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Study Information

1. A Study Comparing Line, Stacked Column, and Waffle Charts for Forecasting Exponential Growth
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3. Description
 - 3.1. We conduct a design evaluation study to assess the efficacy of using three different chart types (line, stacked column, and waffle) to support forecasting exponential growth over time. Early results indicate that waffle charts decrease underestimation, especially for periods far (greater than 4 periods) in the future.
4. Hypotheses
 - 4.1. We believe users that are forecasting out several periods of exponential growth in the future will be more accurate with the use of a waffle chart when compared to the conventional line chart and stacked column chart.

Design Plan

5. Study type
 - 5.1. Observational Study
6. Blinding
 - 6.1. No blinding is involved in this study.
7. Study design

- 7.1. We have a within-subjects design with 3 chart types - line, stacked column, and waffle charts.
- 7.2. To test users' understanding of exponential growth, we created a visualization design evaluation study in which we present line charts, stacked column charts, and waffle charts to participants with data for periods 1 through 6 with given growth rates. Using the growth rates provided for periods 7, 8, 9, and 10, we asked them to predict the values in periods 8 and 10.

The study is composed of 12 questions on bacteria growth with variable growth rates. Of the 12 questions, we evenly split these questions amongst line, stacked column, and waffle charts, resulting in 4 questions for each type. In each 4 questions, there are 4 unique sets of variable growth rates for periods 1 to 10. To guarantee consistency amongst the chart types, we verified that all chart types have comparative growth rates. As stated above, in each of the 12 questions, we will ask participants to predict the values in periods 8 and 10.

Once we developed the data points for all 12 charts, we leveraged Flourish, a data visualization tool to create all the charts amongst the 3 chart types. The goal when creating the charts was to ensure other than the unique stimuli of each graph type, we keep everything as consistent as possible. This included font size, weights, and most importantly the colors used in each of the chart types.

After creating each chart, we created a survey using the Qualtrics software. We made the decision to utilize this software as it allows us a reliable way to administer this survey on a larger scale. Also, the data collection is made extremely easy as we can export participants data into a csv format to run our analysis on the results. In regards to our study, we utilized the 12 charts and created 12 individual questions where a participant would only see 1 question at a time. We also utilized their timing feature which allowed us to limit the time a participant had to answer a question; we used 90 seconds for each question. Due to the nature of these questions requiring interpretation of the growth rates, we also provided 90 seconds between each question to all participants to reset in between each question.

Once the survey was created in Qualtrics, we administered the survey to 100 participants using Amazon Mechanical Turk.

8. Randomization

- 8.1. We will randomize at the question level where each participant will be randomly assigned one question from our 12 survey questions at a time.

Sampling Plan

9. Existing data

- 9.1. Registration prior to creation of data: As of the date of submission of this research plan for pre registration, the data have not yet been collected, created, or realized.

10. Data collection procedures

- 10.1. Participants will be recruited through Amazon mechanical Turk. Participants will be paid \$20 for agreeing to participate (raised to \$30 if our sample size is not reached within 15 days of beginning recruitment). Participants must not have extensive math or statistics expertise or work in a similar field.

11. Sample size

- 11.1. Our target sample size is 100 participants.

Variables

12. Measured variables

- 12.1. Describe each variable that you will measure. This will include outcome measures, as well as any predictors or covariates that you will measure. You do not need to include any variables that you plan on collecting if they are not going to be included in the confirmatory analyses of this study.
- 12.2. The single outcome variable will be the error between each participant's forecasted value and the ground truth for the given period. We will measure this by asking participants "Given a value in period 6 of X, predict the values in periods 8 and 10 given growth rates in periods 7, 8, 9, 10 of g_7, g_8, g_9 , and g_{10} respectively."

Analysis Plan

Statistical models

- 12.3. We will use the difference between the participants' forecasted value (X) and the ground truth value for a given period (Y) to calculate the error percentage. We can define this as the following:

$$\text{Error percentage} = X - Y / Y$$

13. Missing data

- 13.1. If a participant does not complete any of the 12 questions in the survey, that subject will not be included in the analysis.