Collecting and analyzing quantitative (survey) data with statistics

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CS 60081
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Roadmap

- Qualitative Data Analysis
  - Selecting participants
  - Data analysis techniques
- Inter-rater agreement
- Quantitative data analysis

How to analyze quantitative data

Statistics

- In general: analyzing and interpreting data
- Statistical hypothesis testing: How likely is it that any difference/pattern you observe in experiment actually exists real life?
- Statistical correlations: are these things related?

Type of data

- Quantitative/numerical
  - Discrete (e.g., #emails)
  - Continuous (e.g., age)
- Categorical
  - Nominal or no order (e.g., male-female)
  - Ordinal or ordered (e.g., Ex, A, B, …, F)
- Q: Why cannot we just assign 1,2,3,… etc. ordered discrete values to the ordinal variables?

Hypothesis testing

- Causation (X causes Y)
  - vs. correlation (X is related to Y)
- Develop a hypothesis (e.g., age is related to typing speed)
  - Assign to conditions (include a control)
  - Terminology: “Condition” = “Treatment”
- H0 (null hypothesis): there is no effect
- H1 (alternative hypothesis): there is an effect

Way to do the test

- You have a set of values for variable X (e.g., age)
  - x1, x2, x3, …
- You have a set of values for variable Y (e.g., typing speed)
  - y1, y2, y3, …
- Question: Is higher age affect the typing speed? Why do you need a test?

Way to do the test

- You have a set of values for variable X (e.g., age)
  - x1, x2, x3, …
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  - y1, y2, y3, …
- Question: Is higher age affect the typing speed? Why do you need a test?

- You chose a test H (often a python or R function)
  - Statistic, p = H ([x1, x2, x3, …], [y1, y2, y3, …])
  - p – value is essentially a probability that the statistic value occurred randomly (i.e., there is no effect aka H0 is true)
  - So if p is small (generally < 0.05, called α) you reject H0

Is P value enough?

- No! Consider:
  - Effect size (magnitude of the effect of the manipulation)
  - Power (long-term probability of rejecting H0 when there really is a difference)
- Type 1 error: wrongly reject H0 even if there is no effect (α)
- Type 2 error: wrongly fail to reject H0 even if there is an effect (β)

Type I errors

- Type I error (false positive)
  - You would expect this to happen 5% of the time if $\alpha = 0.05$

Type II errors

- Type II error (false negative)
  - There is actually a difference, but you didn't see evidence of a difference
- Statistical power is the probability of rejecting the null hypothesis (no effect) when you should → 1 – Pr(Type II Error)
  - You could do a **power analysis**,
    - Minimum sample size to achieve a given effect size
    - How many times do you have to toss a coin to know that Pr(head) = 0.7?
    - Requires that you can estimate the effect size
    - Bonferroni's correction

How to pick the right test?

- What test to you want? (comparison, correlation)
- Different types of variables?
- Different data distributions? (e.g., normal vs., non-normal)
- Parametric vs. non-parametric tests

What test to you want?

- Depend on your research question
- You want to test if gender is related with height
  - RQ: Is there a correlation between gender and height? (correlation)
  - Alternative RQ: Is the average height of males more than average height of females? (comparison)

Check the variable type

- Important: check types of variables
- You want to see the correlation between age and number of emails sent per day
  - age: independent variable, you can vary it by taking different users
  - #emails/day: dependent variable, you want to measure
  - Technical expertise, job, … : co-variate

Picking the right test: A limited cheat sheet (correlation tests)

Focusing on parametric tests!

		Independent Variable	
		Categorical	**Quantitative**
Dependent Variable	**Categorical**	Chi-Squared Test Fisher's Exact Test	Logistic Regression
	Quantitative	t-Test ANOVA	Correlation Linear Regression

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Parametric vs non-parametric tests

When to use what?

- Finding relations between two numerical variables
  - As the age of a man increases, his/her max running speed decreases
  - Pearson's correlation / Spearman's rank correlation
- Finding relations between two categorical variables
  - People randomly assigned to exercise more than twice a week (as opposed to less than once a week) are more likely to be rated as healthy (as opposed to unhealthy)
  - $\chi 2$, Fisher's exact test

When to use what?

- Comparing a variable value between two groups (numerical)
  - People who exercise more than twice a week (as opposed to less than twice) are more likely to take a shorter time to run a race
  - ANOVA, Kruskal-Wallis, etc.

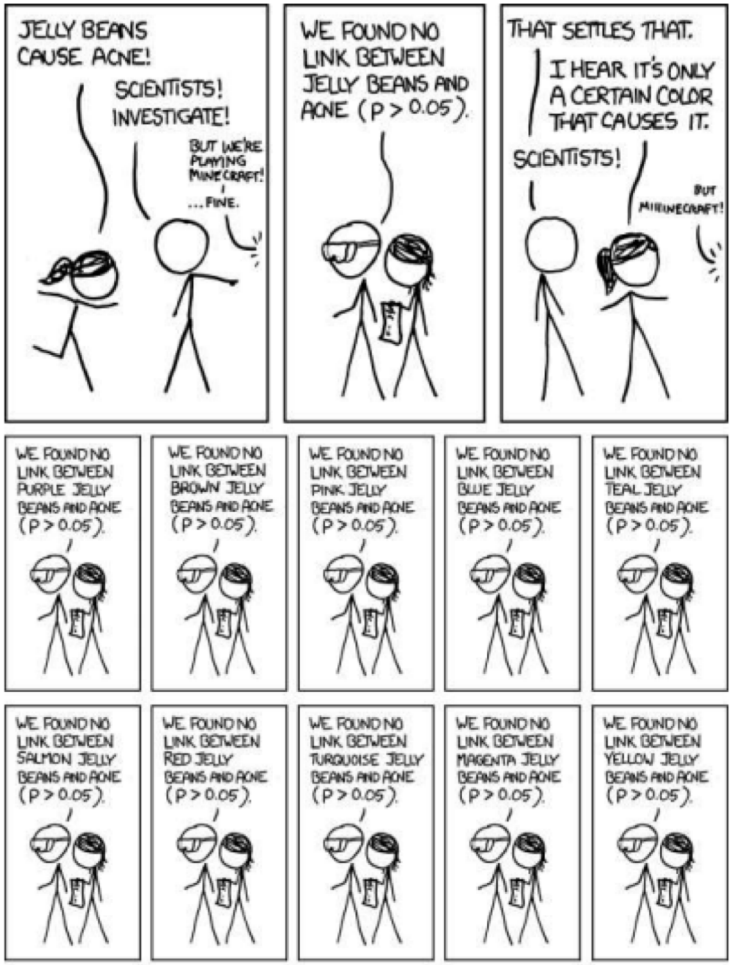
- Lots of factors has effect on the dependent variable (numerical)
  - Regression (Y = a1x1 + a2x2 etc…)
- Lots of factors has effect on the dependent variable (category)
  - Logistic regression

We talked about…

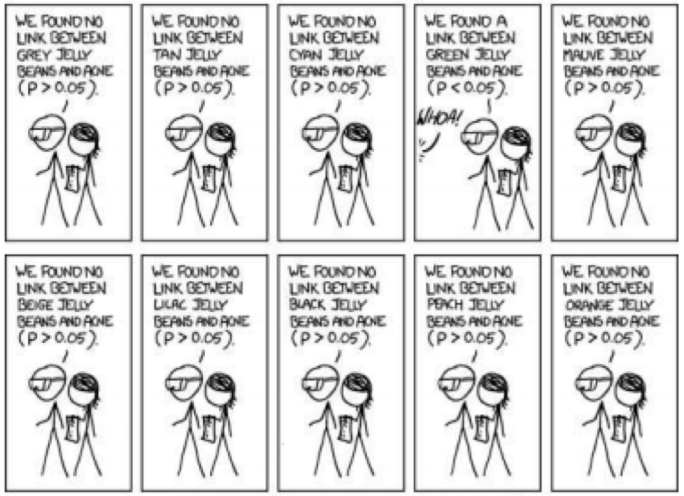
- Type I error : Wrongly reject H0 even if whatever you observed happened due to random chance
  - expect this to happen 5% of the time if $\alpha = 0.05$
- Type II error : Wrongly fail to reject H0 even if whatever you observed happened due to non-random process

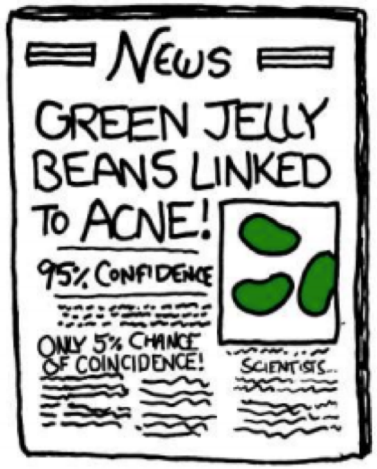
- What happens if you conduct a lot of statistical tests in one experiment?
  - In at least one case $p < 0.05$

A xkcd example



https://xkcd.com/882/





Bonferroni correction

- Divide α by #tests
  - Say you did 1000 tests (age with typing speed, gender with typing speed, etc.)
  - Previous : Likely to get $p < \alpha = 0.05$ for at least one test
  - Now: Much harder to get $p < \alpha /1000 = 0.00005$ even for one test

Case 1:
Dependent variable (DV): Categorical
Independent variable (IV): Categorical

Chi-squared (χ2) Test

- Example research questions
  - Does the gender (male, female) correlate with a user's favorite color?
  - Does the cuisines it ate this month correlate to its privacy concerns?

- H0 : Variable X values are equally distributed across variable Y values (independence or no effect)
- (Not covered today) Goodness of fit: Does the distribution we observed differ from a theoretical distribution?

Contingency table

- Rows are r values of one variable, Columns are c values of other variable

CreateAnnoying Counts:

	0	1
0	161	32
1	165	33
2	168	34
3	170	30
4	164	32
5	161	35
6	167	32
7	129	60
8	128	61
9	154	40
10	153	40
11	154	38
12	142	42
13	121	67
14	124	76

Percentages:

	0	1
0	"83.42%"	"16.58%"
1	"83.33%"	"16.67%"
2	"83.17%"	"16.83%"
3	"85%"	"15%"
4	"83.67%"	"16.33%"
5	"82.14%"	"17.86%"
6	"83.92%"	"16.08%"
7	"68.25%"	"31.75%"
8	"67.72%"	"32.28%"
9	"79.38%"	"20.62%"
10	"79.27%"	"20.73%"
11	"80.21%"	"19.79%"
12	"77.17%"	"22.83%"
13	"64.36%"	"35.64%"
14	"62%"	"38%"

- $\chi 2 = 97.013$, $df = (r - 1)^* (c - 1) = 14$, $p = 1.767e\text{-}14$

Chi-squared (χ2) usage

- Use χ2 if you are testing one categorical variable (usually a demographic factor) impacts another categorical variable
  - If you have < 5 data points in a single cell of your contingency table, use Fishher's exact test

- DO NOT use this test for numerical variables

What about Likert scale?

- Some people treat it as continuous (assign 1 to an option, 2 to another option etc.) (a controversial step)
- Others treat it as ordinal (better choice)
  - In that case, use Mann-Whitney U / Kruskal-Wallis (non-parametric)
- A simple alternative
  - Bin the data into binary agree/non-agree, or comfortable/non-comfortable categories
    - Now you can use Chi squared test (parametric)

Case 2:
Dependent variable (DV): Categorical
Independent variable (IV): Quantitative

Choosing a numerical test

- Do your data follow a normal (gaussian distribution)?
  - Use Shapiro-Wilk normality test
  - Yes → parametric test, No → non-parametric test

- Considerations
  - Is your data independent? → not from same family in case of a skin-color-based hypothesis
  - If not → repeated-measures, mixed models

Why might your data not be independent

- Reason 1: Non-independent sample (change sampling)
- Reason 2: Inherent design, e.g., within subjects design (then its ok)

Numerical data

- Popular question: Are values bigger in one group?
- Normal, continuous data (for comparing mean):
  - H0 : There are no differences in the means
  - 2 conditions: t-test (age vs. typing speed)
  - 3+ conditions: ANOVA

- Non-normal data / ordinal data:
  - H0 : No group tends to have larger values.
  - 2 conditions: Mann-Whitney U (likert scale data vs. likert scale data)
  - 3+ conditions: Kruskal-Wallis

Case 3:
Dependent variable (DV): Quantitative

Correlation

- Popular question: is X related to Y?
- less good: Pearson correlation
  - Assumes both variables as normally distributed
  - Only look for linear relationship
- Preferred: Spearman's rank correlation coefficient (Spearman's ρ)
  - Evaluates a relationship's monotonicity (always going in the same direction or staying the same)

Regressions

- What is the relationship among variables?
  - Generally one outcome (dependent variable)
  - Often multiple factors (independent variables)

- The type of regression you perform depends on the dependent variable i.e., outcome
  - Binary outcome: logistic regression
  - Ordinal outcome: ordinal / ordered regression
  - Continuous outcome: linear regression

Outcome of a regression

- Normally, outcome = ax1 + bx2 + c + …

- Interactions
  - when two variables are not simply additive. Instead, their interaction impacts the outcome
  - Then outcome = ax1 + bx2 + c + d(x1*x2) + …

Example

- Outcome: If a user can complete a task (Yes/No)
  - Logistic regression (binary outcome)

- Independent variables
  - Age
  - #prior takes completed
  - Income
  - Job
  - …

In case of non-independence?

In case of non-independence use

- Repeated measures (multiple measurements of the same thing)
  - e.g., before and after measurements of a unicorn's time to finish a race
- Paired t-test (two samples per participant, two groups)
- Repeated measures ANOVA (more general)

Picking a test [IMPORTANT]

- http://webspace.ship.edu/pgmarr/Geo441/Statistical%20Test%20Flow%20Chart.pdf
- http://abacus.bates.edu/~ganderso/biology/resources/statistics.html
- http://med.cmb.ac.lk/SMJ/VOLUME%203%20DOWNLOADS/Page%2033-37%20-%20Choosing%20the%20correct%20statistical%20test%20made%20easy.pdf

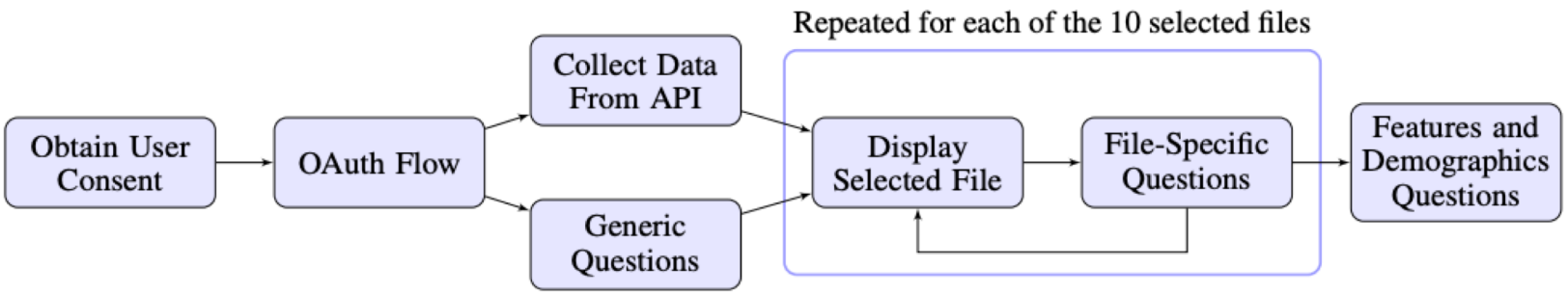
Case study: Longitudinal data management in cloud storage

Khan et. Al., CHI'18

Motivation

- People change over time
  - And so might their privacy/security requirements of their data
  - Question: Identify whether there is a need for longitudinal data management in cloud storage services

Approach



- How to find what factors does privacy decisions depend upon for 100 participants?

Steps

- First the variables:
  - Remembrance (dependent) vs. ownership (independent)
  - Remembrance: remember this file? Strongly agree to Strongly disagree
  - Ownership: owner, editor, viewer

Steps

- First the variables:
  - Remembrance (dependent) vs. ownership (independent)
  - Remembrance: remember this file? Strongly agree to Strongly disagree
  - Ownership: owner, editor, viewer
  - Both categorical

Recap: A limited cheat sheet

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Steps

- First the variables:
  - Remembrance (dependent) vs. ownership (independent)
  - Remembrance: remember this file? Strongly agree to Strongly disagree
  - Ownership: owner, editor, viewer
  - Both categorical AND each combination of these values has more than 5 feedback → Chi Square

Remembrance vs. ownership

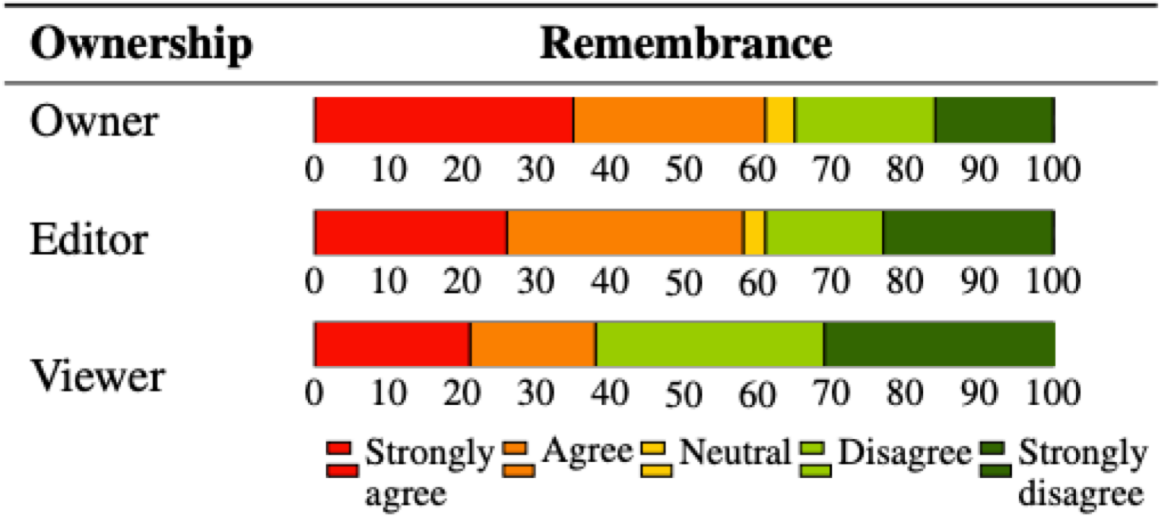

Figure 3: Comparison of file ownership and remembrance (agreement or disagreement that they remembered the file was stored in their cloud account). File ownership had a significant positive correlation with remembering the file was stored in the cloud ($\chi^2(8, N = 862) = 32.244$, $p < .001$).

Remembrance vs. ownership

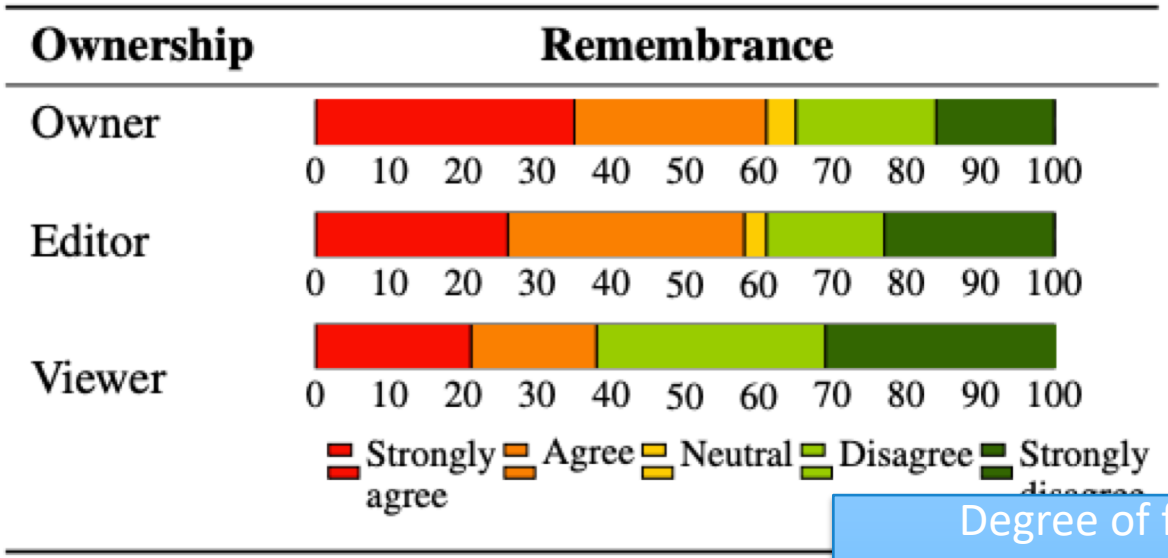

Figure 3: Comparison of file ownership a
(agreement or disagreement that they remem
stored in their cloud account). File ownershi
positive correlation with remembering the
the cloud ($\chi^2(8, N = 862) = 32.244, p < .001$).

Degree of freedom = 8
#observations = 862
Pr(this value of Chi happened due to random chance) < 0.001

Other questions

- Recognition vs. ownership
- Deletion decision vs. ownership
- Participant background (technical/non-technical) vs. ownership
- Keep-sharing decision vs. ownership

- All Chi-square
  - Then answer *why* with qual coding