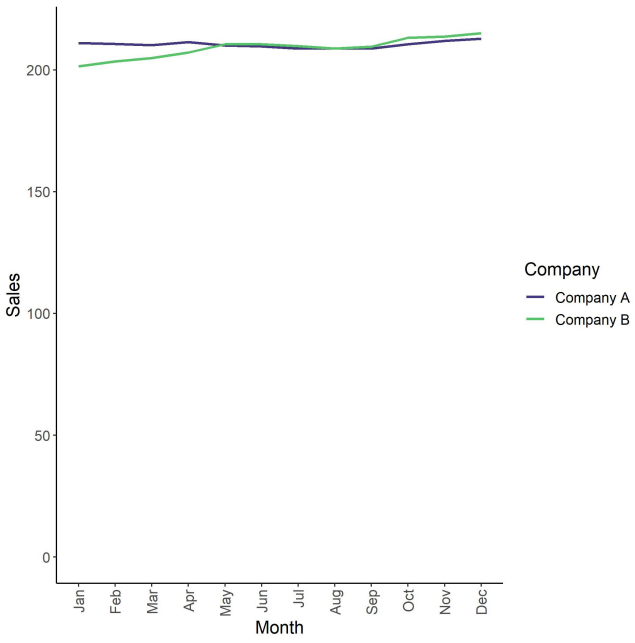
47. How large would you say the drop in sales between April and July of Company A is?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Consider the chart below

Sales - Part 1, Question 3



48. How much would you say sales of each company increased between January and December?

Mark only one oval per row.

	1 (A little)	2	3	4	5	6	7 (A lot)
Company A	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Company B	⬭	⬭	⬭	⬭	⬭	⬭	⬭

49. How large would you say the drop in sales between April and July of Company A is?

Mark only one oval.

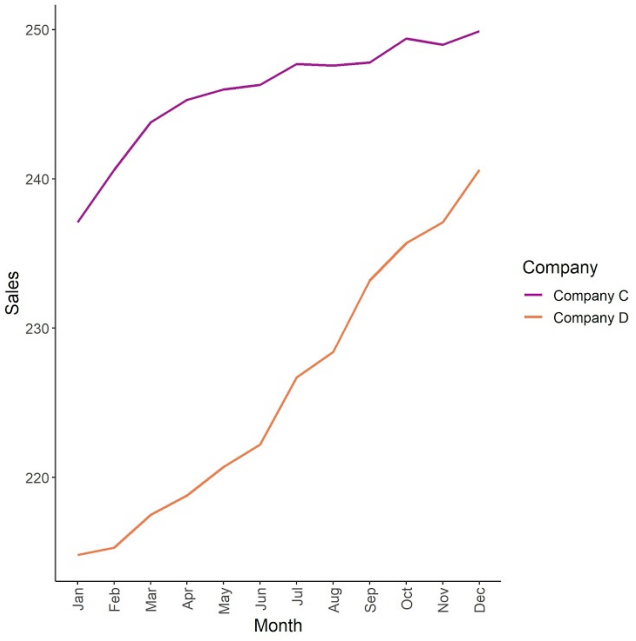
	1	2	3	4	5	6	7	
A little	⬭	⬭	⬭	⬭	⬭	⬭	⬭	A lot

Sales - Part 2

The graphs below show the sales data for two more companies, Company C and Company D.

Sales - Part 2, Question 1

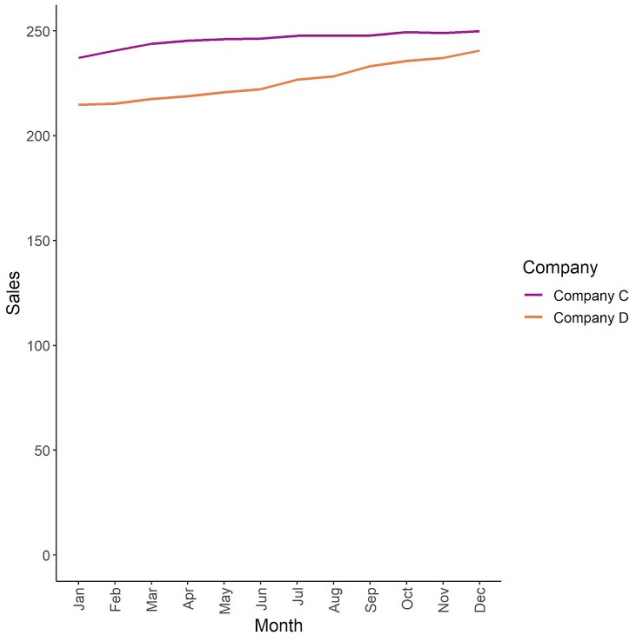
Consider the chart below



50. Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot



51. Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Sales - Part 2, Question 2

Consider the chart below

Thank you for completing this survey.

Reminder - Your responses to this survey will remain anonymous.

If you would like to know more about the use of data visualisation and how different techniques may impact interpretation, please see the links below.
- https://searchbusinessanalytics.techtarget.com/definition/data-visualization
- https://datajournalism.com/read/handbook/one/understanding-data/using-data-visualization-to-find-insights-in-data
- https://heap.io/blog/data-stories/how-to-lie-with-data-visualization
- https://www.idashboards.com/blog/2019/02/27/when-data-visualizations-mislead-and-how-to-prevent-it/

If you are interested in how colour blindness can affect reading of visualisations and colour blind friendly palettes to use for data visualisation, please see the links below:
- https://blog.datawrapper.de/colorblindness-part3/
- https://www.youtube.com/watch?v=xAoljeRJ3lU

Once again, if you have any questions please do not hesitate to contact me at murphyka1@cardiff.ac.uk.

3.1.2 Python

An Empirical Study of Data Visualisation

Thank you for considering taking part in this study, it will take around 25 minutes to complete.

Information for participants:
This study, 'An Empirical Study of Data Visualisation' aims to explore the use and implementation of data visualisation as a tool for understanding data. The survey will ask you subjective questions regarding a series of data visualisations to assess how various factors may impact interpretation of the underlying data.

The survey involves reading charts and giving brief interpretations of them, in the form of multiple choice, ranking or a giving a single number. It is NOT designed to be treated as a test; all answers should be fully subjective and there are no 'correct' answers.

This survey may also investigate the impact of different visualisations on people with disorders in which visual and/or numerical processing may be inhibited. The purpose of this would be to investigate how to create visualisations more accessible to people with such disorders. However, if you feel distressed or overwhelmed by the style of questions presented, please do not hesitate to exit the survey at any point.

The data presented is not expected to involve controversial or distressing information;
- Section 1 will contain data relating to 'American Ninja Warrior'
- Section 2 will involve sales data for some fictional companies.

Important:
1) Participation is voluntary and you may exit the survey at any time. If you decide to cease participation your responses will not be recorded.

2) Post submission, your responses will be saved anonymously in a google sheet <https://www.google.co.uk/forms/about/> and used for analysis, which may be published.

3) If you have any questions please do not hesitate to contact me at murphyka1@cardiff.ac.uk.

*Required

1. If you have read and fully understood the above information and wish to voluntarily participate in the survey, please select 'I agree' below. *

Tick all that apply.

- [ ] I agree

Demographic Information (Optional)

2. Please enter your age

_____

3. If you are a university student or past university graduate please specify your area of study.

Mark only one oval.

- ◯ Science
- ◯ Technology
- ◯ Engineering
- ◯ Maths
- ◯ Arts
- ◯ Social Sciences
- ◯ Humanities
- ◯ Business
- ◯ N/A
- ◯ Other: _____

How strongly do you agree with each of the three following statements?

4. I have good spatial awareness skills

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

5. I have good observational skills

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

6. I have good numerical skills

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

7. Are you colourblind?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Prefer not to answer
- ◯ Other: _____

8. Do you have any disorders that may affect visual processing? (this could be a general visual processing disorder or dyslexia, dyscalculia, ADHD etc)

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Prefer not to answer
- ◯ Other: _____

American Ninja Warrior

The first sets of questions will show you a series of bar charts presenting information regarding how many times some obstacles were used over the course of 10 seasons of the TV show 'American Ninja Warrior'.

For each question you will be asked to look at a bar chart and answer the corresponding questions, where the height of each bar shows how many times the obstacle was used.

Please note that the answers to these questions are meant to be subjective, and that there are no correct answers.

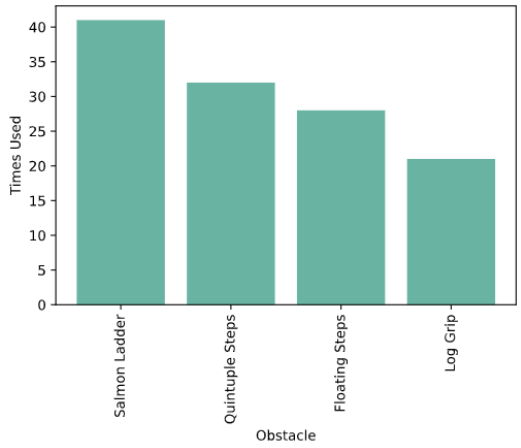
American Ninja Warrior - Part 1

The following bar charts present data for 4 of the most frequently used obstacles. Please look at the following charts and answer the corresponding questions.

American Ninja Warrior - Part 1, Question 1

Please refer to bar chart A, below.

Bar chart A



In relation to bar chart A:

9. Approximately many times would you say the 'Salmon Ladder' was used?

10. Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

11. Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

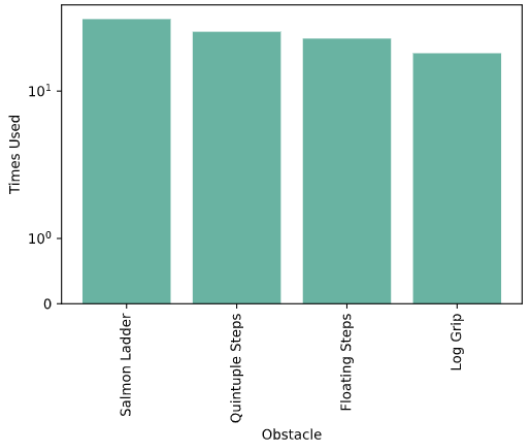
12. In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?

For example, if you think 'Log Grip' was used half as much as 'Salmon Ladder', enter 50%. If you think 'Log Grip' was used a quarter as much as 'Salmon Ladder', enter 25%, and so on.

American Ninja Warrior - Part 1, Question 2

Now consider the below bar chart, B.

Bar chart B



In relation to bar chart B:

13. Approximately many times would you say the 'Salmon Ladder' was used?

14. Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

15. Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

16. In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?

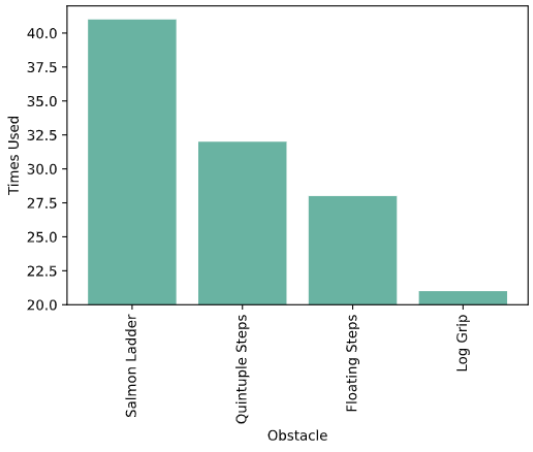
For example, if you think 'Log Grip' was used half as much as 'Salmon Ladder', enter 50%. If you think 'Log Grip' was used a quarter as much as 'Salmon Ladder', enter 25%, and so on.

_____

American Ninja Warrior - Part 1, Question 3

Now consider bar chart C, below.

Bar chart C



In relation to bar chart C:

17. Approximately many times would you say the 'Salmon Ladder' was used?

_____

18. Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

19. Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?

Mark only one oval.

	1	2	3	4	5	6	7	
Not much more	◯	◯	◯	◯	◯	◯	◯	A lot more

20. In your opinion, approximately how many times would you say 'Log Grip' was used, as a percentage of the number of times 'Salmon Ladder' was used?

For example, if you think 'Log Grip' was used half as much as 'Salmon Ladder', enter 50%. If you think 'Log Grip' was used a quarter as much as 'Salmon Ladder', enter 25%, and so on.

_____

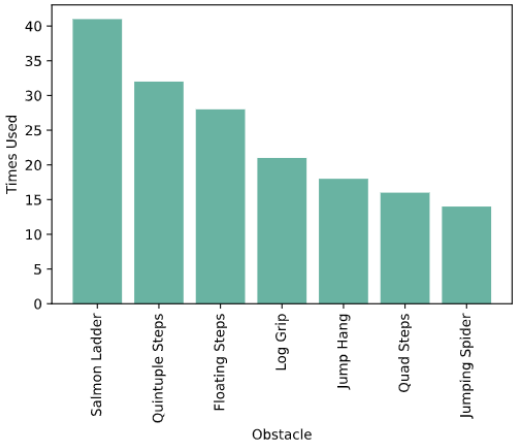
American Ninja Warrior - Part 2

You will now see bar charts regarding 7 of the most frequently used obstacles. Once again, for each question you will be asked to consider the bar chart and answer the corresponding questions. Again note that the answers to these questions are meant to be subjective, and that there are no correct answers.

American Ninja Warrior - Part 2, Question 1

Please see bar chart A, below.

Bar Chart A



In relation to bar chart A:

21. How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

22. How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

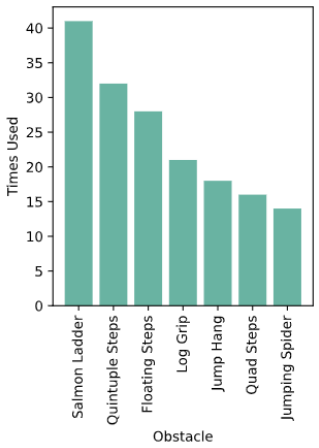
23. How many times would you say 'Floating Steps' were used?

_____

American Ninja Warrior - Part 2, Question 2

Now please see bar chart B.

Bar Chart B



In relation to bar chart B:

24. How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

25. How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

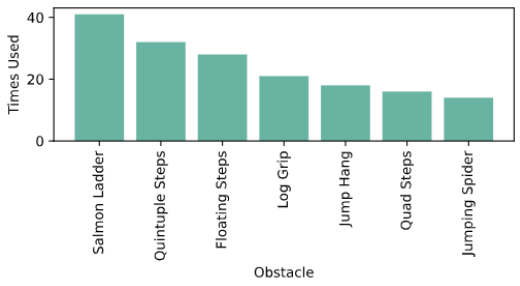
26. How many times would you say 'Floating Steps' were used?

_____

American Ninja Warrior - Part 2, Question 3

Consider bar chart C, below.

Bar Chart C



In relation to bar chart C:

27. How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

28. How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Mark only one oval.

	1	2	3	4	5	6	7	
Very Small	◯	◯	◯	◯	◯	◯	◯	Very Large

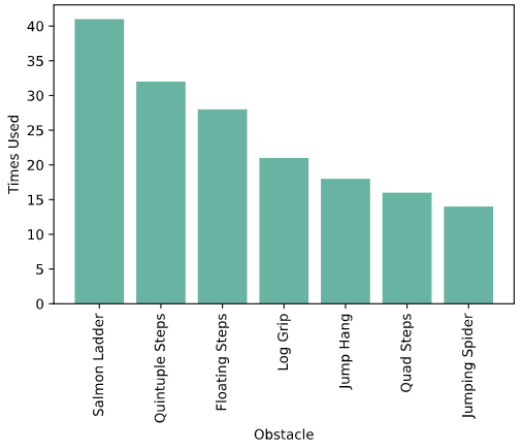
29. How many times would you say 'Floating Steps' were used?

_____

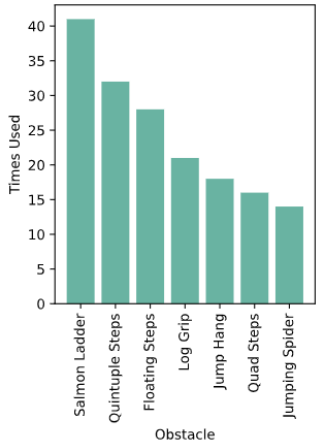
American Ninja Warrior - Part 2, Question 4

You will now see the bar charts A, B and C from part 2 again. Please answer the corresponding questions.

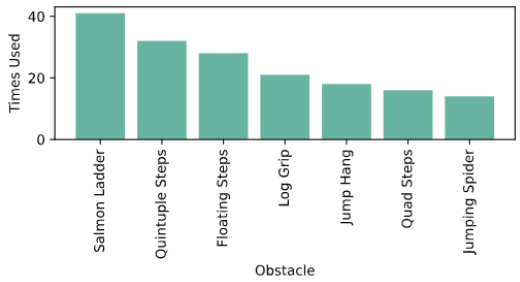
Bar chart A



Bar chart B



Bar chart C



30. Which of the three bar charts do you find most aesthetically pleasing?

Mark only one oval.

- A
- B
- C

31. Which bar chart do you feel is easiest to read and interpret?

This includes ease in reading labels, ease of reading the value of each bar, and ease in seeing the relative differences in values of the bars.

Mark only one oval.

- A
- B
- C

32. Which bar chart do you find hardest to read and interpret?

Mark only one oval.

- A
- B
- C

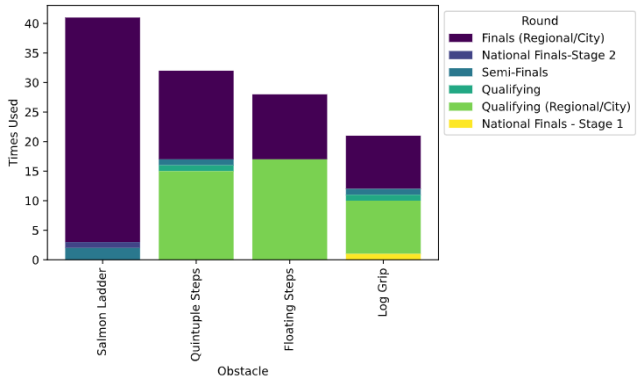
American Ninja Warrior - Part 3

The below plots show the same data as part 1, but are additionally coloured to show how many times each obstacle was used in each stage of the competition.

American Ninja Warrior - Part 3, Question 1

Please answer the questions below, for bar chart A.

Bar chart A



In relation to bar chart A:

33. How many times would you say 'Floating Steps' were used in the Finals (Regional/City) rounds?

_____

34. How many times would you say 'Log Grip' was used in the Finals (Regional/City) rounds?

_____

35. Please select the statement you feel applies to the bar chart above.

Mark only one oval.

- ( ) 'Log Grip' was used MORE in Finals (Regional/City) rounds than in Qualifying (Regional/City) rounds.
- ( ) 'Log Grip' was used LESS in Finals (Regional/City) rounds than in Qualifying (Regional/City) rounds.
- ( ) 'Log Grip' was used an EQUAL number of times in Finals (Regional/City) rounds and Qualifying (Regional/City) rounds.

36. Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?

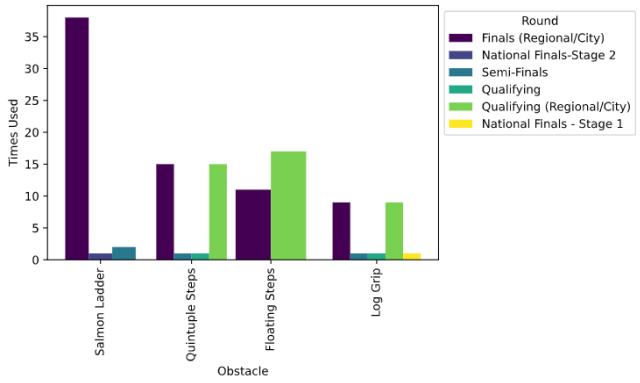
Mark only one oval.

- ( ) 'Log Grip'
- ( ) 'Floating Steps'
- ( ) They were used the same amount of times

American Ninja Warrior - Part 3, Question 2

Now please answer the questions again, for bar chart B.

Bar chart B



In relation to bar chart B:

37. How many times would you say 'Floating Steps' were used in the Finals (Regional/City) rounds?

_____

38. How many times would you say 'Log Grip' was used in the Finals (Regional/City) rounds?

_____

_____

_____

_____

_____

39. Please select the statement you feel applies to the bar chart above.

Mark only one oval.

- ( ) 'Log Grip' was used MORE in Finals (Regional/City) than in Qualifying (Regional/City).
- ( ) 'Log Grip' was used LESS in Finals (Regional/City) than in Qualifying (Regional/City).
- ( ) 'Log Grip' was used an EQUAL number of times in Finals (Regional/City) and Qualifying (Regional/City).

40. Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?

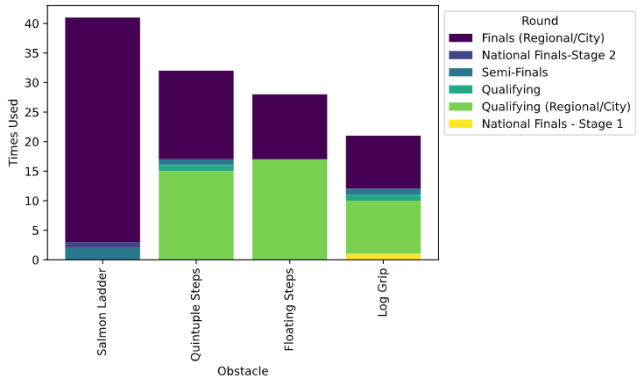
Mark only one oval.

- ( ) 'Log Grip'
- ( ) 'Floating Steps'
- ( ) They were used the same amount of times

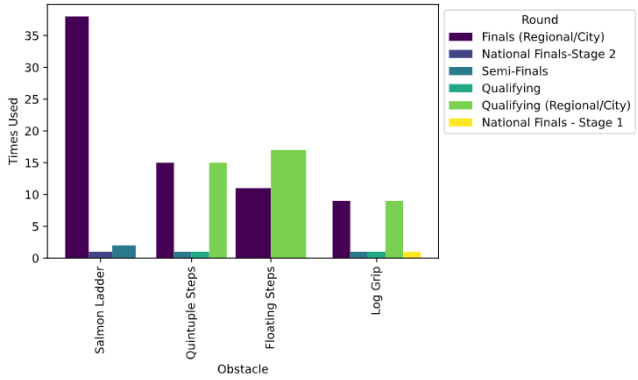
American Ninja Warrior - Part 3, Question 3

You will now see the two bar charts again. Please answer the question below.

Bar Chart A



Bar chart B



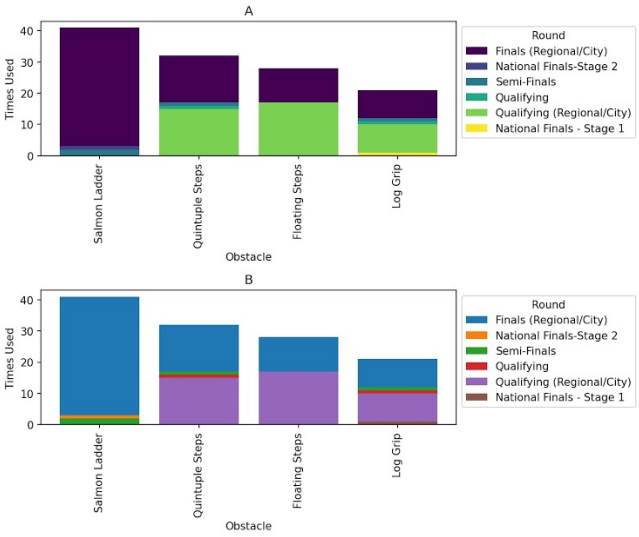
41. Which bar chart do you feel is easiest to read and interpret?

Mark only one oval.

- A
- B

American Ninja Warrior - Part 3, Question 4

Below compares the color scheme of the charts above, colour scheme A with another colour scheme, B.



42. Which colour scheme do you find most aesthetically pleasing?

Mark only one oval.

- A
- B

43. Do you feel that one of the colour schemes makes it easier to read and interpret the data than the other? If so, please select which one.

Mark only one oval.

- No
- Yes, A is easier
- Yes, B is easier

44.

Mark only one oval.

- Option 1

Sales

Thank you for completing the first section of this survey. The second, and final, section is shorter and will show you a series of line graphs relating to monthly sales data from four companies over the course of a year.

Once again, please refer to the following charts and answer the questions.

Please note that the answers to these questions are meant to be subjective, and that there are no correct answers.

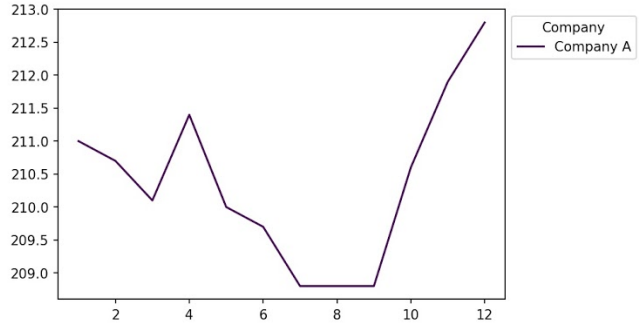
Sales - Part 1

The following section will present graphs showing monthly sales data of two competing companies over the course of a year, and ask you questions relating to the graphs.

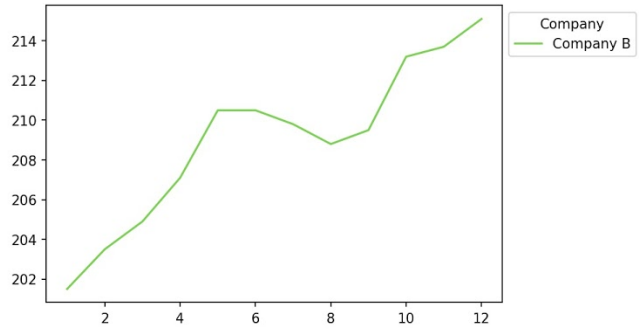
Sales - Part 1, Question 1

Please refer to the two charts below

Sales data for Company A



Sales data for Company B



45. How much would you say sales of each company increased between January and December?

Mark only one oval per row.

	1 (A little)	2	3	4	5	6	7 (A lot)
Company A							
Company B							

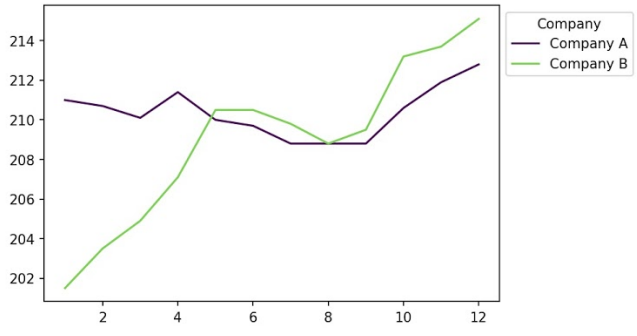
46. How large would you say the drop in sales between April and July of Company A is?

Mark only one oval.

	1	2	3	4	5	6	7	
A little								A lot

Consider the chart below

Sales - Part 1, Question 2



47. How much would you say sales of each company increased between January and December?

Mark only one oval per row.

	1 (A little)	2	3	4	5	6	7 (A lot)
Company A	◯	◯	◯	◯	◯	◯	◯
Company B	◯	◯	◯	◯	◯	◯	◯

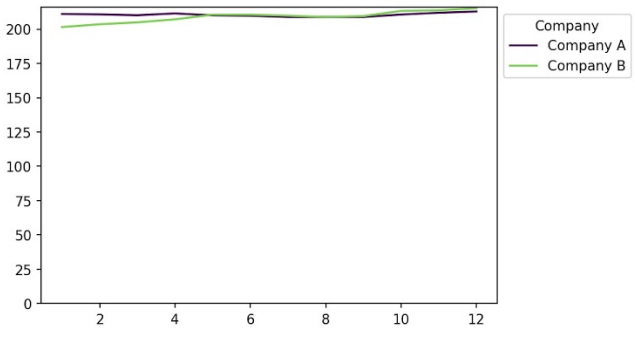
48. How large would you say the drop in sales between April and July of Company A is?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Sales - Part 1, Question 3

Consider the chart below



49. How much would you say sales of each company increased between January and December?

Mark only one oval per row.

	1 (A little)	2	3	4	5	6	7 (A lot)
Company A	◯	◯	◯	◯	◯	◯	◯
Company B	◯	◯	◯	◯	◯	◯	◯

50. How large would you say the drop in sales between April and July of Company A is?

Mark only one oval.

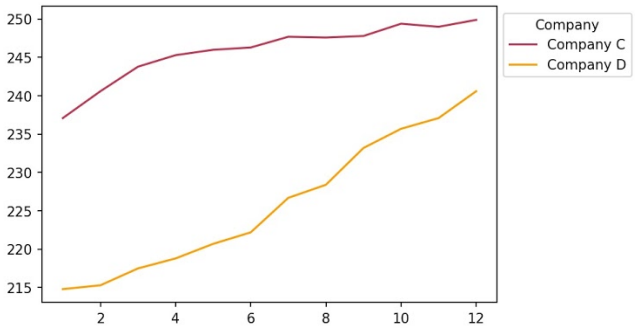
	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Sales - Part 2

The graphs below show the sales data for two more companies, Company C and Company D.

Sales - Part 2, Question 1

Consider the chart below



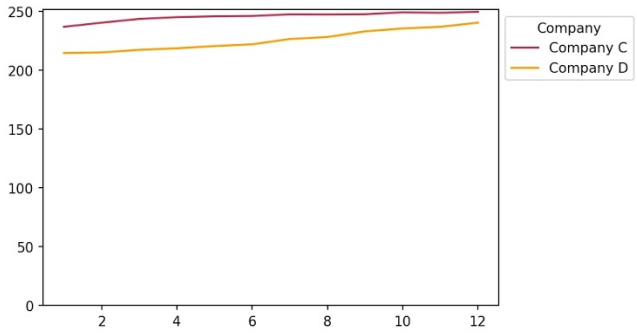
51. Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Sales - Part 2, Question 2

Consider the chart below



52. Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?

Mark only one oval.

	1	2	3	4	5	6	7	
A little	◯	◯	◯	◯	◯	◯	◯	A lot

Thank you for completing this survey.

Reminder - Your responses to this survey will remain anonymous.

If you would like to know more about the use of data visualisation and how different techniques may impact interpretation, please see the links below.
- https://searchbusinessanalytics.techtarget.com/definition/data-visualization
- https://datajournalism.com/read/handbook/one/understanding-data/using-data-visualization-to-find-insights-in-data
- https://heap.io/blog/data-stories/how-to-lie-with-data-visualization
- https://www.idashboards.com/blog/2019/02/27/when-data-visualizations-mislead-and-how-to-prevent-it/

If you are interested in how colour blindness can affect reading of visualisations and colour blind friendly palettes to use for data visualisation, please see the links below:
- https://blog.datawrapper.de/colorblindness-part3/
- https://www.youtube.com/watch?v=xAoljeRJ3lU

Once again, if you have any questions please do not hesitate to contact me at murphyka1@cardiff.ac.uk.

3.1.3

3.2 Appendix 2 - Univariate Analysis

3.3 Ninja Warrior - Part 1

3.3.1 "Approximately many times would you say the 'Salmon Ladder' was used?"

Table 3.1: Summary statistics over the whole population

	Control	Truncated	Logarithmic
N	69.0000000	69.0000000	6.600000e+01
Min.	40.0000000	40.0000000	9.000000e+00
1st Qu.	41.0000000	41.0000000	3.000000e+01
Median	41.0000000	41.0000000	3.500000e+01
Mean	41.1956522	41.3442029	1.515153e+13
3rd Qu.	42.0000000	42.0000000	4.075000e+01
Max.	45.0000000	45.0000000	1.000000e+15
Var	0.7442455	0.7575394	1.515151e+28

Table 3.2: Summary statistics over the whole population after removing outliers in the logarithmic responses

	Control	Truncated	Logarithmic
N	69.0000000	69.0000000	46.00000
Min.	40.0000000	40.0000000	15.00000
1st Qu.	41.0000000	41.0000000	34.00000
Median	41.0000000	41.0000000	35.00000
Mean	41.1956522	41.3442029	36.19565
3rd Qu.	42.0000000	42.0000000	40.00000
Max.	45.0000000	45.0000000	55.00000
Var	0.7442455	0.7575394	75.98309

Table 3.3: Summary statistics relating to the control plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.0000000	32.0000000
Min.	40.0000000	40.0000000	40.0000000
1st Qu.	41.0000000	41.0000000	40.0000000
Median	41.0000000	41.0000000	41.0000000
Mean	41.1956522	41.4729730	40.8750000
3rd Qu.	42.0000000	42.0000000	41.0000000
Max.	45.0000000	43.0000000	45.0000000
Var	0.7442455	0.4159159	0.9516129

Table 3.4: Summary statistics relating to the truncated plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.0000000	32.0000000
Min.	40.0000000	40.0000000	40.0000000
1st Qu.	41.0000000	41.0000000	41.0000000
Median	41.0000000	41.0000000	41.0000000
Mean	41.3442029	41.5540541	41.1015625
3rd Qu.	42.0000000	42.0000000	41.2500000
Max.	45.0000000	45.0000000	44.0000000
Var	0.7575394	0.7747748	0.6486265

Table 3.5: Summary statistics relating to the logarithmic plot responses for comparison between languages

	Whole Pop	R	Python
N	46.00000	37.00000	10.00
Min.	15.00000	30.00000	15.00
1st Qu.	34.00000	35.00000	35.00
Median	35.00000	35.00000	35.00
Mean	36.19565	39.72973	34.60
3rd Qu.	40.00000	40.00000	40.75
Max.	55.00000	120.00000	50.00
Var	75.98309	212.70270	131.60

Table 3.6: Summary statistics of degree subgroups relating to the logarithmic plot responses

	STEM	Humanities	Social Sci	Arts	Business	NA
N	27.00000	3.00000	3.000000e+01	2.00	4.0000	1
Min.	10.00000	9.00000	1.000000e+01	33.00	10.0000	NA
1st Qu.	22.50000	21.50000	3.400000e+01	34.75	10.3750	NA
Median	35.00000	34.00000	3.850000e+01	36.50	10.7500	NA
Mean	34.25926	26.33333	3.333337e+13	36.50	16.6250	NaN
3rd Qu.	40.00000	35.00000	5.375000e+01	38.25	17.0000	NA
Max.	120.00000	36.00000	1.000000e+15	40.00	35.0000	NA
NA's	10.00000	9.00000	1.000000e+01	33.00	10.0000	1
Var	437.12251	226.33333	3.333333e+28	24.50	150.2292	NA

Table 3.7: Degree and self-rated skills for the respondents that submitted invalid or high magnitude answers

	uni	sp_aware	obs_skl	num_skl	log_1
101	Technology	4	4	3	Don't know
121	None	4	3	3	Next to none.
102	Social Sciences	5	5	4	10^15
84	psychology	3	5	1	10^9

Table 3.8: Summary statistics for the subgroups that were shown each of the three plots first. ie. here the control statistics are only for respondents who saw the control plot first etc.

	Control First	Truncated First	Logarithmic First
N	24.000000	23.000000	15.00000
Min.	40.000000	40.000000	30.00000
1st Qu.	41.000000	41.000000	35.00000
Median	41.000000	41.250000	40.00000
Mean	41.125000	41.695652	40.20000
3rd Qu.	41.000000	42.000000	42.50000
Max.	45.000000	45.000000	55.00000
Var	1.070652	1.192935	49.88571

Table 3.9: Summary statistics to compare responses for the control plot between the whole population and those shown the control plot first

	Control Overall	Control First
N	69.0000000	24.000000
Min.	40.0000000	40.000000
1st Qu.	41.0000000	41.000000
Median	41.0000000	41.000000
Mean	41.1956522	41.125000
3rd Qu.	42.0000000	41.000000
Max.	45.0000000	45.000000
Var	0.7442455	1.070652

Table 3.10: Summary statistics to compare responses for the truncated plot between the whole population and those shown the truncated plot first

	Truncated Overall	Truncated First
N	69.0000000	23.000000
Min.	40.0000000	40.000000
1st Qu.	41.0000000	41.000000
Median	41.0000000	41.250000
Mean	41.3442029	41.695652
3rd Qu.	42.0000000	42.000000
Max.	45.0000000	45.000000
Var	0.7575394	1.192935

Table 3.11: Summary statistics to compare responses for the logarithmic plot between the whole population and those shown the logarithmic plot first

	Log Overall	Log First
N	46.00000	15.00000
Min.	15.00000	30.00000
1st Qu.	34.00000	35.00000
Median	35.00000	40.00000
Mean	36.19565	40.20000
3rd Qu.	40.00000	42.50000
Max.	55.00000	55.00000
Var	75.98309	49.88571

Table 3.12: Shapiro-Wilk test results to test for normality

Variable	P-Value
control_1	5.33578754536492e-08
truncated_1	1.25452646831151e-07
logarithmic_1	0.00018516220134098
control_1_r	1.54528619638491e-05
truncated_1_r	3.97529376553e-06
logarithmic_1_r	1.00203928506718e-10
control_1_py	4.34109928466654e-07
truncated_1_py	0.000139164254994752
logarithmic_1_py	0.0692684146080762
con_first_1	0.45
trn_first_1	0.02
log_first_1	0.91

Table 3.13: Symmetry test results to test for symmetric data

Variable	P-Value
control_1	0.018
truncated_1	0
logarithmic_1	0.196
control_1_r	0
truncated_1_r	0
logarithmic_1_r	0
control_1_py	0.352
truncated_1_py	0.378
logarithmic_1_py	0.866

Table 3.14: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
control_1	two.sided	41	0.16275565745309
truncated_1	two.sided	41	0.00393317302223295
truncated_1	greater	41	0.00196658651111647
truncated_1 and control_1	two.sided	0	0.187741558998824
control_1_r	two.sided	41	0.000144958496093972
control_1_r	greater	41	7.2479248046986e-05
truncated_1_r	two.sided	41	0.000728607177733487
truncated_1_r	greater	41	0.000364303588866743
logarithmic_1_r	two.sided	41	2.2361520677805e-05
logarithmic_1_r	less	41	1.11807603389025e-05

Table 3.15: MWW test results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
logarithmic_1	two.sided	41	0.000559493277800611
logarithmic_1	less	41	0.000279746638900306
logarithmic_1 and control_1	two.sided	0	6.9825440850011e-09
logarithmic_1 and control_1	less	0	3.49127204250055e-09
control_1_py	two.sided	41	0.166730310668163
control_1_py	greater	41	0.925860973799317
truncated_1_py	two.sided	41	0.718838518267998
truncated_1_py	greater	41	0.359419259133999
logarithmic_1_py	two.sided	41	0.119901689054139
logarithmic_1_py	less	41	0.0599508445270694
control_1_r and control_1_py	two.sided	0	0.000165813028152289
control_1_r and control_1_py	greater	0	8.29065140761444e-05
truncated_1_r and truncated_1_py	two.sided	0	0.0287523780622182
truncated_1_r and truncated_1_py	greater	0	0.0143761890311091
logarithmic_1_r and logarithmic_1_py	two.sided	0	0.989387291157526
con_first_1 and log_first_1	two.sided	0	0.0327983560266542
con_first_1 and log_first_1	greater	0	0.0163991780133271
trn_first_1 and truncated_1	two.sided	0	0.120790992088065
log_first_1 and logarithmic_1	two.sided	0	0.157715607882296

3.3.2 Approximately how much more than 'Log Grip' would you say 'Salmon Ladder' was was used?

Table 3.16: Summary statistics over the whole population

	Control	Truncated	Logarithmic
N	69.000000	69.000000	69.000000
Min.	3.000000	1.000000	1.000000
1st Qu.	4.000000	5.000000	2.000000
Median	5.000000	6.000000	3.000000
Mean	5.347826	5.869565	3.637681
3rd Qu.	6.000000	7.000000	5.000000
Max.	7.000000	7.000000	7.000000
Var	1.347826	2.026854	2.705030

Table 3.17: Summary statistics relating to the control plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.000000
Min.	3.000000	3.000000	3.000000
1st Qu.	4.000000	5.000000	4.000000
Median	5.000000	6.000000	5.000000
Mean	5.347826	5.486486	5.187500
3rd Qu.	6.000000	6.000000	6.000000
Max.	7.000000	7.000000	7.000000
Var	1.347826	1.312312	1.383064

Table 3.18: Summary statistics relating to the truncated plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.000000
Min.	1.000000	1.000000	1.000000
1st Qu.	5.000000	5.000000	5.750000
Median	6.000000	6.000000	6.000000
Mean	5.869565	5.891892	5.843750
3rd Qu.	7.000000	7.000000	7.000000
Max.	7.000000	7.000000	7.000000
Var	2.026854	1.821321	2.329637

Table 3.19: Summary statistics relating to the logarithmic plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.000000
Min.	1.000000	1.000000	1.000000
1st Qu.	2.000000	3.000000	2.000000
Median	3.000000	5.000000	3.000000
Mean	3.637681	4.216216	2.968750
3rd Qu.	5.000000	5.000000	4.000000
Max.	7.000000	7.000000	7.000000
Var	2.705030	2.507508	2.160282

Table 3.20: Summary statistics for the subgroups that were shown each of the three plots first. ie. here the control statistics are only for respondents who saw the control plot first etc.

	Control First	Truncated First	Logarithmic First
N	24.000000	23.000000	22.000000
Min.	4.000000	1.000000	1.000000
1st Qu.	4.750000	5.000000	3.000000
Median	5.500000	6.000000	5.000000
Mean	5.541667	5.565217	4.136364
3rd Qu.	7.000000	7.000000	5.750000
Max.	7.000000	7.000000	6.000000
Var	1.389493	2.166008	3.075758

Table 3.21: Summary statistics to compare responses for the control plot between the whole population and those shown the control plot first

	Control Overall	Control First
N	69.000000	24.000000
Min.	3.000000	4.000000
1st Qu.	4.000000	4.750000
Median	5.000000	5.500000
Mean	5.347826	5.541667
3rd Qu.	6.000000	7.000000
Max.	7.000000	7.000000
Var	1.347826	1.389493

Table 3.22: Summary statistics to compare responses for the truncated plot between the whole population and those shown the truncated plot first

	Truncated Overall	Truncated First
N	69.000000	23.000000
Min.	1.000000	1.000000
1st Qu.	5.000000	5.000000
Median	6.000000	6.000000
Mean	5.869565	5.565217
3rd Qu.	7.000000	7.000000
Max.	7.000000	7.000000
Var	2.026854	2.166008

Table 3.23: Summary statistics to compare responses for the logarithmic plot between the whole population and those shown the logarithmic plot first

	Log Overall	Log First
N	69.000000	22.000000
Min.	1.000000	1.000000
1st Qu.	2.000000	3.000000
Median	3.000000	5.000000
Mean	3.637681	4.136364
3rd Qu.	5.000000	5.750000
Max.	7.000000	6.000000
Var	2.705030	3.075758

Table 3.24: Shapiro-Wilk test results to test for normality

Variable	P-Value
control_2	6.24342248518355e-05
truncated_2	3.88752234860782e-09
logarithmic_2	0.00262520741543162
control_2_r	0.00391427682982241
truncated_2_r	5.93996971195915e-06
logarithmic_2_r	0.0191854417681526
control_2_py	0.00285808341673906
truncated_2_py	5.97589597973905e-06
logarithmic_2_py	0.0221068279265036

Table 3.25: Symmetry test results to test for symmetric data

Variable	P-Value
control_2	0.002
truncated_2	0.388
logarithmic_2	0
control_2_r	0.024
truncated_2_r	0.598
logarithmic_2_r	0
control_2_py	0.256
truncated_2_py	0.446
logarithmic_2_py	0.884
con_first_2	0.956
trn_first_2	0.13
log_first_2	0.018

Table 3.26: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
truncated_2 and control_2	two.sided	0	0.000191076425836156
truncated_2 and control_2	greater	0	9.55382129180782e-05
logarithmic_2 and control_2	two.sided	0	2.04742334197761e-11
logarithmic_2 and control_2	less	0	1.02371167098881e-11

Table 3.27: MWW test results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
control_2_r and control_2_py	two.sided	0	0.243909916192145
truncated_2_r and truncated_2_py	two.sided	0	0.939010927446889
logarithmic_2_r and logarithmic_2_py	two.sided	0	0.00144016567559996
logarithmic_2_r and logarithmic_2_py	greater	0	0.000720082837799979
con_first_2 and control_2	two.sided	0	0.532490797237705
trn_first_2 and truncated_2	two.sided	0	0.259404475325052
log_first_2 and logarithmic_2	two.sided	0	0.182421844461329

3.3.3 'Approximately how much more than 'Quintuple Steps' would you say 'Salmon Ladder' was used?'

Table 3.28: Summary statistics over the whole population

	Control	Truncated	Logarithmic
N	69.000000	69.000000	69.000000
Min.	1.000000	2.000000	1.000000
1st Qu.	2.000000	3.000000	1.000000
Median	3.000000	4.000000	2.000000
Mean	3.144928	3.797101	2.231884
3rd Qu.	4.000000	5.000000	3.000000
Max.	7.000000	7.000000	6.000000
Var	1.155158	1.281756	1.621910

Table 3.29: Summary statistics relating to the control plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.0000000
Min.	1.000000	2.000000	1.0000000
1st Qu.	2.000000	3.000000	2.0000000
Median	3.000000	3.000000	3.0000000
Mean	3.144928	3.378378	2.8750000
3rd Qu.	4.000000	4.000000	3.0000000
Max.	7.000000	7.000000	5.0000000
Var	1.155158	1.463964	0.6935484

Table 3.30: Summary statistics relating to the truncated plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.000000
Min.	2.000000	2.000000	2.000000
1st Qu.	3.000000	3.000000	3.000000
Median	4.000000	4.000000	4.000000
Mean	3.797101	3.810811	3.781250
3rd Qu.	5.000000	5.000000	4.250000
Max.	7.000000	6.000000	7.000000
Var	1.281756	1.324324	1.273186

Table 3.31: Summary statistics relating to the logarithmic plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.000000
Min.	1.000000	1.000000	1.000000
1st Qu.	1.000000	1.000000	1.000000
Median	2.000000	2.000000	2.000000
Mean	2.231884	2.513514	1.906250
3rd Qu.	3.000000	3.000000	2.250000
Max.	6.000000	6.000000	5.000000
Var	1.621910	1.978979	1.055443

Table 3.32: Summary statistics for the subgroups that were shown each of the three plots first. ie. here the control statistics are only for respondents who saw the control plot first etc.

	Control First	Truncated First	Logarithmic First
N	24.000000	23.0000000	22.000000
Min.	2.000000	2.0000000	1.000000
1st Qu.	2.000000	3.0000000	1.250000
Median	3.000000	3.0000000	2.500000
Mean	3.125000	3.4782609	2.681818
3rd Qu.	4.000000	4.0000000	4.000000
Max.	7.000000	5.0000000	6.000000
Var	1.418478	0.9881423	2.132035

Table 3.33: Summary statistics to compare responses for the control plot between the whole population and those shown the control plot first

	Control Overall	Control First
N	69.000000	24.000000
Min.	1.000000	2.000000
1st Qu.	2.000000	2.000000
Median	3.000000	3.000000
Mean	3.144928	3.125000
3rd Qu.	4.000000	4.000000
Max.	7.000000	7.000000
Var	1.155158	1.418478

Table 3.34: Summary statistics to compare responses for the truncated plot between the whole population and those shown the truncated plot first

	Truncated Overall	Truncated First
N	69.000000	23.0000000
Min.	2.000000	2.0000000
1st Qu.	3.000000	3.0000000
Median	4.000000	3.0000000
Mean	3.797101	3.4782609
3rd Qu.	5.000000	4.0000000
Max.	7.000000	5.0000000
Var	1.281756	0.9881423

Table 3.35: Summary statistics to compare responses for the logarithmic plot between the whole population and those shown the logarithmic plot first

	Log Overall	Log First
N	69.000000	22.000000
Min.	1.000000	1.000000
1st Qu.	1.000000	1.250000
Median	2.000000	2.500000
Mean	2.231884	2.681818
3rd Qu.	3.000000	4.000000
Max.	6.000000	6.000000
Var	1.621910	2.132035

Table 3.36: Shapiro-Wilk test results to test for normality

Variable	P-Value
control_3	3.82103913813318e-06
truncated_3	0.000334440448200324
logarithmic_3	5.94758318053857e-07
control_3_r	0.000556900253104092
truncated_3_r	0.0101814150385497
logarithmic_3_r	0.00101870786334344
control_3_py	0.00187662188224314
truncated_3_py	0.0091928840428001
logarithmic_3_py	5.96901899713831e-05

Table 3.37: Symmetry test results to test for symmetric data

Variable	P-Value
control_3	0.144
truncated_3	0.04
logarithmic_3	0.106
control_3_r	0.024
truncated_3_r	0.272
logarithmic_3_r	0.026
control_3_py	0.258
truncated_3_py	0.192
logarithmic_3_py	0.578
con_first_3	0.5
trn_first_3	0.142
log_first_3	0.628

Table 3.38: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
truncated_3 and control_3	two.sided	0	9.24769992094454e-06
truncated_3 and control_3	greater	0	4.62384996047227e-06
logarithmic_3 and control_3	two.sided	0	1.21152574195093e-07
logarithmic_3 and control_3	less	0	6.05762870975467e-08

Table 3.39: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
control_3_r and control_3_py	two.sided	0	0.105883948775384
truncated_3_r and truncated_3_py	two.sided	0	0.900788473359571
logarithmic_3_r and logarithmic_3_py	two.sided	0	0.0739448816882697
logarithmic_3_r and logarithmic_3_py	greater	0	0.0369724408441348
con_first_3 and control_3	two.sided	0	0.773815433110055
trn_first_3 and truncated_3	two.sided	0	0.267815900033396
log_first_3 and logarithmic_3	two.sided	0	0.191457924192077

3.4 Ninja Warrior - Part 2

3.4.1 "How large would you say the difference between 'Jumping spider' and 'Salmon Ladder' is?"

Table 3.40: Summary statistics over the whole population

	Default	Narrow	Wide
N	69.0000000	69.0000000	69.000000
Min.	4.0000000	3.0000000	2.000000
1st Qu.	5.0000000	6.0000000	5.000000
Median	6.0000000	6.0000000	6.000000
Mean	5.8985507	6.1159420	5.333333
3rd Qu.	7.0000000	7.0000000	6.000000
Max.	7.0000000	7.0000000	7.000000
Var	0.7689685	0.8687127	1.343137

Table 3.41: Summary statistics relating to the default plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.0000000	32.0000000
Min.	4.0000000	5.0000000	4.0000000
1st Qu.	5.0000000	6.0000000	5.0000000
Median	6.0000000	6.0000000	6.0000000
Mean	5.8985507	6.0540541	5.7187500
3rd Qu.	7.0000000	7.0000000	6.0000000
Max.	7.0000000	7.0000000	7.0000000
Var	0.7689685	0.5525526	0.9828629

Table 3.42: Summary statistics relating to the narrow plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.0000000	32.000000
Min.	3.0000000	5.0000000	3.000000
1st Qu.	6.0000000	6.0000000	5.000000
Median	6.0000000	6.0000000	6.000000
Mean	6.1159420	6.3513514	5.843750
3rd Qu.	7.0000000	7.0000000	7.000000
Max.	7.0000000	7.0000000	7.000000
Var	0.8687127	0.4564565	1.232863

Table 3.43: Summary statistics relating to the wide plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.0000000	32.000000
Min.	2.000000	3.0000000	2.000000
1st Qu.	5.000000	5.0000000	4.000000
Median	6.000000	6.0000000	5.000000
Mean	5.333333	5.6756757	4.937500
3rd Qu.	6.000000	6.0000000	6.000000
Max.	7.000000	7.0000000	7.000000
Var	1.343137	0.8363363	1.673387

Table 3.44: Summary statistics for the subgroups that were shown each of the three plots first. ie. here the default statistics are only for respondents who saw the default plot first etc.

	Default First	Narrow First	Wide First
N	24.0000000	22.0000000	23.0000000
Min.	4.0000000	5.0000000	3.0000000
1st Qu.	5.0000000	5.2500000	5.0000000
Median	6.0000000	6.0000000	5.0000000
Mean	5.6666667	6.0454545	5.2173913
3rd Qu.	6.0000000	7.0000000	6.0000000
Max.	7.0000000	7.0000000	7.0000000
Var	0.8405797	0.6168831	0.9960474

Table 3.45: Summary statistics to compare responses for the default plot between the whole population and those shown the default plot first

	Default Overall	Default First
N	69.0000000	24.0000000
Min.	4.0000000	4.0000000
1st Qu.	5.0000000	5.0000000
Median	6.0000000	6.0000000
Mean	5.8985507	5.6666667
3rd Qu.	7.0000000	6.0000000
Max.	7.0000000	7.0000000
Var	0.7689685	0.8405797

Table 3.46: Summary statistics to compare responses for the narrow plot between the whole population and those shown the narrow plot first

	Narrow Overall	Narrow First
N	69.0000000	22.0000000
Min.	3.0000000	5.0000000
1st Qu.	6.0000000	5.2500000
Median	6.0000000	6.0000000
Mean	6.1159420	6.0454545
3rd Qu.	7.0000000	7.0000000
Max.	7.0000000	7.0000000
Var	0.8687127	0.6168831

Table 3.47: Summary statistics to compare responses for the wide plot between the whole population and those shown the wide plot first

	Log Overall	Log First
N	69.000000	23.0000000
Min.	2.000000	3.0000000
1st Qu.	5.000000	5.0000000
Median	6.000000	5.0000000
Mean	5.333333	5.2173913
3rd Qu.	6.000000	6.0000000
Max.	7.000000	7.0000000
Var	1.343137	0.9960474

Table 3.48: Shapiro-Wilk test results to test for normality

Variable	P-Value
default_1	1.18336641940208e-06
narrow_1	2.38320342277826e-08
wide_1	3.28753750941121e-05
default_1_r	2.11400290228233e-05
narrow_1_r	2.99082479168389e-06
wide_1_r	0.000106408994479668
default_1_py	0.000646515703735704
narrow_1_py	0.000259256787785794
wide_1_py	0.0396509726470491

Table 3.49: Symmetry test results to test for symmetric data

Variable	P-Value
default_1	0.248
narrow_1	0.182
wide_1	0
default_1_r	0.554
narrow_1_r	0.006
wide_1_r	0.01
default_1_py	0.03
narrow_1_py	0.24
wide_1_py	0.708
def_first_1	0.16
nar_first_1	0.738
wid_first_1	0.18

Table 3.50: MWW test results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
narrow_1 and default_1	two.sided	0	0.0905049464556912
wide_1 and default_1	two.sided	0	0.00377620509450692
default_1_r and default_1_py	two.sided	0	0.204411271948635
narrow_1_r and narrow_1_py	two.sided	0	0.0553113102848234
wide_1_r and wide_1_py	two.sided	0	0.00805802429702594
def_first_1 and default_1	two.sided	0	0.241886599408831
nar_first_1 and narrow_1	two.sided	0	0.506531556500665
wid_first_1 and wide_1	two.sided	0	0.554828814459765

3.4.2 How large would you say the difference between 'Log Grip' and 'Floating Steps' is?

Table 3.51: Summary statistics over the whole population

	Default	Narrow	Wide
N	69.000000	69.000000	69.0000000
Min.	2.000000	1.000000	1.0000000
1st Qu.	2.000000	2.000000	2.0000000
Median	3.000000	3.000000	3.0000000
Mean	3.072464	3.231884	3.0724638
3rd Qu.	4.000000	4.000000	4.0000000
Max.	7.000000	7.000000	5.0000000
Var	1.303495	1.210145	0.8623188

Table 3.52: Summary statistics relating to the default plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.00000
Min.	2.000000	2.000000	2.00000
1st Qu.	2.000000	2.000000	2.00000
Median	3.000000	3.000000	3.00000
Mean	3.072464	3.054054	3.09375
3rd Qu.	4.000000	4.000000	4.00000
Max.	7.000000	6.000000	7.00000
Var	1.303495	1.219219	1.44254

Table 3.53: Summary statistics relating to the narrow plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.000000	32.00000
Min.	1.000000	2.000000	1.00000
1st Qu.	2.000000	3.000000	2.00000
Median	3.000000	3.000000	3.00000
Mean	3.231884	3.324324	3.12500
3rd Qu.	4.000000	4.000000	4.00000
Max.	7.000000	6.000000	7.00000
Var	1.210145	1.114114	1.33871

Table 3.54: Summary statistics relating to the wide plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.0000000	32.0000000
Min.	1.0000000	2.0000000	1.0000000
1st Qu.	2.0000000	2.0000000	2.7500000
Median	3.0000000	3.0000000	3.0000000
Mean	3.0724638	3.1081081	3.0312500
3rd Qu.	4.0000000	4.0000000	3.2500000
Max.	5.0000000	5.0000000	5.0000000
Var	0.8623188	0.9324324	0.8054435

Table 3.55: Summary statistics for the subgroups that were shown each of the three plots first. ie. here the default statistics are only for respondents who saw the default plot first etc.

	Default First	Narrow First	Wide First
N	24.00000	22.0000000	23.0000000
Min.	2.00000	2.0000000	2.0000000
1st Qu.	2.00000	2.0000000	3.0000000
Median	3.00000	3.0000000	3.0000000
Mean	3.00000	3.0000000	3.3043478
3rd Qu.	3.00000	3.0000000	4.0000000
Max.	7.00000	5.0000000	5.0000000
Var	1.73913	0.8571429	0.8577075

Table 3.56: Summary statistics to compare responses for the default plot between the whole population and those shown the default plot first

	Default Overall	Default First
N	69.000000	24.00000
Min.	2.000000	2.00000
1st Qu.	2.000000	2.00000
Median	3.000000	3.00000
Mean	3.072464	3.00000
3rd Qu.	4.000000	3.00000
Max.	7.000000	7.00000
Var	1.303495	1.73913

Table 3.57: Summary statistics to compare responses for the narrow plot between the whole population and those shown the narrow plot first

	Narrow Overall	Narrow First
N	69.000000	22.0000000
Min.	1.000000	2.0000000
1st Qu.	2.000000	2.0000000
Median	3.000000	3.0000000
Mean	3.231884	3.0000000
3rd Qu.	4.000000	3.0000000
Max.	7.000000	5.0000000
Var	1.210145	0.8571429

Table 3.58: Summary statistics to compare responses for the wide plot between the whole population and those shown the wide plot first

	Log Overall	Log First
N	69.0000000	23.0000000
Min.	1.0000000	2.0000000
1st Qu.	2.0000000	3.0000000
Median	3.0000000	3.0000000
Mean	3.0724638	3.3043478
3rd Qu.	4.0000000	4.0000000
Max.	5.0000000	5.0000000
Var	0.8623188	0.8577075

Table 3.59: Shapiro-Wilk test results to test for normality

Variable	P-Value
default_2	1.51097204656772e-07
narrow_2	2.36142627102639e-05
wide_2	1.34175431618343e-05
default_2_r	6.10374443955261e-05
narrow_2_r	0.00174605528235681
wide_2_r	0.000241526596852485
default_2_py	8.5552767804274e-05
narrow_2_py	0.000995681637986532
wide_2_py	0.00339675280251514

Table 3.60: Symmetry test results to test for symmetric data

Variable	P-Value
default_2	0.508
narrow_2	0.052
wide_2	0.414
default_2_r	0.72
narrow_2_r	0.09
wide_2_r	0.372
default_2_py	0.572
narrow_2_py	0.41
wide_2_py	0.808
def_first_2	0.92
nar_first_2	0.874
wid_first_2	0.13

Table 3.61: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
narrow_2 and default_2	two.sided	0	0.240855973238975
wide_2 and default_2	two.sided	0	0.568090611779764
default_2_r and default_2_py	two.sided	0	0.964601351759711
narrow_2_r and narrow_2_py	two.sided	0	0.36769248037497
wide_2_r and wide_2_py	two.sided	0	0.834196225296706
def_first_2 and default_2	two.sided	0	0.557858137165115
nar_first_2 and narrow_2	two.sided	0	0.380446508309098
wid_first_2 and wide_2	two.sided	0	0.29038053847017

3.4.3 How many times would you say 'Floating Steps' were used?

Table 3.62: Summary statistics over the whole population

	Default	Narrow	Wide
N	69.0000000	69.0000000	69.000000
Min.	26.0000000	23.0000000	24.000000
1st Qu.	27.0000000	27.0000000	27.000000
Median	28.0000000	28.0000000	28.000000
Mean	27.9710145	27.3768116	28.036232
3rd Qu.	28.0000000	28.0000000	29.000000
Max.	33.0000000	29.0000000	30.000000
Var	0.9917945	0.8779838	1.958227

Table 3.63: Summary statistics relating to the default plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.000000	32.0000000
Min.	26.0000000	26.000000	27.0000000
1st Qu.	27.0000000	28.000000	27.0000000
Median	28.0000000	28.000000	28.0000000
Mean	27.9710145	27.972973	27.9687500
3rd Qu.	28.0000000	28.000000	28.0000000
Max.	33.0000000	33.000000	30.0000000
Var	0.9917945	1.082583	0.9183468

Table 3.64: Summary statistics relating to the narrow plot responses for comparison between languages

	Whole Pop	R	Python
N	69.0000000	37.0000000	32.000000
Min.	23.0000000	24.0000000	23.000000
1st Qu.	27.0000000	27.0000000	27.000000
Median	28.0000000	28.0000000	27.000000
Mean	27.3768116	27.4864865	27.250000
3rd Qu.	28.0000000	28.0000000	28.000000
Max.	29.0000000	28.0000000	29.000000
Var	0.8779838	0.7012012	1.080645

Table 3.65: Summary statistics relating to the wide plot responses for comparison between languages

	Whole Pop	R	Python
N	69.000000	37.0000000	32.000000
Min.	24.000000	25.0000000	24.000000
1st Qu.	27.000000	27.0000000	27.000000
Median	28.000000	28.0000000	28.500000
Mean	28.036232	27.8108108	28.296875
3rd Qu.	29.000000	28.0000000	30.000000
Max.	30.000000	30.0000000	30.000000
Var	1.958227	0.7687688	3.271925

Table 3.66: Summary statistics for the subgroups that were shown each of the three plots first. ie. here the default statistics are only for respondents who saw the default plot first etc.

	Default First	Narrow First	Wide First
N	24.0000000	22.000000	23.000000
Min.	26.0000000	23.000000	24.000000
1st Qu.	27.8750000	27.000000	27.250000
Median	28.0000000	28.000000	28.000000
Mean	27.9791667	27.272727	27.891304
3rd Qu.	28.0000000	28.000000	28.500000
Max.	30.0000000	28.000000	30.000000
Var	0.8799819	1.445887	1.999012

Table 3.67: Summary statistics to compare responses for the default plot between the whole population and those shown the default plot first

	Default Overall	Default First
N	69.0000000	24.0000000
Min.	26.0000000	26.0000000
1st Qu.	27.0000000	27.8750000
Median	28.0000000	28.0000000
Mean	27.9710145	27.9791667
3rd Qu.	28.0000000	28.0000000
Max.	33.0000000	30.0000000
Var	0.9917945	0.8799819

Table 3.68: Summary statistics to compare responses for the narrow plot between the whole population and those shown the narrow plot first

	Narrow Overall	Narrow First
N	69.0000000	22.000000
Min.	23.0000000	23.000000
1st Qu.	27.0000000	27.000000
Median	28.0000000	28.000000
Mean	27.3768116	27.272727
3rd Qu.	28.0000000	28.000000
Max.	29.0000000	28.000000
Var	0.8779838	1.445887

Table 3.69: Summary statistics to compare responses for the wide plot between the whole population and those shown the wide plot first

	Log Overall	Log First
N	69.000000	23.000000
Min.	24.000000	24.000000
1st Qu.	27.000000	27.250000
Median	28.000000	28.000000
Mean	28.036232	27.891304
3rd Qu.	29.000000	28.500000
Max.	30.000000	30.000000
Var	1.958227	1.999012

Table 3.70: Shapiro-Wilk test results to test for normality

Variable	P-Value
default_3	9.70159388551055e-10
narrow_3	7.81013921177679e-11
wide_3	2.33999193811929e-05
default_3_r	9.47419208813669e-09
narrow_3_r	2.50020753129336e-08
wide_3_r	5.49878698354199e-05
default_3_py	4.02423544805188e-05
narrow_3_py	7.08573834534838e-07
wide_3_py	0.000292780031974141
def_first_3	0.918
nar_first_3	0
wid_first_3	0.606

Table 3.71: Symmetry test results to test for symmetric data

Variable	P-Value
default_3	0.818
narrow_3	0
wide_3	0.776
default_3_r	0.826
narrow_3_r	0
wide_3_r	0.134
default_3_py	0.856
narrow_3_py	0.09
wide_3_py	0.504

Table 3.72: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
narrow_3	two.sided	28	2.09547579288481e-09
narrow_3	less	28	1.04773789644241e-09
narrow_3 and default_3	two.sided	0	0.000179991126060486
narrow_3 and default_3	less	0	8.99955630302432e-05
narrow_3_r	two.sided	28	0.0001220703125
narrow_3_r	less	28	6.103515625e-05
narrow_3_r and narrow_3_py	two.sided	0	0.147644360229049
nar_first_3 and narrow_3	two.sided	0	0.971314295834775

Table 3.73: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
default_3	two.sided	28	0.56672532578209
wide_3	two.sided	28	0.506674178654124
wide_3 and default_3	two.sided	0	0.381239105342814
default_3_r	two.sided	28	0.401160204990545
default_3_py	two.sided	28	0.928017616229503
narrow_3_py	two.sided	28	0.000113016729448749
narrow_3_py	less	28	5.65083647243744e-05
wide_3_r	two.sided	28	0.227059310644515
wide_3_py	two.sided	28	0.225993872330457
default_3_r and default_3_py	two.sided	0	0.682329364937596
wide_3_r and wide_3_py	two.sided	0	0.0872217518584691
def_first_3 and default_3	two.sided	0	0.847459410138399
wid_first_3 and wide_3	two.sided	0	0.767108139298196

3.5 Ninja Warrior - Part 3

3.5.1 How many times would you say 'Floating Steps' were used in the Finals (Regional/City) round?

Table 3.74: Summary statistics for the stacked and grouped plot responses for the whole population

	Stacked	Grouped
N	69.00000	69.00000
Min.	9.00000	10.00000
1st Qu.	10.00000	11.00000
Median	11.00000	11.00000
Mean	14.39130	11.81159
3rd Qu.	14.00000	12.00000
Max.	35.00000	40.00000
Var	55.35934	13.33163

Table 3.75: Summary statistics relating to the stacked plot responses for comparison between languages

	Whole Population	R	Python
N	69.00000	37.00000	32.00000
Min.	9.00000	9.00000	9.00000
1st Qu.	10.00000	10.00000	10.00000
Median	11.00000	10.00000	11.50000
Mean	14.39130	13.24324	15.71875
3rd Qu.	14.00000	12.00000	16.25000
Max.	35.00000	35.00000	35.00000
Var	55.35934	46.35586	64.20867

Table 3.76: Summary statistics relating to the grouped plot responses for comparison between languages

	Whole Population	R	Python
N	69.00000	37.0000000	32.00000
Min.	10.00000	10.0000000	10.00000
1st Qu.	11.00000	11.0000000	11.00000
Median	11.00000	11.0000000	11.00000
Mean	11.81159	11.2432432	12.46875
3rd Qu.	12.00000	12.0000000	12.00000
Max.	40.00000	12.0000000	40.00000
Var	13.33163	0.4114114	27.93448

Table 3.77: Shapiro-Wilk test results to test for normality

Variable	P-Value
stacked_1	1.16490097384689e-11
grouped_1	1.77605214914826e-16
stacked_1_r	1.58520962564203e-09
grouped_1_r	4.59074801464563e-06
stacked_1_py	2.72192783910971e-06
grouped_1_py	1.83295084072365e-10
stack_first_1	0
grp_first_1	0.066

Table 3.78: Shapiro-Wilk test results to test for normality

Variable	P-Value
stacked_1	0
grouped_1	0
stacked_1_r	0
grouped_1_r	0.008
stacked_1_py	0
grouped_1_py	0
stack_first_1	0
grp_first_1	0.112

Table 3.79: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
stacked_1	two.sided	11	0.608920715404828
grouped_1	two.sided	11	0.00947530427947663
grouped_1	greater	11	0.00473765213973831
grouped_1 and stacked_1	two.sided	0	0.340890941220097
stacked_1_r	two.sided	11	0.16275565745309
stacked_1_py	two.sided	11	0.571588188409806
grouped_1_r	two.sided	11	0.0490417480468759
grouped_1_r	greater	11	0.0245208740234379
grouped_1_py	two.sided	11	0.133800506591798

Table 3.80: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
stacked_1_r and stacked_1_py	two.sided	0	0.0737237477902791
grouped_1_r and grouped_1_py	two.sided	0	0.561973829695235
stack_first_1 and stacked_1	two.sided	0	0.704585465484386
group_first_1 and grouped_1	two.sided	0	0.654750665992632

3.5.2 How many times would you say 'Log Grip' was used in the Finals (Regional/City) round

Table 3.81: Summary statistics for the stacked and grouped plot responses for the whole population

	Stacked	Grouped
N	69.00000	69.000000
Min.	6.00000	2.000000
1st Qu.	8.00000	8.000000
Median	9.00000	9.000000
Mean	10.60870	9.072464
3rd Qu.	10.00000	10.000000
Max.	25.00000	15.000000
Var	24.18286	1.979966

Table 3.82: Summary statistics relating to the stacked plot responses for comparison between languages

	Whole Population	R	Python
N	69.00000	37.00000	32.00000
Min.	6.00000	6.00000	6.00000
1st Qu.	8.00000	8.00000	8.00000
Median	9.00000	9.00000	9.00000
Mean	10.60870	10.16216	11.12500
3rd Qu.	10.00000	10.00000	10.00000
Max.	25.00000	23.00000	25.00000
Var	24.18286	18.75075	30.75806

Table 3.83: Summary statistics relating to the grouped plot responses for comparison between languages

	Whole Population	R	Python
N	69.000000	37.0000000	32.000000
Min.	2.000000	7.0000000	2.000000
1st Qu.	8.000000	9.0000000	8.000000
Median	9.000000	9.0000000	9.000000
Mean	9.072464	9.0810811	9.062500
3rd Qu.	10.000000	10.0000000	10.000000
Max.	15.000000	10.0000000	15.000000
Var	1.979966	0.6321321	3.608871

Table 3.84: Shapiro-Wilk test results to test for normality

Variable	P-Value
stacked_2	3.14087188538367e-11
grouped_2	4.94337899038139e-10
stacked_2_r	9.65363700238903e-09
grouped_2_r	7.75504301811935e-05
stacked_2_py	1.34468066051548e-06
grouped_2_py	5.65036041747099e-06
stack_first_2	0
grp_first_2	0.114

Table 3.85: Shapiro-Wilk test results to test for normality

Variable	P-Value
stacked_2	0
grouped_2	0.56
stacked_2_r	0.02
grouped_2_r	0.388
stacked_2_py	0
grouped_2_py	0.82
stack_first_2	0
grp_first_2	0.302

Table 3.86: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
stacked_2	two.sided	9	0.791366427779181
stacked_2 and stacked_2	two.sided	0	1
stacked_2_r	two.sided	9	1
stacked_2_py	two.sided	9	0.845018982887267

Table 3.87: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
grouped_2 and stacked_2	two.sided	0	0.607570902721681
grouped_2	two.sided	9	0.50198027059749
grouped_2_r	two.sided	9	0.545383797089744
grouped_2_py	two.sided	9	0.749150109631703
grouped_2_r and grouped_2_py	two.sided	0	0.833562194836486
stacked_2_r and stacked_2_py	two.sided	0	0.810854639383072
stack_first_2 and stacked_2	two.sided	0	0.714585422209954
group_first_2 and grouped_2	two.sided	0	0.268977364340368

3.5.3 Please select the statement you feel applies to the bar chart above.

Table 3.88: Table showing responses over the whole population

	Equal	Less	More
Stacked	27	30	11
Grouped	60	5	2

Table 3.89: Table showing responses over the R subgroup

	Equal	Less	More
Stacked	11	19	6
Grouped	29	4	2

Table 3.90: Table showing responses over the Python subgroup

	Equal	Less	More
Stacked	16	11	5
Grouped	31	1	31

3.5.4 Which obstacle do you think was used MORE in Finals (Regional/City) rounds, 'Log Grip' or 'Floating Steps'?

Table 3.91: Table showing responses over the whole population

	Floating Steps	Log Grip	Both the same
Stacked	55	2	12
Grouped	57	4	8

Table 3.92: Table showing responses over the R subgroup

	Floating Steps	Log Grip	Both the same
Stacked	29	8	0
Grouped	32	1	4

Table 3.93: Table showing responses over the Python subgroup

	Floating Steps	Log Grip	Both the same
Stacked	26	2	4
Grouped	25	3	4

3.5.5 Which bar chart do you feel is easiest to read and interpret?

```
                   A  B
Whole Population 32 37
R                17 20
Python           15 17
```

Table 3.94: Description of colour pairings

Colour Set	Main Palette	Secondary Pallette
A	Viridis	Default
B	Default	Viridis
C	Default	Greyscale
D	Greyscale	Default
E	Viridis	Greyscale
F	Greyscale	Viridis

Table 3.95: Table showing responses over the whole population, separated by colour set

	A	B	A Colour	B Colour
Set A	3	9	Viridis	Default
Set B	1	11	Default	Viridis
Set C	9	1	Default	Greyscale
Set D	1	11	Greyscale	Default
Set E	8	3	Viridis	Greyscale
Set F	10	2	Greyscale	Viridis

Table 3.96: Table showing responses over the R sungroup, separated by colour set

	A	B	A Colour	B Colour
Set A	2	5	Viridis	Default
Set B	6	6	Default	Viridis
Set C	4	1	Default	Greyscale
Set D	1	6	Greyscale	Default
Set E	4	1	Viridis	Greyscale
Set F	6	1	Greyscale	Viridis

Table 3.97: Table showing responses over the Python subgroup, separated by colour set

	A	B	A Colour	B Colour
Set A	1	4	Viridis	Default
Set B	1	5	Default	Viridis
Set C	5	5	Default	Greyscale
Set D	5	5	Greyscale	Default
Set E	4	2	Viridis	Greyscale
Set F	4	1	Greyscale	Viridis

3.5.6 Which colour scheme do you find most aesthetically pleasing?

Table 3.98: Table showing responses over the whole population

	A	B	A Colour	B Colour
Set A	3	9	Viridis	Default
Set B	1	11	Default	Viridis
Set C	9	1	Default	Greyscale
Set D	1	11	Greyscale	Default
Set E	8	3	Viridis	Greyscale
Set F	10	2	Greyscale	Viridis

Table 3.99: Table showing responses over the R subgroup

	A	B	A Colour	B Colour
Set A	2	5	Viridis	Default
Set B	0	6	Default	Viridis
Set C	4	1	Default	Greyscale
Set D	1	6	Greyscale	Default
Set E	4	1	Viridis	Greyscale
Set F	6	1	Greyscale	Viridis

Table 3.100: Table showing responses over the Python subgroup

	A	B	A Colour	B Colour
Set A	1	4	Viridis	Default
Set B	1	5	Default	Viridis
Set C	5	0	Default	Greyscale
Set D	0	5	Greyscale	Default
Set E	4	2	Viridis	Greyscale
Set F	4	1	Greyscale	Viridis

3.5.7 Do you feel that one of the colour schemes makes it easier to read and interpret? If so, please select which one.

Table 3.101: Table showing responses over the whole population, separated by colour set

	None	A	B	A Colour	B Colour
Set A	3	6	3	Viridis	Default
Set B	1	11	1	Default	Viridis
Set C	9	1	9	Default	Greyscale
Set D	2	10	2	Greyscale	Default
Set E	11	11	11	Viridis	Greyscale
Set F	1	2	9	Greyscale	Viridis

Table 3.102: Table showing responses over the R subgroup, separated by colour set

	None	A	B	A Colour	B Colour
Set A	0	4	3	Viridis	Default
Set B	1	5	0	Default	Viridis
Set C	0	4	1	Default	Greyscale
Set D	0	1	6	Greyscale	Default
Set E	0	5	0	Viridis	Greyscale
Set F	1	2	4	Greyscale	Viridis

Table 3.103: Table showing responses over the Python subgroup, separated by colour set

	None	A	B	A Colour	B Colour
Set A	3	2	0	Viridis	Default
Set B	0	6	0	Default	Viridis
Set C	0	5	0	Default	Greyscale
Set D	0	1	4	Greyscale	Default
Set E	0	6	0	Viridis	Greyscale
Set F	0	0	5	Greyscale	Viridis

3.6 Sales - Part 1

Table 3.104: Statistics over the whole population

	Separate	Truncated	Zeroed
Min.	1.000000	1.000000	1.000000
1st Qu.	2.000000	2.000000	1.000000
Median	3.000000	2.000000	1.000000
Mean	2.985294	2.347826	1.376812
3rd Qu.	4.000000	3.000000	2.000000
Max.	6.000000	5.000000	3.000000

Table 3.105: Summary statistics relating to the separated plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.000000
1st Qu.	2.000000	2.000000	2.000000
Median	3.000000	2.000000	3.000000
Mean	2.985294	2.918919	3.064516
3rd Qu.	4.000000	4.000000	4.000000
Max.	6.000000	6.000000	6.000000

Table 3.106: Summary statistics relating to the truncated plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.00000
1st Qu.	2.000000	2.000000	1.75000
Median	2.000000	2.000000	2.00000
Mean	2.347826	2.459459	2.21875
3rd Qu.	3.000000	3.000000	3.00000
Max.	5.000000	4.000000	5.00000

Table 3.107: Summary statistics relating to the zeroed plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.00
1st Qu.	1.000000	1.000000	1.00
Median	1.000000	1.000000	1.00
Mean	1.376812	1.486487	1.25
3rd Qu.	2.000000	2.000000	1.00
Max.	3.000000	3.000000	3.00

Table 3.108: Statistics for the subgroup that saw the separated plots first compared to the whole population

	Separated - Whole Population	Separated First
Min.	1.000000	1.000000
1st Qu.	2.000000	2.000000
Median	3.000000	3.000000
Mean	2.985294	3.142857
3rd Qu.	4.000000	4.000000
Max.	6.000000	6.000000

Table 3.109: Statistics for the subgroup that saw the Truncated plot first compared to the whole population

	Truncated - Whole Population	Truncated First
Min.	1.000000	1.00
1st Qu.	2.000000	1.00
Median	2.000000	2.00
Mean	2.347826	2.00
3rd Qu.	3.000000	2.25
Max.	5.000000	4.00

Table 3.110: Statistics for the subgroup that saw the zeroed plot first compared to the whole population

	Zeroed - Whole Population	Zeroed First
Min.	1.000000	1.000000
1st Qu.	1.000000	1.000000
Median	1.000000	1.000000
Mean	1.376812	1.333333
3rd Qu.	2.000000	1.250000
Max.	3.000000	3.000000

Table 3.111: Shapiro-Wilk test results to test for normality

Variable	P-Value
trn_ab_1a	6.7809735872021e-06
zero_ab_1a	9.50105229042584e-13
trn_ab_1a_r	0.000749269347280919
zero_ab_1a_r	6.72655664829562e-08
trn_ab_1a_py	0.000342433023227564
zero_ab_1a_py	6.92541983845556e-10
trn_first_ab	0.00167817869906907
zero_first_ab	3.5205920680761e-07

Table 3.112: Shapiro-Wilk test results to test for normality

Variable	P-Value
sep_ab_1a	0.924
trn_ab_1a	0.002
zero_ab_1a	0
sep_ab_1a	0.924
trn_ab_1a_r	0.048
zero_ab_1a_r	0
sep_ab_1a	0.91
trn_ab_1a_py	0.102
zero_ab_1a_py	0
sep_ab_1a	0.926
trn_first_ab	0.94
zero_first_ab	0

Table 3.113: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
trn_ab_1a and zero_ab_1a	two.sided	0	1.774136393351e-13
trn_ab_1a and zero_ab_1a	greater	0	8.870681966755e-14

Table 3.114: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
trn_ab_1a and sep_ab_1a	two.sided	0	0.0114489869100508
trn_ab_1a and sep_ab_1a	less	0	0.0057244934550254
sep_ab_1a and zero_ab_1a	two.sided	0	4.84412010817655e-13
sep_ab_1a and zero_ab_1a	greater	0	2.42206005408828e-13
trn_ab_1a_r and trn_ab_1a_py	two.sided	0	0.256454315230702
zero_ab_1a_r and zero_ab_1a_py	two.sided	0	0.0911448601307526
sep_ab_1a_r and sep_ab_1a_py	two.sided	0	0.507624800317214
trn_first_ab and trn_ab_1a	two.sided	0	0.159694483903836
zero_first_ab and zero_ab_1a	two.sided	0	0.868025459965406
sep_first_ab and sep_ab_1a	two.sided	0	0.648710126691048

3.6.1 How much would you say sales of each company increased between January and December? [Company B]

Table 3.115: Statistics over the whole population

	Separate	Truncated	Zeroed
Min.	1.000000	1.000000	1.000000
1st Qu.	4.000000	4.000000	1.000000
Median	4.000000	4.000000	1.000000
Mean	4.132353	4.323529	1.376812
3rd Qu.	5.000000	5.000000	2.000000
Max.	6.000000	6.000000	3.000000

Table 3.116: Summary statistics relating to the separated plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	2.0000
1st Qu.	4.000000	3.750000	4.0000
Median	4.000000	4.000000	4.0000
Mean	4.132353	4.083333	4.1875
3rd Qu.	5.000000	5.000000	4.2500
Max.	6.000000	6.000000	6.0000

Table 3.117: Summary statistics relating to the truncated plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.000000
1st Qu.	4.000000	4.000000	4.000000
Median	4.000000	4.000000	4.000000
Mean	4.323529	4.405405	4.225807
3rd Qu.	5.000000	5.000000	5.500000
Max.	6.000000	6.000000	6.000000

Table 3.118: Summary statistics relating to the zeroed plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.00
1st Qu.	1.000000	1.000000	1.00
Median	1.000000	1.000000	1.00
Mean	1.376812	1.486487	1.25
3rd Qu.	2.000000	2.000000	1.00
Max.	3.000000	3.000000	3.00

Table 3.119: Statistics over the whole population

	Separate	Truncated	Zeroed
Min.	1.0	1.000000	1.000000
1st Qu.	4.0	4.000000	1.000000
Median	4.0	4.000000	1.000000
Mean	4.3	4.405405	1.486487
3rd Qu.	5.0	5.000000	2.000000
Max.	6.0	6.000000	3.000000

Table 3.120: Shapiro-Wilk test results to test for normality

Variable	P-Value
trn_ab_1b	2.90958251317478e-06
zero_ab_1b	9.50105229042584e-13
trn_ab_1b_r	0.000176521266596845
zero_ab_1b_r	6.72655664829562e-08
trn_ab_1b_py	0.00215780969368076
zero_ab_1b_py	6.92541983845556e-10
trn_first_ab	0.000176521266596845
zero_first_ab	6.72655664829562e-08

Table 3.121: Shapiro-Wilk test results to test for normality

Variable	P-Value
sep_ab_1b	0.21
trn_ab_1b	0.016
zero_ab_1b	0
sep_ab_1b	0.234
trn_ab_1b_r	0.018
zero_ab_1b_r	0
sep_ab_1b	0.232
trn_ab_1b_py	0.222
zero_ab_1b_py	0
sep_ab_1b	0.206
trn_first_ab	0.036
zero_first_ab	0

Table 3.122: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
trn_ab_1b and zero_ab_1b	two.sided	0	4.53967704636226e-22
trn_ab_1b and zero_ab_1b	greater	0	2.26983852318113e-22
trn_ab_1b and sep_ab_1b	two.sided	0	0.216726883336969
trn_ab_1b and sep_ab_1b	greater	0	0.108363441668485
sep_ab_1b and zero_ab_1b	two.sided	0	6.33798016153557e-23
sep_ab_1b and zero_ab_1b	less	0	1
trn_ab_1b_r and trn_ab_1b_py	two.sided	0	0.543592761305094
zero_ab_1b_r and zero_ab_1b_py	two.sided	0	0.0911448601307526
sep_ab_1b_r and sep_ab_1b_py	two.sided	0	0.984369424315388
trn_first_ab and trn_ab_1b	two.sided	0	0.739783066691471
zero_first_ab and zero_ab_1b	two.sided	0	0.370578612557692
sep_first_ab and sep_ab_1b	two.sided	0	0.3983478324832

3.6.2 How large would you say the drop in sales between April and July of Company A is?

Table 3.123: Statistics over the whole population

	Separate	Truncated	Zeroed
Min.	1.000000	1.000000	1.000000
1st Qu.	3.000000	2.000000	1.000000
Median	4.000000	3.000000	1.000000
Mean	4.057971	2.826087	1.376812
3rd Qu.	5.000000	3.000000	2.000000
Max.	7.000000	7.000000	3.000000

Table 3.124: Summary statistics relating to the separated plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.00000
1st Qu.	3.000000	2.000000	3.00000
Median	4.000000	4.000000	4.50000
Mean	4.057971	3.864865	4.28125
3rd Qu.	5.000000	5.000000	5.00000
Max.	7.000000	7.000000	7.00000

Table 3.125: Summary statistics relating to the truncated plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.00
1st Qu.	2.000000	2.000000	2.00
Median	3.000000	3.000000	3.00
Mean	2.826087	2.891892	2.75
3rd Qu.	3.000000	4.000000	3.00
Max.	7.000000	7.000000	6.00

Table 3.126: Summary statistics relating to the zeroed plot responses for comparison between languages

	Whole Pop	R	Py
Min.	1.000000	1.000000	1.00
1st Qu.	1.000000	1.000000	1.00
Median	1.000000	1.000000	1.00
Mean	1.376812	1.486487	1.25
3rd Qu.	2.000000	2.000000	1.00
Max.	3.000000	3.000000	3.00

Table 3.127: Shapiro-Wilk test results to test for normality

Variable	P-Value
trn_ab_2	5.29930577781549e-05
zero_ab_2	9.50105229042584e-13
trn_ab_2_r	0.00567304991996842
zero_ab_2_r	6.72655664829562e-08
trn_ab_2_py	0.00336626681055323
zero_ab_2_py	6.92541983845556e-10
trn_first_ab	0.00175118305553834
zero_first_ab	3.5205920680761e-07

Table 3.128: Shapiro-Wilk test results to test for normality

Variable	P-Value
sep_ab_2	0.808
trn_ab_2	0.174
zero_ab_2	0
sep_ab_2	0.75
trn_ab_2_r	0.602
zero_ab_2_r	0
sep_ab_2	0.738
trn_ab_2_py	0.0740000000000001
zero_ab_2_py	0
sep_ab_2	0.78
trn_first_ab	0.314
zero_first_ab	0

Table 3.129: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
trn_ab_2 and zero_ab_2	two.sided	0	1.9068302492542e-11
trn_ab_2 and zero_ab_2	greater	0	9.53415124627099e-12

Table 3.130: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
trn_ab_2 and sep_ab_2	two.sided	0	0.000101660231966154
trn_ab_2 and sep_ab_2	less	0	5.08301159830768e-05
sep_ab_2 and zero_ab_2	two.sided	0	1.77342530165489e-16
sep_ab_2 and zero_ab_2	greater	0	8.86712650827445e-17
trn_ab_2_r and trn_ab_2_py	two.sided	0	0.925389597527489
zero_ab_2_r and zero_ab_2_py	two.sided	0	0.0911448601307526
sep_ab_2_r and sep_ab_2_py	two.sided	0	0.34145561474615
trn_first_ab and trn_ab_2	two.sided	0	0.66777647424621
zero_first_ab and zero_ab_2	two.sided	0	0.868025459965406
sep_first_ab and sep_ab_2	two.sided	0	0.934480957603288

3.7 Sales - Part 2

3.7.1 Based on the above graph, how large would you say the difference is between the number of sales Company C makes and the number of sales Company D makes?

Table 3.131: Statistics over the whole population

	Truncated	Zeroed
Min.	2.000000	1.000000
1st Qu.	4.000000	2.000000
Median	4.000000	3.000000
Mean	4.304348	2.710145
3rd Qu.	5.000000	3.000000
Max.	7.000000	5.000000

Table 3.132: Statistics for the R subgroup

	Truncated	Zeroed
Min.	2.000000	1.000000
1st Qu.	4.000000	2.000000
Median	4.000000	2.000000
Mean	4.324324	2.648649
3rd Qu.	5.000000	3.000000
Max.	7.000000	4.000000

Table 3.133: Statistics for the Python subgroup

	Truncated	Zeroed
Min.	2.00000	1.00000
1st Qu.	3.75000	2.00000
Median	4.00000	3.00000
Mean	4.28125	2.78125
3rd Qu.	5.00000	3.00000
Max.	7.00000	5.00000

Table 3.134: Statistics for the subgroup that saw the truncated plot first compared to the whole population

	Truncated - Whole Population	Truncated First
Min.	2.000000	2.000000
1st Qu.	4.000000	4.000000
Median	4.000000	4.000000
Mean	4.304348	4.166667
3rd Qu.	5.000000	5.000000
Max.	7.000000	7.000000

Table 3.135: Statistics for the subgroup that saw the zeroed plot first compared to the whole population

	Zeroed - Whole Population	Zeroed First
Min.	1.000000	1.000000
1st Qu.	2.000000	2.000000
Median	3.000000	3.000000
Mean	2.710145	3.030303
3rd Qu.	3.000000	4.000000
Max.	5.000000	5.000000

Table 3.136: Shapiro-Wilk test results to test for normality

Variable	P-Value
trn_cd	0.000379700189309497
zero_cd	2.80855241186179e-06
trn_cd_r	0.0180545424093602
zero_cd_r	9.39903013991829e-05
trn_cd_py	0.0245137395260841
zero_cd_py	0.000814074994084011
trn_first_cd	0.00524991461743558
zero_first_cd	0.00400338047851882

Table 3.137: Shapiro-Wilk test results to test for normality

Variable	P-Value
trn_cd	0.014
zero_cd	0.022
trn_cd_r	0.014
zero_cd_r	0
trn_cd_py	0.082
zero_cd_py	0.124
trn_first_cd	0.176
zero_first_cd	0.774

Table 3.138: Sign test results for data considered non-normal and asymmetric

Variable(s)	Alternative	Null Value	P-Value
trn_cd and zero_cd	two.sided	0	8.88178419700125e-15
trn_cd and zero_cd	greater	0	4.44089209850063e-15

Table 3.139: MWW results for data considered non-normal but symmetric, and also comparisons of asymmetric data for which the two samples are of different sizes

Variable(s)	Alternative	Null Value	P-Value
trn_cd_r and trn_cd_py	two.sided	0	0.920095620069404
zero_cd_r and zero_cd_py	two.sided	0	0.616940624250758
trn_first_cd and trn_cd	two.sided	0	0.581624723113106
zero_first_cd and zero_cd	two.sided	0	0.070256975666455

3.7.2

3.8 Appendix 3 - Multivariate Analysis

3.8.1

3.9 Appendix 4 - Interview Transcripts

Chapter 4

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