CPSC 583 Final Report

Michael Hung (10099049), Colin Au Young (30044237), and Nathan Meulenbroek (30002822)

April 15th, 2020

CONTENTS

I. INTRODUCTION

In this report, we discuss the design process, implementation, and reflections on an interactive web-based visualization for the World Health Organization (WHO) 2019 World Happiness Report. This visualization is intended to be used by a general audience for curiosity driven short exploration on standard desktop PC displays. Although the entire dataset includes entries by year detailing the values of various factors, this visualization is concerned with a subset of the data that omits these details in favour of showing the overall contributive impact of these factors on a given country's Happiness Score during the period of 2016-2018.

There are three components to the final implemented visualization: (1) the overall happiness score is shown as a function of a color gradient on a choropleth Mercator-projection map, which can be changed to a grid of hexagonal tiles (hex-tiles) that display the 3-letter codes for each country for easier identification by those unfamiliar with the shapes and locations of specific countries; (2) radial bar charts that break down the value of each contributive factor for a given country, shown upon clicking a hex-tile, which adds to/removes from (3) a stacked-bar plot for easier comparison between multiple countries and their overall happiness scores.

Our key takeaways from doing this project are predominantly meta in nature. Experiencing the iterative, inconclusive nature of design was incredibly valuable, as was developing the ability to use widely-accepted visualization mediums such as D3. From doing this project, we gained insights into considerations that can be used in further design work.

In the following sections, we first describe the three datasets that we initially considered and explain why we chose the WHO 2019 World Happiness Report from these. Next, we present a series of reflections on a collective 120 sketches used to ideate visualization ideas. Then, using a selection of sketches informed by the previous reflections and a static, mid-fidelity prototype, we present 9 implemented static variations of the modular elements that make up the final design. Finally, we present the complete implementation and discuss its interactive elements, design decisions, and final reflections.

II. DATA DESCRIPTION

In this section, we discuss three datasets that we initially considered for this project. Specifically, we outline the pros and cons of each dataset and detail the reasoning behind our ultimate decision to use the WHO 2019 World Happiness Report.

A. Datasets

1. World Happiness Report (2019)

This dataset accompanies the 7th World Happiness Report (2019) by the United Nations Sustainable Development Solutions Network. Each year, "happiness" is represented using different themes; the 2019 report focuses on the links between government and happiness, including perceptions of corruption, the power of prosocial behaviour, and changes in information technology. Some of the variable names are somewhat cryptic and are further elaborated upon in Statistical Appendix 1 of the report. For instance, "ladder" is a general happiness score based on the Cantril life ladder, measuring from 0 (worst possible life) and 10 (best possible life). Positive affect is an average of happiness, laugh, and enjoyment factors; similarly, negative affect is an average of anger, worry, and sadness. Other factors include GDP per capita (using data from 2016), variations and statistics on the ladder scores, healthy life expectancy, perceptions of social support, freedom, and corruption, confidence in the national government, generosity (averaging on whether respondents made recent donations to charities), wealth distribution, and general trust. A subset of this dataset that does not have a temporal axis charts the overall contribution of each variable (Dystopia + residual, GDP, social support, life expectancy, freedom to make life choices, generosity, and perceptions of corruption) on the overall hap-

piness score, where Dystopia refers to a fictional baseline country.

Interestingly, while the report considers sub-country territories such as Hong Kong, not all countries have been included due to insufficient data. For all valid countries, the largest available samples were used.

2. Power at Sea: A Naval Power Dataset, 1865–2011

This dataset and accompanying paper provides an overview of the world's naval capacity throughout the last 150 years. The key focus of the dataset is the displacement tonnage of each country's navy in a given year, described in in three ways: total tonnage of the given navy (totton), the ratio of that country's naval displacement compared to the displacement of all navies (tonn_prop) and the ratio of that county's naval displacement versus the total displacement of navies within that country's region as defined by the region code (region_prop). The dataset also provides a high level overview of the breakdown of ships in each navy, particularly looking at the number of battleships, submarines (conventional diesel, nuclear and intercontinental ballistic missile (ICBM) equipped) and aircraft carriers each country possesses. In addition, the dataset gives CINC (Composite Indicator for National Capacity) for each country, along with some CINC-relevant fields such as total population, urban population, iron and steel capacity, military expenditures and number of military personnel. What makes this dataset interesting is, in part, the time span. It covers both World Wars as well as a full range of modern wars; as such, it covers several major expansions and contractions of world military capacities throughout modern history as well as major changes in the dominant powers. The count of specific types of warships may also provide interesting insight into the evolution of the modern navy and how it's appearance has changed over the last 150 years.

3. Decoding Pi

Pi is not a dataset in the traditional sense, but is rather an infinite, non-repeating, irrational number. In theory, and with enough digits, digits of pi encoded into different representations (e.g. ASCII or n-digit numbers) will reveal human-recognizable patterns. For example, decoding the digits of pi into ASCII might reveal excerpts of literature such as Shakespeare's Macbeth. While incredibly unlikely for us to discover Macbeth, it is still possible for interesting patterns to emerge. Given that the digits of pi are generally seen to be random, visualizing them with the techniques we're learning in class presents an interesting case of finding meaning.

For this analysis, the Bailey–Borwein–Plouffe formula and corresponding Spigot algorithm would be used to calculate arbitrary digits of pi. This will allow for the user to interactively decide which digits of pi they would like to investigate, while minimizing memory-related constraints as much as possible. After the specific digits are chosen, several options for decoding them are available such as: converting to ASCII, binning into single-, two-, three- and subsequent-digit numbers, converting into audio signals, images, etc. The decoded data would then be converted into visualizations which may present as meaningful to the user.

B. Pros and Cons of Datasets

1. World Happiness Report (2019)

Because the data accompanies a full report by the United Nations, there may not be anything novel in our findings that hasn't already been discussed in much more depth and nuance. Furthermore, because there is missing data for some countries (e.g., confidence in government and perception of corruption in China), it might be difficult to make meaningful comparisons among major world powers. Additionally, it may be necessary to do some investigation to provide context for data trends; for example, world events, economics, etc. to remain unbiased in the presentation of the data. Fortunately, the report and its appendices provide a starting point by summarizing their conclusions. That said, we must again take care not to accidentally

plagiarize the report's findings.

More interestingly, the World Happiness Report has met with criticism by philosophers and statisticians, citing flawed methodologies. For instance, there are some concerns that income and financial security disproportionately impact the metrics as contributing factors. It may prove fruitful to cross this dataset with other factors of national wellbeing such as the GNW Index, a global development measurement framework published in 2005 by the International Institute of Management in the United States. By combining each framework's dimensions, we may be able to paint a more accurate picture of global happiness.

2. Power at Sea: A Naval Power Dataset, 1865–2011

Given the nature of the dataset, a large number of data points are missing given a combination of incomplete government reporting, lost or unrecorded historical data, or the fact that this dataset is built upon several older data sets which may have not covered certain years or countries. This is particularly pronounced with the additional data used to give context to the CINC as these data points in particular are not the focus of the dataset. As such, there are many missing years for certain countries; some of the columns also lack meaningful descriptions of the particular measure (for example, iron and steel capacity).

Another downside is the nature of this dataset as an overview of the international system as there is quite a bit of information not shown in this data. For example, much of the older data is missing meaningful ships counts because the categories of some ships simply did not exist during these times. In addition, it hides important nuance. For example, it groups both traditional and nuclear aircraft carriers together. As such, it may not provide a full picture of the naval capacities of each country. However, the dataset still carries value as a high level analysis and communication tool. It provides one of the more understandable and easily digestible measures of naval military power. The ships used for counting are perhaps among the more meaningful in the modern era and the additional information, while not complete, serves as an interesting comparison tool.

3. Decoding Pi

While this dataset does not hold inherent meaning, it allows for a case study of confirmation bias. Assigning meaning to patterns found in data known to be random underscores the importance of using proper statistical methods to confirm results rather than looking for evidence to justify a claim. By providing the user with the tools necessary to find their own meaning, we are exploring the propensity for people to find these patterns from otherwise random noise through their own exploration, and expose how this may not always be an appropriate way of drawing conclusions from data. This dataset also allows us to interpret it as nominal, ordinal or ordered, depending on how we encode the digits.

There are several challenges associated with working with this dataset. First, is the extra computation required to analyse it. This computation must be efficient enough to be performed in real time in a browser and will provide an upper limit to the number of digits which we can process based on the memory of the computer being used. There is also the difficulty of decoding the digits of pi in real time as well. Again, this would be computationally expensive process when computed alongside the visualizations required. Finally, there is some difficulty in motivating the user to care about the results. While some might be innately curious, there is little real-world impact when analyzing this data and interesting patterns may be difficult to find.

C. Data set decision

From our investigation, we have come to the conclusion that the World Happiness Report would be the best dataset for this project. While not the most original dataset for analysis, it presents many straightforward ways for us to represent the data and contains a good mixture of nominal, ordinal and quantitative data. Although we ultimately decided to refrain from contrasting the data with current events and enrich it by juxtaposing against other well-being frameworks, these are easy next-steps if we wish to further pursue this visualization

project.

The concepts presented in the dataset, for example, sense of freedom, also present opportunities for ideating novel and innovative ways of visual representations. Overall, this dataset seemed to be the best fit for the purposes of this project in terms of potential for novelty as well as easily affording designs grounded in established visualization practice.

III. DESIGN PROCESS

In this section, we discuss the design process of our final visualization. We begin with the sketchable data subsets we developed use in our sketching and then move onto the 10+10 sketching process itself. This helped us to ideate, generating creative and novel concepts for visualizing the WHO dataset. From there, we used our sketches to develop a mid-fidelity prototype concept that we implemented as three modular prototypes with 3 variation each. Finally, using those prototypes, we developed a high fidelity prototype and used it to design interactions into our visualization.

A. Sketchable data

We created three sketch-able subsets were created order to begin ideation and decide which parts of the data we wanted to focus on due to the large scope of the WHO dataset.

Subset 1 took a small number of horizontal slices from the set of all measurements in the main database, while preserving overall trends. We did not discriminate on columns, keeping the subset highly dimensional. Leaving it as such provided us the opportunity to explore how many variables we can fit on screen at once without losing clarity and focus. It also presented an interesting conflict between keeping detailed information (e.g. numerical precision) and abstracting units away in favour of encodings such as length. The former presents the most detailed representation for the user and the latter allows different variables to be compared directly and more intuitively. It was intended that sketches of this subset need not include all of the columns, but were to include variables that complemented each other well whether that's all of them or only two.

The subset was taken using a uniform random sample across all countries and years. It was acknowledged that this would split up time series for different countries, but it was decided that it was more important to get a sample representative of all data points so some macroscopic trends (both temporal and geopolitical) would be visible. We considered simply taking the first 15 rows, but concluded that it would be more representative to take a random sample instead.

Subsets 2 and 3 were designed with the intention to explore and contrast trends in the dataset. Different types of variation are more visible depending on the type of subset taken: primarily macroscopic and microscopic. Both subsets drew from the same source (the set of happiness scores and contributive factors joined by country with the set of happiness score changes) and took the same number of samples (15), but were sampled in different ways to elicit both macro- and microscopic trends. Subset 2 was randomly sampled, whereas subset 3 took the 5 highest happiness scores, 5 happiness scores from the middle, and the 5 lowest happiness scores. A uniform random sample was chosen for its ability to reveal trends in the overall dataset (macroscopic), such as the linear relation between two contributive factor. The high-mid-low groupings was chosen because it allows us to see the trends in contributive factors for countries with similar aggregates scores (microscopic). Our hypothesis was that subset 2 would allow us to determine which factors demonstrated the strongest upwards trends as you approach the highest happiness scores and subset 3 would allow us to determine where variability in contributive factors is interesting, but less important.

To elicit some more variation in the data, one sketcher performed some aggregate calculations on the subset, including calculating correlation and average happiness over countries by continents/regions.

B. Design Direction

In this section, we present selected examples of the initial sketches produced as a first round of de-

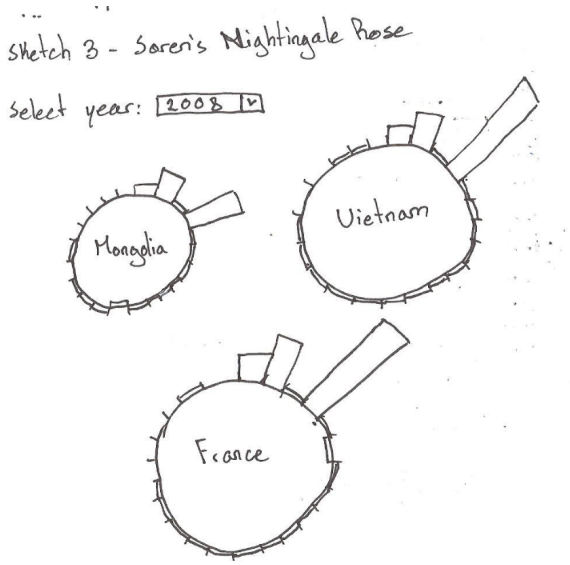


FIG. 1. A variation on a Nightingale rose inspired by Soren's in class example.

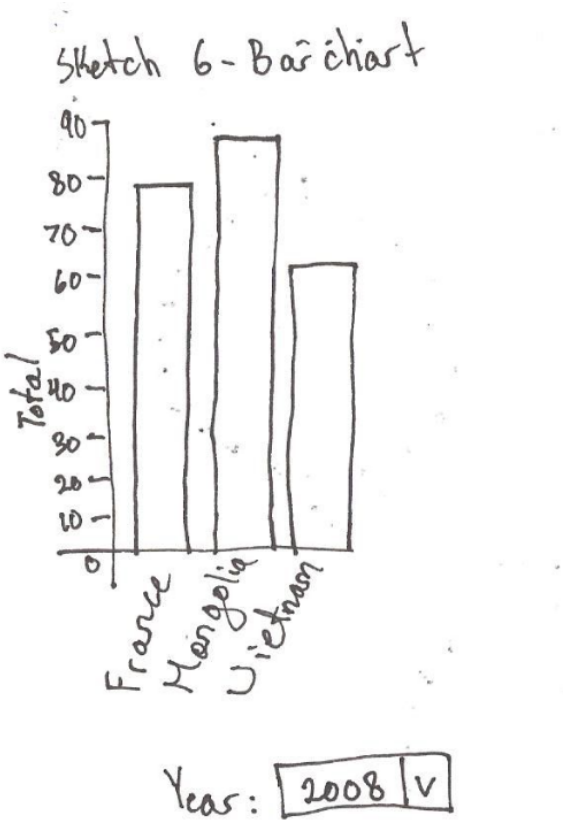


FIG. 2. A simple bar chart of the life ladder for countries with data in 2008.

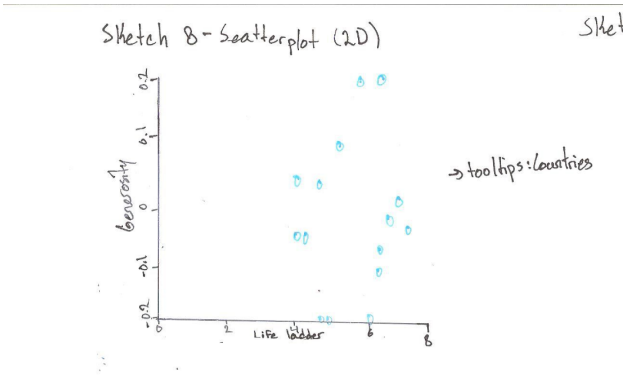


FIG. 3. A simple 2D scatterplot of life ladder data vs. generosity. Datapoints would have tooltips for countries.

sign iterations, and the variations produced in the second round of iterations. We identify common threads and themes found in these sketches and discuss reflections on the design process as a whole. Next, we discuss how we formed a general design direction from selections from these sketches and present variations of mid-fidelity prototypes in D3 of both static visualizations and interactive elements.

1. First Sketches

For subset 1, there were two common ideas among the sketches: a variant of the NEB's Nightingale-rose-inspired visualization (Fig. 1 and Fig. 6) and a stacked-ring visualization (Fig. 8 and Fig. 9). Outside of those two, the direction of sets were very different. One set of sketches focused on classic data analysis. Visualizations such as sketches Fig. 2, Fig. 3 and Fig. 4 leveraged the analytical power of graphing individual data points. The other set of sketches utilized more novel ways of communication using pictographic approaches, such as Fig. 5 and Fig. 7, focusing on communicative impact.

For subset 2, the focus of the sketches varied among the two sketchers. One focused most of their sketches on being able to compare how each country's happiness was explained, thus leading to many variations of "stacked" representations; the other sketcher focused on the ability to compare each country's happiness to each other leading to more line chart and scatter plot variants. Both sketchers proposed a heat map of happiness overlaid on top of a world map due to the situated nature of the data.

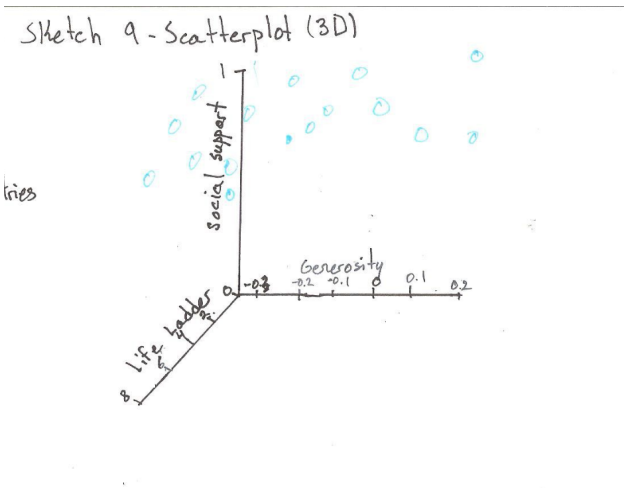


FIG. 4. A 3D scatterplot of life ladder vs. social support vs. generosity. Ideally this would be able to be manipulated by the user so they could rotate the plot and view it at different angles. A 3D scatterplot of life ladder vs. social support vs. generosity. Ideally this would be able to be manipulated by the user so they could rotate the plot and view it at different angles.

Finally, a common theme for sketches of subset 3 was the abstraction of contributive factors to lengths. This very easily allows for comparison of which factors contribute the most to an individual country's happiness score and was augmented by contrasting factors with different colours. Amongst the sketches, there were many novel metaphors employed by each representation. For example, both sketchers produced visualizations focusing on the mixing of water (Fig. 10 and Fig. 11). While most showed the happiness score as an aggregate and the contributive factors as components, some sketches took a granular approach, visualizing a single variable.

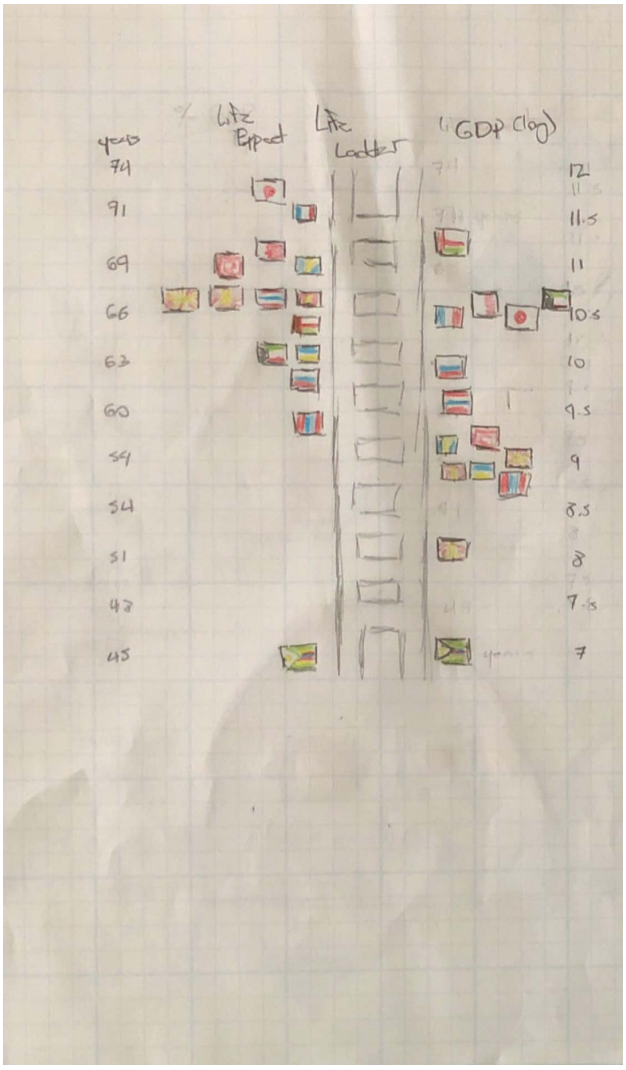


FIG. 5. A variation of a bar chart, using each country's flag to represent its respective data. Currently it only uses the height of each flag to represent from left to right respectively healthy life expectancy and national GDP.

2. *Variations*

The owner of subset 1 chose to expand on the tree-rings visualization in Sketch 16. However, they immediately encountered a challenge due to the nature of subset 1: tree rings naturally lend themselves to time series, but the subset had insufficient data with at one entry per country and few in the same year. Thus it was necessary to refer back to the original dataset and pull out more data per country.

The owner of subset 2 looked to expand on the common element between the two sets, the heatmap of happiness on the world map. The owner struggled with varying the actual heatmap itself as adding more elements would make it harder to read. Thus the owner decided to focus on adding and varying the tooltips provided over the heatmap using some of the previous sketches as inspiration.

Finally, The owner of subset 3 decided to expand on the line plot approach. While they did vary the line plot in some cases, similar to the the owner of subset 2, looked to adding expandable elements

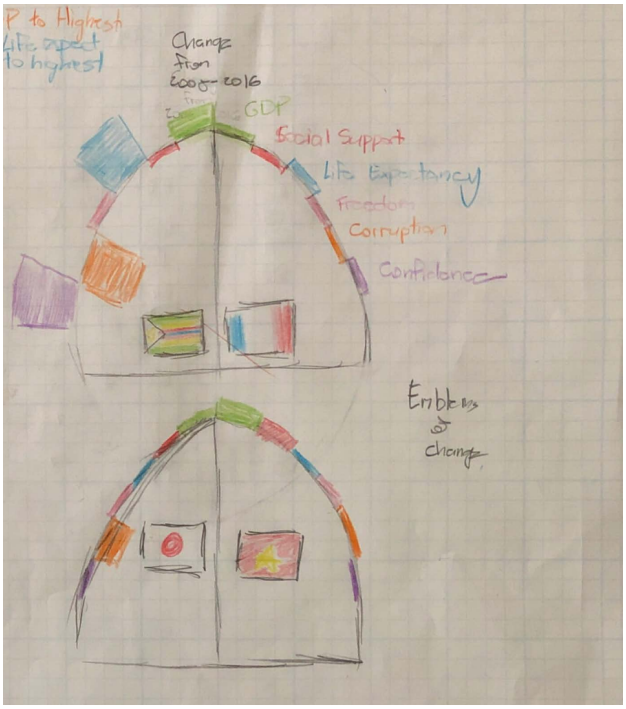


FIG. 6. A variation of the Nightingale rose inspired visualization from the CER project. Uses the height of each bar on the emblem to represent each data point for each country. Each emblem contains two countries at certain years to allow for easy comparison between both different countries and different times.

which added the ability to look at more factors than just the happiness score on the line plot such as contributive factors and change in happiness.

C. Process

In creating the first 10 sketches for each subset, it was interesting to note that it was easy to think of one or two different ways to represent data, but all members struggled when working on the last two sketches for their respective subsets. This is potentially because it's difficult to make many sketches which are unique based on how the data is encoded, but a contributing factor may have also been the subsets chosen, the abstract nature of some of the factors, and the lack of obvious relationships between factors.

Subset 1 contained the most varied data which was not inherently related, and the conscious decision to prioritize country-wise comparison over a time series hurt our ability to generate visualiza-

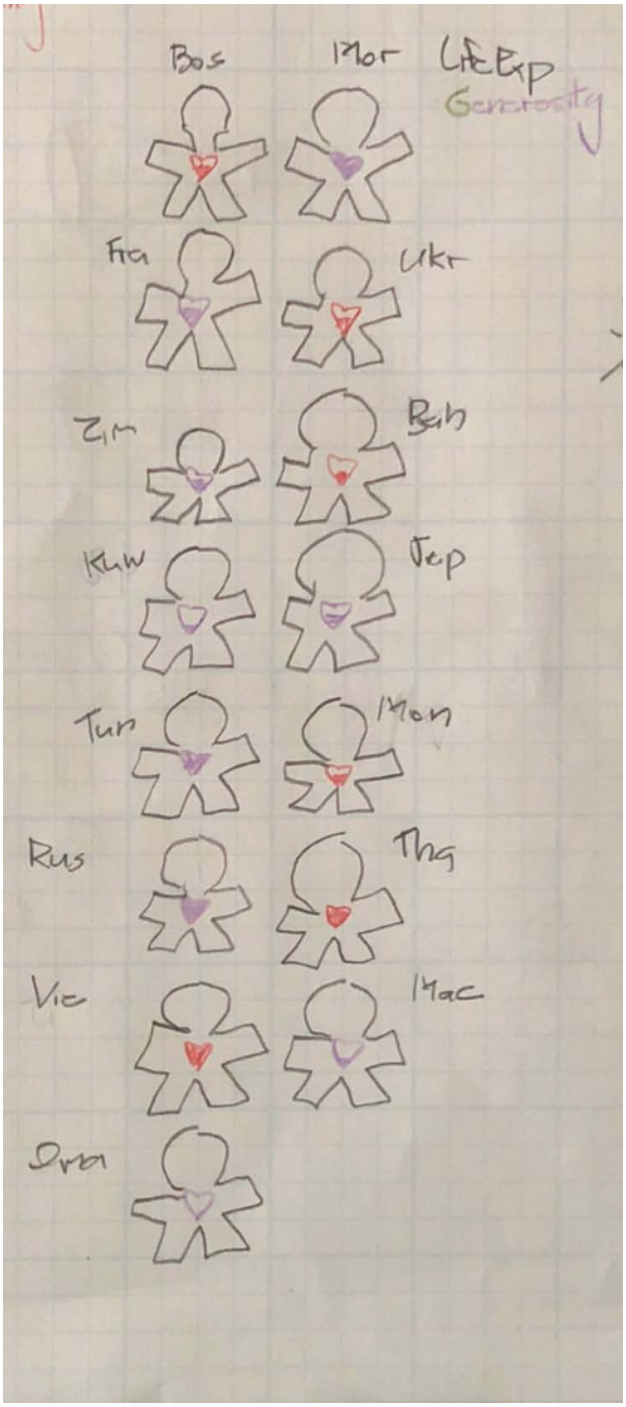


FIG. 7. Paper hearts. Each country at a given year is represented as a paper person. The height (thus overall size) of the person represents their life expectancy relative to the highest life expectancy of any country at any year. The heart is similar to those found in Subset1 Sketch17 as such the heart represents generosity which was either a positive or negative value from 0 to 1. Purple hearts represent negative values while red represents positive values. The fill of the heart represents the closeness of the value to either -1 or 1 respectively.

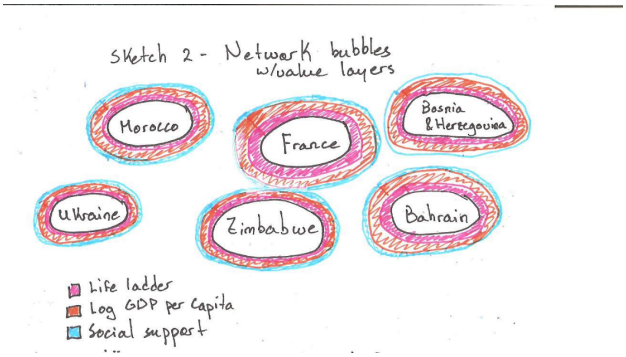


FIG. 8. A variation on a bar chart. Data is unitless and intended to be compared relatively.

tions with considerations for temporal trends. For example: national GDP, perception of corruption, and life expectancy were all measured in different units, making it difficult to produce single, unified visualizations that presented all the data simultaneously. Thus, most of the sketches focused on a small number of these data points for each country at each time period.

Subset 2 contained the same columns as subset 3, i.e., the happiness rating of each country, which was the sum of six ”Explained by:” factors and a baseline ”Dystopia” factor. This subset did not include a time series and instead provided a summary of the proportional impact of said factors for each country. This led to similar sketches as in subset 3 in terms of design, emphasizing proportional comparisons between countries. However, because the factors were in proportion to each other, they didn't make sense when decoupled from one another, again limiting the scope of possible designs. Indeed, some sketches that explored visualizing a single factor (See Appendix: Subset 3 - Sketches 11, 13, 14) are perhaps better suited for representing data from subset 1 instead.

It was both difficult to represent everything together as well as to extract meaning from individual columns of data. The sketchable subsets, however, helped us to more quickly iterate on ideas and to abort from flawed ideas. It was valuable to quickly gain a breadth of experience with the data rather than lots of experience with a particular representation, as well as get a feel for what kinds of visualizations the data most afforded.

Interestingly, all sketchers included preliminary considerations for interactive elements in the visualizations, such as sliders, dropdown menus, drag-and-drop operations, and so forth.

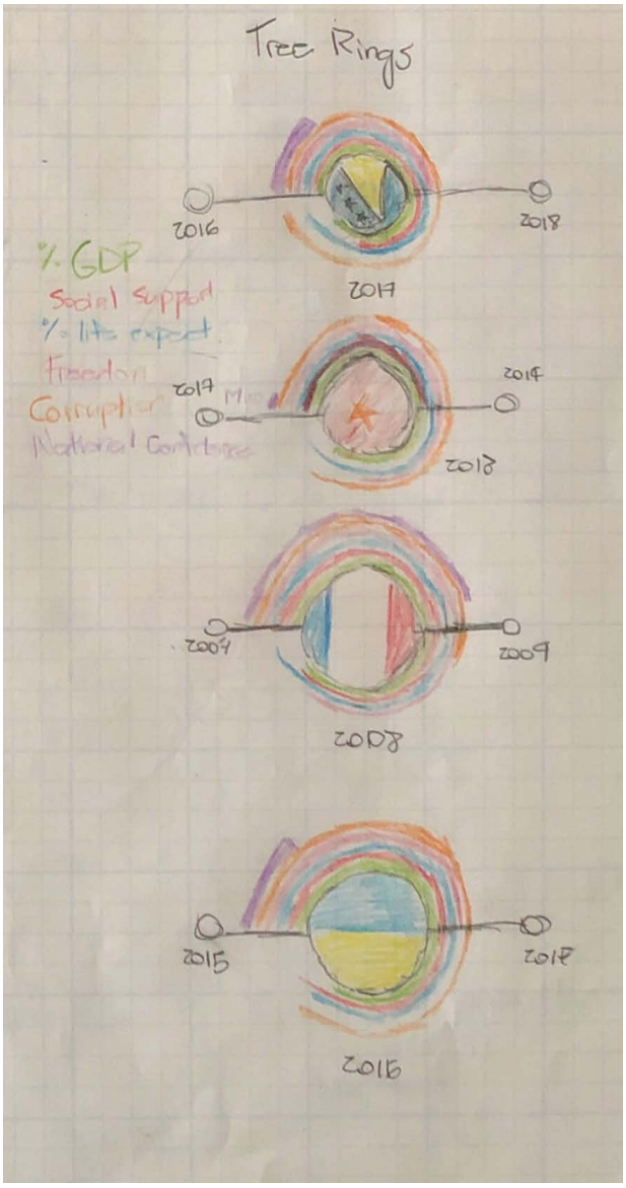


FIG. 9. Each circle represents a country at a given year. The two bubbles on either side allow for changing the year. Each ring represents a different data point. Each data point was a percentage (for GDP and Life expectancy which were not, a ratio between that country at that point and the highest of any country at any time was used). The arc of each ring represents the percentage of each data point.

It seems clear that there's a distinct trade off between some of the more interesting sketches and some of the more useful ones. For instance, many of the novel visual metaphors make it very diffi-

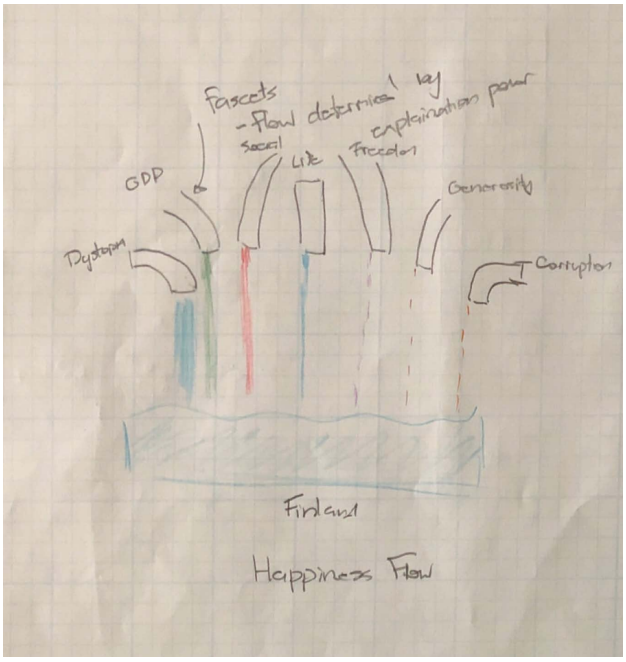


FIG. 10. This sketch shows a sketch where a country is represented by a tub. The water line in the tub shows the total happiness score (fuller, the happier). Then each faucet represents an explanatory factor with the flow of water represents the degree to which that factor explains the happiness score (higher flow, the more that it can explain the happiness score).

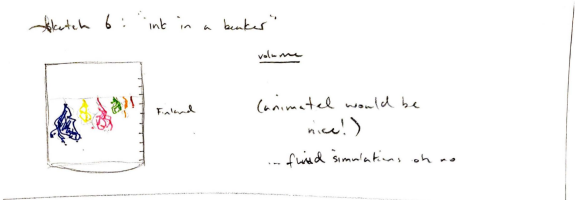


FIG. 11. The proportional contribution of each factor is showed as ink spreading in a beaker until fully mixed into a unique colour. Seems like it would be pretty when animated.

cult to pull out exact numbers but are useful for conveying data at a glance and are easily digestible by a casual user; whereas the sketches using more classic data visualizations such as scatter plots and bar charts are more readable, but perhaps not as visually powerful or interesting. Due to the sheer scope of the original dataset, it was difficult to create subsets that would facilitate our creation of the sketches. In hindsight, it may have been fruitful to purposefully scale down early.

For instance, subset 1 could have consisted of only a couple countries over more years, placing more emphasis on the temporal nature since we are not actually interested in actual data analysis; the country choice would have been somewhat arbitrary. Additionally, subsets 2 and 3 could have used aggregates from the temporal data to support and contrast against its proportional data and provide more context for some of those proportions.

D. General Design Directions

Based on our reflections in the previous section, we narrowed down our intention for this project: to create a representation that facilitates the comparison of the happiness scores on a country-by-country basis. It is also at this point that we fully pivoted to designing visualizations for general users with easily digestible visualizations. With this in mind, we concluded that a choropleth heatmap would be the most readable way to directly compare a large number of values concurrently while leveraging a user's existing geographical knowledge. This is especially important given our assumed primary task: comparing countries to one another. To accommodate users who may be interested in a further breakdown of the happiness scores, we implemented a design similar to Fig. 12, which includes situated breakdowns of the scores of each country.

Fig. 12 Top shows situated stacked-bar charts on a choropleth heatmap, where each coloured segment denotes the contribution of a factor to the total happiness score of that country. While stacked-bar charts are easier to compare to each other, there are some drawbacks. Bar charts are easiest to compare when they share a common zero. This is not the case when the bars are situated at the approximate center of a country on a map. We later realized this problem could be addressed by combining map variations, leading to the hex-grid implementation and standardizing the zeroes of the bars on the same axis by plotting the bars on a chart separate from the map itself.

Fig. 12 Bottom depicts the same choropleth heatmap, but this time overlaid with radial bar charts. While the radial charts are harder to directly

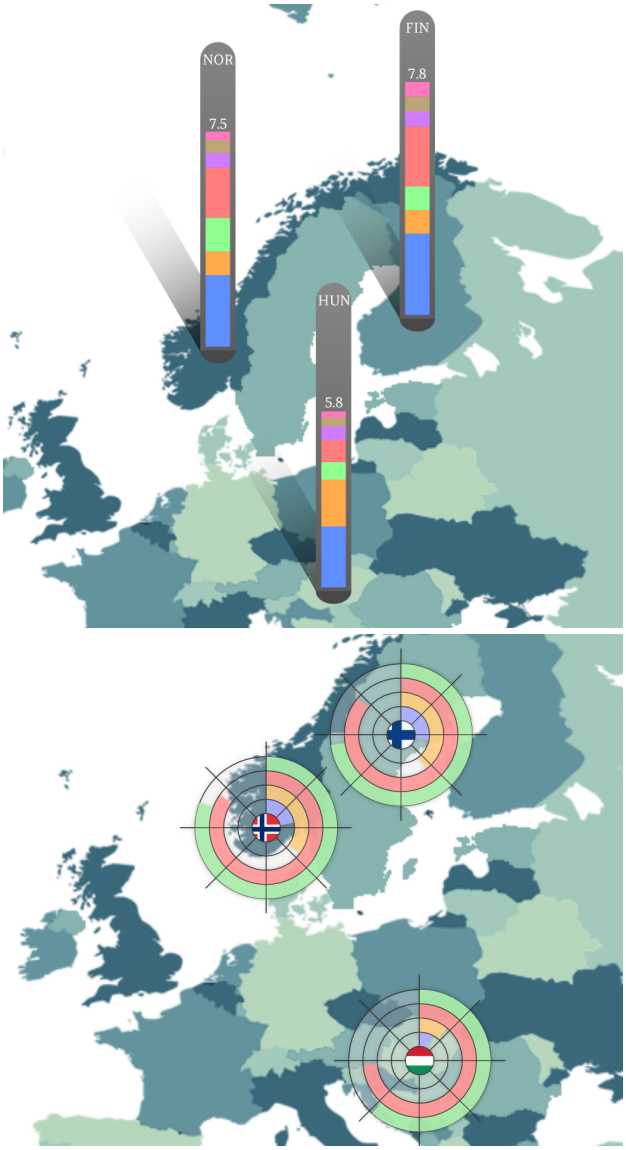


FIG. 12. **Top:** Detailed drawing of a heat map depicting happiness scores, with situated stacked-bar charts. **Bottom:** A similar heat map with radial bars instead of stacked-bar charts.

compare against one another, they provide a better conceptualization of the quantities of each contributive factor by country. Because radial charts boil down to reading angles, they are independent of the placement of individual charts on the map, also solving the non-common zero problem from the situated stacked bars. However, radial plots inevitably require more area to display than a stacked-bar chart, and the occlusion issue for regions densely populated with smaller countries also contributed to our move towards implementing a hex-tile representation in the final design.

Another concept that we were exploring at this stage to help deal with these issues is an interactive, multi-layered approach to represent the spatial aspect of the data. Specifically, the map begins as a standard Mercator projection while zoomed out. As users zoom in, more detailed visualizations are revealed, such as the stacked or radial bar charts. While we acknowledge that this adds complexity to using the visualization, we believed that the exploration potential helps us bridge the gap between casual, at-a-glance users and users looking for deeper insights. This exploration ultimately inspired the map view toggle between Mercator projection and hex-tile grid and synonymizing selection with converting hexes to their corresponding radial charts.

It is also at this stage that we finalized the decision to scope our visualization down to only the happiness scores and contributive factors rather than the entire dataset. While the raw data has interesting features, many of those features are also present within the explanatory data. Contributive factors also have units normalized to the same scale, which is ideal for comparison purposes. As a trade-off, however, we lose all the temporal aspects and corresponding nuances of individual factors included in the raw data. Nevertheless, we don't feel that its removal is detrimental to our final visualization and provides a good starting point for potential future work.

Overall, stacked-bar charts present a stronger potential for direct comparison between countries, whereas radial plots allow a user to better read data from individual factors for a given country. As we moved forward to the next steps of this design process, we ultimately decided that both were necessary and found a way to include the advantages of all our designs in the final implementation.

E. Prototyping Variations

Because we knew that we wanted all of the previously mentioned components, instead of creating prototypes of the same visualization, we instead decided to prototype the three pieces that we would eventually combine; the base choropleth map, ideas for situated stack bars charts and ideas of situated radial bar charts. These individual pieces were

modular enough that isolated variation upon each seperate plot was a plausibility, and we would later discuss which variations were suitable for the final visualization.

1. Variations in Choropleth Maps

For the choropleth map we were inspired by the tile grid maps shown in Lecture 15 and informed by our earlier observations of the shortcomings of a Mercator projection map for our purposes. The consistent size of the tiles allows us to more easily situate data within them without occlusion and helped comparison tasks by keeping the situated visualization on a grid and thus a similar axis. However we still wanted to maintain a traditional map because we felt that users being able to quickly locate their country in particular was a key advantage. Thus, we want to move between the two easily with a toggle button. For representing data, Happiness score data itself, we went with using D3's Viridis drawn from mathplotlib. As we discussed in Lecture 11 and in particular because we were thinking in terms of installation, the uniform perception of Viridis across between various colour blindnesses was important to us. However a secondary benefit was that use of green and yellow in the gradient when combined with a blue background gives the visualization a very traditional map appearance allowing us to draw more on user's existing mental models of maps to help the them navigate the visualization

Variation 1 (Link): A combination of Fig. 16 and Fig. 17. Allows the user to toggle between two representations using a button at the top left corner. Users can click on countries to zoom in onto that country and then click again to reset the zoom.

Variation 2 (Link): A combination Fig. 16 and Fig. 18. Allows the user to toggle between two representations using a button at the top left corner .Users can click on countries to zoom in onto that country and then click again to reset the zoom.

Variation 3 (Link): A combination Fig. 16 and Fig. 18. Allows the user to toggle between two representations using a button at the top left corner. Users can click on countries to zoom in onto that country and then click again to reset the zoom. However, unlike Variation 2, enforces the two level approach changing into the representation of Fig. 18 when users click to zoom on a country and upon resetting zoom returns the representation to that of Fig. 16.

2. Variations in Stacked Bars

The design decisions that went into the variations for the stacked-bar charts focused around visibility and comparisons between bars rather than between the contributive factors that made up the individual bars themselves. Although at the point of the creation of these stacked bars, we were still uncertain as to whether they would be part of the situated visualization or live on their own in a separate plot, it was unavoidable that these bars would be relatively small and hard to distinguish specific details without interactive elements. This was especially the case since these variations were intended to be static representations, although we had been exploring interactive elements throughout the design process. Therefore, the primary design goal for these bars was not the ability to discern all the features of the data, but only the most important ones (though of course, the notion of what constitutes an "important feature" remains somewhat if not entirely subjective), as well as designing for legibility.

For all the variations, a low-saturation, pastel colour scheme was chosen to be easier on the eyes and de-emphasize the importance of each individual bar segement. All text is in a sans-serif font and takes on the most contrasting shades in the visualization for greater legibility, and their size are a direct function of their value as reinforcement. However, this changing size was ultimately left out of the final implementation due to the lack of utility and readability compared to its aesthetic value.

In Variation 1 (Figure 13) the emphasized feature was the overall happiness score, situated at the upper end of the stacked bar, not only leveraging position as the primary comparison point but also preventing confusion with its value as being that of one of the contributive factors. Additionally, the scale is normalized to 10 so as to somewhat presumptuously leverage the user's intuition for 1-10 rating scales.

Variation 2 (Figure 14) focuses instead on the percentage contribution of each contributive fac-

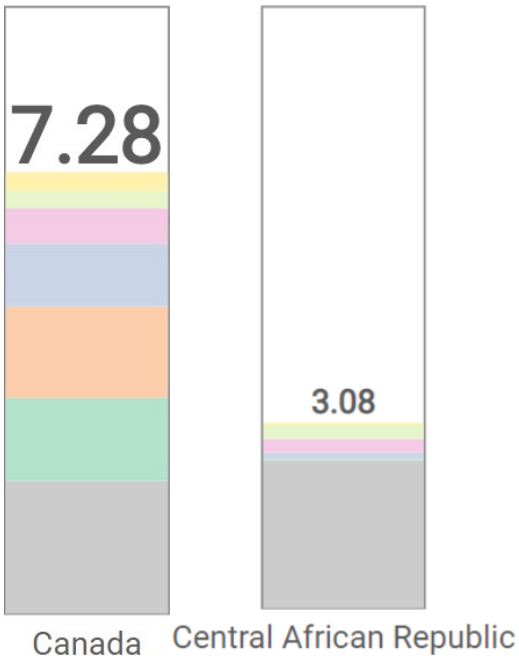


FIG. 13. A stacked-bar chart indicating the total happiness score of the given country; each segment corresponds to a contributive factor.The chart's maximum range is 10.

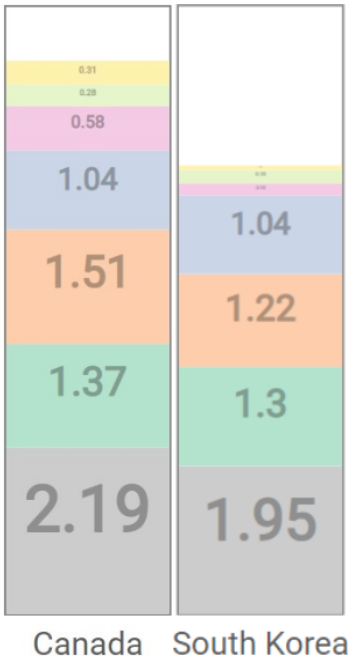


FIG. 15. To aid in this comparison task, the range is at just over the highest happiness score (Finland, at 7.77). In this way, visual discrepancies between overall bar lengths are made more dramatic.

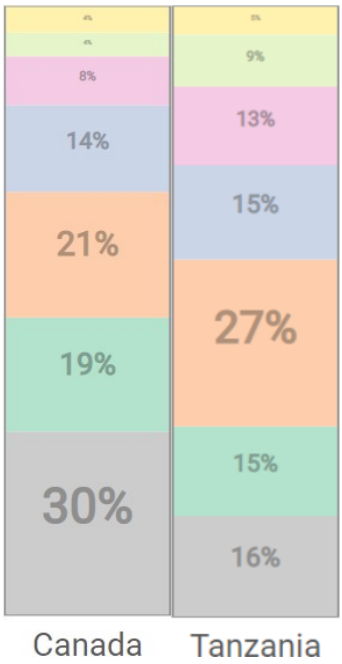


FIG. 14. A stacked-bar chart with the factor normalized to the respective country's happiness score, displaying the percentage contribution of each contributive factor.

tor of the happiness score of that country; i.e., the range is normalized to the happiness score of the country. Although the happiness score is no longer readable from this chart (and would instead appear on perhaps the radial chart, for instance), the percentage contribution is situated over its corresponding factor allowing easier comparison of factors between countries. This was done to circumvent the difficulty of factors that weren't the on the bottom having a non-common zero; listing the percentage helps to eliminate any ambiguity in that sense. The font sizes are once again tied to the amount of contribution. While it becomes immediately clear which factor carries the greatest weight and also helps to address the difficulty of comparing sizes of segments in collocated stacked-bar charts, the trade-off is that minimally impactful factors are hardly legible.

Variation 3 (Figure 15) similarly forgoes showing the overall happiness score of the country but combines design elements from both 1 and 2, leaning into the comparison of contribution factors against charts against one other chart. To aid in this comparison task, the bar scale has been changed

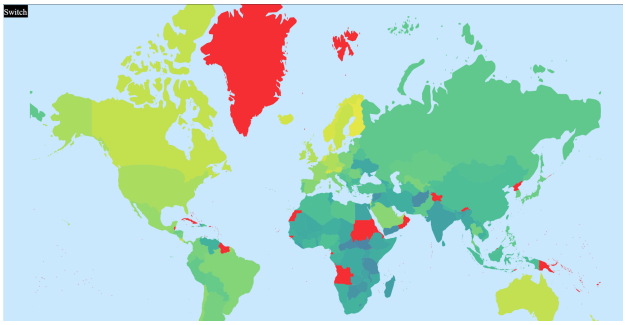


FIG. 16. Heatmap done using Mercator Projection and Eurostat's country borders data set. Red indicates countries which are not represented in the WHO dataset. Additionally, not shown are mouseover tooltips which show country names and the exact happiness score.

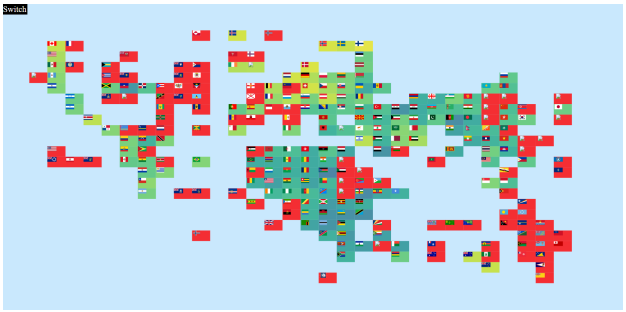


FIG. 17. Heatmap shown in a tile map form. Each tile represents a country and also displays country flags. Color coding is the same as Figure 2. The tiles are placed spatially roughly where they would be in a Mercator projection. Additionally not shown are mouseover tooltips which show country names and the exact happiness score.

from the arbitrary 10-scale to topping out at just over the highest happiness score (Finland, at 7.77). In this way, visual discrepancies between overall bar lengths are made more dramatic and the values of each factor are once again shown on each bar segment to aid in comparing segment sizes.

3. Variations in Radial Plots

Variations in radial plots was focused on finding a useful and aesthetic representation. The first variation, found in Fig. 19, depicts all of the contributing factors to the happiness scores. This is the most detailed representation, but we found that the

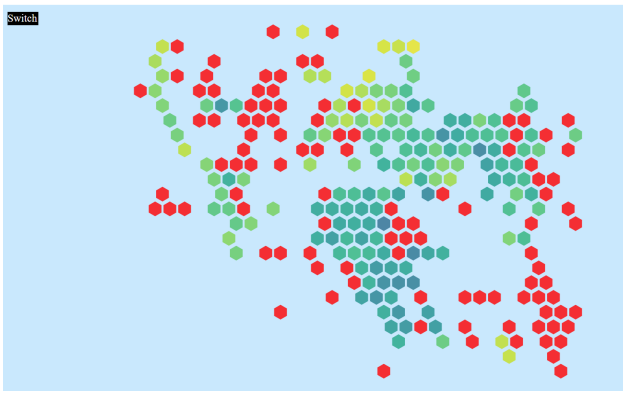


FIG. 18. Heatmap using a hexagonal grid representation. Each hexagon represents a country and, like Figure 3, places them spatially similar to a Mercator projection. Same color encoding as Figure 2. Additionally, not shown are mouseover tooltips which show country names and the exact happiness score.

dystopia score was consistently much larger than the rest of the bars. This reduces readability of smaller bars on the same scale and presents has less aesthetic. To remedy this, we moved onto Fig. 20. This depiction simply removed the dystopia bar and placed it in the tooltip for the center instead. Given that the dystopia score is the most obtuse contributor to the overall score, we felt that this change increased readability and reduces confusion amount a casual viewer.

The final variation was that changed the direction of the bars (Fig. 21). By switching to bars that radiate directly away from center, areas instead of length are more naturally compared by the user. This, however, we decided was not as helpful to a user trying to compare different metrics. Encoding data in arcs with a common zero rather than an area is a more exact and intuitive way to compare data in between small multiples, we concluded. Thus, we concluded that the second variation provided the best balance of trade-offs for our specific application.

F. Implementation Process

Visualizing all the countries' data at once was useful for determining that the dystopia scores were much larger compared to other measures. Thus, removing it may benefit scale comparisons of the re-

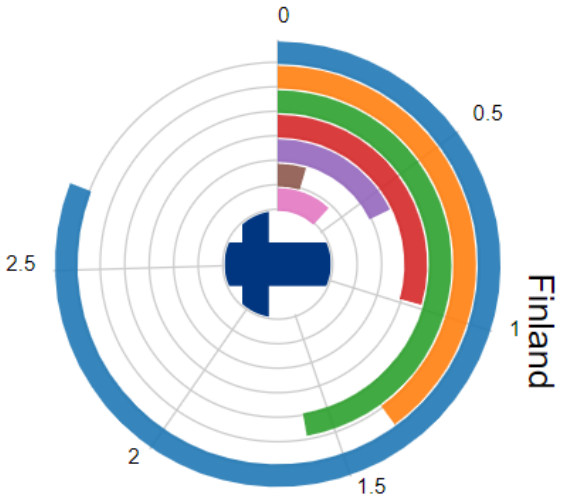


FIG. 19. Radial bars, including all contributing factors to the happiness score. Not depicted are tooltips which give exact values for all of the different bars. Units are not listed for the scale since values are arbitrary without the context of other countries' scores. The scale is determined based on the maximum score out of all countries so that all bars are directly comparable.

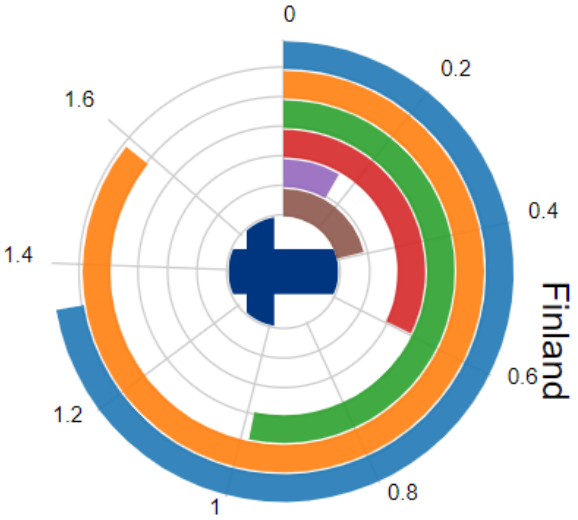


FIG. 20. Similar to Fig. 19, this variation depicts the same contributing factors although excluding the more obtuse dystopia score, which is consistently much larger than the rest of the variables, and therefore results in a better fitting scale for the remaining variables. Not depicted are tooltips for all bars, as well as a tooltip for the flag which displays the name of the country as well as the dystopia score.

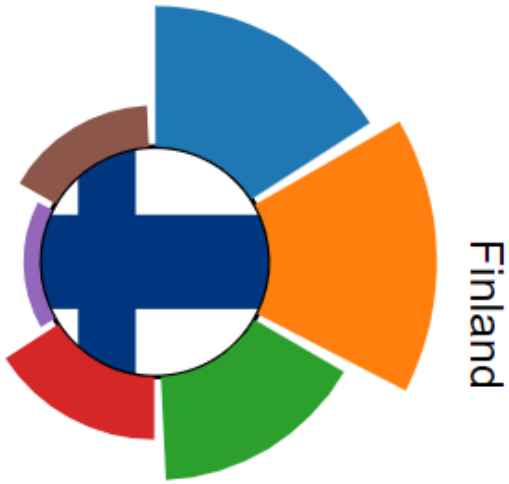


FIG. 21. Rather than bars which rotate around the center, this plot explores bars which radially emit from the center. This seems even more aesthetic than the other two variations, although it loses some information due to the lack of axes. Comparison from country to country would be hampered somewhat in comparison to the other two as there is no independent reference to which the eye can anchor lengths, similar to the problem experienced by situated bars.

maining measures (especially as it's difficult to intuit what "dystopia" represents). Hence, in Figs. 20 and 21, we removed dystopia. It was also interesting to see how these plots were more aesthetically pleasing when implemented than when sketched, especially when experimenting with animations. Direct comparison may be hindered by the nature of a radial plot, but this may or may not be outweighed by the appeal to a general audience. That being said, we decided to retain the Dystopia measure in the stacked bar plots due to its direct impact on the happiness score.

Although we realized that comparing contributive factors is difficult with situated plots, spatially contextualizing the plot on the choropleth heatmap is essential. The heatmap provides direct comparison of happiness scores while the individual plots focus on the score breakdown and not necessarily comparison. This is exemplified in the design seen in Figure 14: comparing the contribution percentage of contributive factors is not as useful between

countries; however, the common maximum makes it much easier for a reader to internalize the impact of each measure.

Another interesting revelation was seeing how many countries were missing from the data set, especially with the grid-/hex-based representation: an aspect that went previously unnoticed when sketching from data subsets. Finally, disputed territories were highlighted when using EuroStat's (an arm of the EU) map data to generate the heatmap. Unlike the WHO, Eurostat does not include Taiwan in its dataset.

G. Final Static Design

For the final static design, we decided to work with Figs. 16, 18, 13 and 20. The aesthetics of the hexagon grid choropleth map presented the positions of the countries in a cleaner manner and, in particular, maintained the shape of the regions better, thus making it easier to read. We felt that keeping with the two view design of starting in a traditional map and click to zoom in on the hexagon tile map was the strongest way of presenting the data as it starts users off in a view that is very familiar and directly linking that to the more complex unfamiliar view of the hexagon tile map giving the user a strong scaffold to learn the visualization.

While we had originally thought of only situated one visualization on the tile map, we ended up using both and trying to leverage the advantages of both. The radial plot are more aesthetically pleasing and easier to situate given the choice hexagon components, yet the stack bar charts provided a strong ability to compare countries directly to one another. We felt that integrating both was an important aspect of providing functionality to both groups of users that we hoped to accommodate in casual at-a-glance users as well as users looking for more detail explorations of the data.

We decided that we wanted to situate the radial plots on the map leveraging it's ability to tie to the hexagon tiles while using the stack bars in a side visualization leveraging it's comparability. One of the key things that we wanted to change about the these static implementation was the way that we presented missing data. In Fig. 18, we visualize all countries regardless if have data for them. While that suggested an interesting story about who is represented in this type of data, it made the visualization cluttered and hard to read. The result is in part that the countries started to become, as Tufte's describes it, chart junk. They told a story, but not the one were aiming to present and, in fact, made that story that we wanted to present harder to understand. While we originally used red to indicate these countries, we decided to change it to a more neutral color because while red is easily distinguishable from the green that we use for data encoding, we felt that it portrayed too negative of a connotation.

For the radial plots, we decided to use Fig. 20 because we felt that the dystopia score, while it is important to understand the exact make up of the Happiness scores, the scale of the radial bars with the dystopia scores limited the ability to read how the values add up to Happiness scores. We liked the internal comparability of the radial bars as opposed to the aesthetically pleasing but harder to read Nightingale style visualization of Fig. 21. Thus the proportion that each factor plays into the happiness scores is the key insight that we wanted users to take away from this visualization and the dystopia score would not be understand easy for our target of a general audience and thus was not worth the trade off of making the other factors harder to read. Finally for stack bar chart, we decided to use Fig. 13 as while the exact numbers are interesting to present like in Fig. 15, ultimately in many cases it becomes unreadable and while proportions are interesting as presented in Fig. 14, one of the key use cases that we identified was "how does my country stack against others" in which being able to compare the total happiness scores was critical.

H. Prototyping Interactions

Our goal for our interaction was to enable rich exploration on the part of the users. We started with a template for the choropleth map that already had the ability to switch in between a Mercator projection and a hex map. Recognizing that we wanted to keep the hex map in an organization similar to that of a standard map, we reorganized the hexes so that there is an intuitive analogue for where all countries are situated. We realized, however, that this

was still slightly disorienting, thus we added region highlighting and selection. By clicking on the different region colours in the bottom right legend, the user is able to highlight/de-emphasize desired regions. Beyond this, we also explored alternative methods for moving around the map. Click and drag to pan, and scroll wheel to zoom are standard implementations of how to interact with a map, although we also wanted to highlight selected countries. For this reason, we implemented a function which centers the view port on whichever country is clicked on.

To switch between the hex map and the Mercator projection, we explored several options. First was to click on a country to transform, then click again on the countrys currently at the center of the viewport at the go back. We also considered a similar, yet more complicated, workflow with the added steps of triggering/dismissing radial plots before you can get back to the main projection. We found this approach to be overly complex as it took the user three clicks to return to the Mercator projection. In the end, we decided that we wanted the hex map to be focused on enabling users to create their own small multiples by clicking on a country to add/dismiss it as active[1]. As a result, we removed the switching functionality from the hexes themselves and implemented a button in the top left to switch directly between views. We also allow for clicking anywhere on the background to return to the Mercator projection from the hex map.

Finally, we wanted the stacked bars to be directly related to the radial plots. We thus immediately decided that we wanted them to be triggered at the same time as the radial plots. However, we recognize that the user might turn their attention from the map to focus on these bars, so we added the ability to highlight the country corresponding to a stacked bar through hovering. This will cause the border on a hex to expand similarly to if you hovered over a tile. Overall, most of the prototyping that we did at the beginning of the final step was implemented with a few notable exceptions to simplify the workflow for a user and to add quality of life features.

IV. FINAL IMPLEMENTED VISUALIZATION

(Live Final Visualization Link)

The visualization begins as a Mercator-projection choropleth map as shown in Fig. 22. Each country is coloured according to the happiness score recorded by the WHO. Those with low happiness scores are colored with a dark blue-green and those with a high happiness scores are colored with a light lime green. Countries that do not have a happiness score record from the WHO are colored light grey and fades into the background to indicate that there is no data for that country. Hovering over a country shows the user a tooltip with the name of the country and the exact happiness score for that country. The visualization implements D3's zoom functionality allowing the user to pan and zoom around the map. As shown in Fig. 22 once again, a small legend is shown informing the user of the color coding of the map.

When a user clicks on a country or clicks on the toggle button on the upper left corner (shown in Fig. 23), the map transforms into a hexagon tile grid (hex-tile) as shown in Fig. 25. This displays each country as a hexagon with its three letter code shown in the middle. The color of the border in the hex-tile mode (as well as the one that is used when a user hovers a country in the Mercator projection) denotes the region of that country as shown in the lower right legend. To return to the previous view, the user can either click the toggle in the upper left corner or anywhere on the map besides a hex-tile.

When in hex-tile mode, the user can click on a hex-tile to see a radial bar chart of the contributive factors for the happiness score of that country as well as a stacked bar chart of that same data in the upper right hand corner, as shown in Fig. 26. Clicking on another hex-tile will transform that hex-tile into a radial bar chart and add that a stacked bar for that country into the upper right hand corner. When a user clicks again on the center of a radial bar chart, it transforms back into a hex-tile and removes the corresponding stacked bar. Hovering over a bar in a a radial bar chart shows a tooltip with the contributive factor that the bar represents and the exactly value that factor contributes to the happiness score. Also in radial bar chart mode, the tooltip will

also show the dystopia score for that country. Hovering over the stacked bar chart in the upper right hand corner will show a legend for the color coding of the stack bar chart as show in Fig. 27 and hovering over individual bars will highlight the radial bar chart on the map as shown in Fig. 28. The stacked bar chart's window's opacity is halved by default, returning to full opacity upon mousing over it so that the user can focus on the map or on the stacked plot as needed without occlusion becoming a major liability.

We imagine this visualization being used in an open environment, similar to interactive exhibits in a science museum or library, on a large scale display. The primary audience, therefore, would be passerby. Thus we see it mainly being used in short explorations to simply get a feel of the dataset rather than a detailed analysis. In particular, the primary use case that we see is for a visitor to compare their home country to a handful of countries, or other small subset comparisons. In this case, we imagine having the Mercator-projection as a familiar starting point to invite passersby to interact with the visualization, gradually showing more complex data subsets as the visitor requests them.

The key insight that we hope to present through this visualization is a better sense of how life is around the world and in particular how life compared to where you live. We hope that by allowing people to compare places that they know to other countries that gives them a deeper data driven appreciation for how they're life and how it compares around the world.

A. Process Reflection

Throughout the implementation of the final visualization, we observed interesting interactions with how our three separate visualizations integrated with each other. Given our three individual static prototypes, each with separate purposes, we decided immediately that we wanted to take a no-compromises approach, retaining as much of the original designs as possible. Each of the individual plots had different strengths and weaknesses which complemented each other. For example, the choropleth map presents a cohesive overview of the data and the ability to change from a Mercator pro-

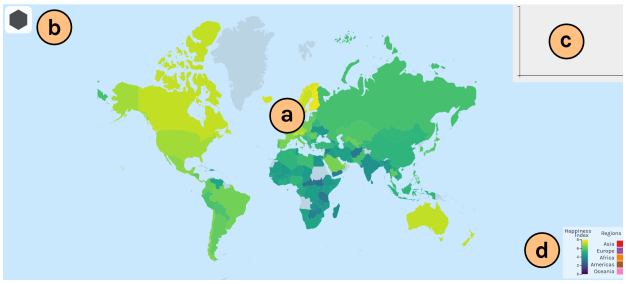


FIG. 22. The initial screen. (a) The Mercator-projection with colored choropleths depicting happiness score. (b) The toggle button to switch between Mercator view and hex-tile view. (c) The area where stacked-bar breakdown for selected countries will appear upon selection. (d) A color legend for regions and happiness scores.

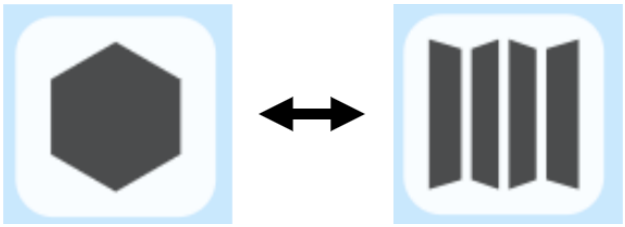


FIG. 23. The toggle button switches between active views: hex tiles (left) and Mercator (depicted as a folded map; right).

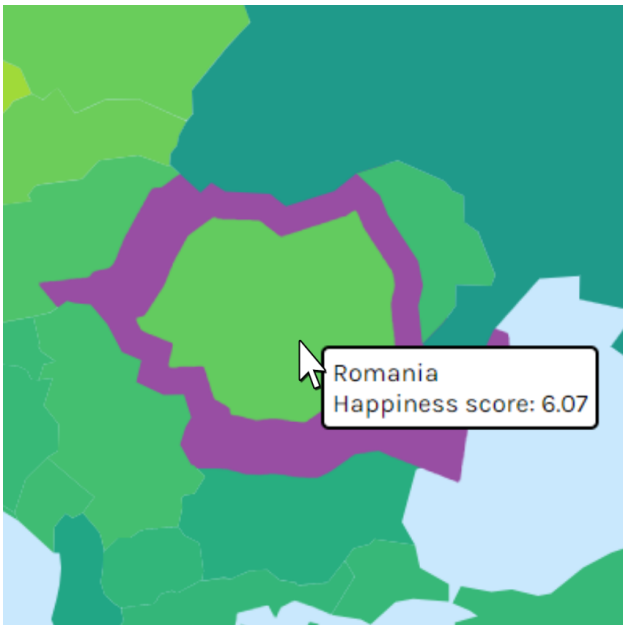


FIG. 24. The user hovers over a choropleth. A tooltip appears, depicting the country's name and happiness score.

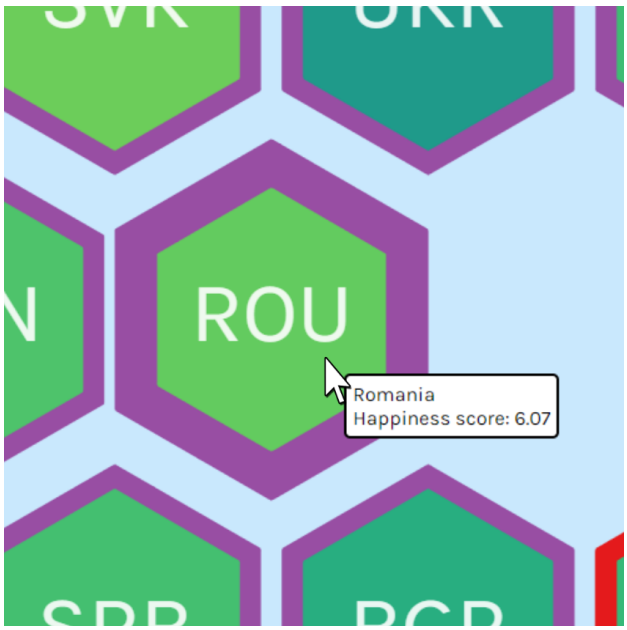


FIG. 25. The user has clicked the country, automatically switching over to hex-tile view. Countries now have a 3-letter code identifying them on each hex. Hovering conjurs the same tooltip, and the border size increases for visual aid. Clicking outside of any hex will return the visualization mode to Mercator projection, deselecting all countries.

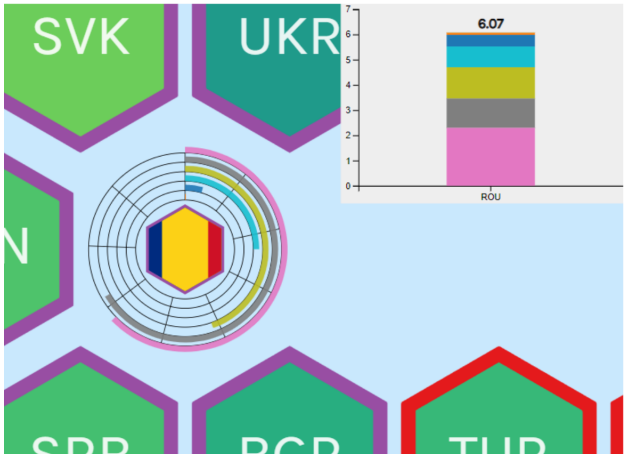


FIG. 26. Clicking a hex turns it into a radial bar chart (synonymous with selection) and adds the stacked-bar breakdown in the plot area.

jection into a hex grid representation, allowing the user to identify trends in a more territory-agnostic context. The radial bars presented an aesthetically pleasing, location-agnostic comparison that allows a user to explore each individual factor of the country. Finally, the stacked bars present a much needed way to compare selected country with a common zero, and the always-visible numerical value of the country's happiness score allow precise comparisons at-a-glance.

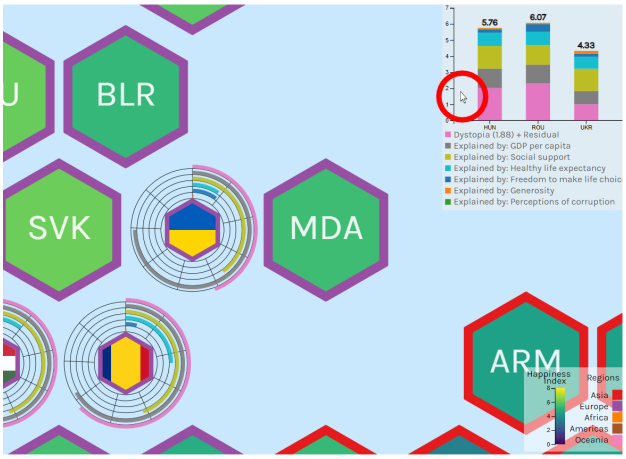


FIG. 27. Hovering over the bar plot brings up the color legend for the bars.

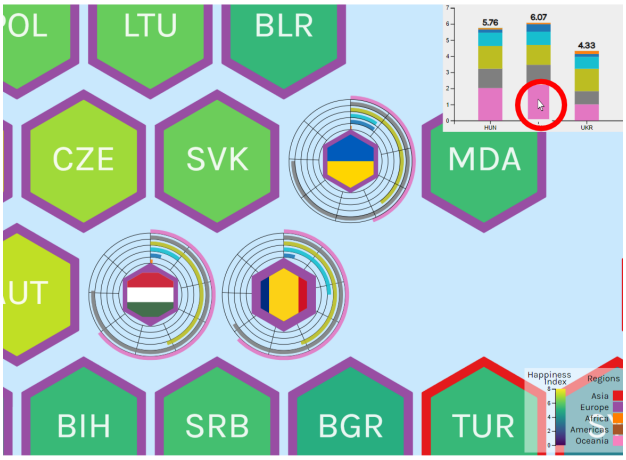


FIG. 28. Hovering over the bars will increase the border size of the corresponding country's hex as visual aid

Each separate visualization brought more opportunities for the user to interact and, by integrating them into one visualization, increased information density simultaneously. While making the static visualization interactive, we continually discovered opportunities previously unconsidered where the overall experience could be elevated. In particular, these manifested in strategies to let the user know which elements of the visualization were related to one another. These range from simple decisions such as using the country's 3-letter codes as both

labels for the hexes and stacked-bars to visual aids such as increasing the border-thickness of a country's hex when the user mouses over its stacked-bar so that the user can find these corresponding elements quickly.

Considering interaction in the last step of the project made us notice how, while the figures were complementary, they were far from the only direction in which we could have taken this project. By starting earlier, we might have decided that we wanted to approach selection by choosing different regions to focus on instead of having to manually click on different countries. Additionally, planning interactions early on would have allowed us to standardize our approaches with regards to programming the visualization in general; for example, using the country name as a class for all elements related to the country for easy selection, or synthesizing the various data files so that all data is readily accessible no matter the context.

While we don't believe that we would have ended up with a vastly different end product, revisiting the design process potentially could result in rich, tighter interactions which would simplify the experience for novice users and allow more exploration for expert users.

V. DISCUSSION

In this section, we perform a preliminary and informal evaluation of our final visualization using Tufte's heuristics. We also present potential avenues for future work.

A. Heuristic Evaluation using Tufte's Guidelines

We performed a preliminary evaluation of our final visualization using applicable Tufte's heuristics[2] as a guiding framework to criticize the resultant design from a more objective perspective. We have omitted the heuristic regarding 3D design as it is inapplicable to our visualization.

1. Minimize Ink while Maximizing Data Ink

Although there are no glaring examples of erroneous data ink, the y-axis on the stacked-bar plots could be argued to be unnecessary due to how the happiness score is already annotated above the bars themselves. Additionally, although the circles between the bars on the radial plots provide clear divisions, their prominence perhaps makes the bars themselves more difficult to read. Decreasing their opacity so that that the tangential ticks take centerstage, or removing the circles entirely could aid in visual acuity.

2. Maximize Data Density

The original intention of the visualization was to reveal more data as the user zoomed in, preserving the microstructures found in the dataset. Although that idea was mostly foregone, the implicit interrelationships between the data is still visible, especially in the Mercator projection and hex-tiles (geographical context, clusters of similarly-rated happiness scores). The unfortunate side-effect of situated graphs means that those charts located further from one another are harder to directly compare as previously discussed, but this is somewhat alleviated with the separate stacked-bar plot.

3. Avoid Chartjunk

All elements of the visualization are either relevant to the data shown or integral to the visualization (e.g., the toggle button).

4. Create Multi-functioning Graphics

Although the interaction and graphical encoding are hardly cryptic, they could benefit from tighter integration with each other. This is likely a result of our development of each element (map, radial plots, and bar plots) in isolation from one another, though it could be argued that the synonymization of activating the radial plot and adding the selected country to the displayed stacked-bars is an example of multifunctionality.

5. Parallelism

The radial plots can be argued as examples of situated small multiples. It is often easier to design around parallelism when the data contains a time series, which we have omitted for this iteration of the visualization.

6. Consider Colour Carefully

Consideration for colours took place at various points during the entire design process. The final visualization contains elements of this with the perceptually-uniform Viridis colour scale for happiness scores (to aid the visually impaired), and the use of colour to depict continents and other macro-regions. However, there is considerable overlap between the hues used for radial/stacked-bars and those used to denote the region to which a country belongs to, and no special consideration for color-blindness was made for the radial/stacked bar palettes.

B. Future Work

Overall we are really happy with we were able to do in this project. Although the purpose of the visualization changed from the initial proposal to juxtapose the WHO's data against other frameworks fore measuring global well-being to a more general use case, we ended up with a finished product that we're proud of.

One of the key things that we think would be fruitful is to continue iterating on the interaction design. While we think our current build is strong, there's still more space to expand and polish. For example the use of a lasso or brush may provide improve the speed and overall experience of selection. Another thing we could not quite get working was unambiguously linking interactions between the radial and stacked-bar charts; e.g., mousing over a stacked bar segment would highlight its corresponding bar on the radial chart of the same country, and vice versa. Thus there is still a lot of space left to explore the interactions between the two.

Additionally, there is more consideration to be had with regards to the aesthetics of the project. While we are happy with current presentation being simple and easy to understand, we believe the use of colour should be revisited to establish a tighter connection between the data and the visuals. As discussed above, more consideration is required for choosing the hues for radial/stacked-bars and the macro-regions.

Other iterations worth exploring include altering the bars of the radial plots to a hexagons in order to increase visual cohesion between the plots and surrounding hex tiles. Even with what we did, it feels like we have only touched the tip of the iceberg in terms of what can be done with this dataset. There is still so much room to explore augmenting the visualization with more navigation tools, more filtering tools and tools for accelerating discovery. It may also prove worthwhile to revisit the omitted time-domain from this dataset, or perform comparisons against the happiness scores and measures performed by other organizations as suggested in the original proposal.

Finally, with so many interactive features, it would prove useful to eventually perform a basic heuristic evaluation using Nielsen's usability heuristics[3].

VI. CONCLUSION

The core advantage of this visualization is how we designed the visualization for learning and early discovery. It presents itself initially in a form that almost everyone can understand, and then gradually provides the user with complexity in manageable chunks. This gives them space to explore the data without being overwhelmed. As an installation on a large display and intended for a general audience, this level of exploration depth makes sense. However, when you move from a casual viewer to a more advanced user who wants to compare whole regions (or larger subsets) in great detail, this model doesn't provide the types of tools required to efficiently select large sets or compare two countries with a fine-toothed comb. While those users were a group that we want to provide some support to, ultimately we had to make the trade off because of time and complexity, opting to retain simplicity of use for our core envisioned audience. Once again, this a wide open space to explore through further

work. A key disadvantage of the model we went with is that it does require a lot of interaction and many of them require discovery or prior knowledge as we did not include a tutorial or any usage instructions. There are a number of steps to compare countries, starting with moving from the map to the tile grid to finding the country you are interested in. To a curious passerby that may be an engaging experience, but to a user with a very specific objective or no idea where to start, it may be frustrating to have to go though a complex workflow to get to the desired result.

The key lesson that we learned was that the visualization process is incredibly open. Even with the simple visual elements like the stacked bars or the choropleths, there were many decisions, each with trade offs that needed to be considered. From how to present missing data, to how to align our axes, there were numerous things to play with that we could have been at it forever and not explored everything we could have. From that we had to learn how to focus our attention on what mattered to the story we were trying to tell and the audience we were trying to tell it to in order to narrow our sights on something that is feasible. One of the things that we discovered working on this project is that the declarative programming style of D3, and by extension JavaScript, helps streamline simple visualization, but linking multiple elements and states, d3 showed several limitations. These limitations are sparsely covered in D3 documentation because of how fundamental the Document Object Model is to the language as well as wildly fluctuating standard practices and functions dependent on the version of D3, of which past versions tend to appear most commonly when trying to search for documentation and other resources. In conclusion, we produced a visualization that focuses exploration and discovery of the WHO World Happiness Report with a focus usage

REFERENCES

[1]S. Knudsen, "W11L19 - Presentation, Multiple views, View Coordination - CPSC 583 - (Winter 2020) - Introduction to Information Visualization," (2020).

[2]S. Knudsen, "W12L21 - Tasks & Evaluation, Tufte - CPSC 583 - (Winter 2020) - Introduction to Information Visualization," (2020).

[3]J. Nielsen, in *Proceedings of the SIGCHI conference on Human Factors in Computing Systems* (1994) pp. 152–158.

[4]"d3/d3-scale-chromatic: Sequential, diverging and categorical color scales." (2020).

[5]J. R. Nuñez, C. R. Anderton, and R. S. Renslow, PLoS ONE **13** (2018), 10.1371/journal.pone.0199239.

[6]S. Knudsen, "W6L11 - Color, Color Tools, Other Tools - CPSC 583 - (Winter 2020) - Introduction to Information Visualization," (2020).

Appendix A: Sketchable Data Subsets

What follows are the three data subsets we used for sketching

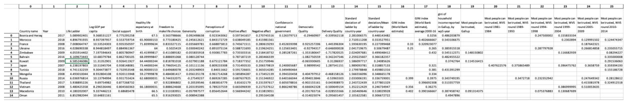


FIG. 29. SSubset 1 took a small number of horizontal slices from the set of all measurements in the main database, while preserving overall trends.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	Country	Happiness score	Whisker-high	Whisker-low	Dystopia (1.88) + residual	Explained by: GDP per capita	Explained by: Social support	Explained by: Healthy life expectancy	Explained by: Freedom to make life choices	Explained by: Generosity	Explained by: Perceptions of corruption	Changes in happiness scores	Whisker-high	Whisker-low
1	Denmark	7.60010004	7.666658401	7.533541679	2.39289093	1.383438587	1.572595	0.996018887	0.592356086	0.252319992	0.410473198	-0.341033459	-0.252307625	-0.429759292
2	Norway	7.553899765	7.61563921	7.49216032	2.240764141	1.487766981	1.581548333	1.028122902	0.60349983	0.27130419	0.340883523	0.029889107	0.140475129	-0.080696916
3	Iceland	7.493599892	7.613283157	7.373916626	2.400875568	1.380163193	1.623651147	1.025652528	0.590905368	0.354356408	0.117979728	0.60529995	0.835070556	0.375529343
4	Netherlands	7.48759985	7.542098045	7.433101654	2.392894745	1.396020412	1.521903396	0.999313712	0.557075202	0.322439581	0.297978073	-0.02821207	0.056406944	-0.112831085
5	Montenegro	5.522900105	5.620594501	5.425205708	1.821559906	1.050553441	1.360719085	0.870898545	0.196936682	0.142251536	0.079953268	0.326557159	0.571516738	0.081597581
6	Tajikistan	5.467299938	5.568359375	5.366240501	2.396641254	0.49311772	1.097571731	0.717802763	0.388559431	0.229705334	0.143859774	0.764082909	0.885358793	0.642807024
7	Croatia	5.431799889	5.509877682	5.353722095	1.659908533	1.154682159	1.265782356	0.913788199	0.296157688	0.119423844	0.022072921	-0.389091969	-0.227836102	-0.550347835
8	Hong Kong S.A.R. of	5.430399895	5.523323059	5.33747673	0.609068871	1.437999249	1.276592731	1.122139812	0.439627707	0.257670522	0.287329525	0.100288868	0.244110457	-0.043532721
9	Dominican Republi	5.425300121	5.559331417	5.291268826	1.518515587	1.015422583	1.401476383	0.778674066	0.496892959	0.112933204	0.101404041	0.42163372	0.602175747	0.241091694
10	Yemen	3.379800081	3.478829861	3.280770302	1.138842344	0.286910504	1.162668467	0.462539971	0.143069744	0.108465463	0.077344313	-1.097291946	-0.928765002	-1.265818891
11	Rwanda	3.333800077	3.425188065	3.24241209	0.467254639	0.359488189	0.711047769	0.61399585	0.554569781	0.216654509	0.410825759	-0.939872742	-0.819828391	-1.059917093
12	Tanzania	3.230700016	3.347132683	3.114267349	0.530644417	0.475853741	0.884855092	0.498772502	0.417150706	0.276293755	0.147166774	-0.981668234	-0.831949109	-1.131387359
13	Afghanistan	3.203299999	3.277512074	3.129087925	1.793060184	0.349630922	0.517003238	0.360616267	0	0.158151418	0.024875212	-0.520252705	-0.367131063	-0.673374346
14	Central African Rep	3.082999945	3.226581812	2.939418077	2.455649376	0.026408311	0	0.10534554	0.225276604	0.235050067	0.035267804	-1.077131987	-0.884917818	-1.269346155

FIG. 30. Subset 2 was randomly sampled from the set of happiness scores and contributive factors joined by country with the set of happiness score changes

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	Country	Happiness score	Whisker-high	Whisker-low	Dystopia (1.88) + residual	Explained by: GDP per capita	Explained by: Social support	Explained by: Healthy life expectancy	Explained by: Freedom to make life choices	Explained by: Generosity	Explained by: Perceptions of corruption	Changes in happiness scores	Whisker-high	Whisker-low
1	Cameroon	5.043700218	5.16989994	4.917500496	2.649462223	0.54896003	0.910110652	0.330502898	0.3809807	0.186872318	0.036784157	0.880005836	1.028352602	0.731659071
2	Botswana	3.488399982	3.611435652	3.365364313	0.183267355	1.040944576	1.145317674	0.538402438	0.455443174	0.024992935	0.100037552	-1.606223583	-1.428819333	-1.783627833
3	Zimbabwe	3.663199902	3.780338764	3.546061039	1.149109364	0.365784705	1.113996267	0.433069229	0.360839635	0.151060909	0.089291245	0.236431599	0.3911675	0.081695697
4	Netherlands	7.48759985	7.542098045	7.433101654	2.392894745	1.396020412	1.521903396	0.999313712	0.557075202	0.322439581	0.297978073	-0.02821207	0.056406944	-0.112831085
5	Bangladesh	4.455800056	4.538150787	4.373449326	1.406029701	0.562269628	0.928245068	0.72272855	0.527391553	0.165772662	0.143401638	-0.195450783	-0.087840989	-0.303060576
6	South Africa	4.722199917	4.83756876	4.606831074	1.368621826	0.959680498	1.350676179	0.46916759	0.389366806	0.129988983	0.054727621	-0.490183353	-0.345718584	-0.634648123
7	Pakistan	5.652999878	5.731922626	5.574077129	2.923630714	0.676521182	0.88627249	0.535022736	0.313266665	0.220373973	0.097903647	0.702796459	0.822191263	0.583401656
8	Norway	7.553899765	7.61563921	7.49216032	2.240764141	1.487766981	1.581548333	1.028122902	0.60349983	0.27130419	0.340883523	0.029889107	0.140475129	-0.080696916
9	Palestinian Terri	4.69630003	4.80589819	4.58670187	1.726990461	0.656588614	1.24704206	0.671695411	0.224934652	0.102886073	0.066178463	0.279308796	0.42854536	0.130072232
10	Haiti	3.596899986	3.750535965	3.443264008	1.580646515	0.322931051	0.688321054	0.449383378	0.025854424	0.419497848	0.110238858	-0.203227043	-0.008162342	-0.398291744
11	Congo (Brazzavil	4.811500072	4.955009937	4.667990208	2.262392998	0.67264992	0.798868179	0.508152843	0.371835202	0.104942366	0.092648983	0.991698265	1.20974778	0.77364875
12	Bolivia	5.779300213	5.875899792	5.682700634	2.375586033	0.775684595	1.209193707	0.706299722	0.511490107	0.136560887	0.064449407	0.34635973	0.471421441	0.221298018
13	Finland	7.768899918	7.829887867	7.707911968	2.713677883	1.340242863	1.587275743	0.98614496	0.59589535	0.152708426	0.392912716	0.097318649	0.189357343	0.005279955
14	Mongolia	5.285399914	5.362427711	5.208372116	1.5504601	0.947823763	1.530638218	0.666763842	0.316532463	0.235220835	0.037966382	0.73545599	0.848070206	0.622841774

FIG. 31. Subset 3 took the 5 highest happiness scores, 5 happiness scores from the middle, and the 5 lowest happiness score from the set of happiness scores and contributive factors joined by country with the set of happiness score changes

Appendix B: Initial Sketches

What follows is all of the 90 initial ideation sketches.

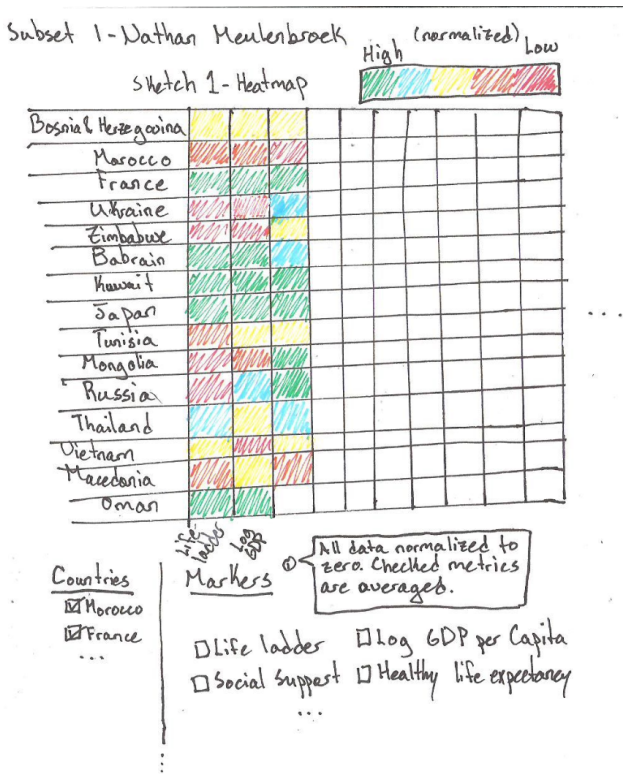


FIG. 32. Subset1 Sketch1: A partial heatmap of the values of the different metrics for each country. Interactive elements below to make data more compact for the user.

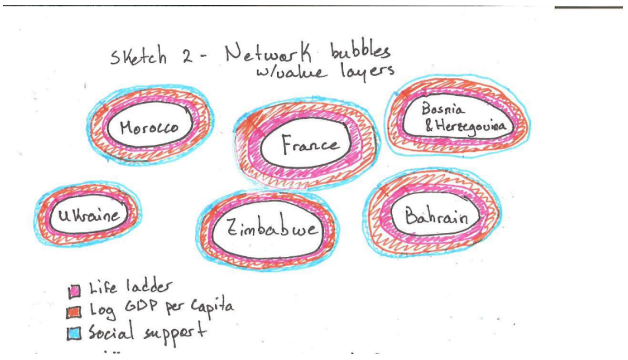


FIG. 33. Subset1 Sketch2: A variation on a bar chart. Data is unitless and intended to be compared relatively.

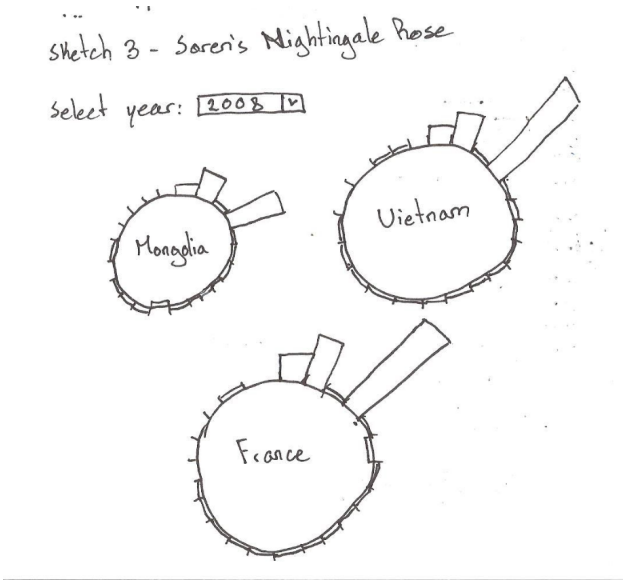


FIG. 34. Subset1 Sketch3: A variation on a Nightingale rose inspired by Soren's in class example.

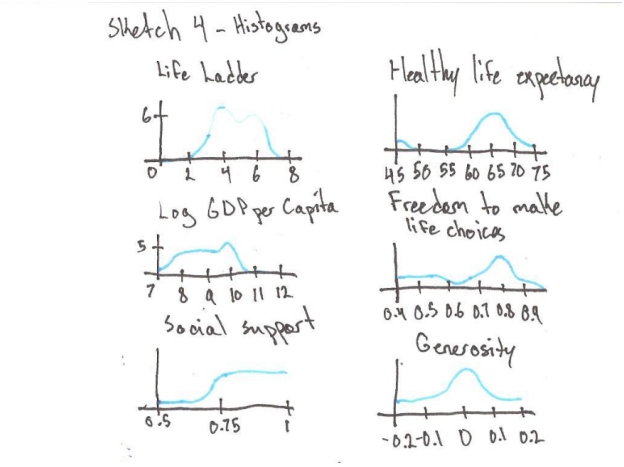


FIG. 35. Subset1 Sketch4: Line histograms of the different metrics. Truncated for brevity.

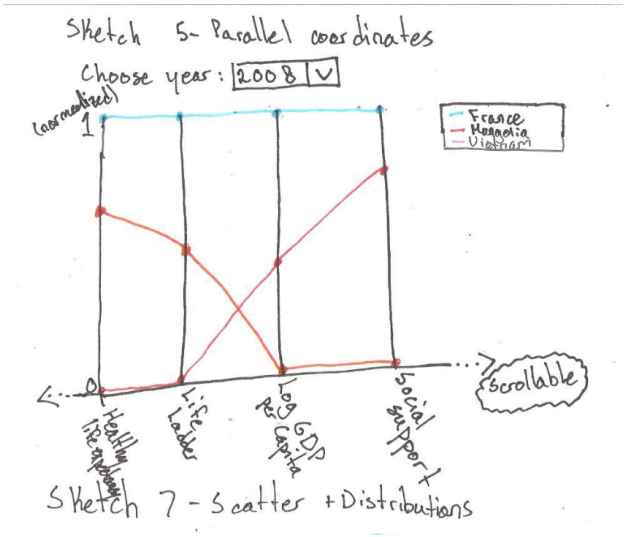


FIG. 36. Subset1 Sketch5 : A parallel coordinates plot for all countries with data in 2008. Data would be scrollable so that changes are visible to the naked eye instead of overlapping.

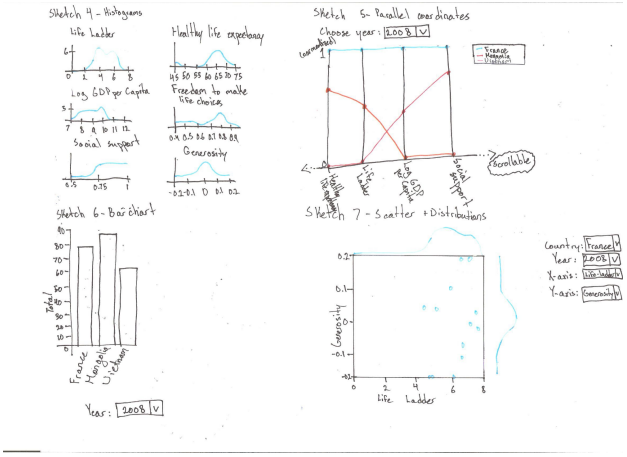


FIG. 38. Subset1 Sketch7: A scatter plot of life ladder vs. generosity, with the histogram distribution overlayed outside of the scatterplot.

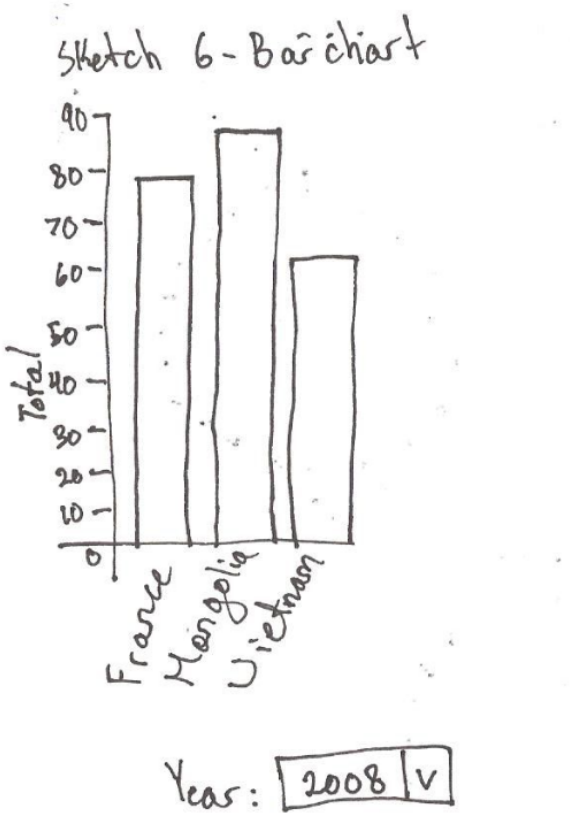


FIG. 37. Subset1 Sketch6: A simple bar chart of the life ladder for countries with data in 2008.

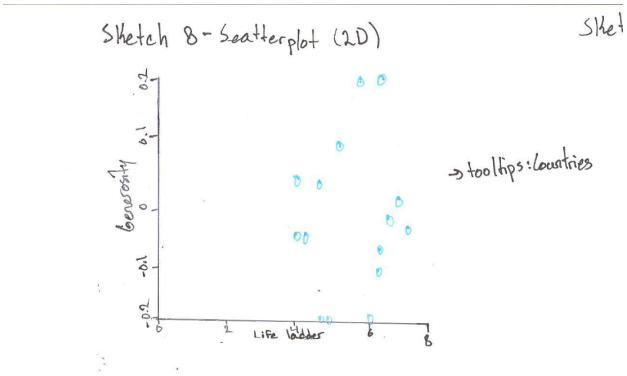


FIG. 39. Subset1 Sketch8: A simple 2D scatterplot of life ladder data vs. generosity. Datapoints would have tooltips for countries.

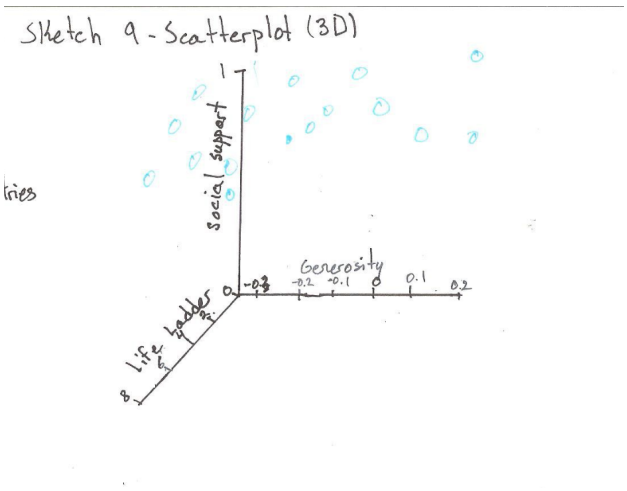


FIG. 40. Subset1 Sketch9: A 3D scatterplot of life ladder vs. social support vs. generosity. Ideally this would be able to be manipulated by the user so they could rotate the plot and view it at different angles.

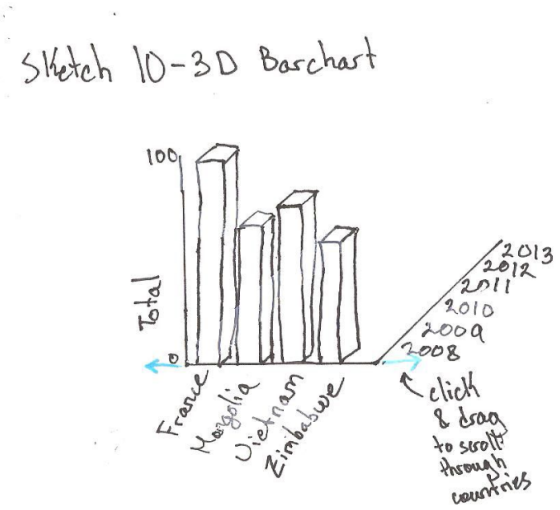


FIG. 41. Subset1 Sketch10: A 3D bar chart showing the time progression of life ladder data for different countries. Again, this should be interactive for the user so they can view it from all angles. Perhaps heatmap colour should also be employed.

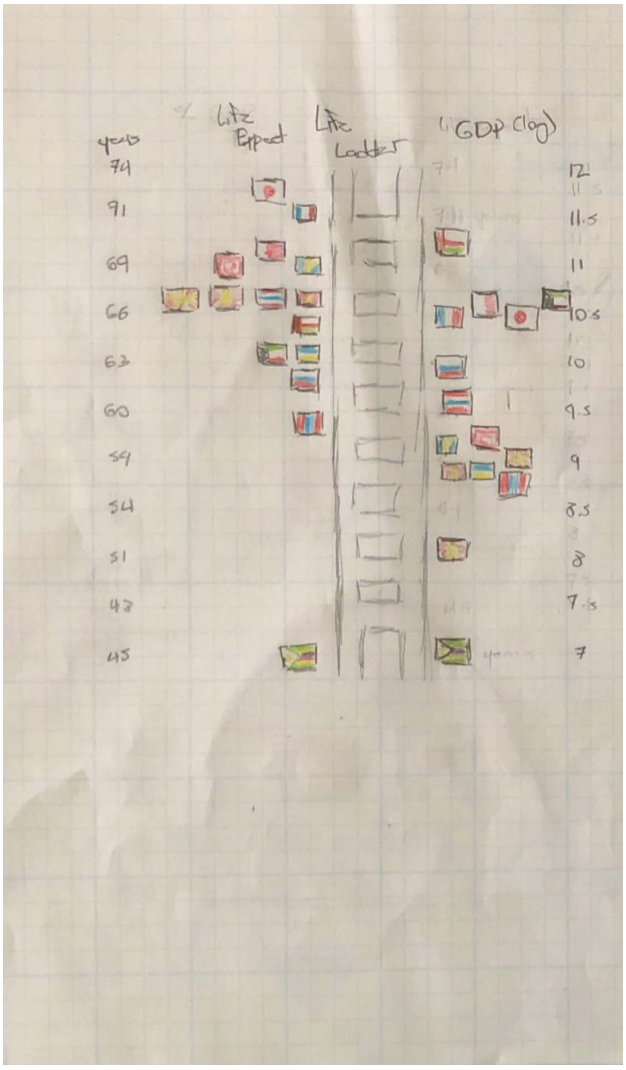


FIG. 42. Subset1 Sketch11: A variation of a bar chart, using each country's flag to represent its respective data. Currently it only uses the height of each flag to represent from left to right respectively healthy life expectancy and national GDP.

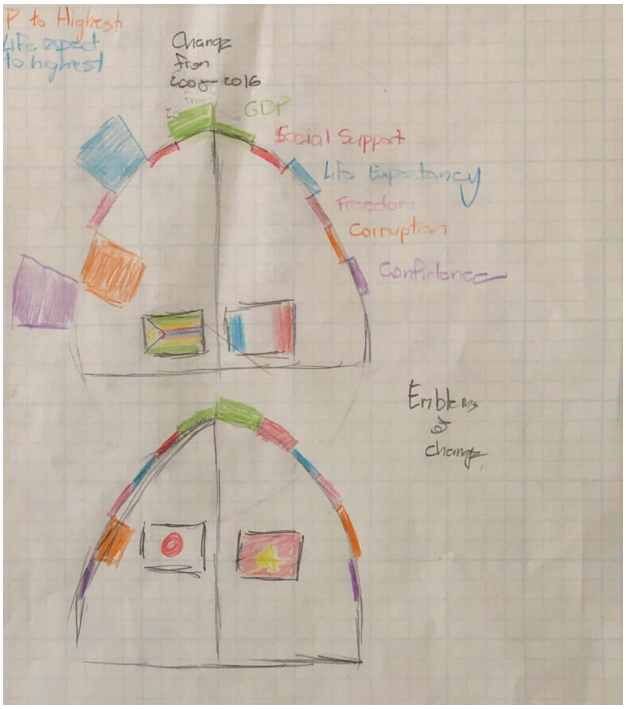


FIG. 43. Subset1 Sketch12: A variation of the Nightingale rose inspired visualization from the CER project. Uses the height of each bar on the emblem to represent each data point for each country. Each emblem contains two countries at certain years to allow for easy comparison between both different countries and different times.

FIG. 44. Subset1 Sketch13: Places a heatmap over a map of the earth. Looks to represent the change in life expectancy from 2008-2015 for each country with darker shades of red representing greater increases in life expectancy during that period and darker shades of blue to represent greater decreases in life expectancy during that period.

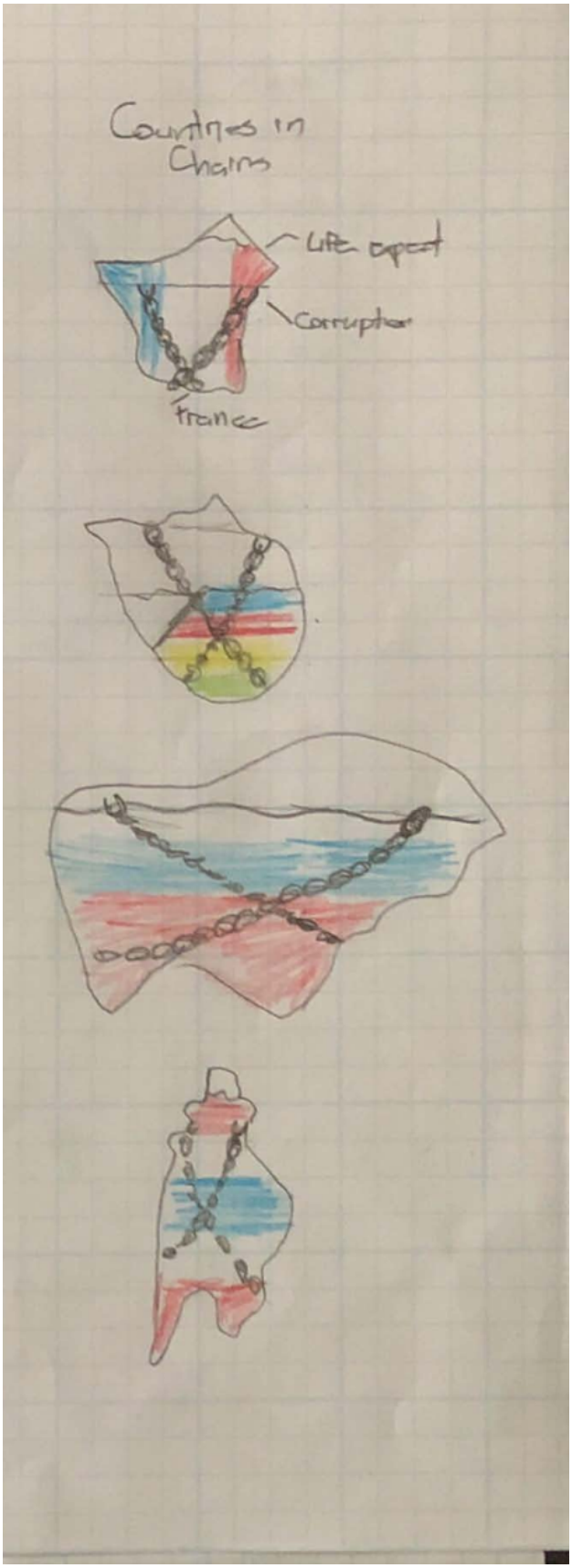


FIG. 45. Subset1 Sketch14: Looks to visualize each country's life expectancy compared to it's perception of corruption. Uses the shape of the country to distinguish which country is which. The height of filled in flag represents the life expectancy relative to the highest life expectancy. The height of the chains represent the percep-

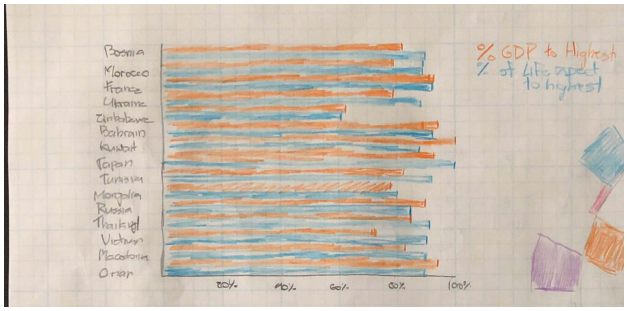


FIG. 46. Subset1 Sketch15: Dual horizontal bar chart with the top (orange) bar representing the GDP of that nation relative to the highest GDP of any country at any point and the bottom (blue) bar representing the life expectancy of that country relative to the highest life expectancy of any country at any point.

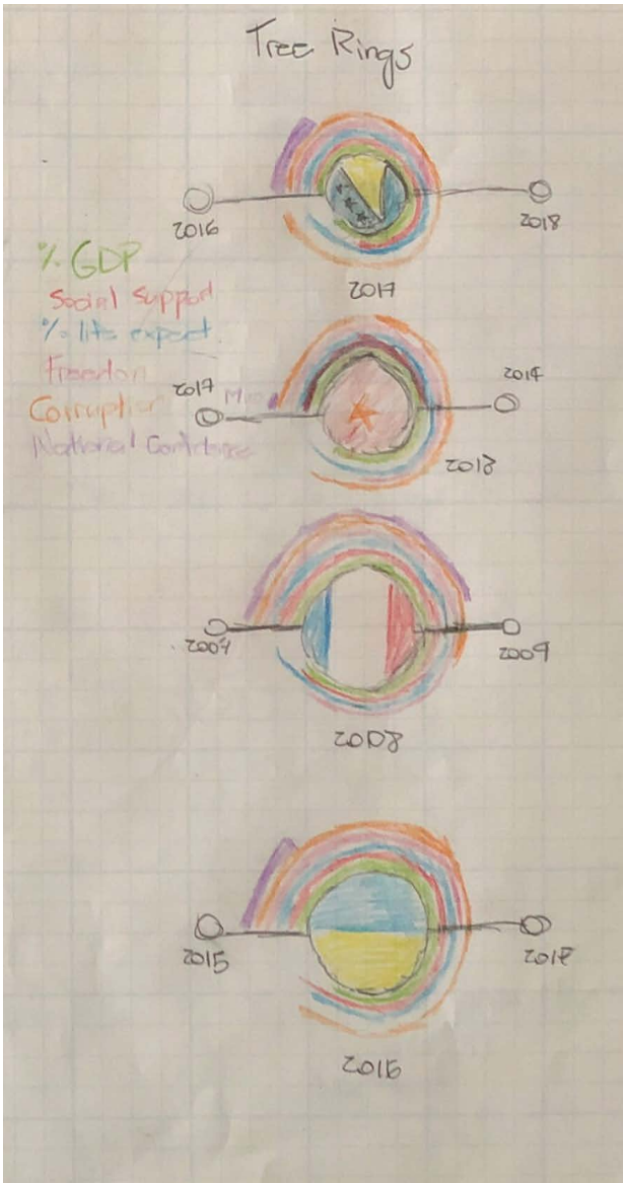


FIG. 47. Subset1 Sketch16: Each circle represents a country at a given year. The two bubbles on either side allow for changing the year. Each ring represents a different data point. Each data point was a percentage (for GDP and Life expectancy which were not, a ratio between that country at that point and the highest of any country at any time was used). The arc of each ring represents the percentage of each data point.

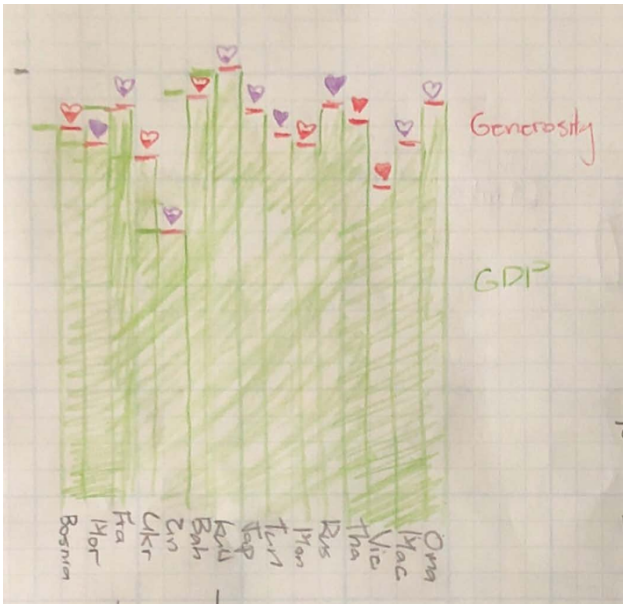


FIG. 48. Subset1 Sketch17: A bar chart variation. Each bar is a different country at a given year. The height of each bar represents the GDP (again relatively to the highest) of each country. The heart at the top of the bar represents generosity which was either a positive or negative value from 0 to 1. Purple hearts represent negative values while red represents positive values. The fill of the heart represents the closeness of the value to either -1 or 1 respectively.

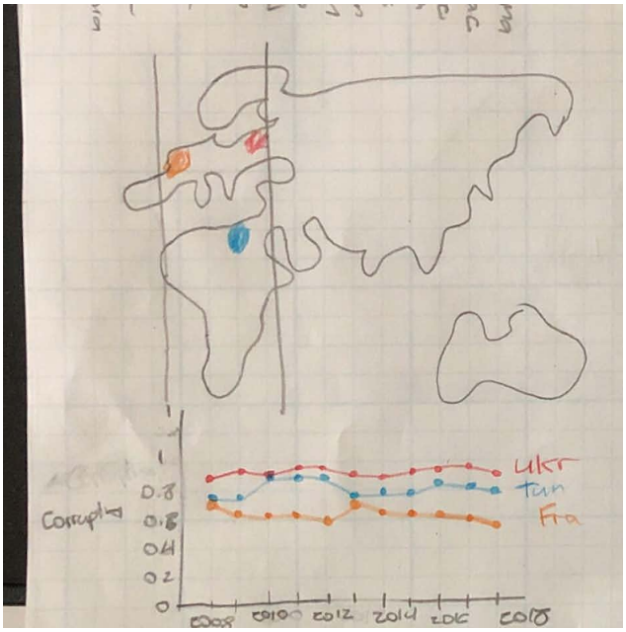


FIG. 49. Subset1 Sketch18: A geo coordinate line chart. The line chart at the bottom shows the perception of corruption (y axis) for each year (x axis) for all selected countries. The top is a map that allows for selection of a number of countries based on a latitude bounding.

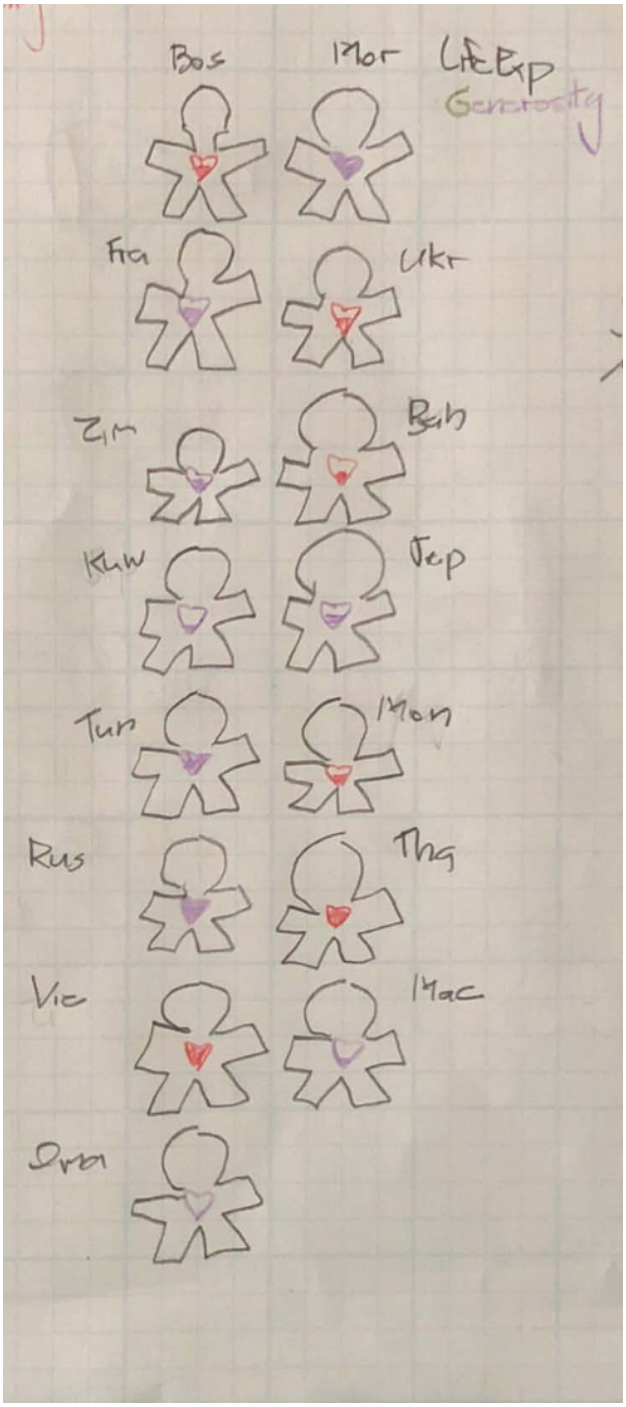


FIG. 50. Subset1 Sketch19: Paper hearts. Each country at a given year is represented as a paper person. The height (thus overall size) of the person represents their life expectancy relative to the highest life expectancy of any country at any year. The heart is similar to those found in Subset1 Sketch17 as such the heart represents generosity which was either a positive or negative value from 0 to 1. Purple hearts represent negative values while red represents positive values. The fill of the heart represents the closeness of the value to either -1 or 1 respectively.

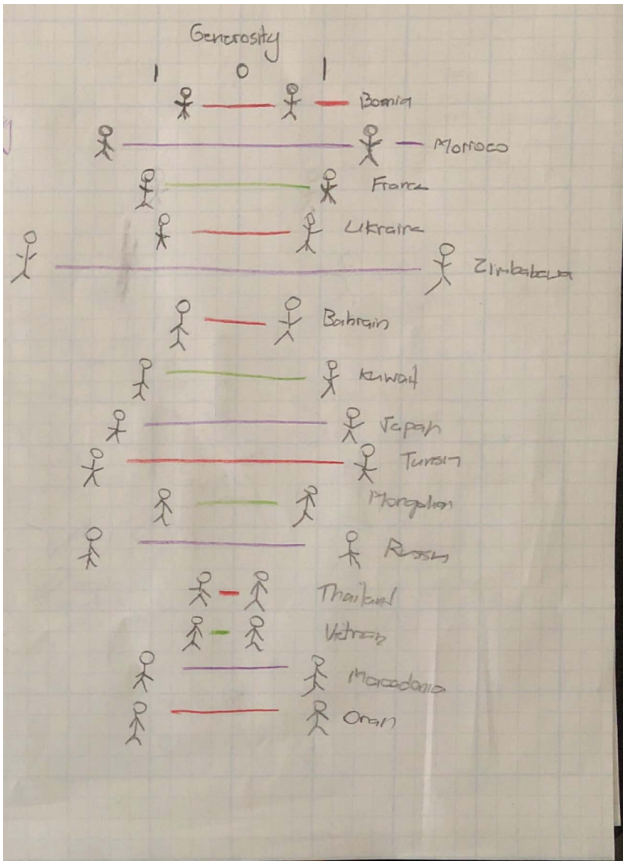


FIG. 51. Subset1 Sketch20: Represents generosity via distance between people. The top lines show at which distance was the 0 value. Each country was represented by two people. The closer the people were the more positive the generosity value for that country and the further the more negative the values were.

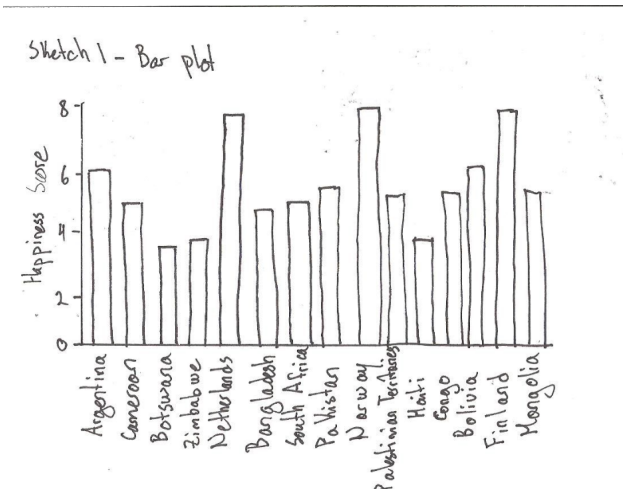


FIG. 52. Subset2 Sketch1: Simple bar chart of happiness scores for different countries.

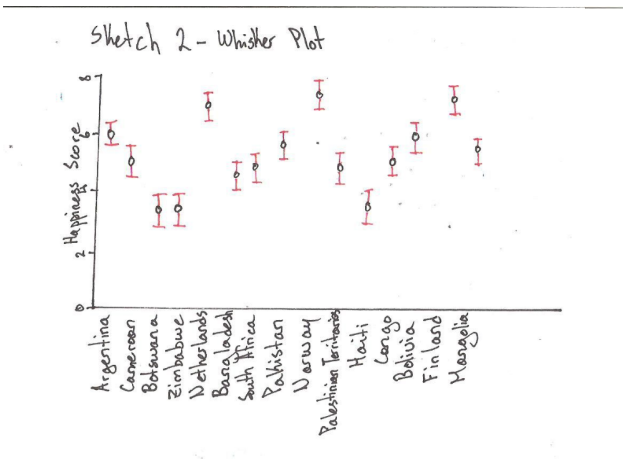


FIG. 53. Subset2 Sketch2: Simple whisker plot of happiness scores for different countries to visualize error.

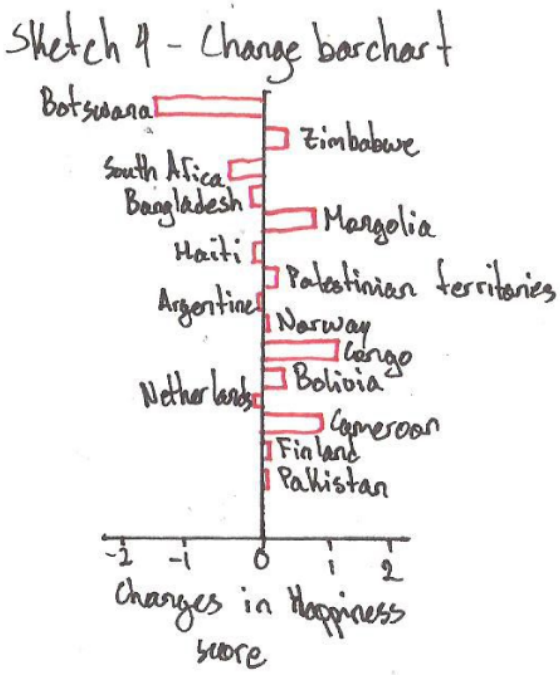


FIG. 55. Subset2 Sketch4: Changes in happiness visualized by a bar chart.

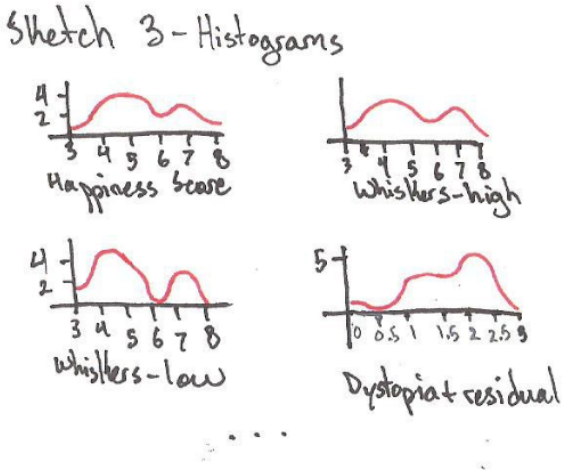


FIG. 54. Subset2 Sketch3: Line histograms for all variables. Truncated for brevity.

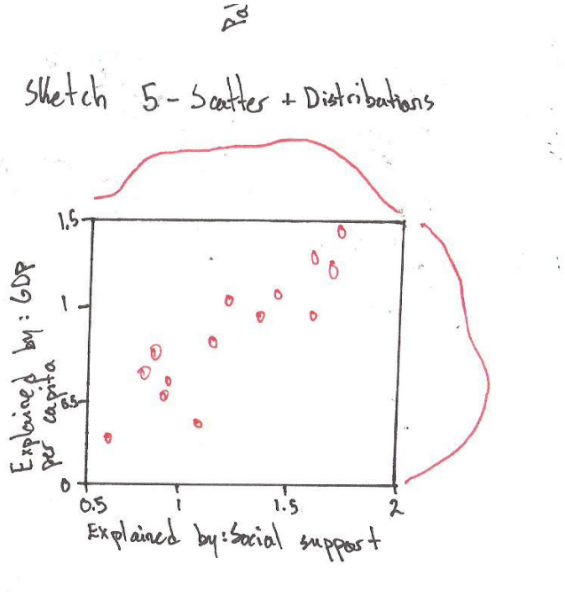


FIG. 56. Subset2 Sketch5: Two explainer variables plotted against each other with distributions overlaid outside of the scatterplot space. Notice that the variables appear to be linearly related.

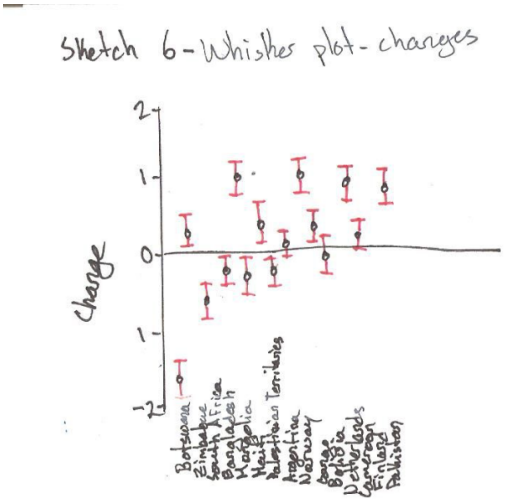


FIG. 57. Subset2 Sketch6: Simple whisker plot for changes in happiness scores. Country labels may be better served as tooltips instead of at the bottom of the plot.

FIG. 58. Subset2 Sketch7: An interactive map of the world that allows you to select a country and view its numerical data. Country is filled with colour when selected.

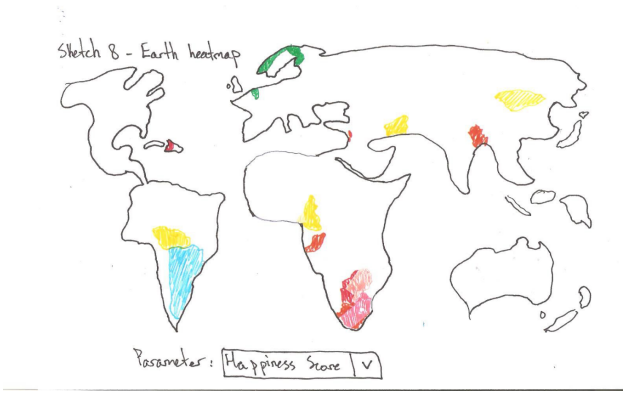


FIG. 59. Subset2 Sketch8: Similar to sketch 7, but instead of displaying numerical values it's a heat map with a toggle-able parameter.

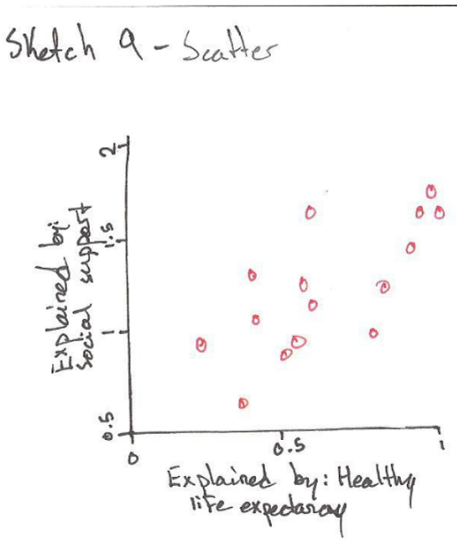


FIG. 60. Subset2 Sketch9: Simple scatterplot of two explainer variables. Notice again that these variables appear to be linearly related.

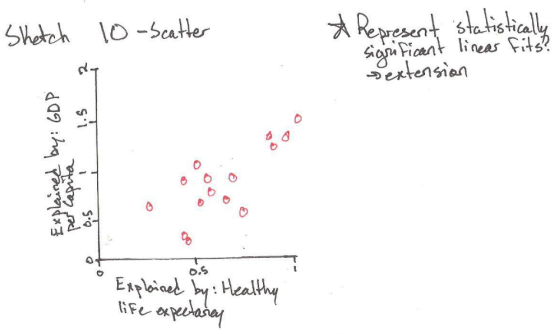


FIG. 61. Subset2 Sketch10: A scatterplot of two explainer variables. Here, a pattern was noticed in that they appear to be linearly related to each other. This could be highlighted more by different representations and allow users to come to their own interesting conclusions.

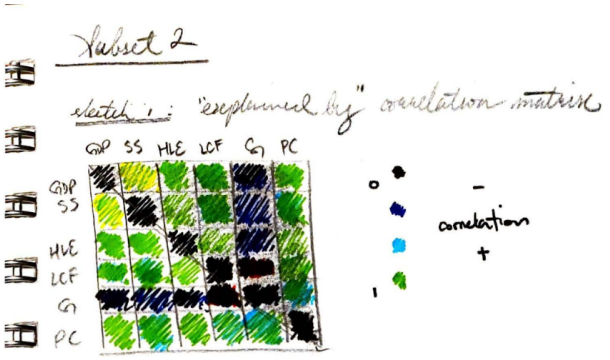


FIG. 62. Subset2 Sketch11: A correlation matrix between measures (GDP, Social Support, Healthy Life Expectancy, Freedom to Make Life Choices, Generosity, Perception of Corruption). Black indicates no correlation, blue indicates negative correlation, and green indicates positive correlation.

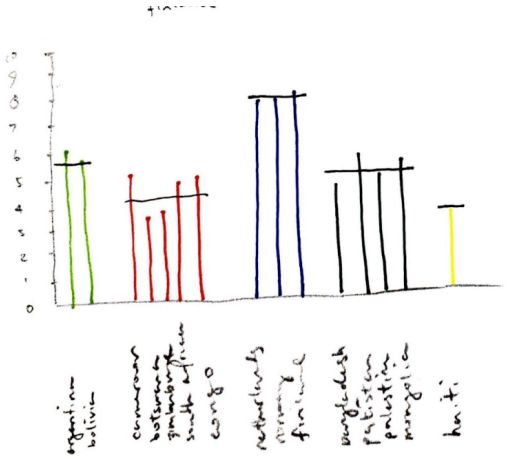


FIG. 63. Subset2 Sketch12: Happiness scores of countries organized by continent; the black, horizontal line indicates the average happiness score of the continent.

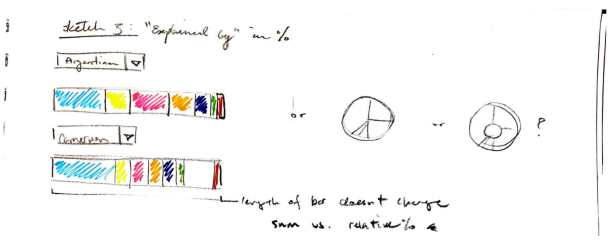


FIG. 64. Subset2 Sketch13: By hiding the actual happiness score away and fixing the length of the overall bar, this visualization emphasizes the proportional (%) impact of each measure on happiness for the country. A pie chart or donut chart was also considered but not explored further here.

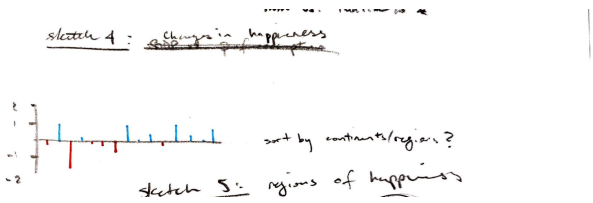


FIG. 65. Subset2 Sketch14: Shows the change in happiness measure. Would have been more useful to have sorted this by region like Subset2 Sketch12.

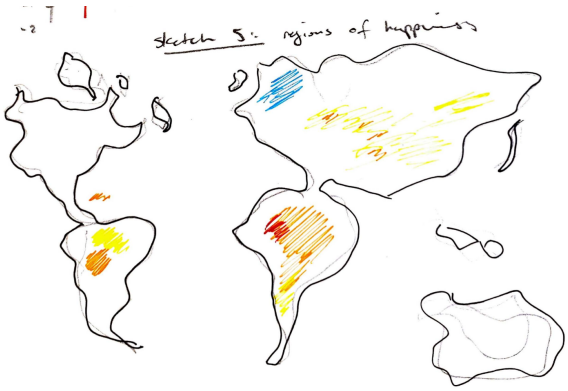


FIG. 66. Subset2 Sketch15: A heatmap of regions of happiness, where warmer colours represent less happiness and colder colours represent more happiness.

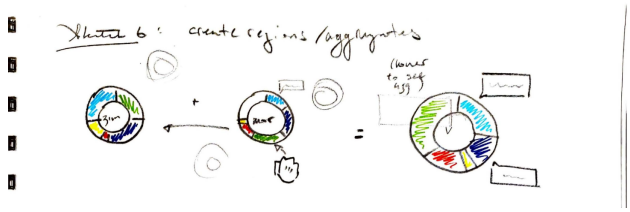


FIG. 67. Subset2 Sketch16: Proposing making aggregations of countries into user-defined regions, with the regions updating as countries are added and removed (drag a donut onto another). Tooltips appear upon mouseover events.

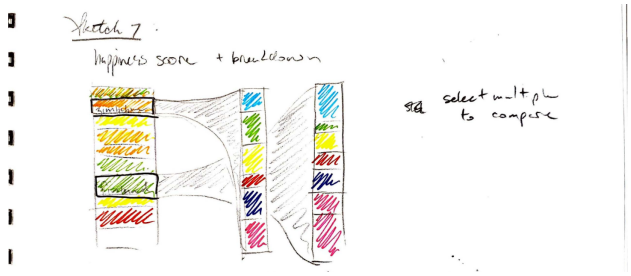


FIG. 68. Subset2 Sketch17: An unsorted list of countries on the left, color coded to display their happiness score. When clicked, the breakdown of happiness measures is anchored to the right so multiple countries can be contrasted. This solves the problem from Subset2 Sketch13 where a country's happiness score had been abstracted. However, there is no good reason for the country list not to be sorted in some way.

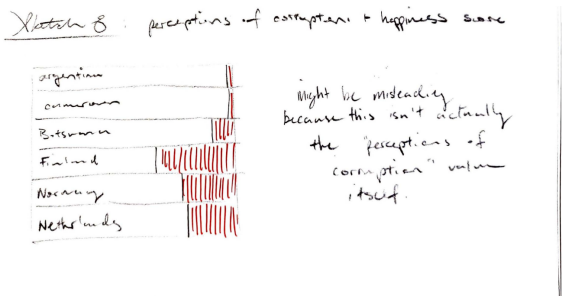


FIG. 69. Subset2 Sketch18: Shows the proportion of a single measure for each country.However, might be misleading because this shows the impact of corruption perceptions on happiness, not the level of perception of corruption in a given country itself.

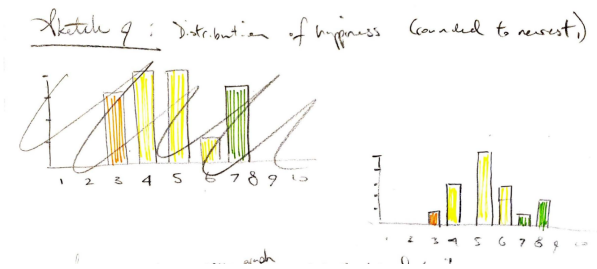


FIG. 70. Subset2 Sketch19: Binning countries by rounding to the nearest whole number to show global happiness trends.

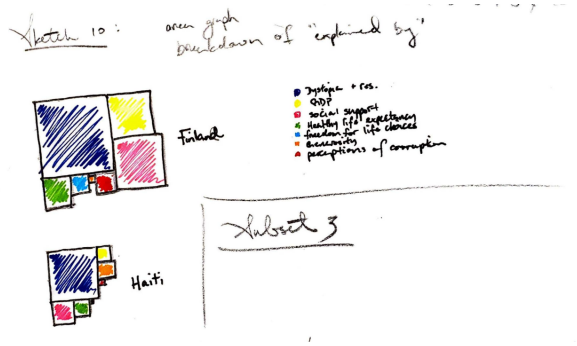


FIG. 71. Subset2 Sketch20: Using the measure as a length of a side of a square, resulting in area charts.

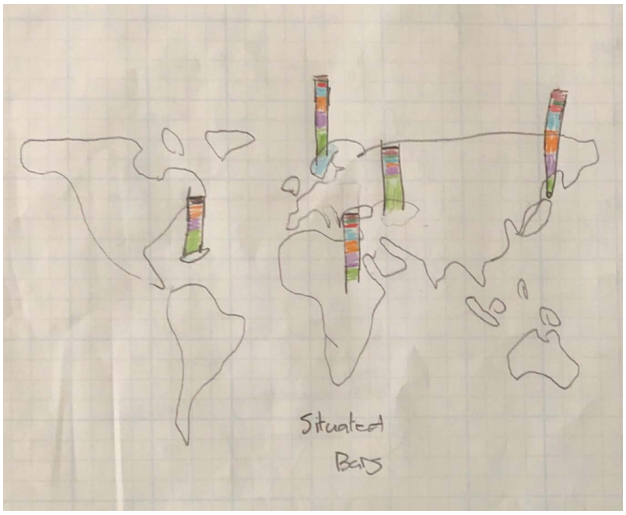


FIG. 72. Subset3 Sketch1: This sketch situates a stacked bar chart in a given country. Each segment of a bar represents how much the happiness score for that country could be explained by a given factor with the overall height of the bar representing the happiness score of that country.

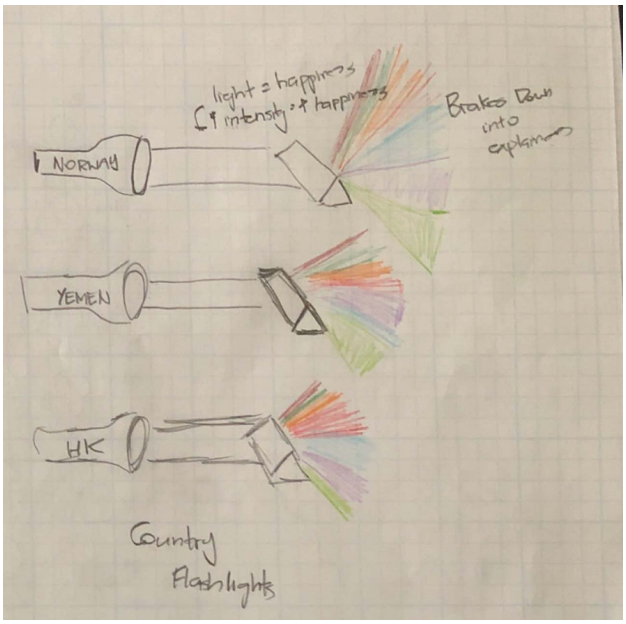


FIG. 73. Subset3 Sketch2: Each country is represented as a flashlight with the strength of it's beam of light representing the happiness score of that country. The brighter and wider the beam of light, the higher the happiness score. Then when that light is ran through a prism, it breaks into each explanatory factor, the wider the segment of a given color the more that factor explained a given factor.

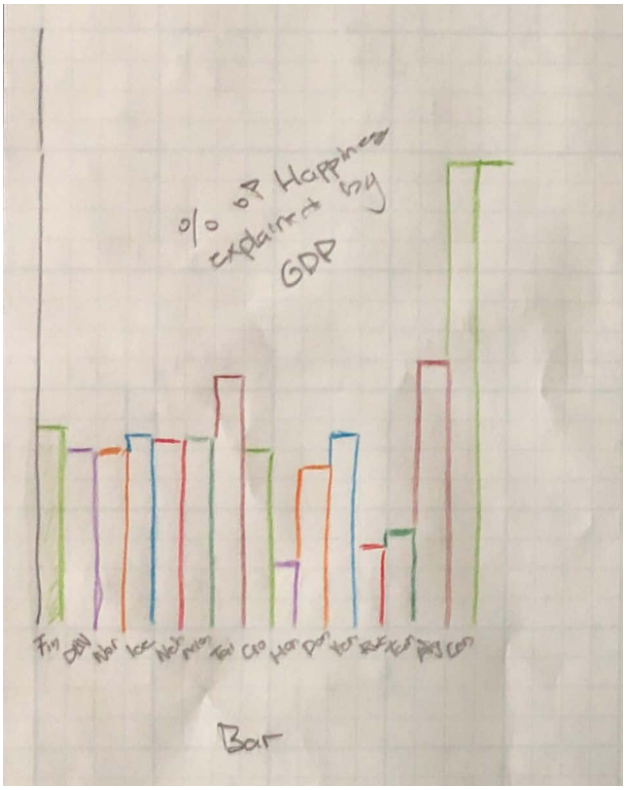


FIG. 74. Subset3 Sketch3: A simple bar chart show what percent of a country's happiness could be explained by GDP

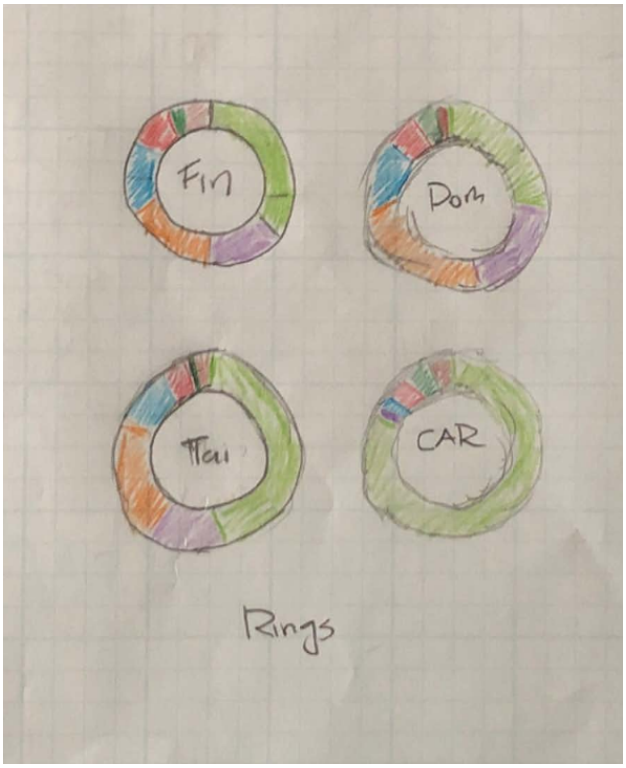
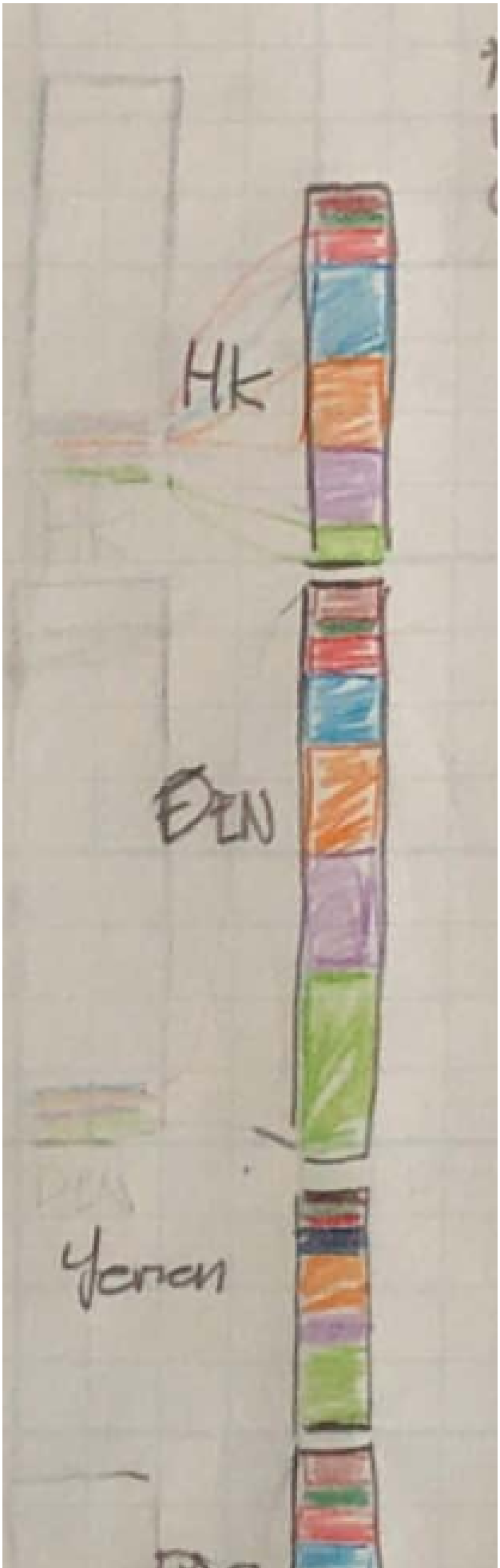


FIG. 75. Subset3 Sketch4: Each circle represents a country with the arc of each colored segment representing the percentage of the happiness score of that country could be explained by a given factor.



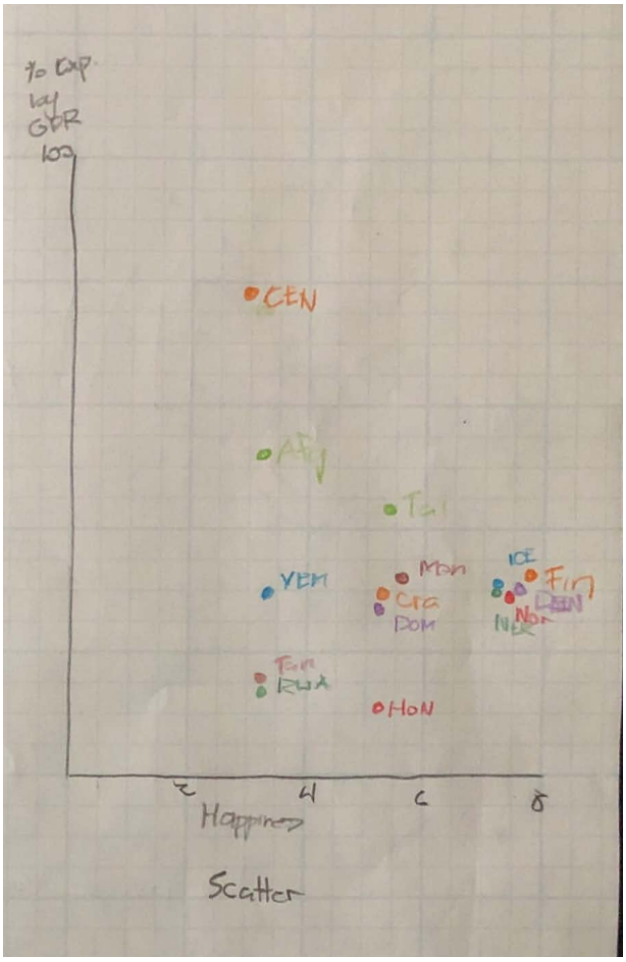


FIG. 77. Subset3 Sketch6: A scatterplot showing with each colored dot representing a country and it's x position representing it's happiness score and it's y position representing the percent of it's happiness score could be explained by its GDP.

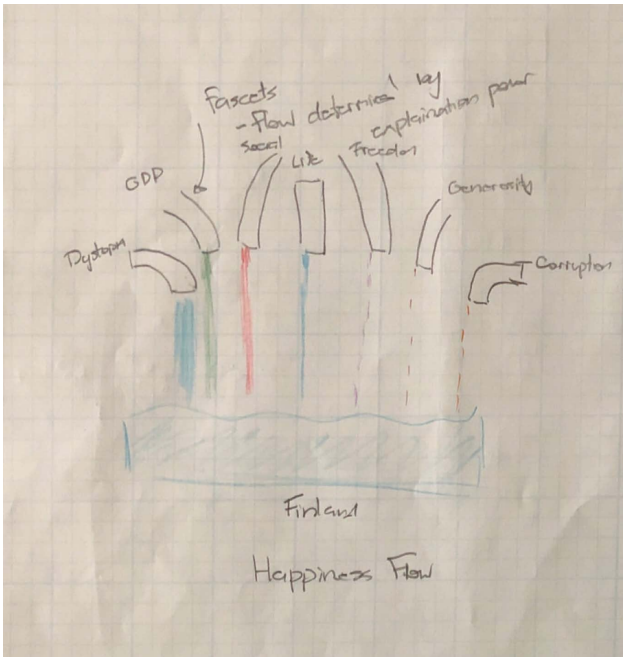


FIG. 78. Subset3 Sketch7: This sketch shows a sketch where a country is represented by a tub. The water line in the tub shows the total happiness score (fuller, the happier). Then each faucet represents an explanatory factor with the flow of water represents the degree to which that factor explains the happiness score (higher flow, the more that it can explain the happiness score).

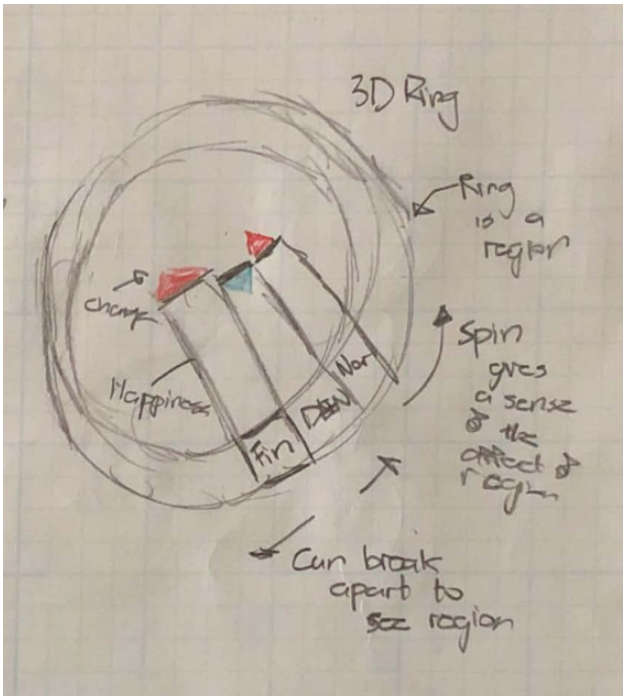


FIG. 79. Subset3 Sketch8: Each region is represented by a 3d ring of bars. Each bar is a country with it's height representing that country's happiness score and the top section (red or blue) representing the change in happiness for that country. The larger the red arrow, the more the happiness score increased and the larger the blue arrow, the more the happiness score has decreased. The ring could be spun to give a sense of the general characteristics of a region. Then the ring could also be split into a flat line in order to see all the countries at once.

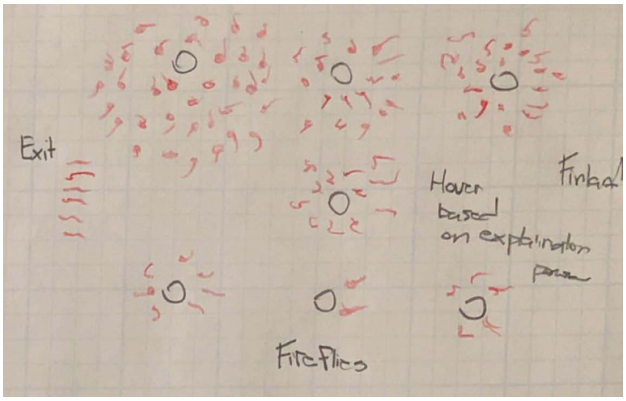


FIG. 80. Subset3 Sketch9: The happiness score of a given country is represented by a field of fireflies. The total number of fireflies represents the happiness score of the country. Each explanatory factor is a point in space and the density of fireflies around that point represents how much that explanatory factor explains the happiness score.

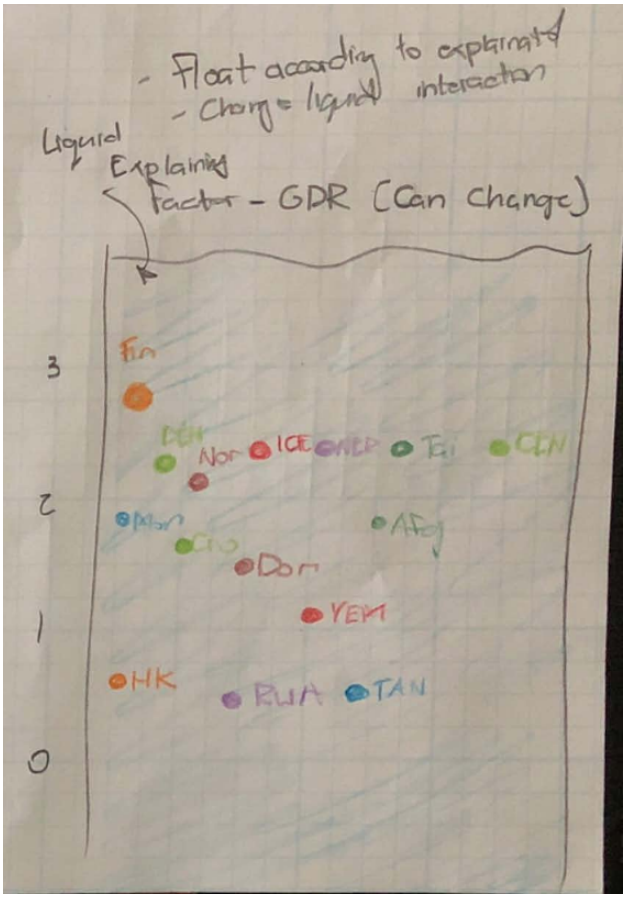


FIG. 81. Subset3 Sketch10: This sketch shows a tubs as the graph. The tub is filled with a liquid. That liquid represents either the happiness score or an explanatory factor. Each country is a ball in that liquid. The ball's buoyancy represents either the happiness score or the power of that explanatory factor in that country.

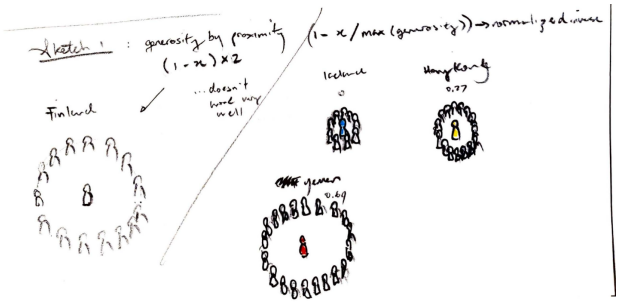


FIG. 82. Subset3 Sketch11: Normalizing the inverse of the generosity measure to translate to proximity. The tighter the circle, the higher impact that generosity has on that country's happiness. However, is misleading and misrepresents the data in subset3 and is better suited for subset1

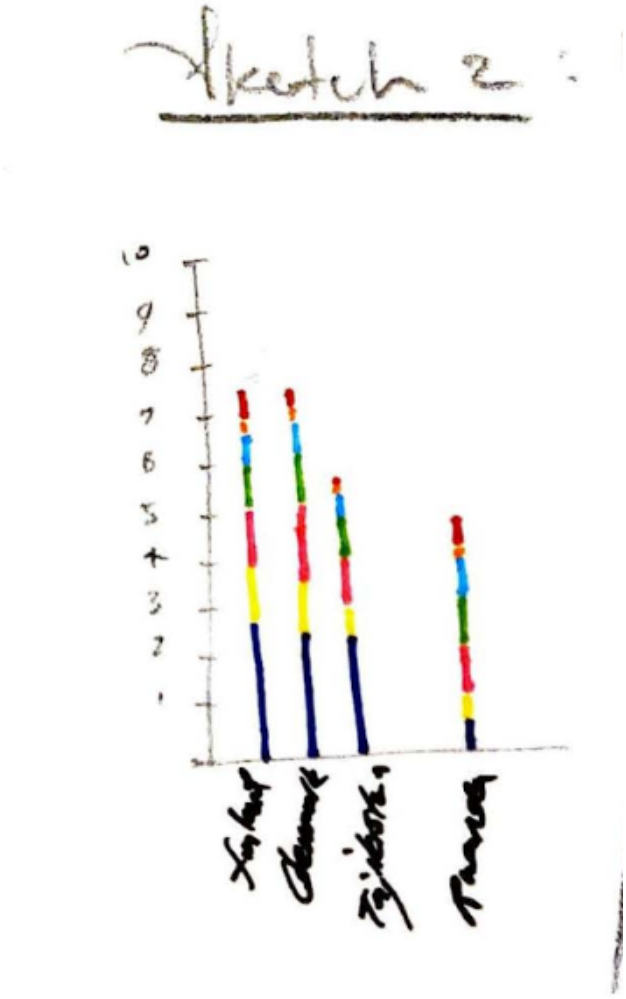


FIG. 83. Subset3 Sketch12: Classic stacked bar chart of happiness and the measures that sum it up.

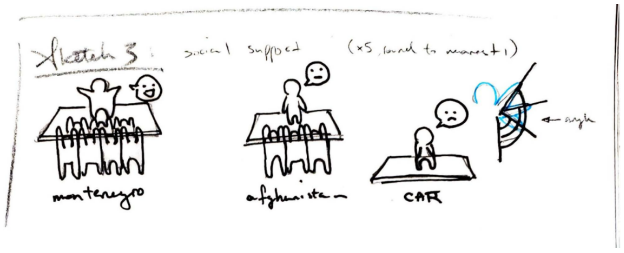


FIG. 84. Subset3 Sketch13: Multiplying the social support measure and rounding to the nearest whole number to generate a number of people to hold up the platform. The more people present underneath, the higher the contribution of social support to that country's happiness. Also considered tying arm angle to this number. However, is misleading and misrepresents the data in subset3 and is better suited for subset1

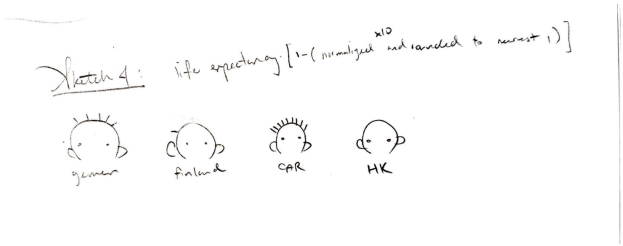


FIG. 85. Subset3 Sketch14: Taking the inverse of the normalized and rounded life expectancy measure. The less hairs, the higher the contribution of life expectancy to that country's happiness. However, is misleading and misrepresents the data in subset3 and is better suited for subset1.

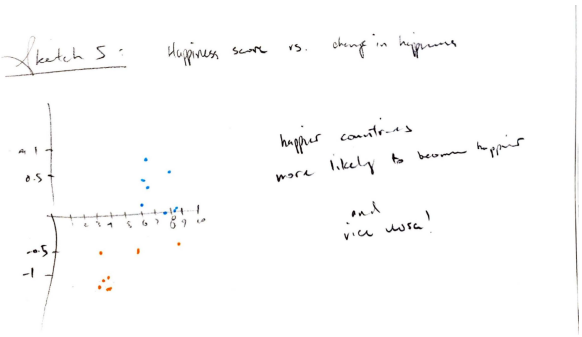


FIG. 86. Subset3 Sketch15: Plotting happiness and change in happiness. It turns out that countries that are already happy tend to continue becoming happier, while countries that have less happiness tend to continue declining in happiness.

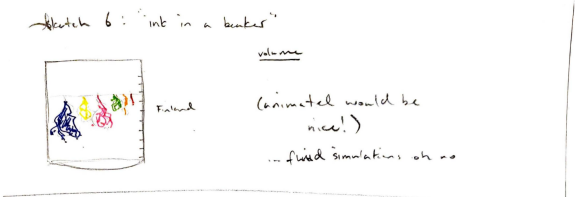


FIG. 87. Subset3 Sketch16: The proportional contribution of each measure is showed as ink spreading in a beaker until fully mixed into a unique colour. Seems like it would be pretty when animated.

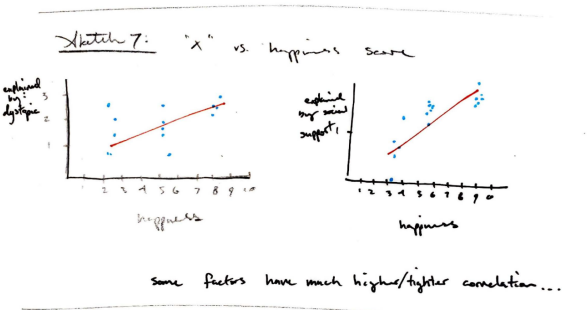


FIG. 88. Subset3 Sketch17: Plotting happiness against individual measures to see which measures tend to have more impact on the happiness score.

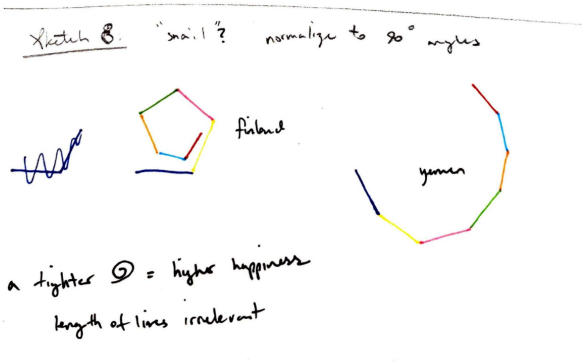


FIG. 89. Subset3 Sketch18: Normalizing the measures to fit between 0-90 degrees. The tighter the spiral, the happier the country. The length of each line is irrelevant.

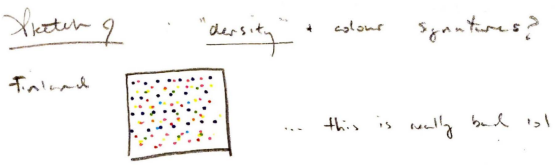


FIG. 90. Subset3 Sketch19: A density plot. However, there are too many colours and too many points and is not useful at all.

Appendix C: Variation Sketches

What follows is all of the 30 variation ideation sketches that were drawn from the initial sketches

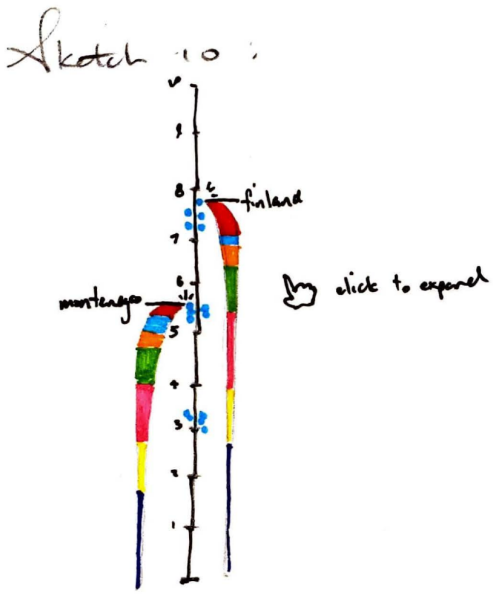


FIG. 91. Subset3 Sketch20: Plotting all countries on a happiness scale, and expanding the country's breakdown of measures upon clicking each point.

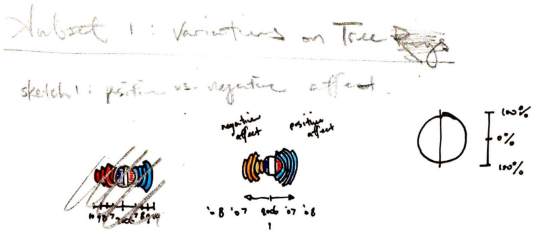


FIG. 92. Subset1 Variation1: Positive affect vs negative affect. The center is the earliest year (2006) and counts up the further away from the center. The measure translates to distance between angles, centered on the horizontal axis.

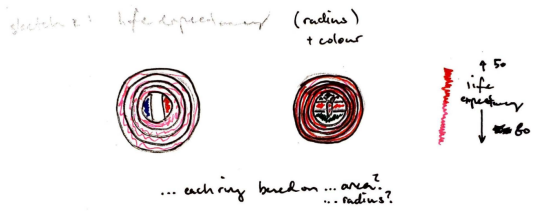


FIG. 93. Subset1 Variation2:Tree rings representing life expectancy. Higher life expectancy is pink, while lower is red. The distance between rings is also dependent on the life expectancy of that year, so shorter life expectancies result in a small overall tree ring chart.

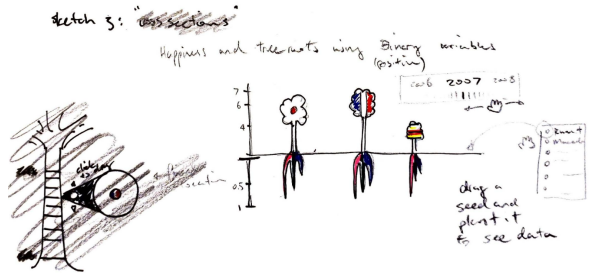


FIG. 94. Subset1 Variation3: Continuing with the tree metaphor but branching away from tree rings; showing only the variables measured in binary averages and the life ladder rating of that country, by year. Show data for new countries by dragging its ”seed” (legend) into the ”soil” (horizontal axis).

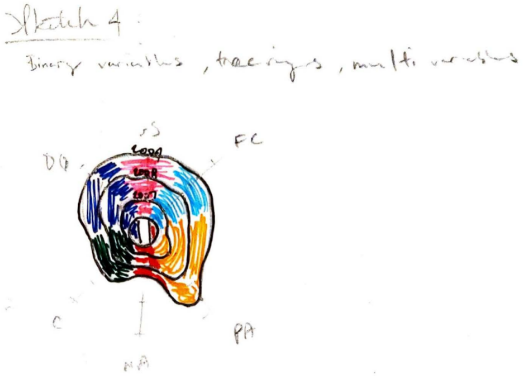


FIG. 95. Subset1 Variation4: Showing variables of binary average by year to emphasize growth or decline in each variable over time.

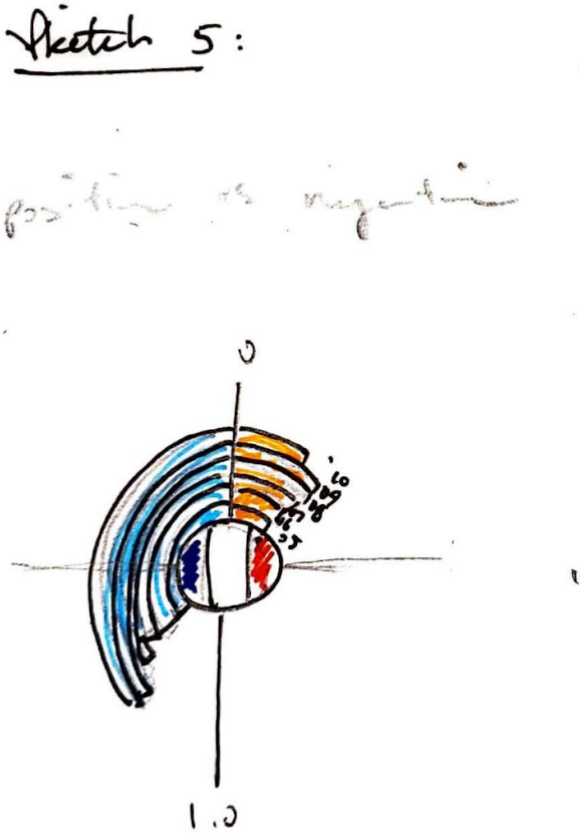


FIG. 96. Subset1 Variation5: Positive vs negative affect, starting from the y axis.

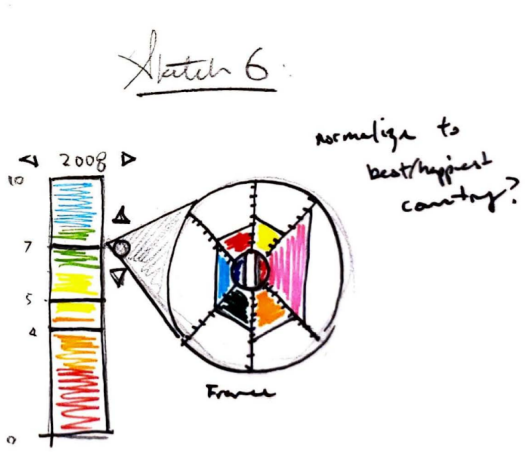


FIG. 97. Subset1 Variation6: Taking cross sections from the life ladder rating and showing measures (non binary measures such as life expectancy and GDP are normalized to the maximum values in the subset), by year.

FIG. 98. Subset1 Variation7: Direct country vs country comparisons of measures. Non binary measures such as life expectancy and GDP are normalized to the maximum values in the subset, by year.

FIG. 99. Subset1 Variation8: Highly similar to Subset1 Variation5, but for all measures. Non binary measures such as life expectancy and GDP are normalized to the maximum values in the subset, by year.

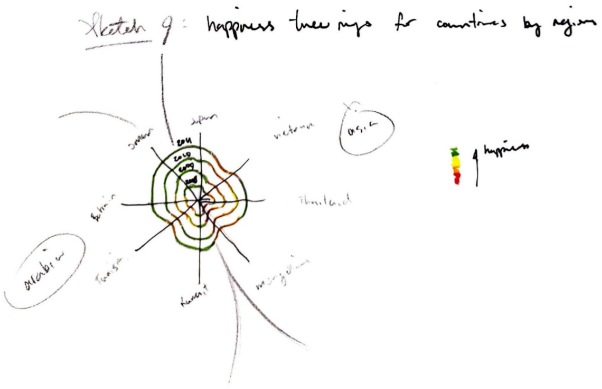


FIG. 100. Subset1 Variation9: Showing happiness levels by year for every country, grouped by proximity and region. Happiness values for each year are encoded in colour, thus showing periods of growth and decline and overall standing on a global/regional scale. Would be interesting to have interactive elements to choose time periods.

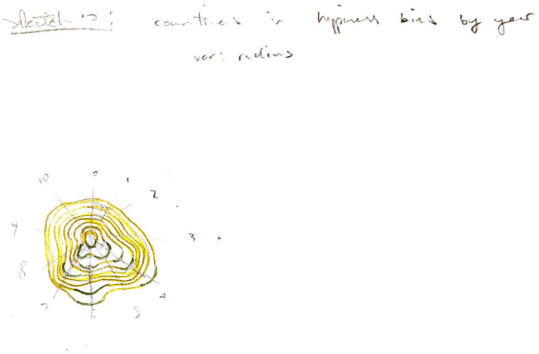


FIG. 101. Subset1 Variation10: Binning countries into nearest whole number values for life ladder rating. Shows overall trends in global life-ladder rating growth or decline by year. Yellow indicates no change for that bin, green indicates new data points in that bin.

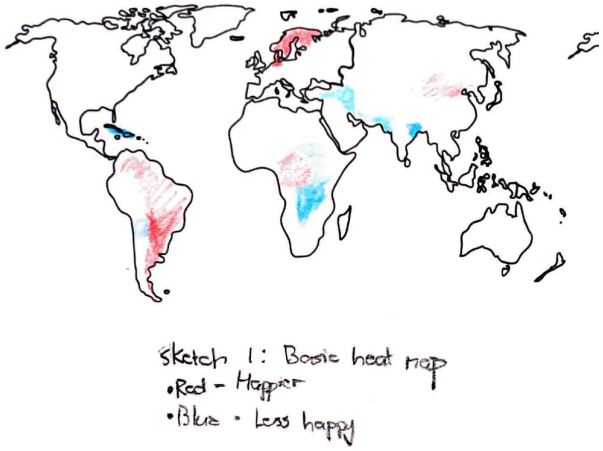


FIG. 102. Subset2 Variation1: A simple heatmap of happiness scores, the redder the country the happier and the bluer the less happy.

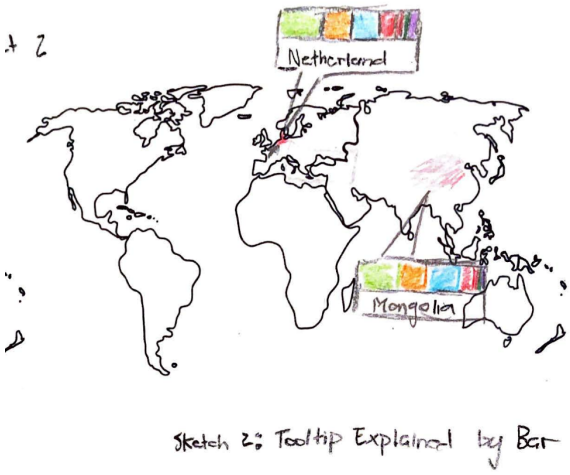


FIG. 103. Subset2 Variation2: A simple heat map from Subset2 Variation1 overlaid with a tooltip. That tooltip has a bar that shows the percentage each explanatory factor was able to explain the happiness score.

FIG. 104. Subset2 Variation3: Similar to Variation2, however has the tooltip represented in a circle with the percentages as arcs that circle.

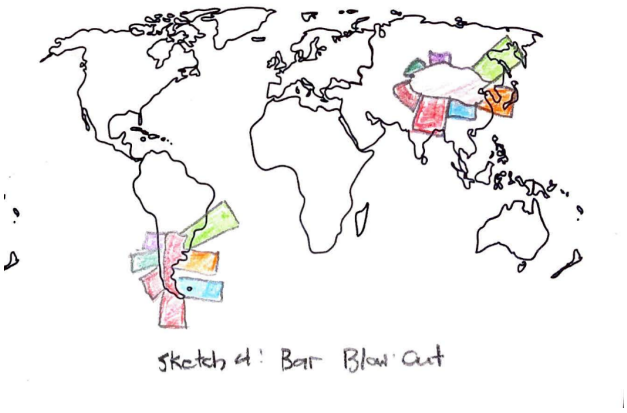


FIG. 105. Subset2 Variation4: Heatmap of variation1 with each country having a bars coming out of it when hovered over with each bar showing the power of a explanatory factor in that country.

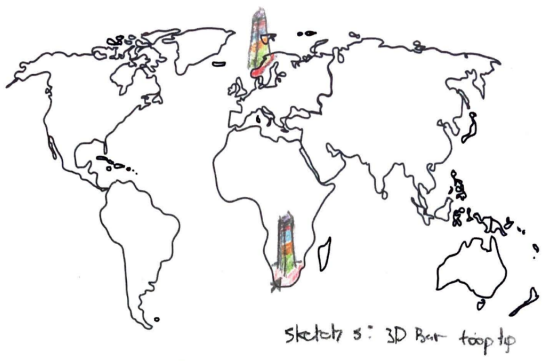


FIG. 106. Subset2 Variation5: The heatmap of variation1 with situated stacked bars with hovered over. The percent that each section takes up shows the percentage of the happiness score that could be explained by a given explanatory factor.

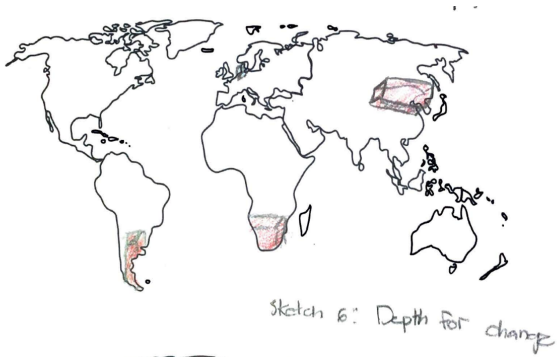


FIG. 107. Subset2 Variation6: The heat map of variation1, but each country is either protruding out or in. The height of protruding out shows the increase in happiness score (higher, more happy) and the depth of the protruding in shows the decrease in happiness (deeper, less happy)

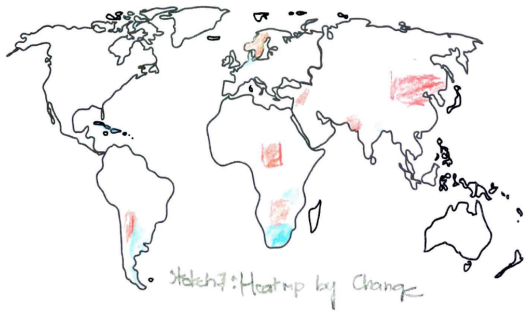


FIG. 108. Subset2 Variation7: Heatmap, but instead of representing the happiness score, shows the change in happiness. (more red more happy and more blue less happy).

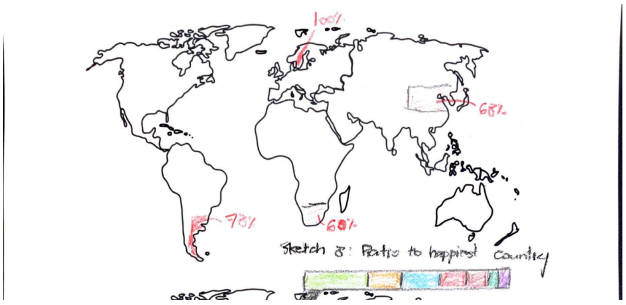


FIG. 109. Subset2 Variation8: Heatmap similar to variation1, but with tooltips that shows the ratio of that country's happiness compared to the happiest country.

FIG. 110. Subset2 Variation9: Similar with variation2, but with the bar's total size representing the happiness score.

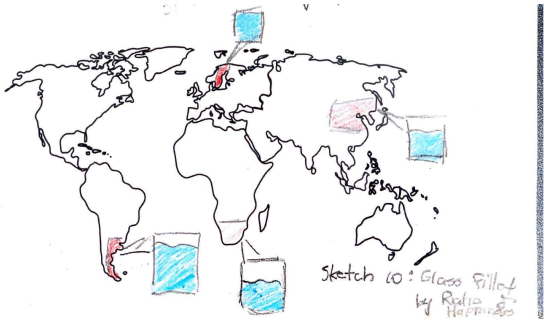


FIG. 111. Subset2 Variation10: Similar to variation8, but instead of just writing the percentage, shows the ratio of a country's happiness compared to the most happy country as water in the cup. The more water, the closer it is to the happiest country.

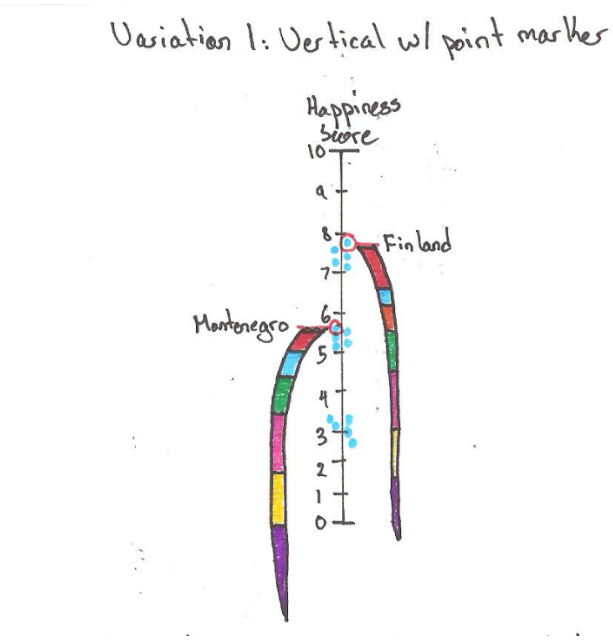


FIG. 112. Subset3 Variation1: A small variation on the expandable number line plot. Added a red point marker for selected points.

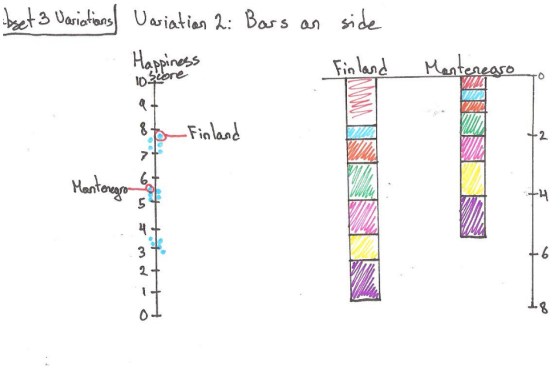


FIG. 113. Subset3 Variation2: Variation 2 moves the toggle-able bar charts to the side, separate from the graph.

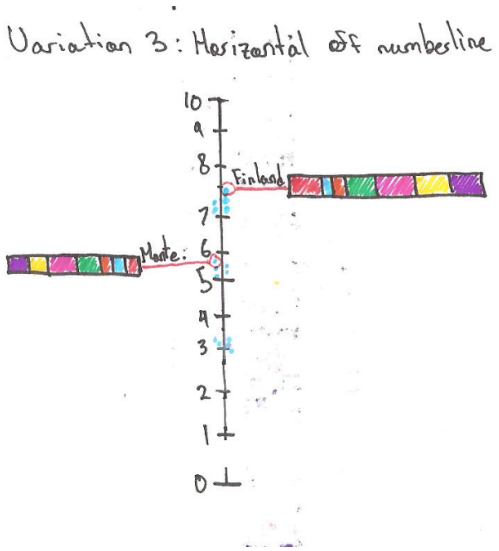


FIG. 114. Subset3 Variation3: Variation 3 changes the orientation of the bars to be horizontal and removes the tapering. This variation appears to be harder to directly compare than the vertical orientations.

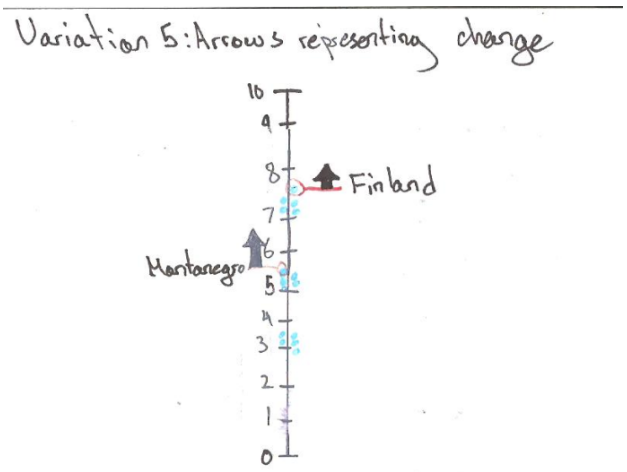


FIG. 116. Subset3 Variation5: Removal of bars in favour of arrows representing the magnitude of the change in happiness score compared to the previous year rather than details about the score.

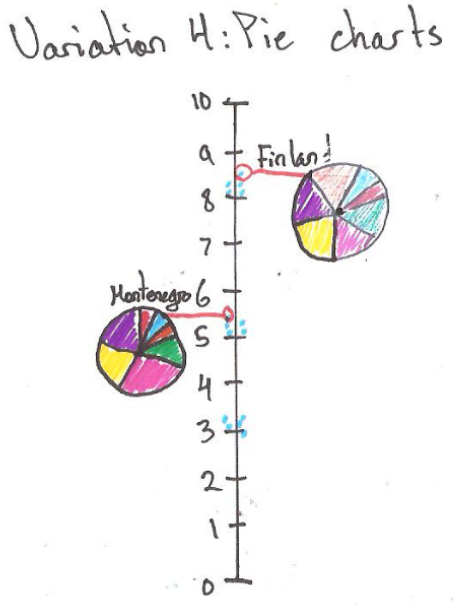


FIG. 115. Subset3 Variation4: Rather than bars, pie charts are used. While this helps with internal comparison of the components of the happiness score, it appears to hinder inter-comparison somewhat at first glance.

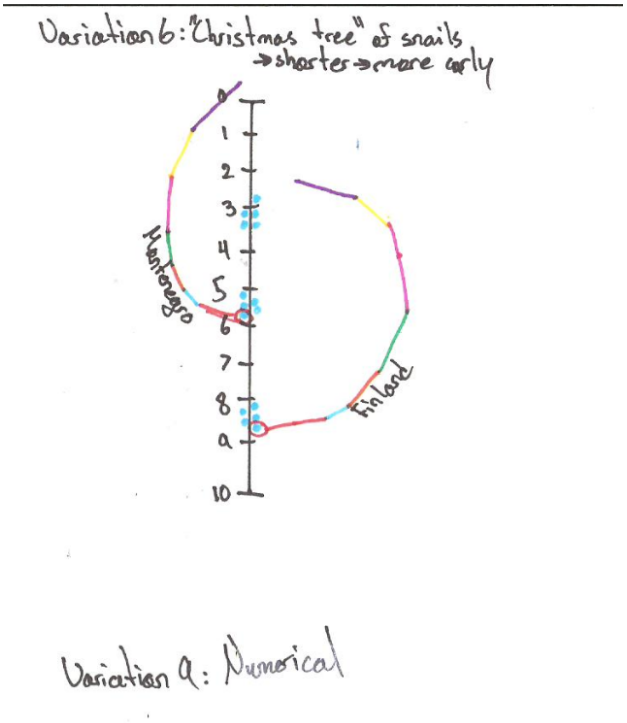


FIG. 117. Subset3 Variation6: Bars are modified slightly to lines which curve inwards with a radius based on their length. Higher scores curve less quickly, while smaller scores curve more quickly and can be nested inside larger scores.

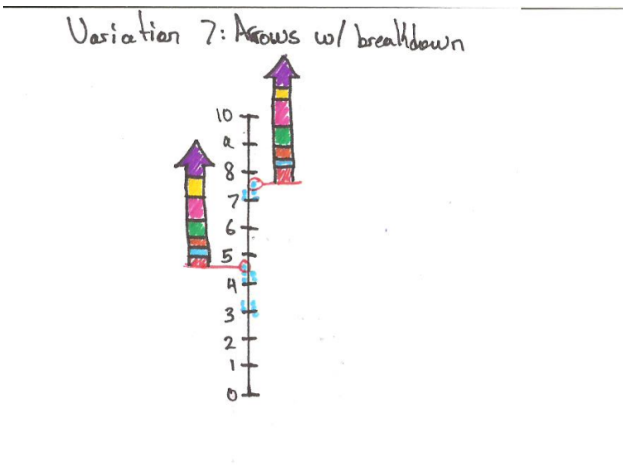


FIG. 118. Subset3 Variation7: Arrows representing the direction. Magnitude of the arrows is not important. Composed of the different metric values.

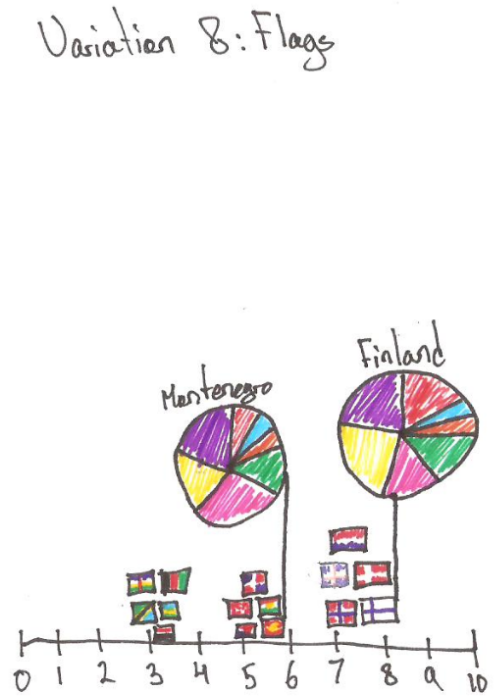


FIG. 119. Subset3 Variation8: Here, flags are substituted in place of points. Provides more information than points, but takes up more space.

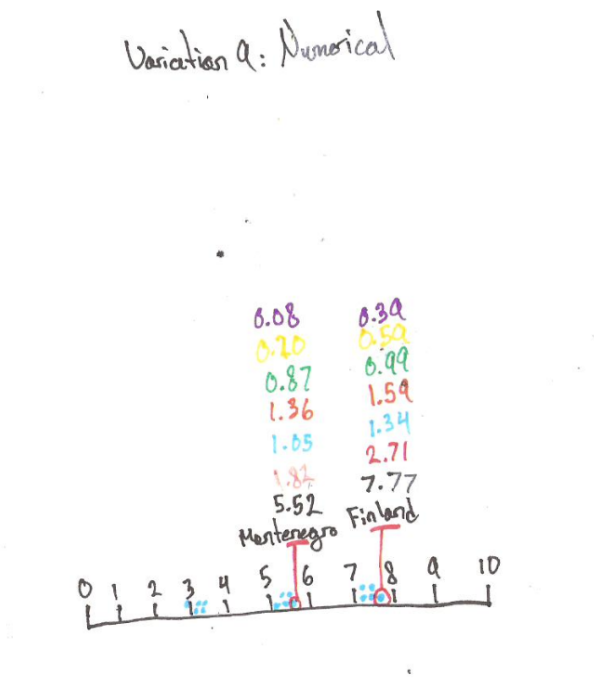


FIG. 120. Subset3 Variation9: Instead of bars, numerical values are used, coloured to match their metric.

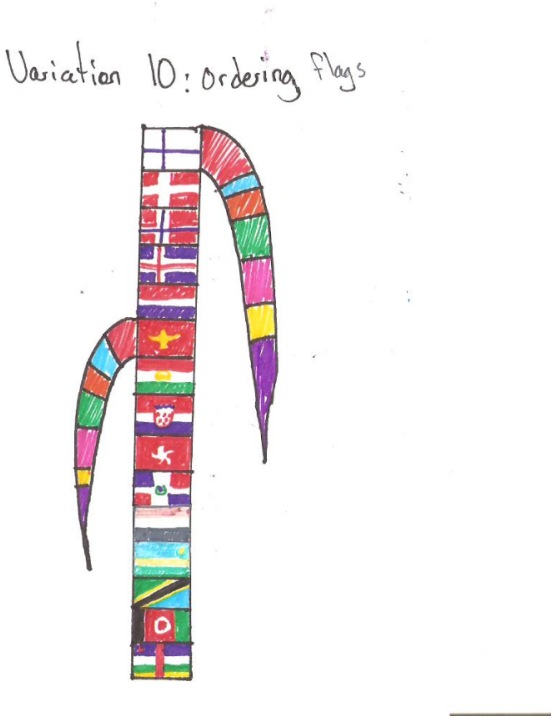


FIG. 121. Subset3 Variation10: In this variation, the number line is scrapped in favour of ordering flag icons based on decreasing score.