Analysis of Color Scheme and Usability

How does color affect user behavior?

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CSE 8316
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Abstract

In this project, I attempted to collect and analyze usability data based off one independent variable: color scheme. I implemented a custom website that utilizes A/B testing to collect data on users. The site, a simple user survey, collected usability information like success rate, time to completion, and overall user satisfaction. Variation came from changing the primary and accent colors of the website for different users. I then analyzed the resulting data in order to better predict how color scheme influences user behavior.

My hypothesis for this experiment was as follows:

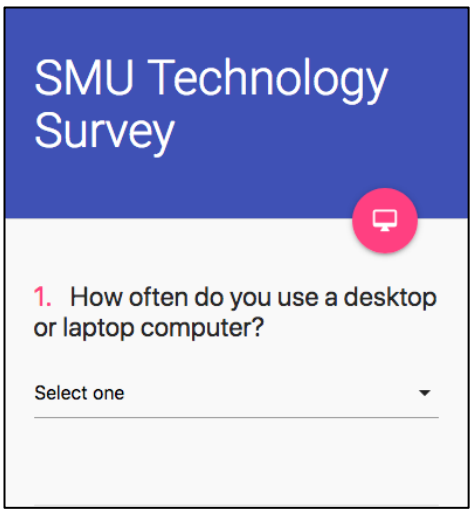
Difference in a website's color scheme will account for a measurable difference in user behavior.

Background Problem

Designers often have to make difficult decisions when choosing to implement a design. When given two options, which should designers choose? One problem in this decision making process is a real lack of data associated when choosing things like colors, fonts, and overall design styles. Most designers have to make decisions based off customer preference, but if given the choice, what are the perfect design decisions to make? Thankfully, a technique called A/B testing was created to help designers use data to decide. With A/B testing, designers give users different versions of the same website and collect information on user behavior in order to improve usability.

Strategy

My plan for testing my hypothesis was to implement a website that utilized this A/B testing technique and then to analyze the resulting user data to see if I could detect a noticeable difference in user behavior across color schemes. My plan could be broken down as follows:

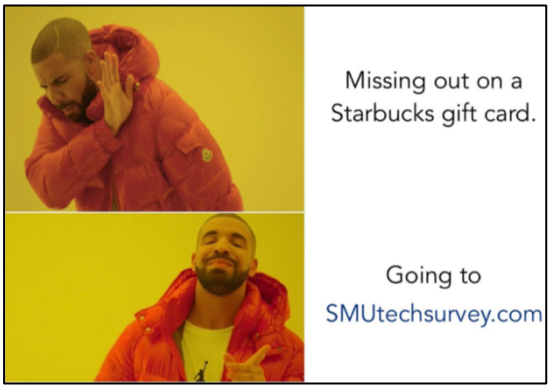


Part 1: Build the Site

I first implemented a custom website that featured built in A/B testing of different color schemes: i.e. a site that changed colors for different users. This site was in the form of a basic survey that users completed. It was hosted at SMUTechSurvey.com to allow users to easily reach the survey.

In order to meet the complex requirements, I knew from the beginning that the website would have to be implemented from scratch. The development took about three weeks, including testing. For a detailed explanation of the implementation, see Technical Implementation.

Part 2: Spread the Word



When the website was complete, I posted flyers and distributed small leaflets around SMU's campus that encouraged people to fill out the form. Using the chance to win a $25 Starbucks gift card as motivation, my plan was to get as many students to fill out the form in a week as possible. I mainly targeted Fondren Library, because I thought that would attract the broadest and most representative set of SMU students. I also tried not to tell many friends about the website, because I thought our relationship would add bias to their responses.

Part 3: Process and Analyzing Data

```
df = pd.read_json('./Data/db_export.csv',
                  encoding='ISO-8859-1')
df = df.drop(['email'], axis=1)
df[df.columns[-3:]].describe()
```

	computerButtonClicked	themeChosen	timeToComplete
count	58.000000	58.000000	58.000000
mean	0.051724	2.672414	108.829293
std	0.291542	1.114308	60.477376
min	0.000000	1.000000	51.131000
25%	0.000000	2.000000	75.006750
50%	0.000000	3.000000	86.352000
75%	0.000000	4.000000	120.200250
max	2.000000	4.000000	412.624000

A Pandas data frame from the Notebook describing some of the user data collected.

The final part of this project was an analysis of the data collected. The main focus of this analysis was to see if any conclusions about usability could be drawn based off changing color scheme.

To accomplish this, I exported the data collected from the site into a Jupyter Notebook, which is an interactive document for sharing data visualizations. I then used the Python libraries Pandas and Matplotlib to process and visualize the data from the site. I wrote this Notebook to be as dynamic as possible, so if I wanted to collect more data in the future, there would be no need to change any of the code that produces the visualizations.

To see the complete Notebook, see Appendix: Source Code and Data Analysis.
For a complete analysis of the data, see Results.

The Website

Questions Asked and Data Collected

The survey itself consisted of 17 simple questions. The first 10 questions asked students about their use of technology - how much they used technology, how technologically savvy they were, and basic demographic questions. I thought this information would be useful later to weight user responses.

The last seven questions were based off the NASA Task Load Index [1] or NASA-TLX. This assessment tool helps to measure the effort that the users put into a task by asking questions about mental demand and exertion. I used this evaluation technique and adapted it to fit my

survey, because it included questions like *"How rushed were you while completing this task?"* and *"How frustrated did completing this task make you?"*, which I believed would correlate with color scheme.

The site also kept track of basic user behavioral information like the time it took to complete the form and whether or not the form was completed, as well as other technical statistical data that could be used to analyze user behavior. I theorized that these too would be affected by color scheme.

The animation that played over the computer button as users clicked.

But I was also curious to see if color also affected a user's desire to take an action. So I created a dummy button that appeared on every page of the form. This button, which had a computer icon, did absolutely nothing for the user except play an animation when the user clicked or tapped. In the background, however, the site was keeping track of how many times that button was clicked. I thought that different color buttons would make users more or less likely to click.

For a complete list of questions asked, see Appendix: Survey Questions.

Technical Implementation

The software implementation of the website followes a simple LEMP (Linux, Nginx, MySQL, PHP) stack. Users fill out an HTML5 form that is posted to a MySQL database using PHP. Responses are stored in the database as JSON dictionaries of questions and the user responses.

```
@import 'materialize';

.heading, #nextBtn {
    @extend .red;
}
```

NEXT

Extending Materialize with SASS to create the red button in Theme 3.

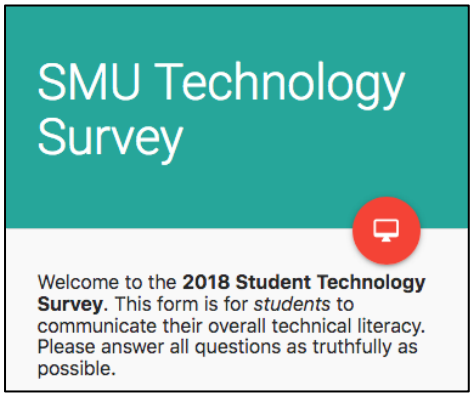
The website utilizes the CSS extension SASS and the JavaScript framework jQuery to display a responsive frontend to the user. I used the CSS library Materialize [2] to bootstrap most of the styling for the site. I chose to use SASS because it allows developers to use inheritance in stylesheets. This way, I had a base stylesheet that controlled the look and feel of the website. Then four stylesheets all with different color schemes inherited from this base stylesheet.

The backend was developed in the lightweight PHP framework Slim 3. For development, I ran a virtual server on my local machine using VirtualBox and Vagrant. Once development was finished, I pushed the site to a production Linux server under the domain smutechsurvey.com.

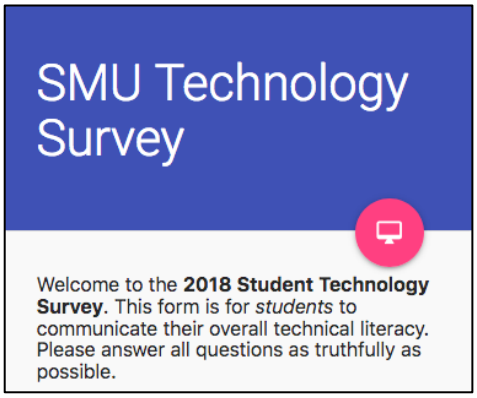
Colors Schemes

I selected four color schemes to act as the different themes that could be presented to the user. Each theme was designed to bring about a specific behavior. Themes 1 and 2 featured "cooler" primary colors: teal and indigo. I hypothesized that these colors would slow down the pace at which the user completed the form. The first two themes also had brighter accent colors: red and pink. These were meant to urge the user to click on the "Computer Button" that was present at the top of the site.

Theme 3 was the inverse of Theme 2 - it featured a "warmer" primary theme color and a cooler accent theme color (red and light blue, respectively). This theme was meant to make the user feel rushed and ultimately decrease the time it took to complete the form.

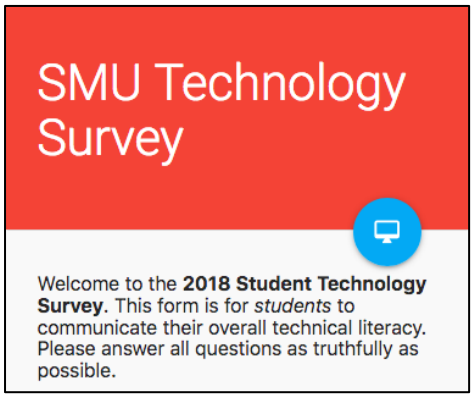


Theme 1: Teal and Red



Theme 2: Indigo and Pink

Theme 4 was meant to be more of a wild card: a theme that was purposefully bad to annoy the user. The purple color used is actually supposed to be used as an accent and not the main color of a site. The reverse is true for the yellow color used: it is supposed to be a primary color of a site but was used as an accent. I thought these colors would make text more difficult to read and the website generally less pleasant to look at, which would be reflected in the user's responses on the last page of the form. However, Theme 4 wasn't meant to be so bad that the user could not use the site at all.



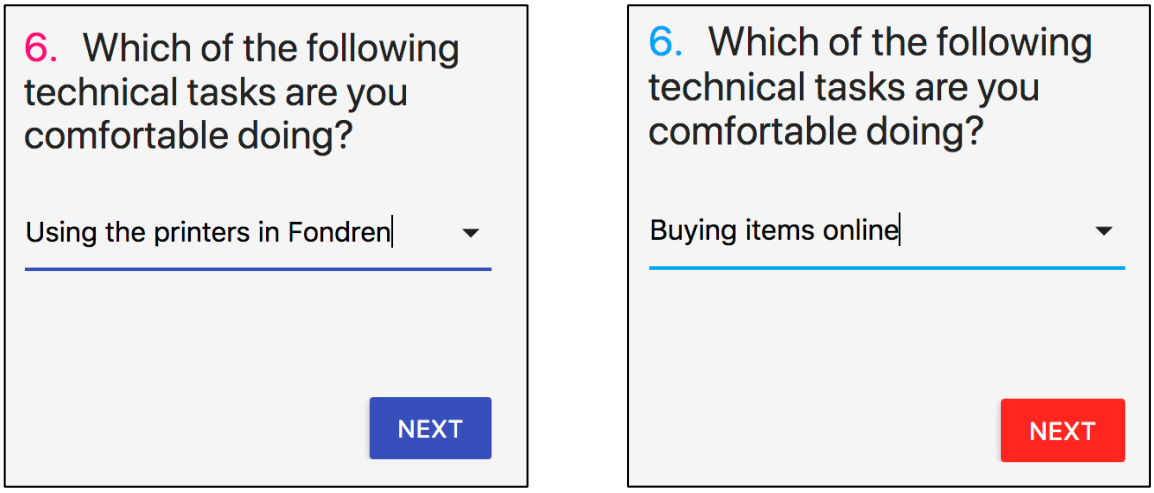
Theme 3: Red and Light Blue

Theme 4: Purple and Yellow

Material Design

The website followed the rules laid out in Google's Material Design Principles [3]. I went with a material design, because I wanted the site to mimic the look and feel of a Google Forms survey. I thought this would make user less suspicious of the form they were filling out.

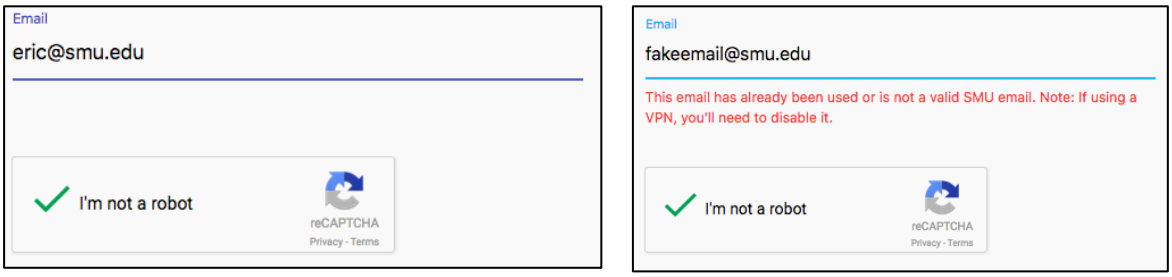
All the elements of the site (buttons, dropdowns, text fields, etc.) matched those elements found on a Google Forms survey. However, each of these elements changed with the color scheme that the user was given. This attention in detail was time consuming, but ultimately worth it.



An example of elements changing based off the site's random color scheme.

Security Considerations

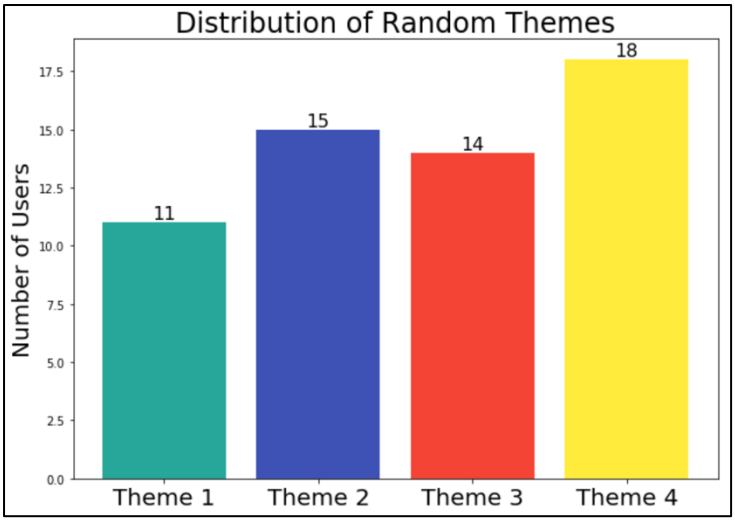
Because this survey was distributed on a college campus, there was a high possibility that someone with enough technical knowledge would try to tamper with the site. For this reason, I implemented several features to try to improve the security of the form. The first, a Google reCaptcha prevented any malicious bots from filling out the form. Furthermore, an email text field allowed only those users with an SMU email to access the form. This email field didn't just validate the text of the email a user provided, it also queried SMU's email servers to see if the email existed. This way, users had to use a *valid* SMU email to access the form. All user input was also validated before the form could be submitted, and strings were escaped on the backend before being processed to prevent injection attacks.



Examples of real and fake emails being used to try to access the site.

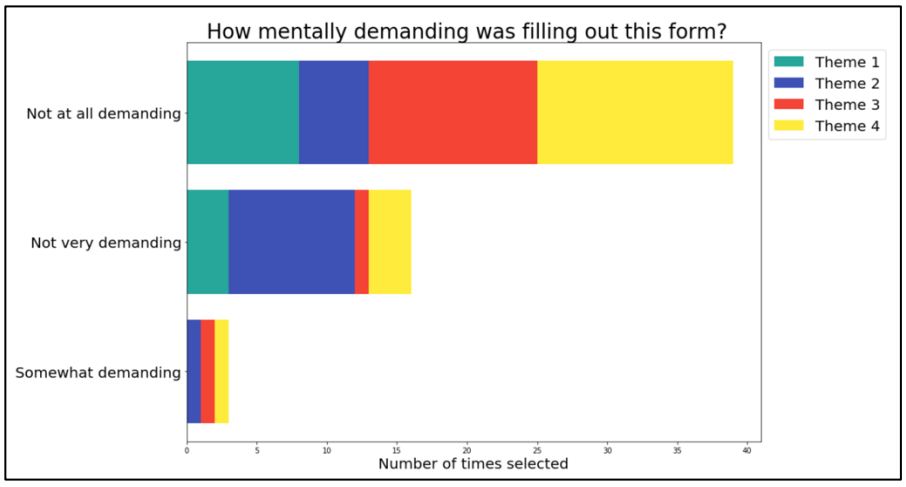
Results

Over the course of a week, 58 students responded to the survey. Based off the demographic information collected, the average user was an undergraduate female, aged 20 to 22 with intermediate technical capability. Surprisingly, only 15 men responded to the survey. Most respondents attended Dedman, Lyle, or Cox. 70% of users said that they use a computer more than five hours every day, but only 32% of users said they were comfortable compiling and running Java code. All 58 survey correspondents completed the survey in its entirety.



The random theme generator did an okay job of evenly distributing the different themes to users. Most users were given the wildcard theme, Theme 4. Although this was not ideal, I'm glad that each theme was used at least 10 times.

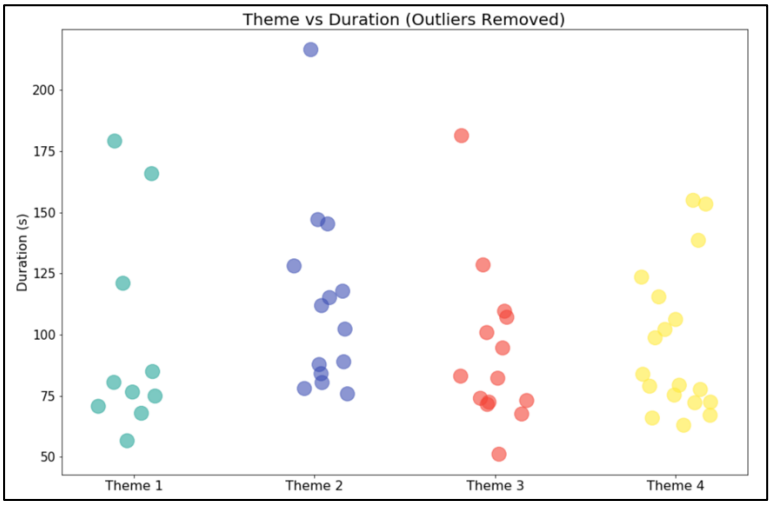
For most of the questions on the last page of the survey (those that were designed to measure usability), results were reasonably consistent across color schemes. For example, those users who were given a vibrant red color scheme were no more likely to say they felt rushed during the process than those who were given calmer indigo or teal color scheme. The same is true for those questions that asked users about mental demand, question difficulty, and overall happiness. This data was consistent across user technical expertise as well.



Survey responses regarding mental demand organized by color scheme.

However, not all of the responses were consistent across color scheme. For example, the final question asked users to recall the very first question of the form. Only two people answered this

question incorrectly, both of whom were given the yellow color scheme. Also, more than half of the users who described themselves as “happy” while using the form were given the red color scheme. Meanwhile, the fake computer button that was on the site was only clicked by two users. One user, who was given Theme 2, clicked their pink button once. The other user, given Theme 4, clicked their purple button twice.



Time of responses by theme (outliers removed)

Interestingly, the median “time to complete” was 30 seconds longer for those users who were given Theme 2, the indigo and pink theme. If outliers are thrown out of the data (those users whose time it took to complete the form was outside three standard deviations), the median time to complete for Theme 2 is still more than 20 seconds more than the other themes.

Results Analysis

My hypothesis, that color scheme would affect user behavior and satisfaction, was certainly not proven through this experiment. However some key takeaways are as follows:

- Color does not appear to affect usability to a measurable degree for users of intermediate technical skills.
- Calmer colors like indigo *may* have an effect on the time it takes users to complete tasks.
- Bright accent colors like pink and purple *may* make users more likely to click on a button.
- Warm colors like red *may* make users describe themselves as “happy”.
- Overwhelming colors like bright yellow *may* reduce the ability of users to retain information.

Areas of Improvement

I certainly do not think that this sample of 58 students (mostly female undergraduates with intermediate tech capabilities) is representative of the entire SMU student population. Nor do I think this is representative of most users. If I were to run the experiment again, I would try to give the survey to a larger and more diverse user base. Also, I wouldn't give these users the incentive of a Starbucks gift card, because this probably introduced some bias into their responses.

As far as technical implementation is concerned, I'm not sure I would have included the reCaptcha at the beginning of the site. These cause a lot of users trouble and may have accounted for a large percentage of users dropping off before they even answered the first question. Also, I wish I had kept track of what type of device people used to take the survey. This website took a long time, and I think that feature just slipped my mind.

Moving Forward

I would be very interested in doing formal academic research on a topic similar to this one. And if I were able to collect enough data, I'm curious to see if I could train a machine learning model to predict user behavior.

Citations

[1] NASA Task Load Index: https://humansystems.arc.nasa.gov/groups/tlx/

[2] Materialize CSS Framework: http://materializecss.com/

[3] Google Material Design Principles: https://material.io/guidelines/

Appendix

Source Code and Data Analysis

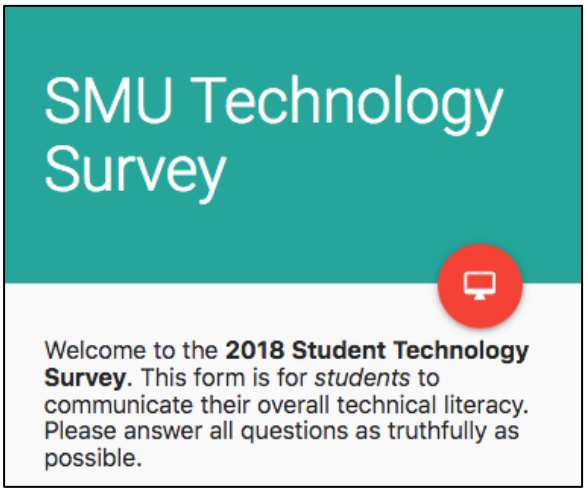
The complete source code of the survey website can be found on my GitHub at https://github.com/smitheric95/AB-Testing-Form.

A live version of the website can be seen at https://SMUTechSurvey.com

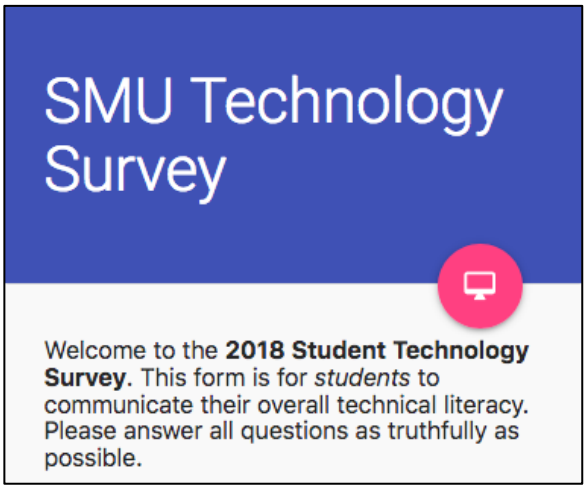
Note: You will need a valid SMU email to take the form. Refresh the page a few times to see it change themes.

The Jupyter Notebook that I made to do all the data analysis can be found at https://github.com/smitheric95/AB-Testing-Form/blob/master/Data Analysis/Survey Data Analysis.ipynb

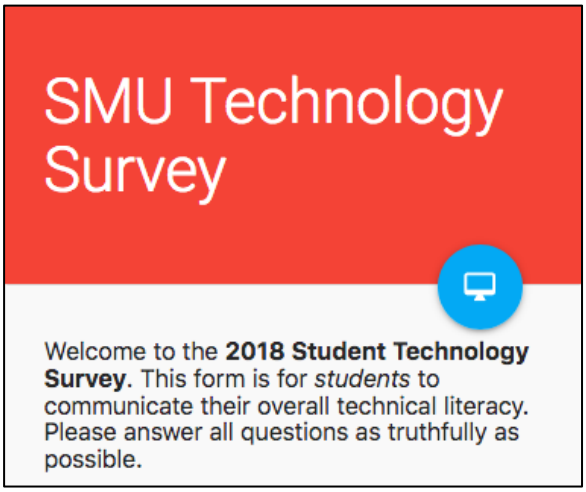
Themes



Theme 1: Teal (#26a69a) and Red (#f44336)



Theme 2: Indigo (#3f51b5) and Pink (#ff4081)



Theme 3: Red (#f44336) and Light Blue (#03a9f4)

Theme 4: Purple (#e040fb) and Yellow (#ffeb3b)

Survey Questions

Section 1

1. How often do you use a desktop or laptop computer?
    - 5+ hours a day
    - < 5 hours a day
    - Not everyday

2. What kind of computer do you own?
    - Mac (MacOS/OSX)
    - PC (Windows)
    - Linux
    - I'm not sure
    - I don't own a computer.

3. What kind of smartphone do you use?
    - iPhone
    - Android
    - I don't own a smartphone.

4. How technologically savvy are you?
    - Expert
    - Intermediate
    - Beginner
    - I'm not sure

5. How relevant is technology to your major?
    - Extremely relevant
    - Somewhat relevant
    - Not very relevant
    - Not at all relevant

6. Which of the following technical tasks are you comfortable doing? (Select all that apply.)
    - Typing a paper in Word
    - Using a classroom projector
    - Compiling and running Java code
    - Using the printers in Fondren
    - Buying items online
    - Python list comprehension

Section 2

1. Which school do you attend?
    - Dedman
    - Dedman Law
    - Meadows
    - Cox
    - Lyle
    - Perkins
    - Simmons

2. What year are you?
    - Undergraduate
    - Graduate
    - PhD Candidate

3. What's your gender?
    - Male
    - Female
    - Other

4. How old are you?
    - 17-19
    - 20-22
    - 23-25
    - 25+

Section 3

1. How rushed did you feel while completing this form?
    - Very rushed
    - Somewhat rushed
    - Not very rushed
    - Not at all rushed

2. How mentally demanding was filling out this form?
    - Very demanding
    - Somewhat demanding
    - Not very demanding
    - Not at all demanding

3. How many questions did you find difficult to answer?
    - Many questions

- A few questions
- No questions

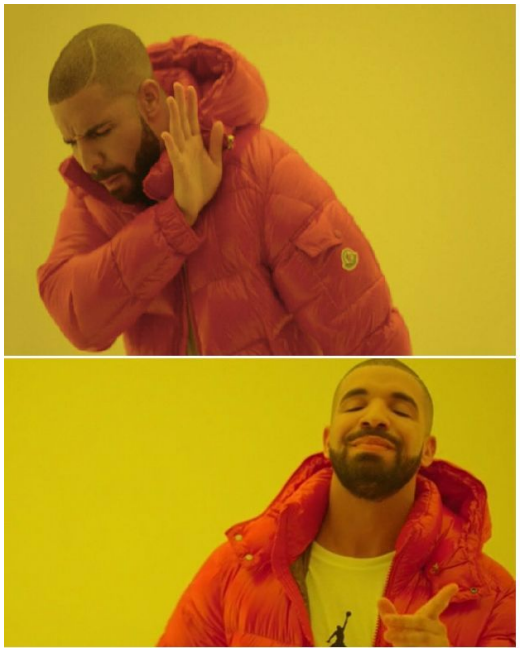
4. How frustrated or confused were you while completing this form?
    - Very frustrated
    - Somewhat frustrated
    - Not very frustrated
    - Not at all frustrated

5. How happy were you completing this form?
    - Happy
    - Somewhat happy
    - Neutral
    - Unhappy

6. How likely are you to share this form?
    - Very likely
    - Somewhat likely
    - Not very likely
    - Not at all likely

7. What was the first question in this form?
    - How often do you use a desktop or laptop computer?
    - What school do you attend?
    - How technologically savvy are you?

Flyers



Missing out on a Starbucks gift card.

Going to SMUtechsurvey.com

Want to win a $25 Starbucks gift card?

Take a quick survey at SMUtechsurvey.com and provide feedback about your technology experience at SMU. You'll be entered for a chance to win a Starbucks gift card.

This survey is for *students* only and must be completed by 4/13. You will be asked to provide your SMU email.

Questions or comments?
Contact: eric@smu.edu

Want a chance to win a $25 Starbucks gift card?

SMUtechsurvey.com

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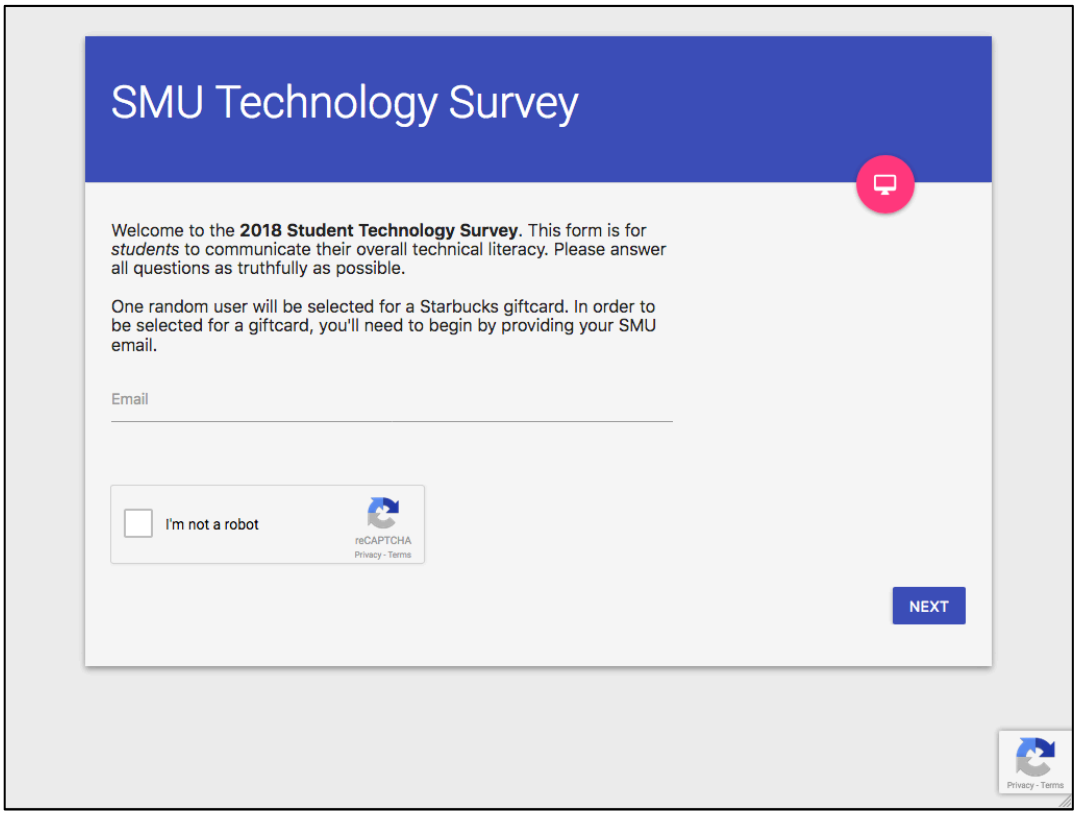
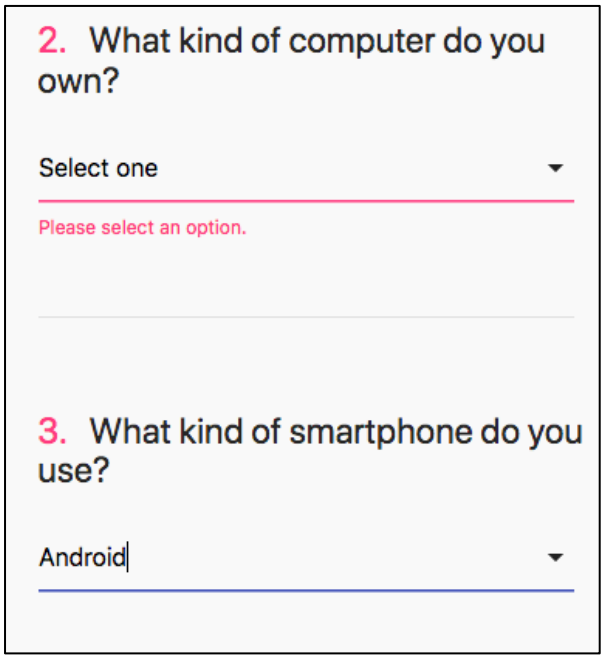
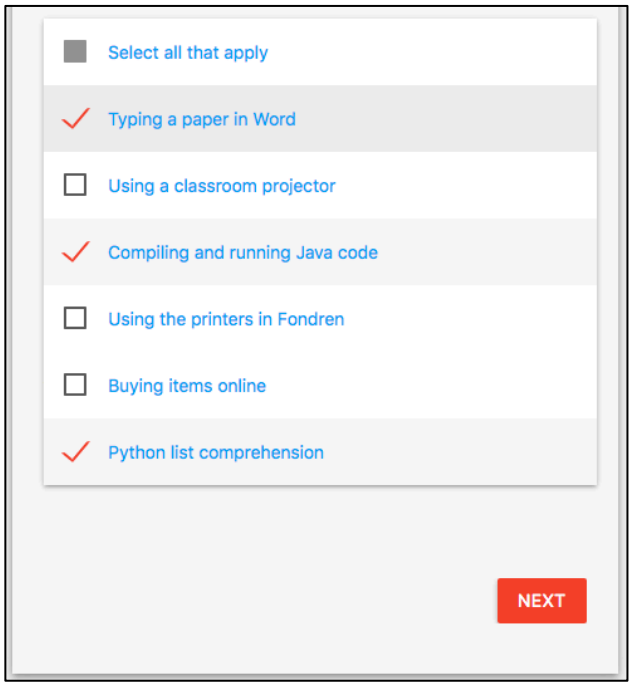
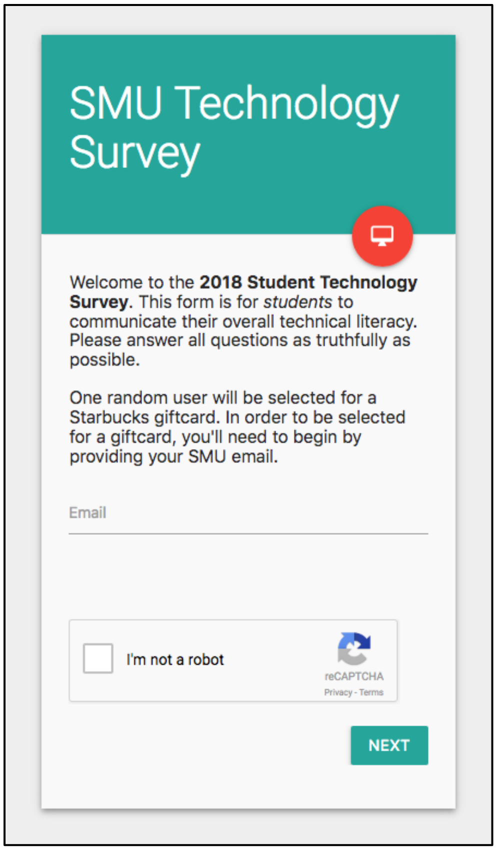
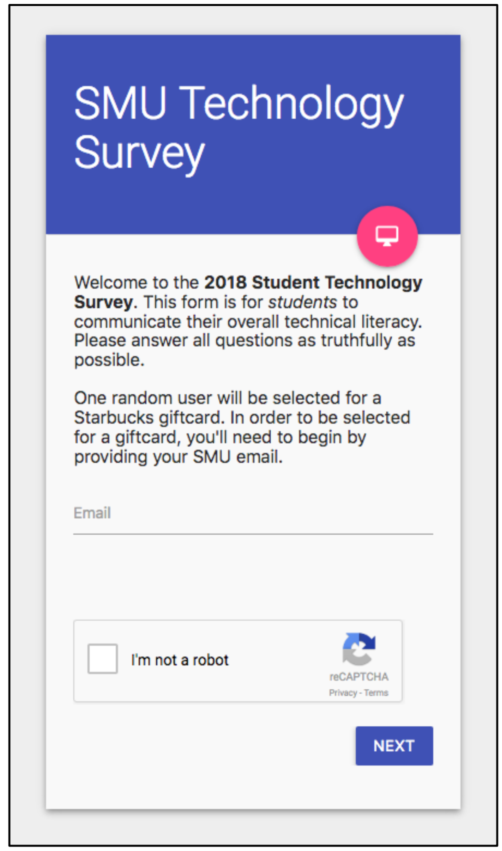
Screenshots








SMU Technology Survey
Welcome to the 2018 Student Technology Survey. This form is for students to communicate their overall technical literacy. Please answer all questions as truthfully as possible.
One random user will be selected for a Starbucks giftcard. In order to be selected for a giftcard, you'll need to begin by providing your SMU email.
Email
I'm not a robot
reCAPTCHA
Privacy - Terms
NEXT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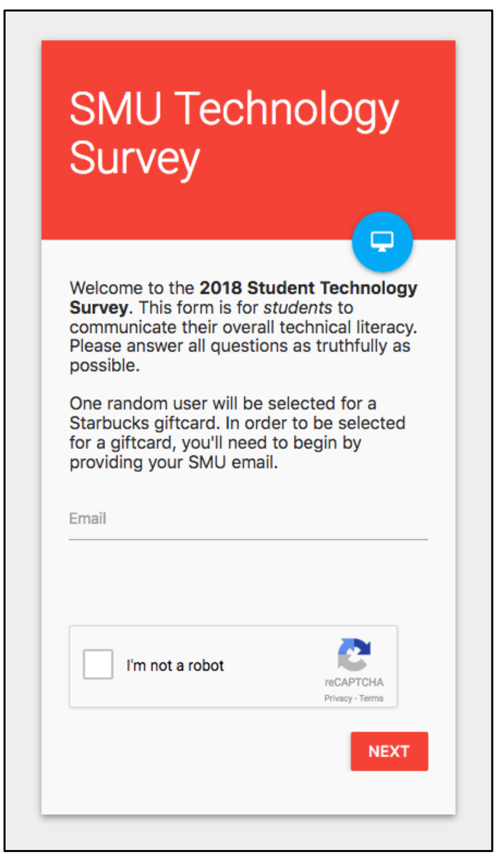
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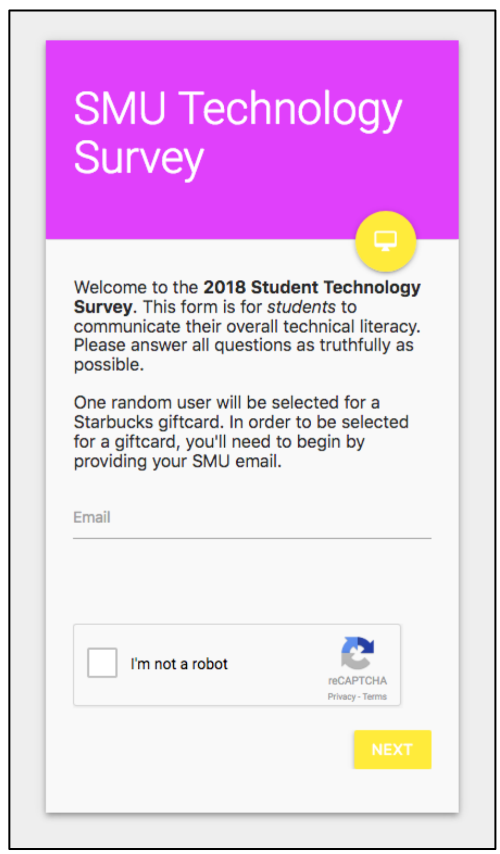
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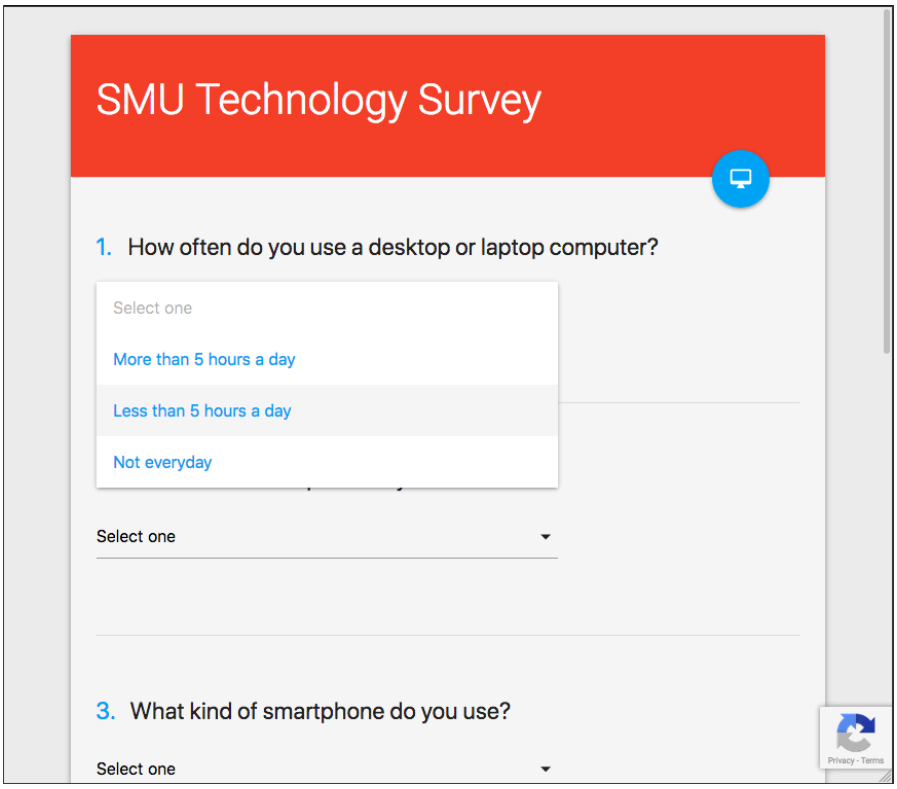


3. How many questions did you find difficult to answer?

A few questions

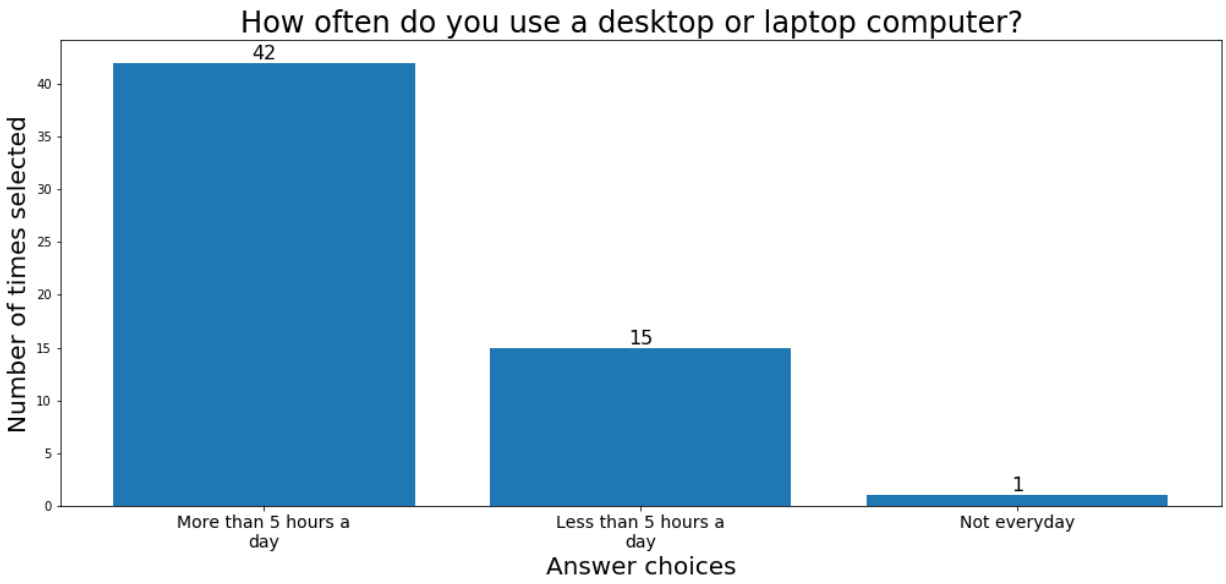
4. How frustrated or confused were you while completing this form?

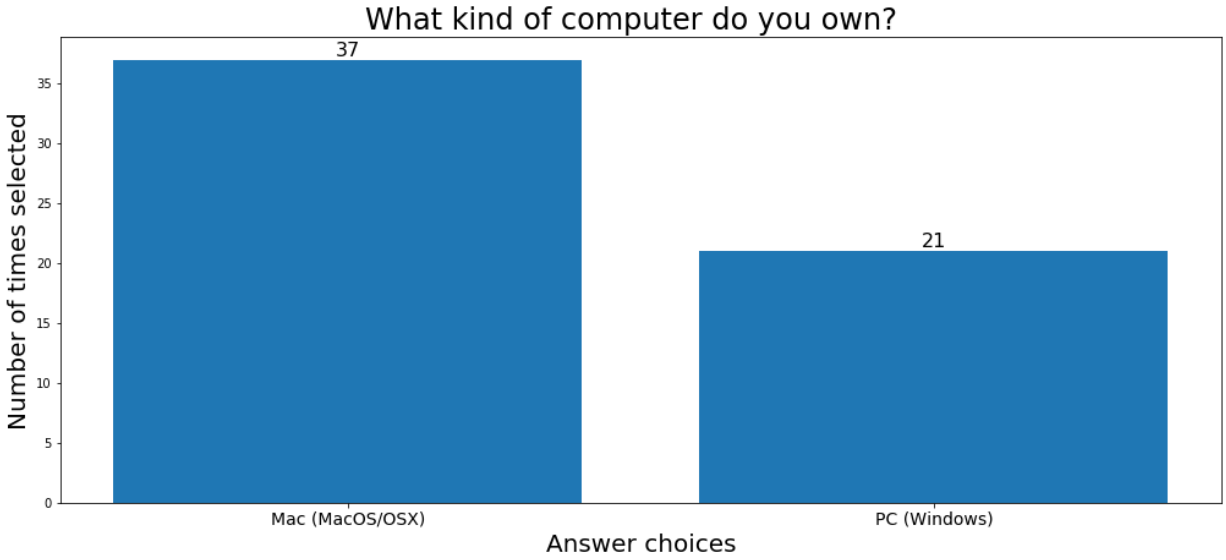
Somewhat frustrated

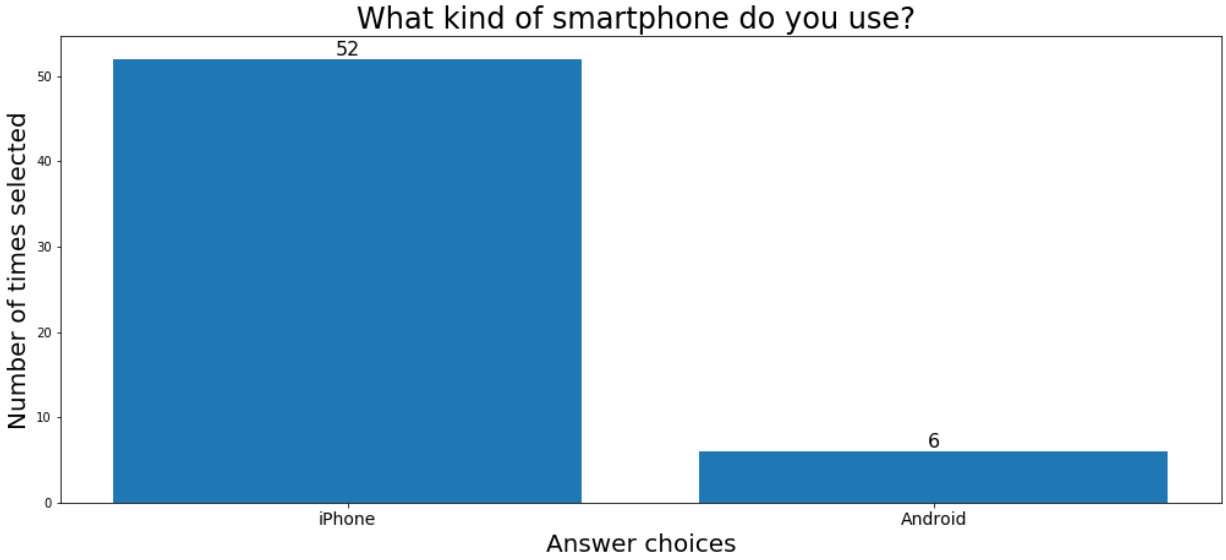
5. How happy were you completing this form?

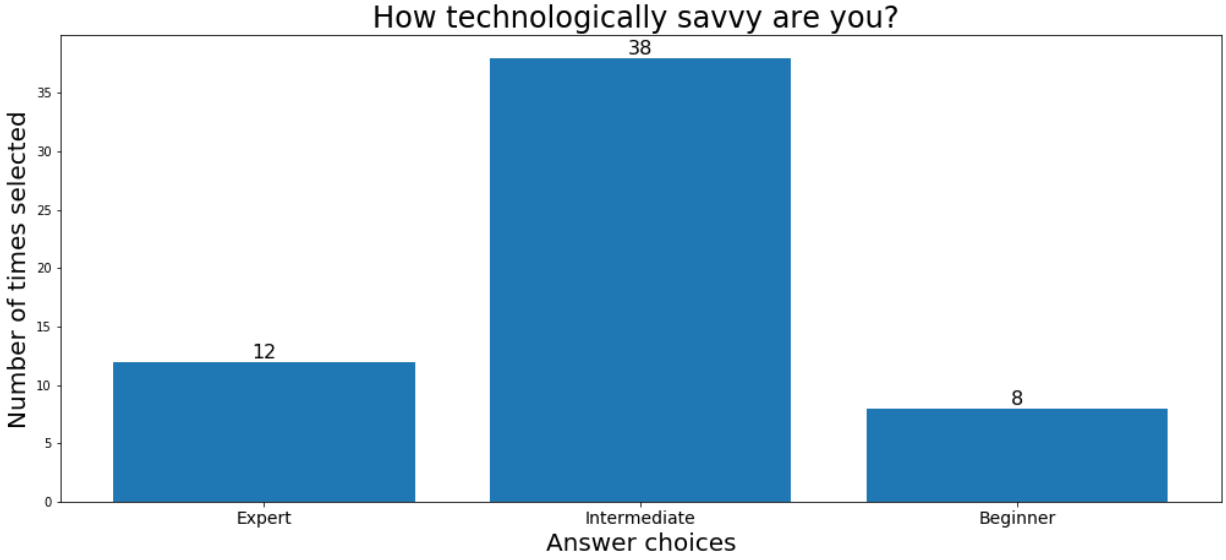
Happy

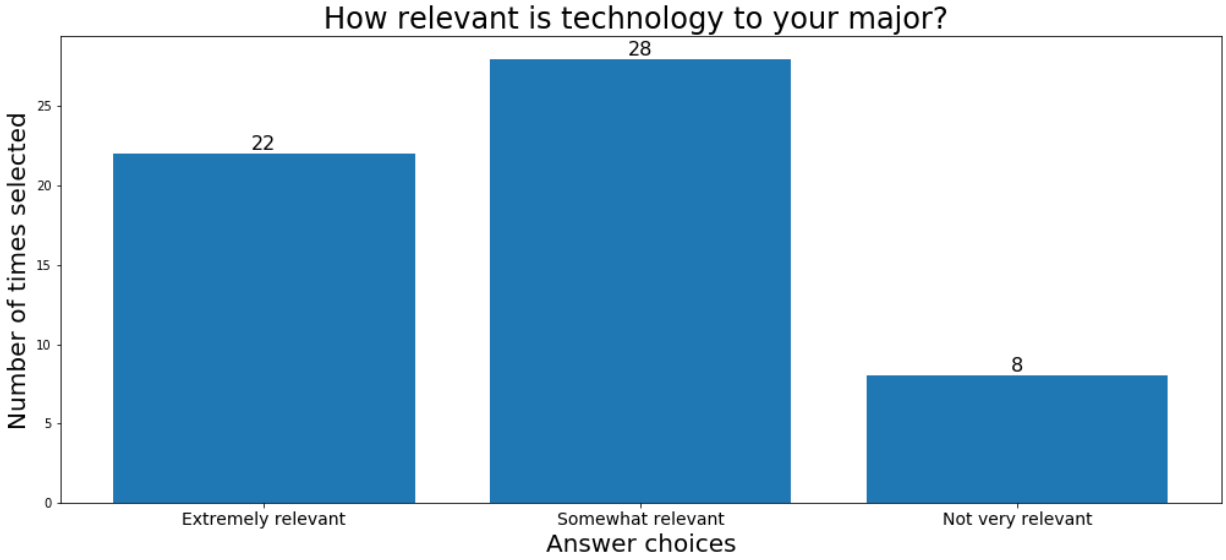
Graphs

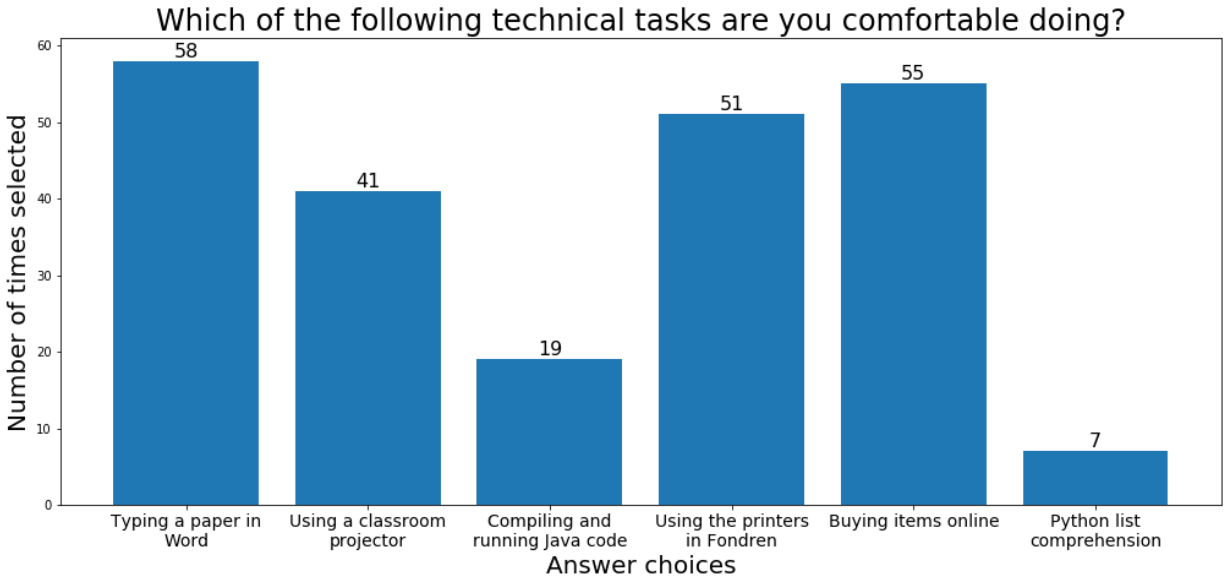

How often do you use a desktop or laptop computer?
Number of times selected
42
15
1
More than 5 hours a day
Less than 5 hours a day
Not everyday
Answer choices

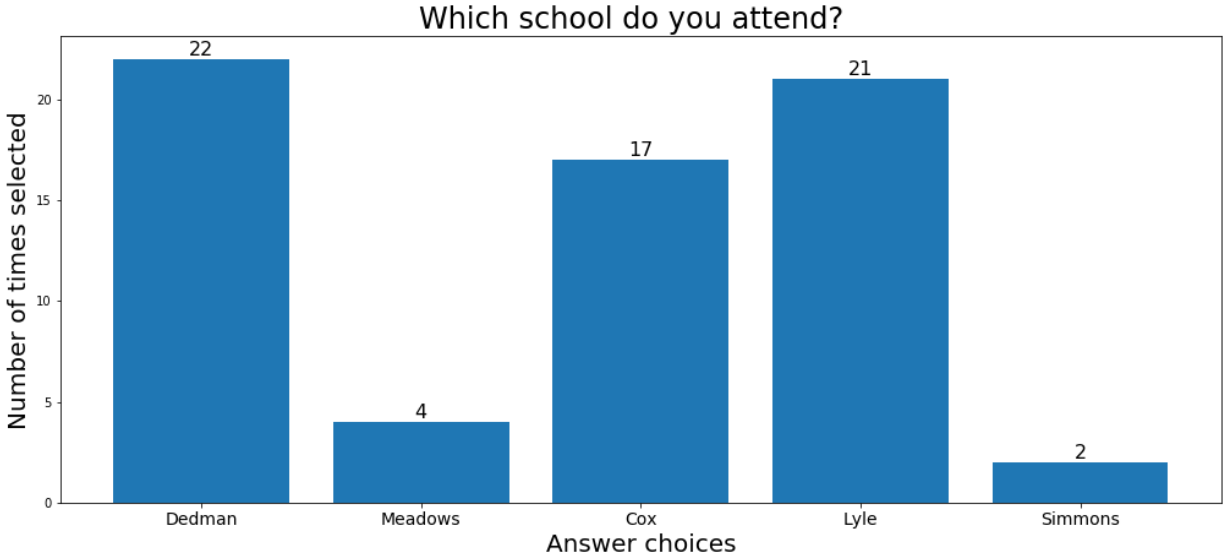

What kind of computer do you own?
Number of times selected
37
21
Mac (MacOS/OSX)
PC (Windows)
Answer choices

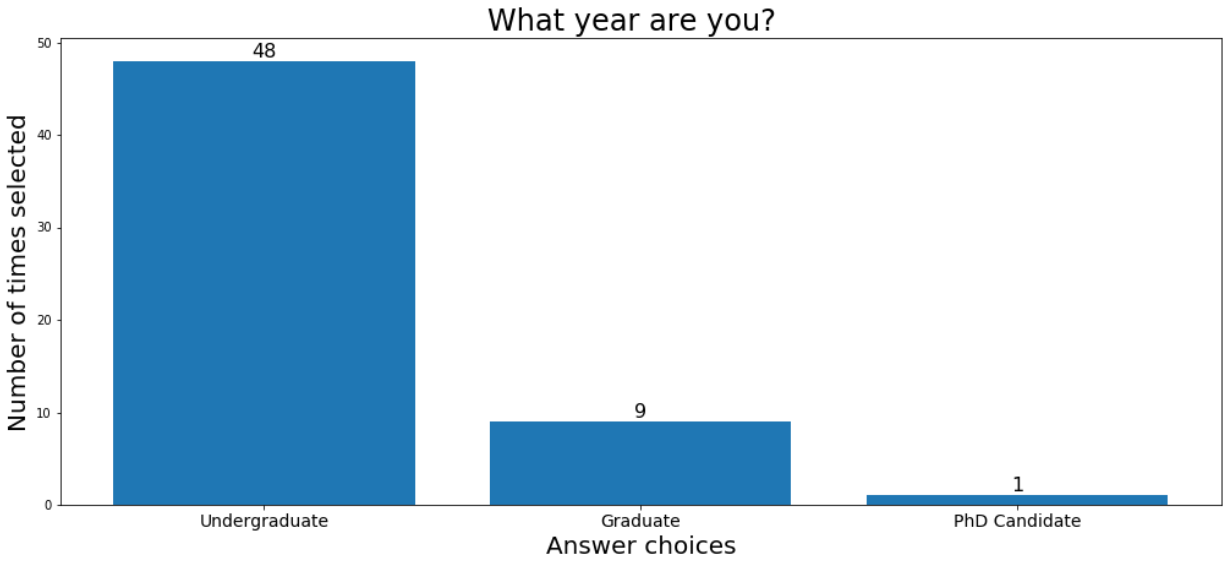

What kind of smartphone do you use?
Number of times selected
0
10
20
30
40
50
52
6
iPhone
Android
Answer choices

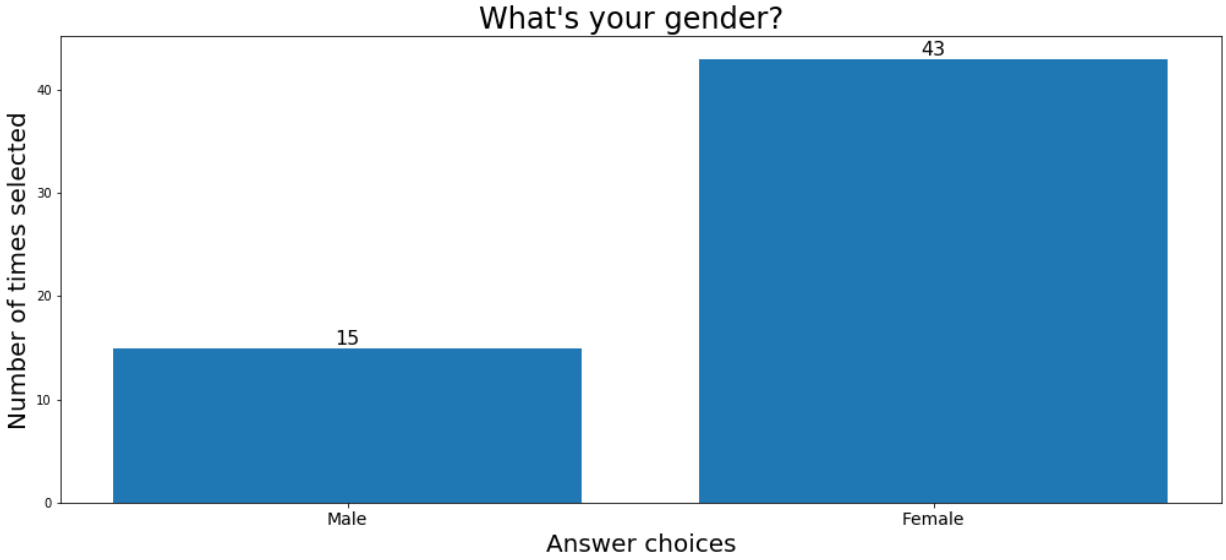

How technologically savvy are you?
Number of times selected
0
5
10
15
20
25
30
35
12
38
8
Expert
Intermediate
Beginner
Answer choices

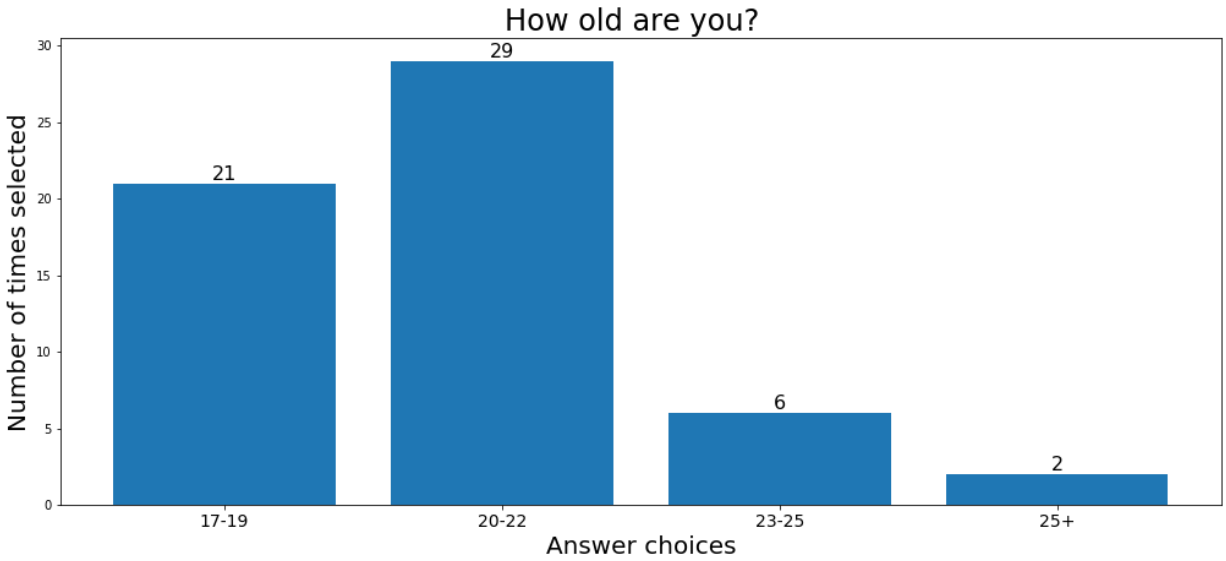

How relevant is technology to your major?
Number of times selected
0
5
10
15
20
25
22
28
8
Extremely relevant
Somewhat relevant
Not very relevant
Answer choices

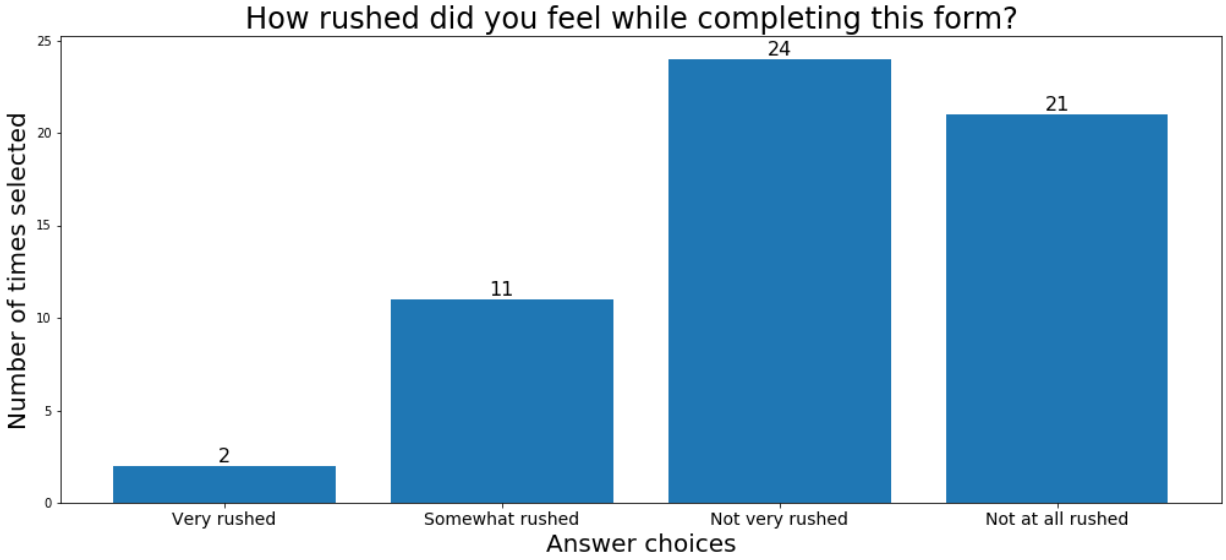

Which of the following technical tasks are you comfortable doing?
Number of times selected
0
10
20
30
40
50
60
58
41
19
51
55
7
Typing a paper in Word
Using a classroom projector
Compiling and running Java code
Using the printers in Fondren
Buying items online
Python list comprehension
Answer choices

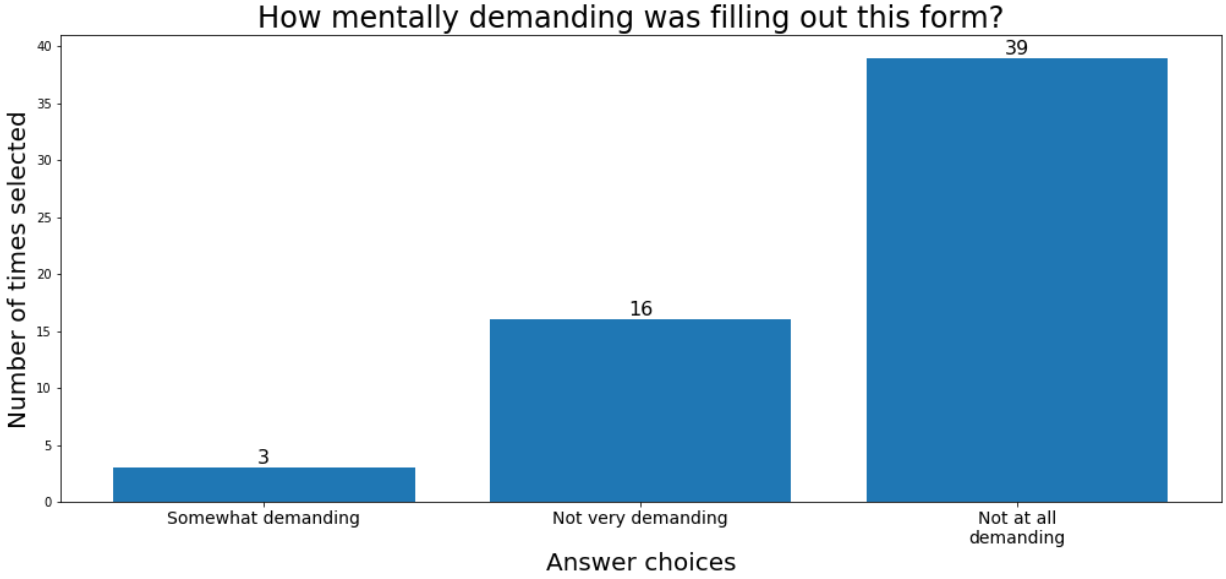

Which school do you attend?
Number of times selected
0
5
10
15
20
22
4
17
21
2
Dedman
Meadows
Cox
Lyle
Simmons
Answer choices

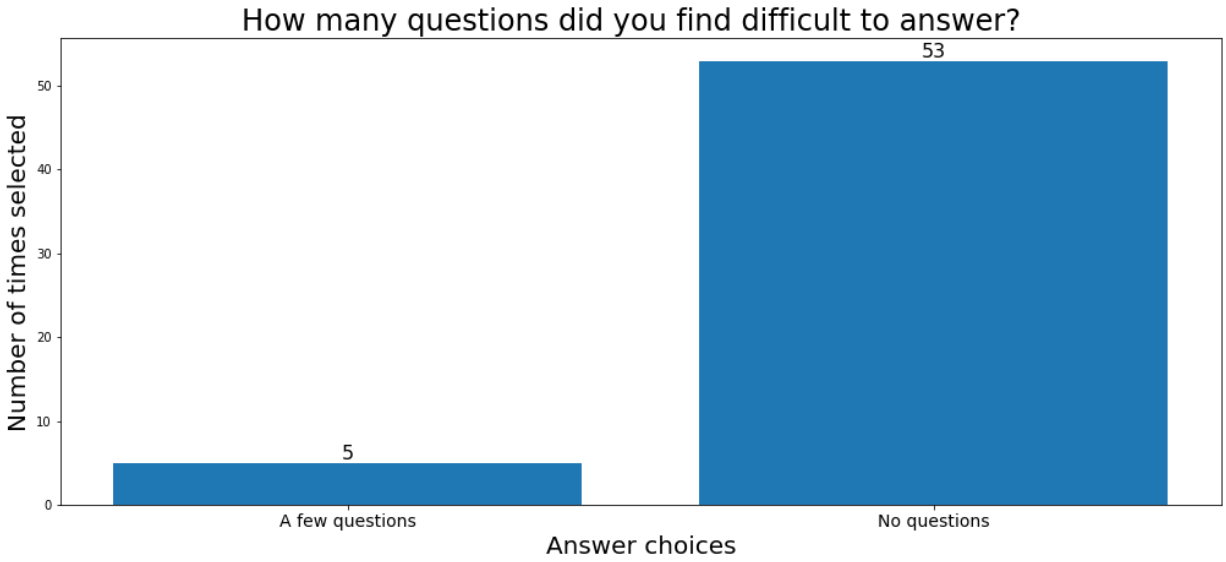

What year are you?
Number of times selected
0
10
20
30
40
50
48
9
1
Undergraduate
Graduate
PhD Candidate
Answer choices


What's your gender?
Number of times selected
0
10
20
30
40
15
43
Male
Female
Answer choices

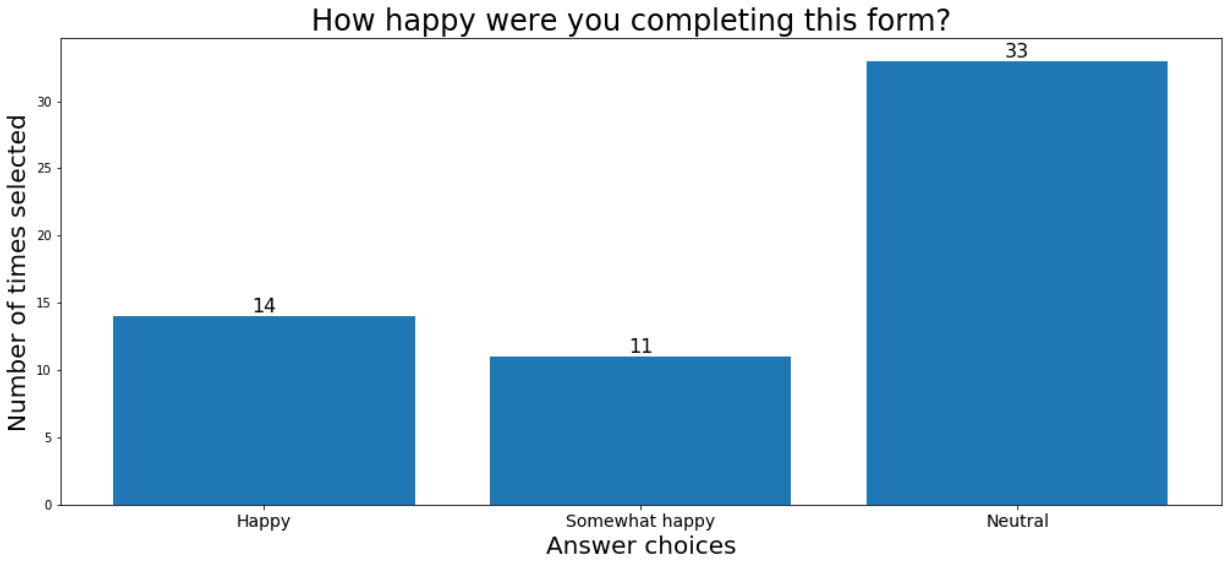

How old are you?
Number of times selected
0
5
10
15
20
25
30
21
29
6
2
17-19
20-22
23-25
25+
Answer choices

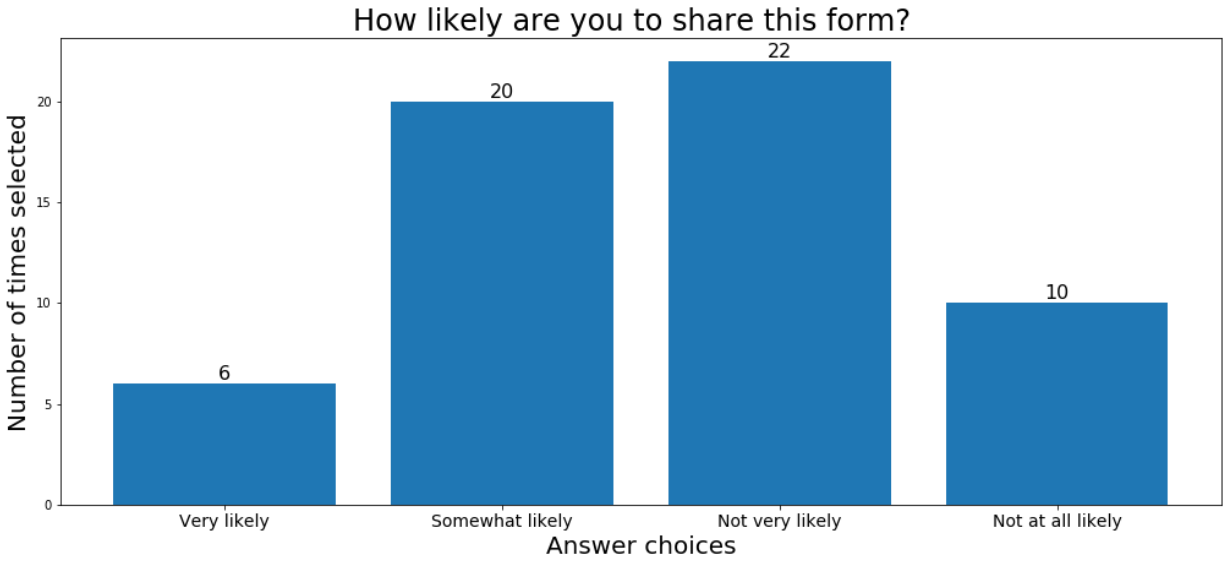

How rushed did you feel while completing this form?
Number of times selected
0
5
10
15
20
25
2
11
24
21
Very rushed
Somewhat rushed
Not very rushed
Not at all rushed
Answer choices

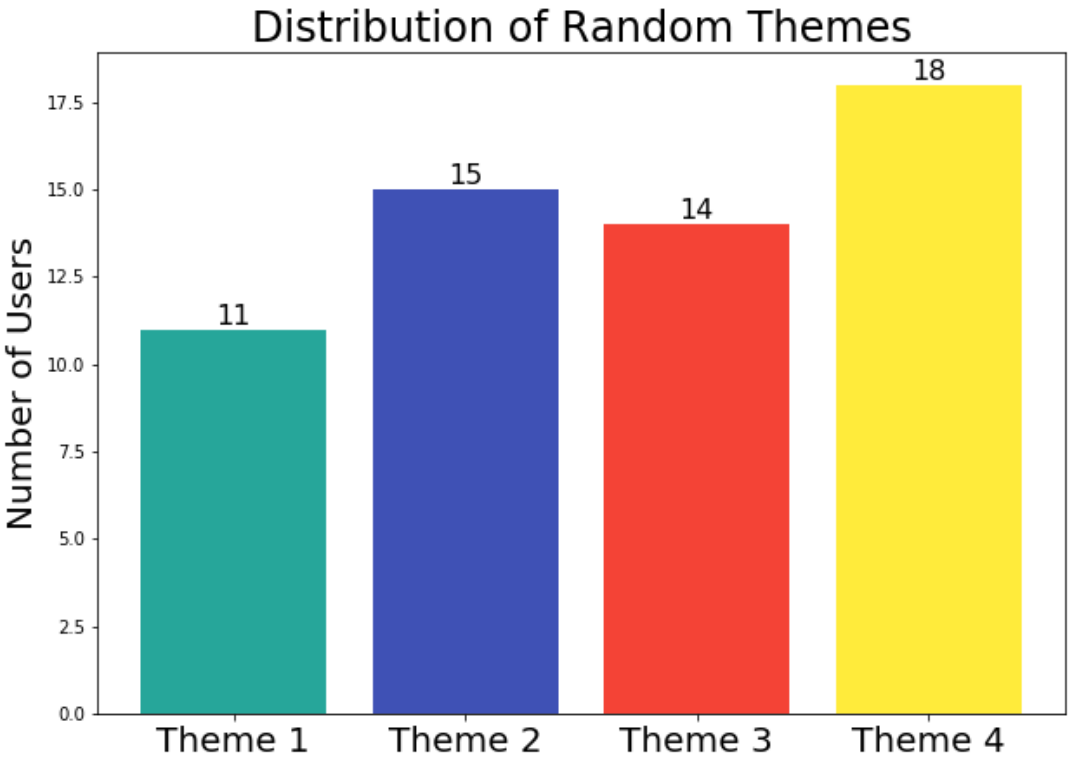

How mentally demanding was filling out this form?
Number of times selected
0
5
10
15
20
25
30
35
40
3
16
39
Somewhat demanding
Not very demanding
Not at all demanding
Answer choices

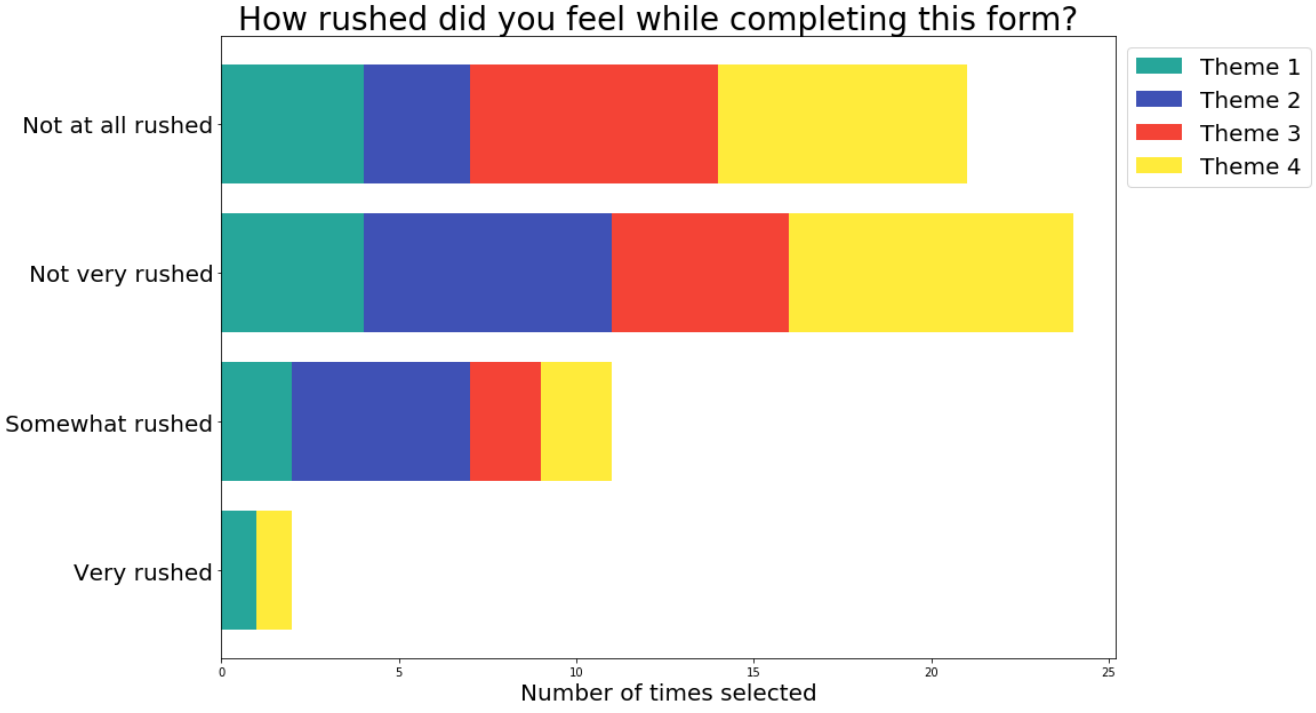

How many questions did you find difficult to answer?
Number of times selected
0
10
20
30
40
50
5
53
A few questions
No questions
Answer choices

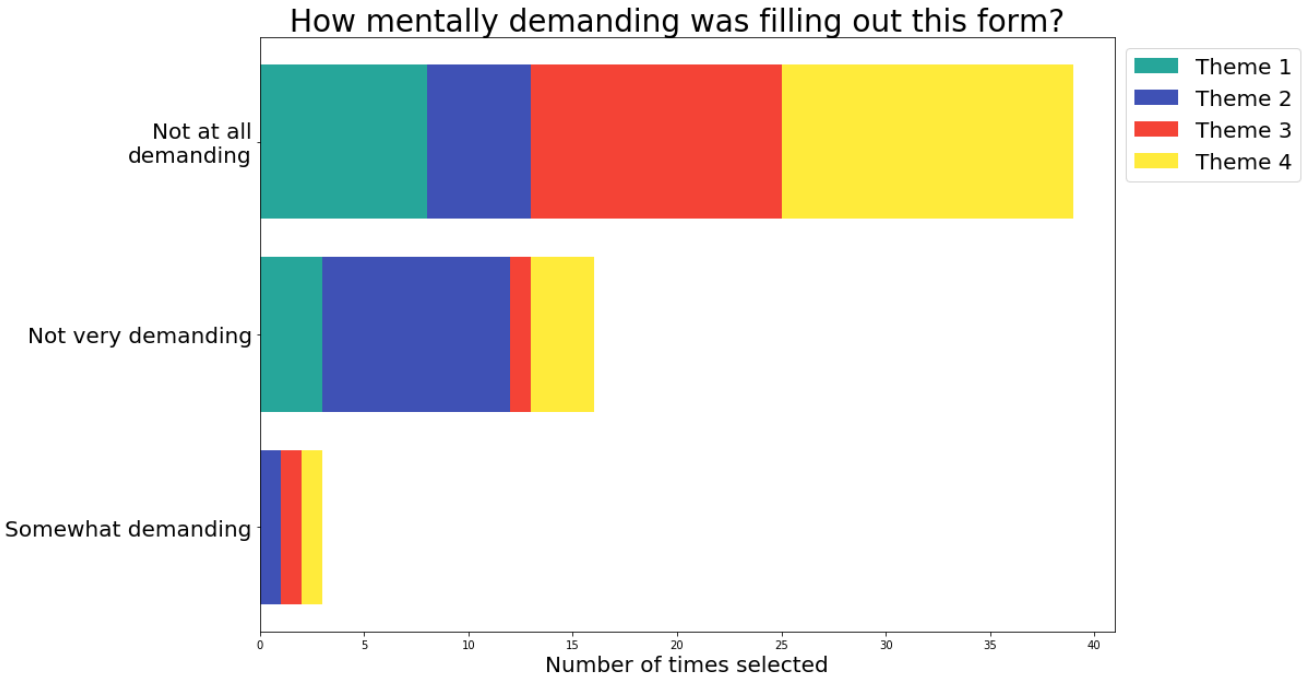

How frustrated or confused were you while completing this form?
Number of times selected
0
10
20
30
40
50
3
7
48
Somewhat frustrated
Not very frustrated
Not at all frustrated
Answer choices

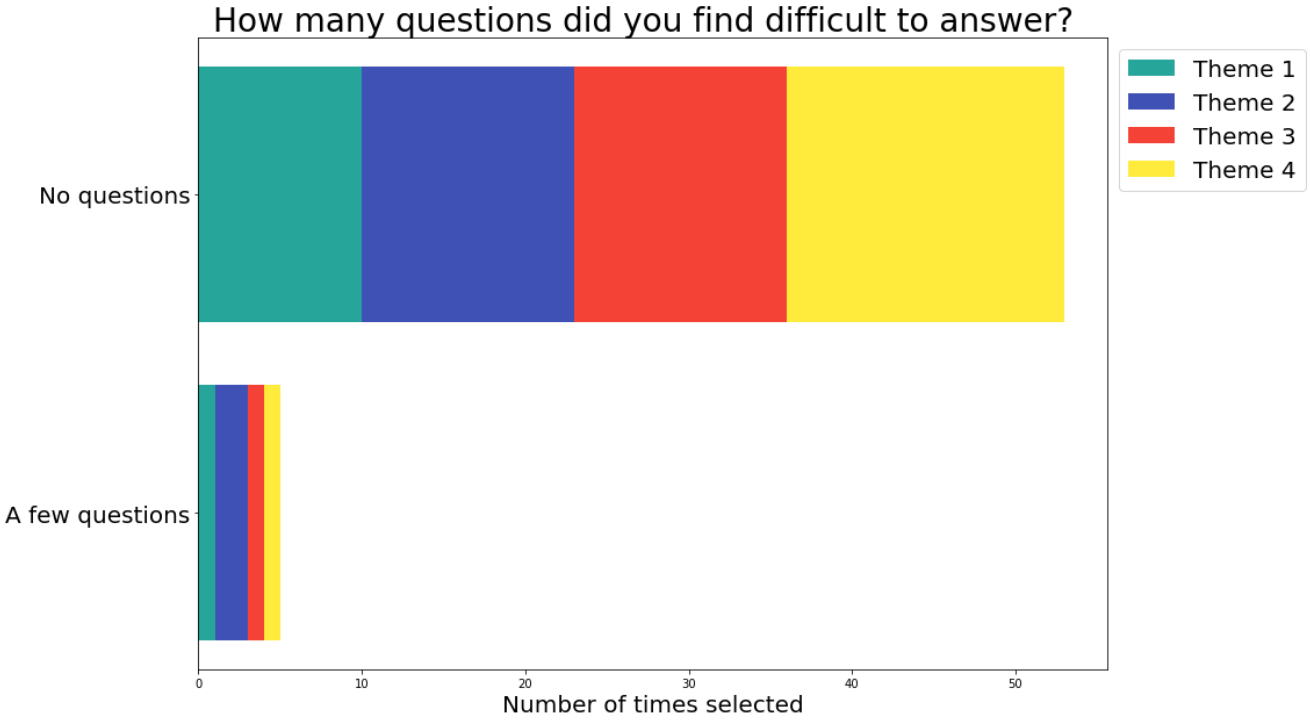

How happy were you completing this form?
Number of times selected
0
5
10
15
20
25
30
14
11
33
Happy
Somewhat happy
Neutral
Answer choices

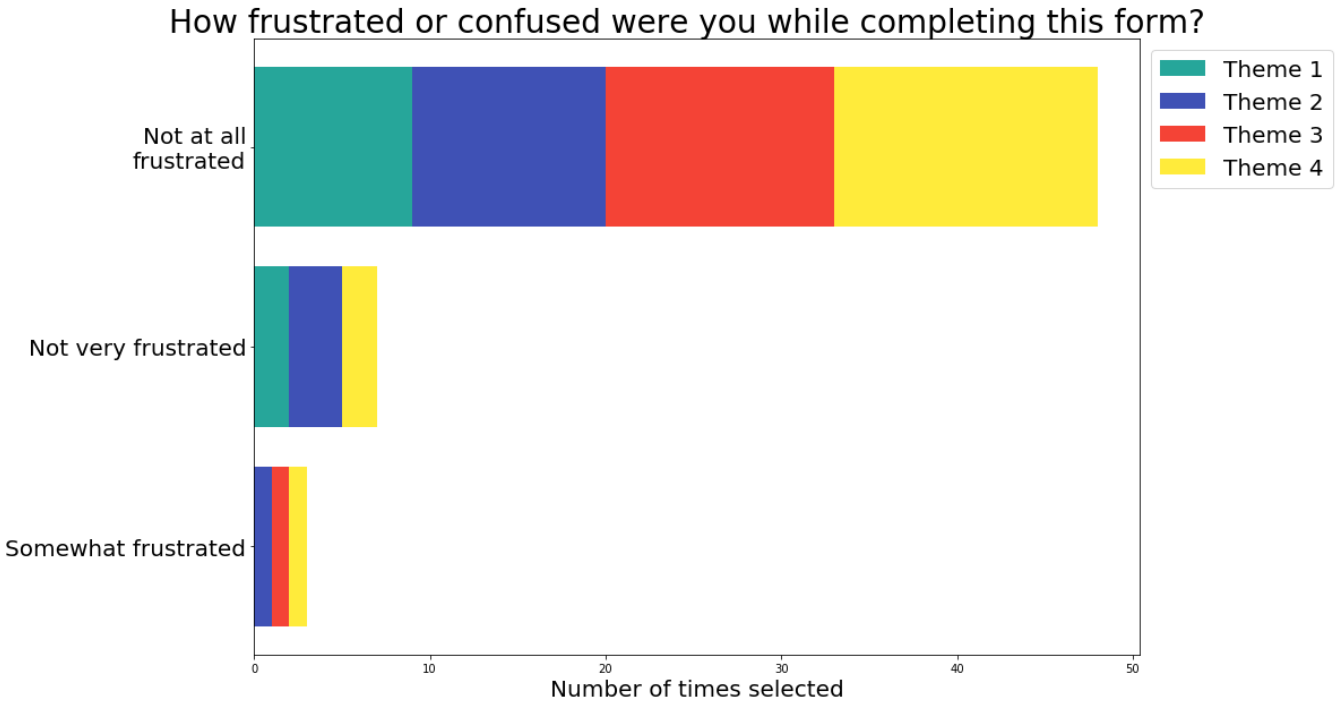

How likely are you to share this form?
Number of times selected
0
5
10
15
20
6
20
22
10
Very likely
Somewhat likely
Not very likely
Not at all likely
Answer choices

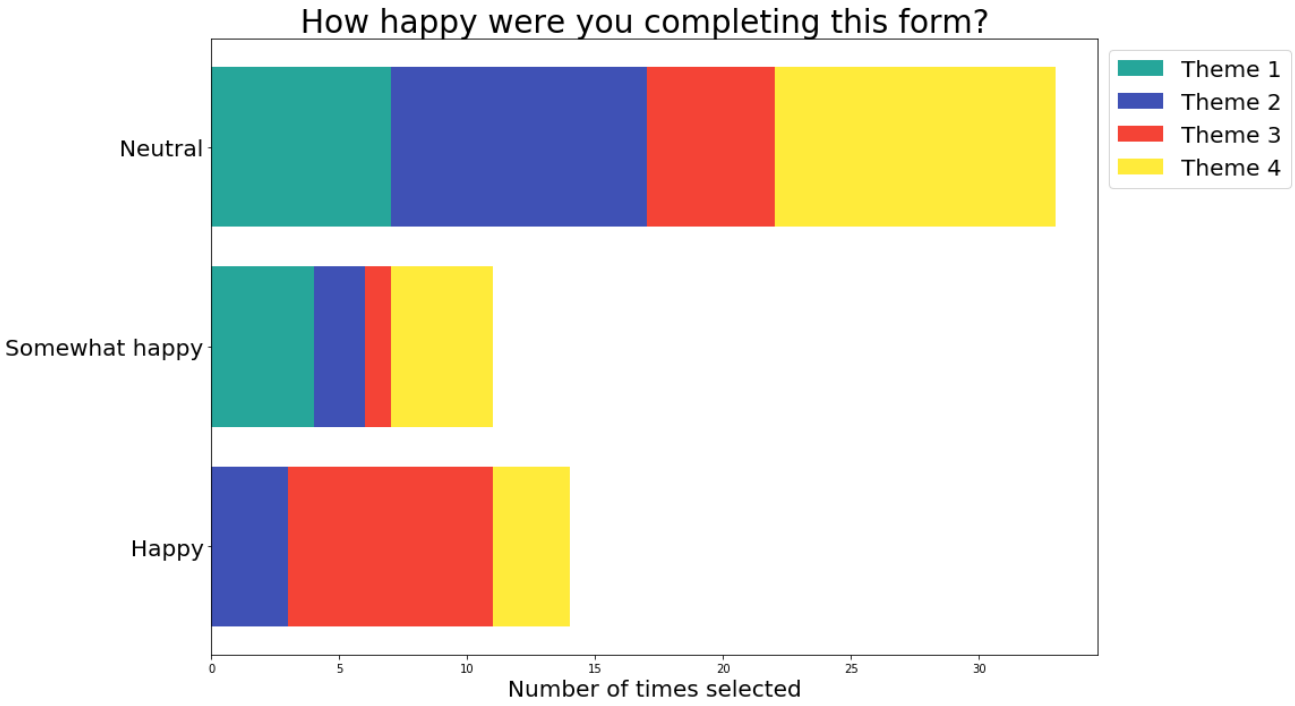

Distribution of Random Themes
Number of Users
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
11
15
14
18
Theme 1
Theme 2
Theme 3
Theme 4

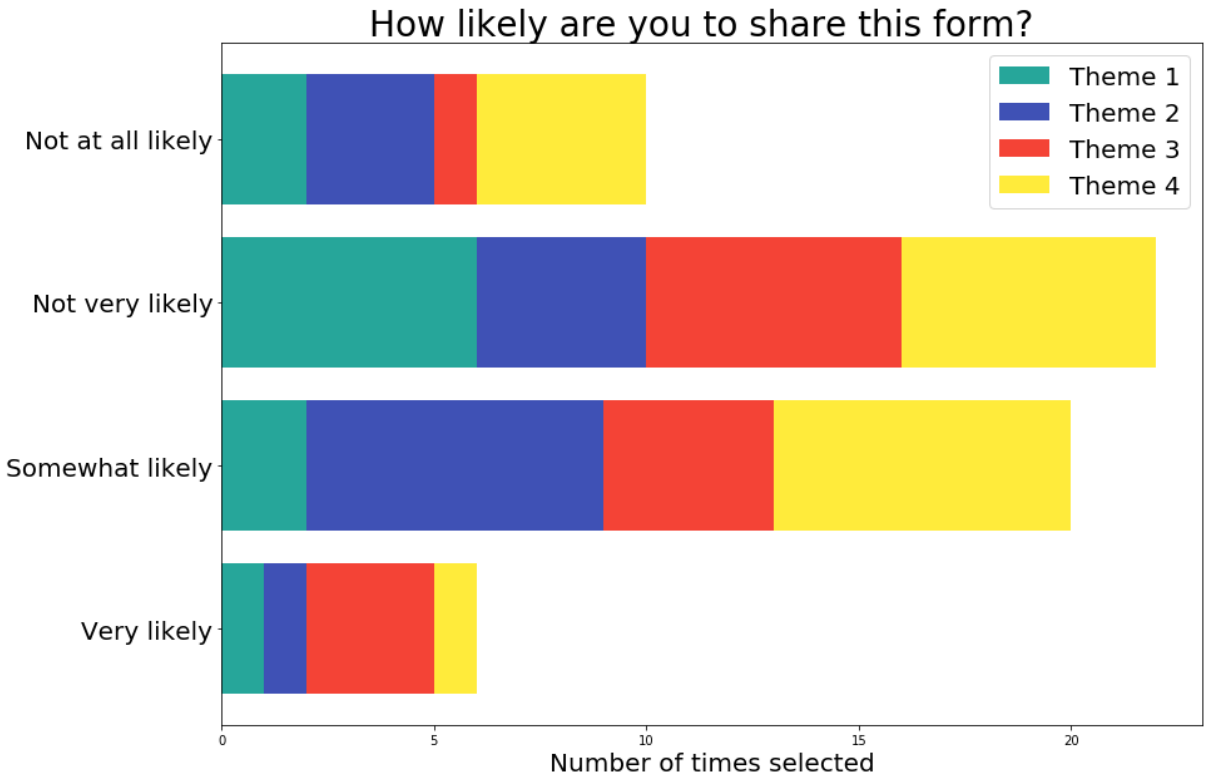

How rushed did you feel while completing this form?
Not at all rushed
Not very rushed
Somewhat rushed
Very rushed
0
5
10
15
20
25
Number of times selected
Theme 1
Theme 2
Theme 3
Theme 4

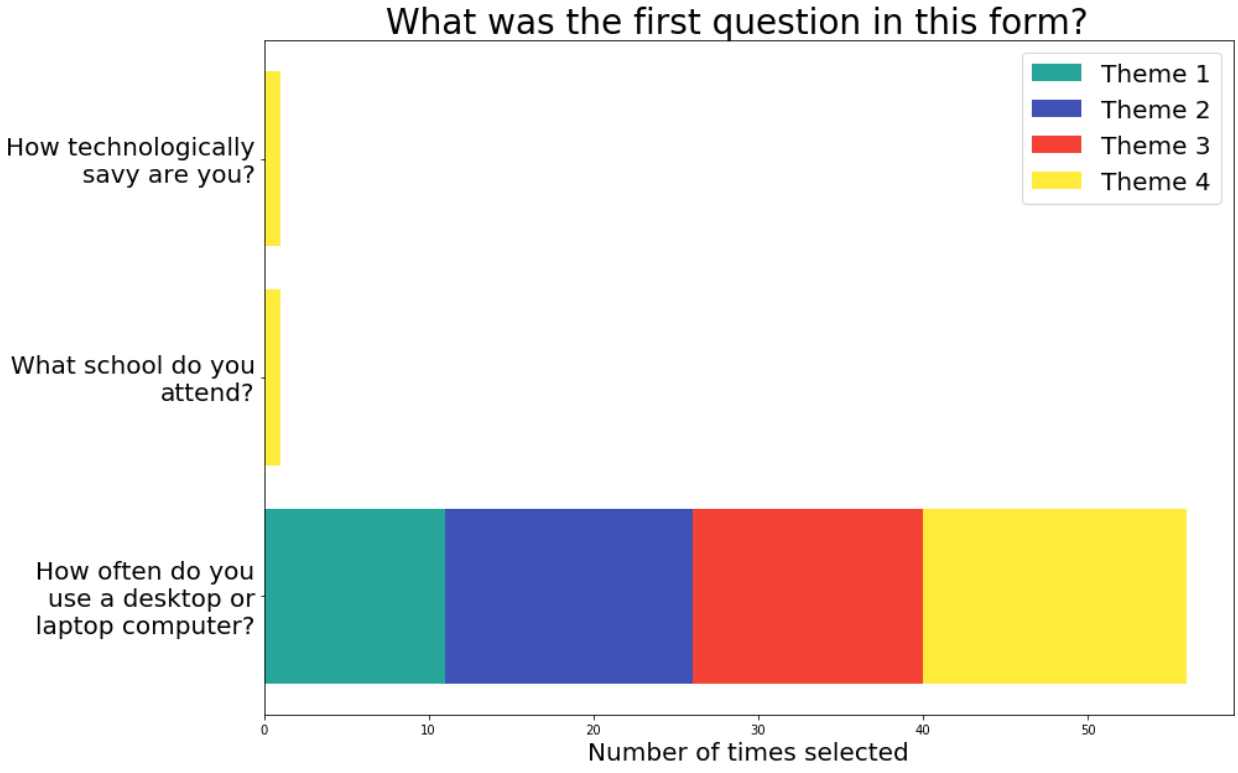

How mentally demanding was filling out this form?
Not at all demanding
Not very demanding
Somewhat demanding
0
5
10
15
20
25
30
35
40
Number of times selected
Theme 1
Theme 2
Theme 3
Theme 4

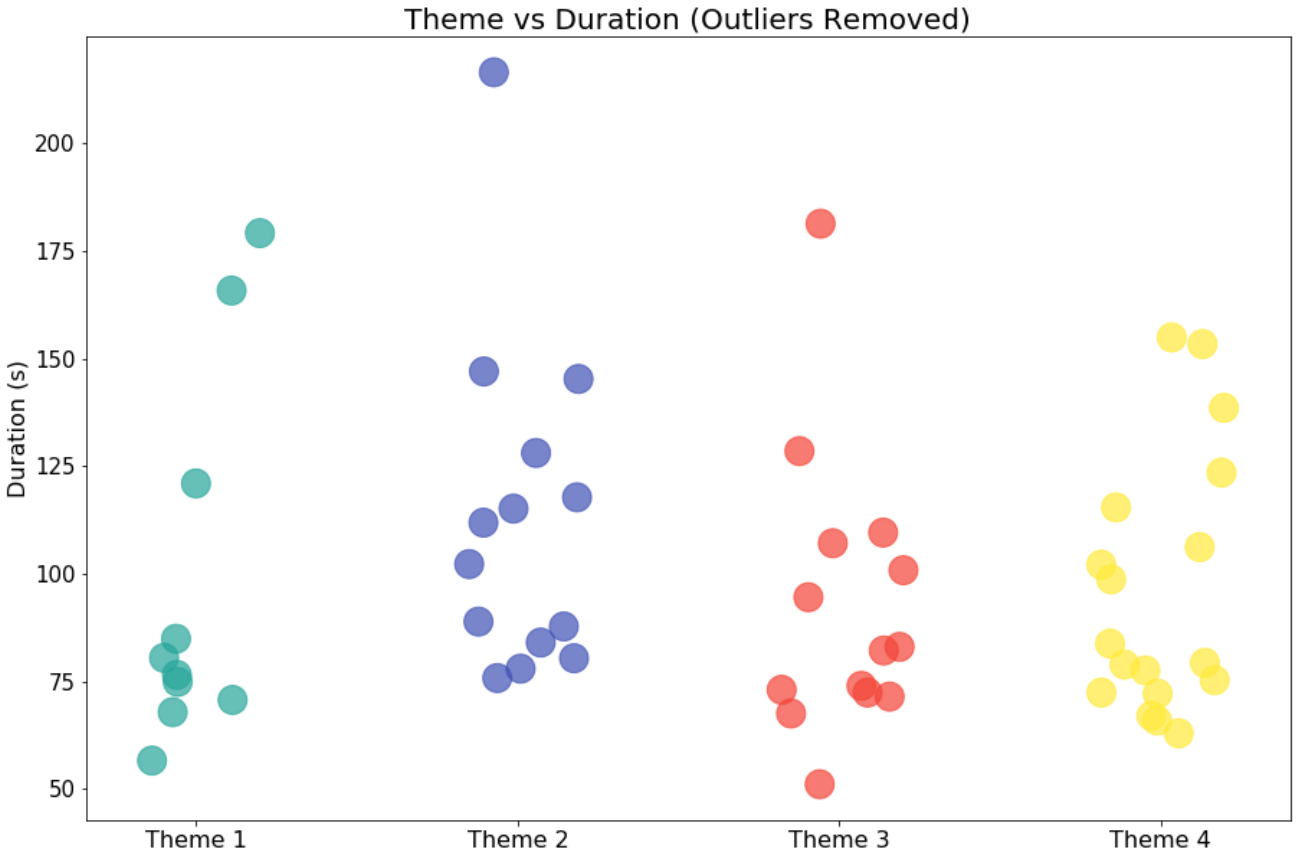

How many questions did you find difficult to answer?
No questions
A few questions
0
10
20
30
40
50
Number of times selected
Theme 1
Theme 2
Theme 3
Theme 4


How frustrated or confused were you while completing this form?
Not at all frustrated
Not very frustrated
Somewhat frustrated
0
10
20
30
40
50
Number of times selected
Theme 1
Theme 2
Theme 3
Theme 4


How happy were you completing this form?
Neutral
Somewhat happy
Happy
0
5
10
15
20
25
30
Number of times selected
Theme 1
Theme 2
Theme 3
Theme 4


How likely are you to share this form?
Theme 1
Theme 2
Theme 3
Theme 4
Not at all likely
Not very likely
Somewhat likely
Very likely
0
5
10
15
20
Number of times selected


What was the first question in this form?
Theme 1
Theme 2
Theme 3
Theme 4
How technologically savy are you?
What school do you attend?
How often do you use a desktop or laptop computer?
0
10
20
30
40
50
Number of times selected


Theme vs Duration (Outliers Removed)
Duration (s)
200
175
150
125
100
75
50
Theme 1
Theme 2
Theme 3
Theme 4