Methods to measure usability of secure/private systems

Mainack Mondal

CS 60081
Autumn 2024

Roadmap

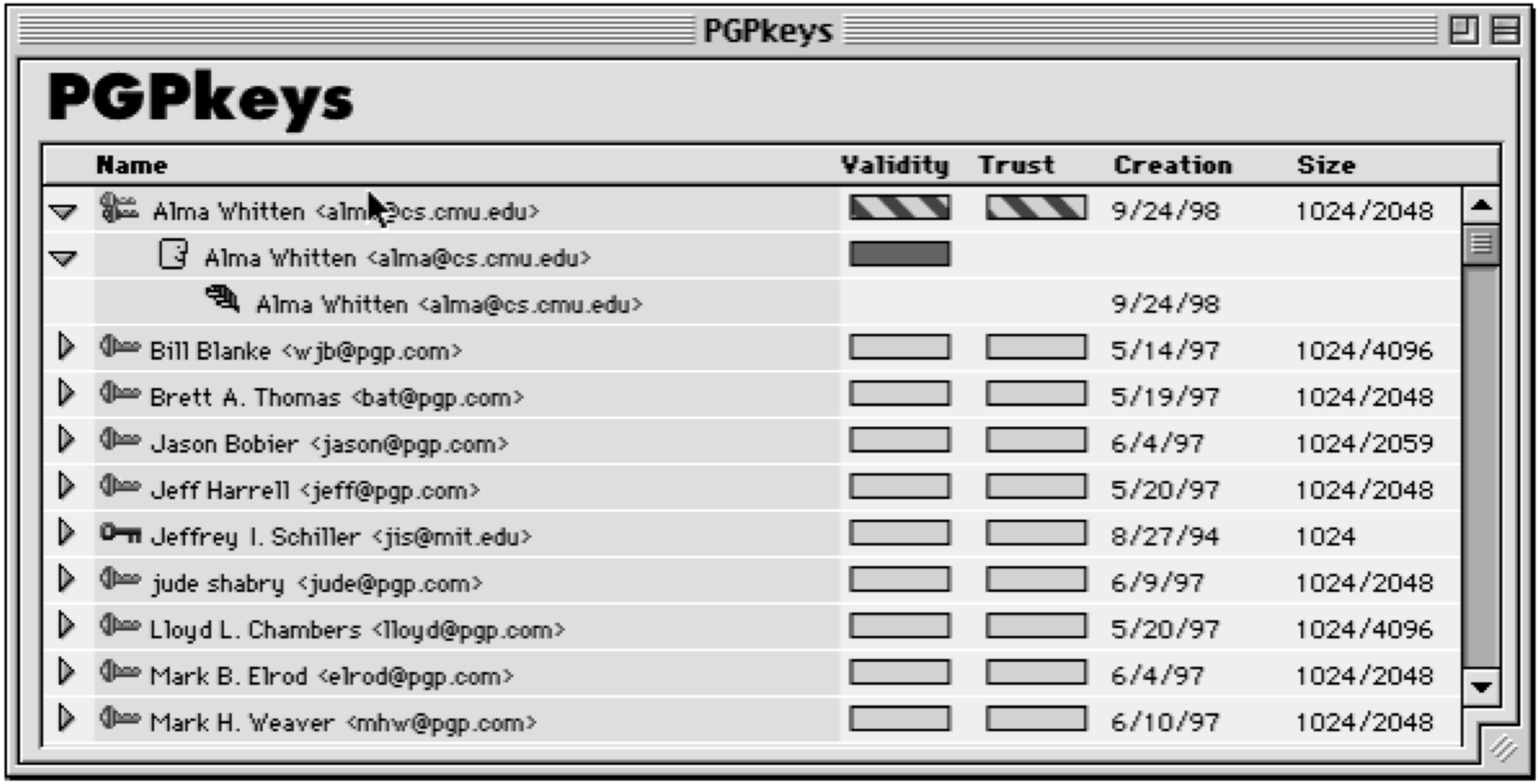
- Example of a classic usable security study
- General methods/workflow for assessing usability in secure/private systems

Material is often based on lectures from: Lorrie Cranor, Blase Ur, Kami Vaniea, Michelle Mazurek, Elissa Redmilles, https://www.usabilitybok.org/

Why Johnny can’t encrypt

- Classic paper in usable security (1999)
- A bit of history …

Why Johnny can’t encrypt

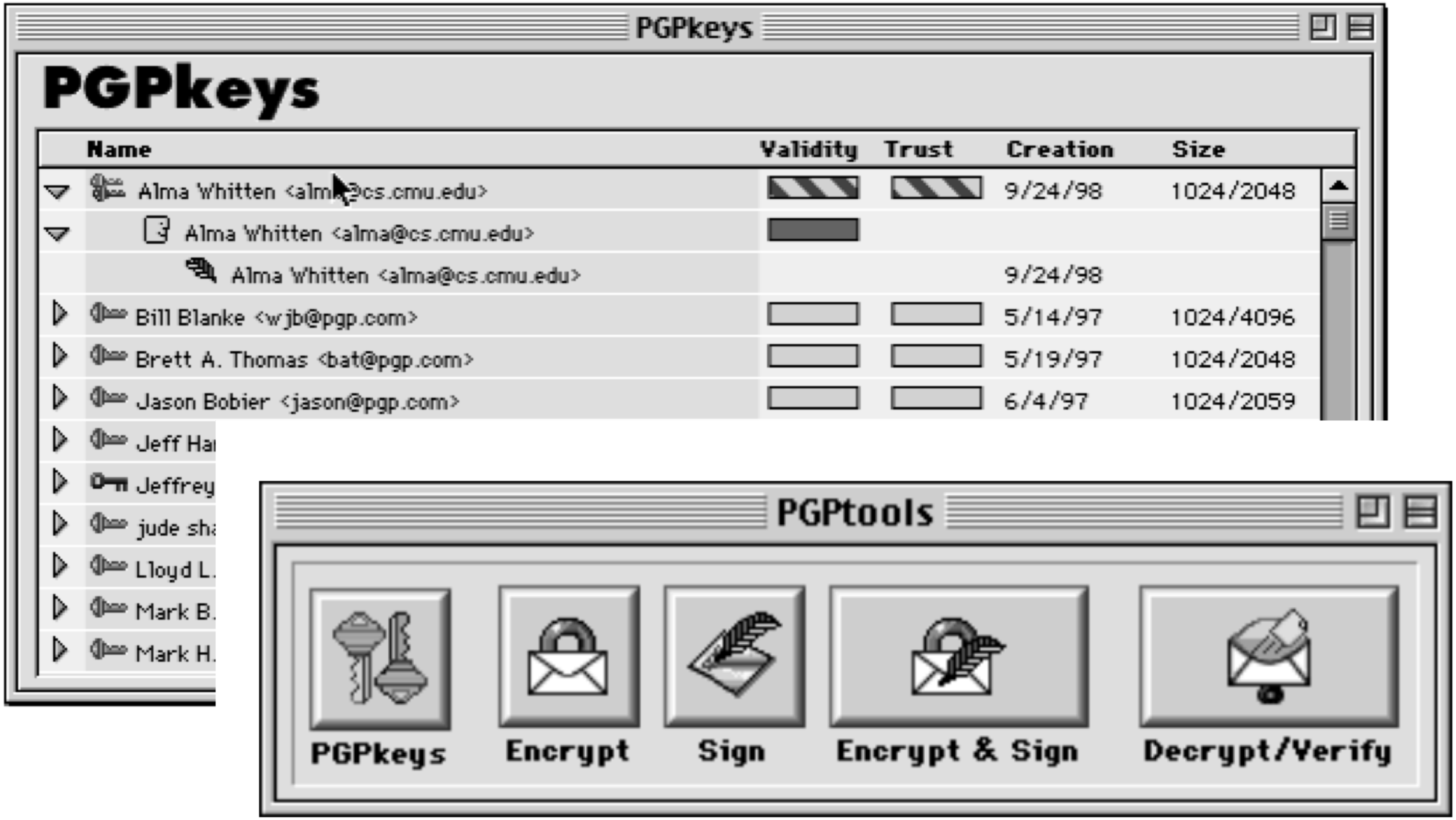


PGPkeys

PGPkeys

Name	Validity	Trust	Creation	Size
Alma Whitten <alma@cs.cmu.edu>	▨	▨	9/24/98	1024/2048
Alma Whitten <alma@cs.cmu.edu>	■			
Alma Whitten <alma@cs.cmu.edu>			9/24/98	
Bill Blanke <wjb@pgp.com>	□	□	5/14/97	1024/4096
Brett A. Thomas <bat@pgp.com>	□	□	5/19/97	1024/2048
Jason Bobier <jason@pgp.com>	□	□	6/4/97	1024/2059
Jeff Harrell <jeff@pgp.com>	□	□	5/20/97	1024/2048
Jeffrey I. Schiller <jis@mit.edu>	□	□	8/27/94	1024
jude shabry <jude@pgp.com>	□	□	6/9/97	1024/2048
Lloyd L. Chambers <lloyd@pgp.com>	□	□	5/20/97	1024/4096
Mark B. Elrod <elrod@pgp.com>	□	□	6/4/97	1024/2048
Mark H. Weaver <mhw@pgp.com>	□	□	6/10/97	1024/2048

Why Johnny can’t encrypt



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Jeff Ha				
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Why Johnny can’t encrypt

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- A bit of history …
- So, why can’t Johnny encrypt?
  - Why was it so hard for the users?
  - How did the experiments motivate the tasks?

Why Johnny can't encrypt

- Classic paper in usable security (1999)
- A bit of history …
- So, why can't Johnny encrypt?
  - Why was it so hard for the users?
  - How did the experiments motivate the tasks?
- Findings
  - Interfaces are "bad", metaphors are confusing, non-transparent, key management is difficult

Define usable secure software

- Security software is usable if the people who are expected to use it:
  - Are reliably made aware of the security tasks they need to perform
  - Are able to figure out how to successfully perform those tasks
  - Don't make dangerous errors
  - Are sufficiently comfortable with the interface to continue using it

Question

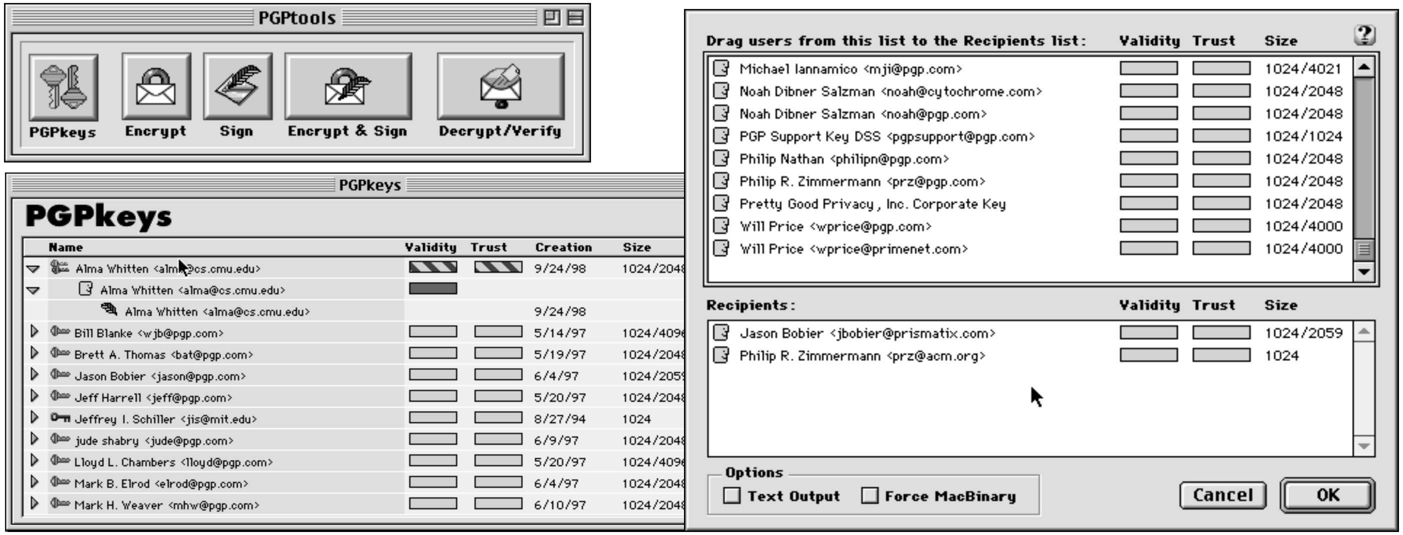
If an average user of email feels the need for privacy and authentication, and acquires PGP with that purpose in mind, will PGP's current design allow that person to realize what needs to be done, figure out how to do it, and avoid dangerous errors, without becoming so frustrated that he or she decides to give up on using PGP after all?

Security evaluation of PGP 5.0

- PGP 5.0
  - Pretty Good Privacy
  - Software for encrypting and signing data
  - Plug-in provides “easy” use with email clients
  - Modern GUI, well designed by most standards at that time

Usability Evaluation Methods

- Cognitive walk through
  - Mentally step through the software as if we were a new user.
  - Focus on interface learnability



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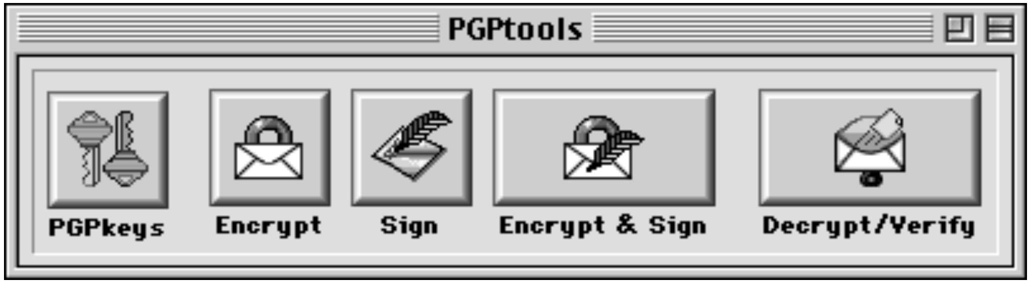
Drag users from this list to the Recipients list:	Validity	Trust	Size
Michael Iannamico <mji@pgp.com>	▭	▭	1024/4021
Noah Dibner Salzman <noah@cytochrome.com>	▭	▭	1024/2048
Noah Dibner Salzman <noah@pgp.com>	▭	▭	1024/2048
PGP Support Key DSS <pgpsupport@pgp.com>	▭	▭	1024/1024
Philip Nathan <philipn@pgp.com>	▭	▭	1024/2048
Philip R. Zimmermann <prz@pgp.com>	▭	▭	1024/2048
Pretty Good Privacy, Inc. Corporate Key	▭	▭	1024/2048
Will Price <wprice@pgp.com>	▭	▭	1024/4000
Will Price <wprice@primenet.com>	▭	▭	1024/4000

Recipients:	Validity	Trust	Size
Jason Bobier <jbobier@prismatix.com>	▭	▭	1024/2059
Philip R. Zimmermann <prz@acm.org>	▭	▭	1024

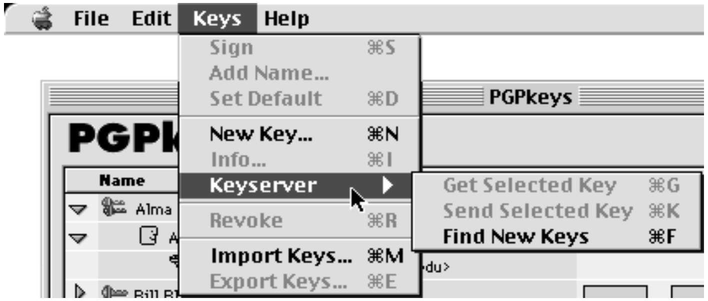
Options
☐ Text Output ☐ Force MacBinary

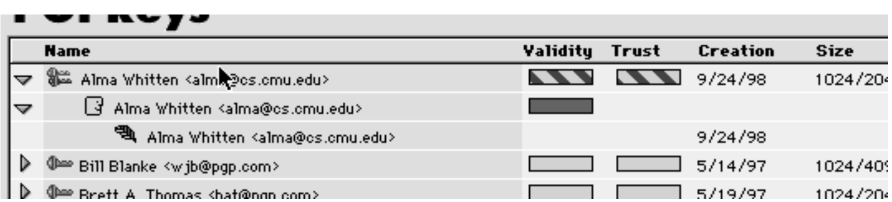
Cognitive Walk Through Results



- Visual metaphors: What does the pen mean?
- Confusion with keys
  - Different keys
  - What is key server? (non-transparent)
  - What is key management? (non-transparent)

Cognitive Walk Through Results (contd)





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- Irreversible actions: Need to prevent costly errors
- Consistency: Status message was “Encoding” (and icon message was …)
- Too much information
  - More unneeded confusion
  - Suggestion: show the basic information, make more advanced information available only when needed.

Lab usability study with users

- User Test
  - PGP 5.0 with Eudora
  - 12 participants: at least attended college; none with advanced knowledge of encryption
  - Participants were given a scenario with tasks to complete within 90 min
  - Tasks built on each other
  - Participants could ask some questions through email

Lab study results

- 3 users accidentally sent the message in clear text
- 7 users used their public key to encrypt and only 2 of the 7 figured out how to correct the problem
- Only 2 users were able to decrypt without problems
- Only 1 user figured out how to deal with RSA keys correctly.
- A total of 3 users were able to successfully complete the basic process of sending and receiving encrypted emails.
- One user was not able to encrypt at all

Lab study results: Summary

- Interfaces are bad
- Metaphors are wrong (and confusing)
- Opaque process
- Key management is difficult

Roadmap

- Example of a classic usable security study
- General methods/workflow for assessing usability in secure/private systems

Planning a research study

1. Define your research question
2. Identify your variables
3. Pick one/multiple study methods
4. Run your study
5. Evaluate the outcome

1. Defining research questions

Bad research questions

Is [a password manager] usable?

Would [you] fall for a phishing attack?

Is [Institute] fun?

Is [person name] knowledgeable in computer security?

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Not measurable/ testable

Need to be more specific

What is a good research question?

- Specific topic (not how you feel about your privacy)
- Theoretical/practical significance (you should likely to uncover something novel)
- Viable / answerable
- Concrete Ability to know when answered (should have a concrete final anticipated answer)

How to create good research questions : rule of thumb

- Relationship between at least two variables
- Testable, falsifiable
- Variables are clearly defined
- Relationship / how you measure it is clearly defined
- Should be *interesting*

Example research questions

Is [a password manager] usable?	Can users use [new password manager] faster and with less errors than [old password manager]?
Would [you] fall for a phishing attack?	Would [a user] click on a malicious url communicated via email from a known sender? Would [set of factors] will increase/decrease the clicking rate?
Is [Institute name] fun?	Do students of [Institute A] spend equal time in [academic activity] and [non academic activity] than [Institute B]?
Is [person name] knowledgeable in computer security?	Can [person A] write down correct definition of [set of security definition] faster and with less errors without consulting external resources compared to [person B]?

Revisit: usable encryption

- Define what is “usable”
  - Do task within X minutes, #errors, remember the steps etc.
- Identify what your users need to be able to do using your system
- The goals need to be specific and easy to identify if they have or have not been completed
- Example: Digitally sign an email
- Bad example: Show me how to use the sign functionality

1. Define your research question

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Variable measure …

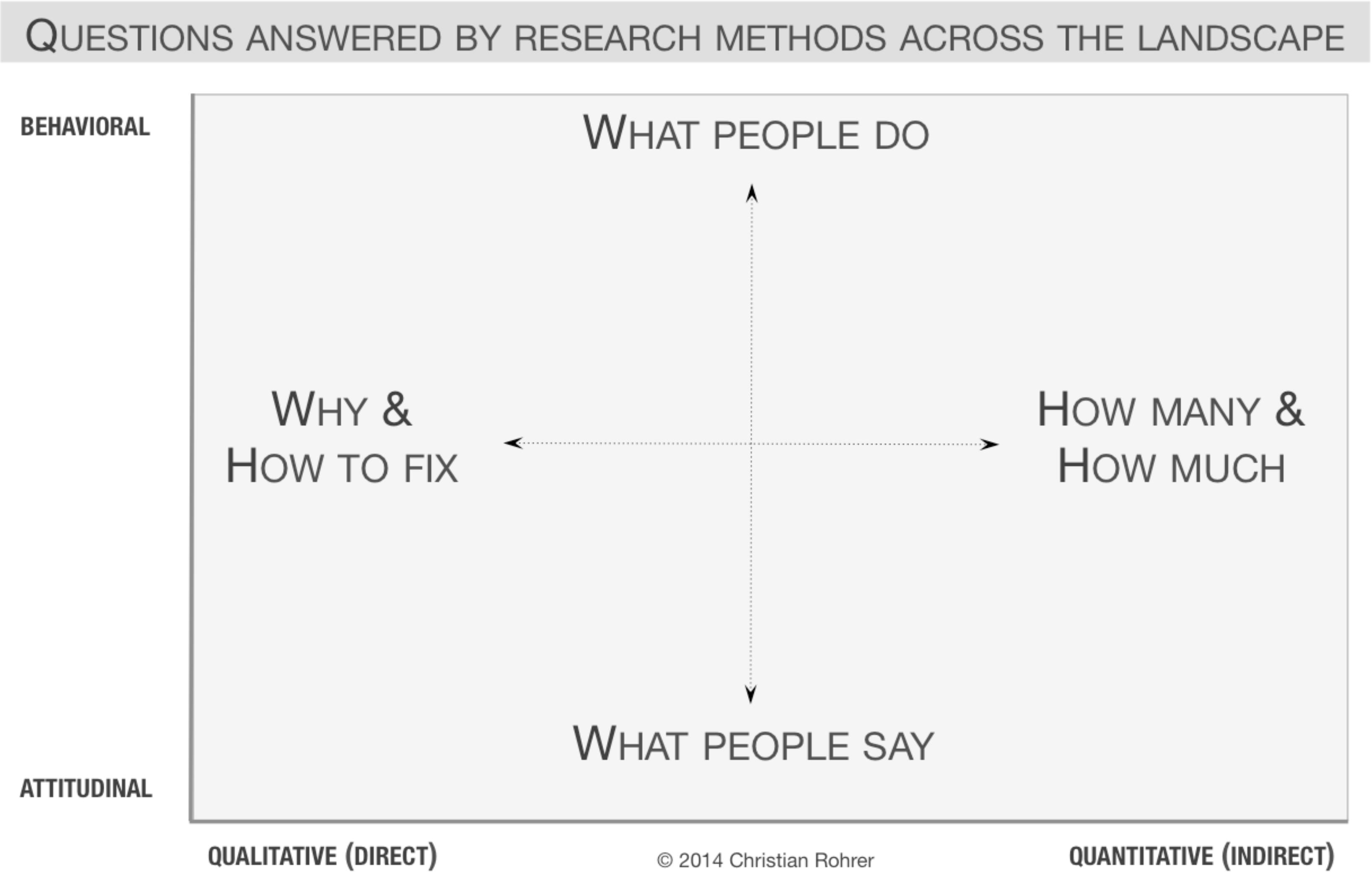
- Variables are a proxy for measuring the concepts you want to know
    - These proxies are called “constructs”

- You can measure:
    - Facts: characteristics, frequency of behaviors
    - Attitudes, preferences

2. Identify your variables

- Attitudinal: User attitudes and opinions
- Behavioral: What the user actually does or is capable of doing

- Qualitative: Unstructured data. Typically unstructured language data
- Quantitative: Structured data. Typically numerical data that can be summed or counted or do mathematical analysis on



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https://www.nngroup.com/articles/which-ux-research-methods/

More on quantitative variables

- Two types of measurements (variables): dependent and independent
- Dependent / outcome variable
  - “Dependent” on the study
  - Measures the usability goal
- Independent variable
  - Anything you are directly manipulating
  - An element of the study which is under your control
  - A pre-existing feature of your participant

Example

- Research question: Can users use [new password manager] faster and with less errors than [old password manager]?
- Dependent / outcome variable
  - Time spent to create a password
  - #errors while inputting the password
- Independent variables
  - Study group (which interface shown, old or new)
  - If the password was meant to be used for bank or Facebook
  - Order of the tasks
  - Time of day
  - Demographics of participants

Common dependent things to measure

- #dangerous errors made
- Time spent in errors
- Time to complete task
- Percent of task completed per unit of time
- Ratio of successes to failures
- Percent or number of errors
- Frequency of help and documentation use

1. Define your research question

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Study methods

- A/B Testing
- Affinity Diagraming
- Card Sorting
- Case Studies
- Cognitive Walkthrough
- Competitive Testing
- Critical Incident Technique
- Customer Experience Audit
- Desirability Testing
- Diary Studies
- Ergonomic Analysis
- Experience Sampling
- Experiments
- Eye tracking
- Fly-on-the-wall Observation
- Focus Groups
- Graffiti Walls
- Heuristic Evaluation
- Interviews
- KJ Technique
- Lab studies
- Observation
- Participatory Design
- Surveys
- Think aloud

1. Lab studies

- Concept: Have a participant come to a lab and interact with the interface there
- You setup the lab so that it mimics the situation you need to have (e.g., set up a really badly designed password manager)
- Pros:
  - Full control over the environment
  - Detailed data, you can ask “why”
- Cons:
  - Small sample size
  - Being in the lab changes user (the can feel safer or stressed)

2. Think aloud studies

- Concept: A participant uses the interface and speak while doing it
- Can be very versatile, long or short, detailed or minimal, planned or ad-hoc
- Pros:
  - Learn what the user is trying to do and why they do some things
  - Detailed data,
  - Requires small sample
- Cons:
  - Talking aloud might change how the user will think about the task
  - You CANNOT measure timing

Requirements of think aloud

- You need to know more than your participant
  - What the participant must do?
  - What errors are dangerous?
- Pre-planning
  - Make sure tasks are interesting to researcher
  - Know what you want to take notes on (or you can record)
- Precise
  - Don’t bias the user, know exactly what you will say
  - Give tasks they can perform
- Analysis
  - Measure # and types of errors. What caused them?

3. Field studies

- Concept: Similar to think aloud, but observe in real world
- Observation may be either direct, where the investigator is actually present during the task, or indirect, where the task is viewed by some other means like a video recorder set up in an office
- Pros:
    - Greater “ecological validity” than think aloud
- Cons:
    - Limited scope
    - Active questions can again change user behavior

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Contextual enquiry is a between think aloud and field studies

4. Diary studies

- Concept: Participants keep track of activities or events in some form of diary or log for a particular period of time.
- Track specific items like mobile device usage or general activities (what you did for each day from 1 pm to 2pm)
- Pros:
  - Information about the user's experience over time.
  - Less lag between feedback
- Cons:
  - All are self-reported
  - Users forget

5. Interviews

- Concept: You ask participants questions (with or without aid of data or interface)
- Can be structured (exact questions), or semi structured (let the user speak after you ask initiation question to set context)
- Pros:
  - Detailed data,
  - Good for exploration (identify themes, gains new perspectives)
- Cons:
  - Usually don't generalize
  - Potential for extra bias from the interviewer

Summary: broad types of studies

- What people want
  - Contextual inquiry
  - Interviews
  - Focus groups (discussion with a group of people with moderator)
  - Surveys (will come next)
  - Diary study (prompt people)

- What/how users think
  - Interviews
  - surveys

Summary: broad types of studies

- Expert evaluation of usability
    - Cognitive walkthrough
- Usability test
    - Laboratory (“think aloud”)
    - Survey
    - Log analysis
- Controlled experiment to test causation
    - A/B testing
- Varying the independent variables
    - Full factorial?

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- What/how users think
  - Interviews
  - surveys

6. Survey and question creation

Questions to ask

Biases to avoid

Pre-testing / piloting

6. Surveys

- Ask participants to answer a set of pre-defined questions.
- Pros:
  - gather data from a large number of people quickly
  - can determine how prevalent an issue or concern is □close-ended questions are easy to analyze
- Cons:
  - can only gather data you know about
  - careful planning is required before running a questionnaire
  - open-ended questions can take a lot of time to analyze and require careful setup

Why surveys?

- Understanding people
  - Understand the target population, mental models
- Testing a theory
  - Do people think that A==B?
- Testing a prototype design
  - How do people interpret functions of my interface?
- Testing the final design
  - How are people actually using my tool?
  - What do people think after they use it?

Common questions

- Attitudes
  - Are you comfortable using X?, Would using X work?
- Behaviors
  - How often do you use X?, Do you regularly do X?
- Knowledge
  - What is the best definition of X?
- Expectations
  - If the webpage did X what would you expect to happen?
- Capabilities
  - Can you write a “hello world” code?

Common parts of a survey

- Single and multiple choice checkboxes
- Matching
    - Rank the following from 1 to 5
- Rating scales
    - Likert Scales (3, 5, 7 points scales, agree or disagree)
- Semantic scales (“very comfortable” to “not comfortable at all”)
- Open ended responses

Open ended vs. close ended

Open ended

Where does this URL go? What does it do?

Close-ended

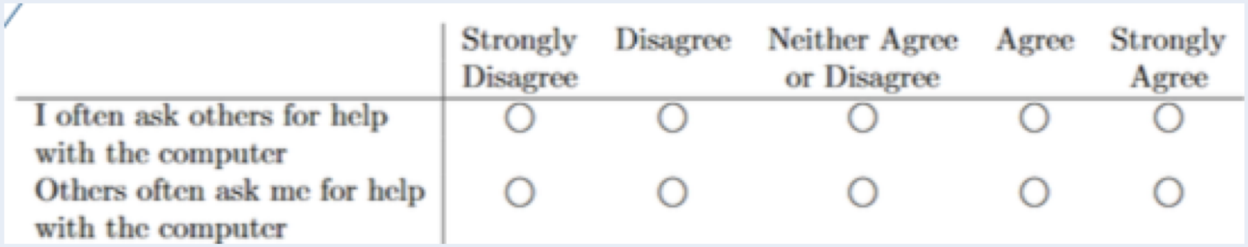
If you clicked on the link above, what web page would open?

○ IIT Kgp's main page
○ Amazon's main page
○ SBI's main page
○ I will be taken to one of the sites above, but not their main page
○ I will be taken to a website not listed above
○ Other _________

Easier to write, harder to analyze

Harder to write, easy to analyze

Types of questions

<table>
<tr><td>Fill in the blank</td><td>What is your age __________</td></tr>
<tr><td>Typical MCQ</td><td>What is the highest level of education you have achieved?
○ High school or less ○ Some college ○ Bachelors degree
○ Masters degree ○ Doctoral degree</td></tr>
<tr><td>Scale where multiple questions are meant to be summed together</td><td>To what extent do you agree or disagree with the following statement (select one answer per row)

<table>
<tr><th></th><th>Strongly Disagree</th><th>Disagree</th><th>Neither Agree or Disagree</th><th>Agree</th><th>Strongly Agree</th></tr>
<tr><td>I often ask others for help with the computer</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>Others often ask me for help with the computer</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
</table></td></tr>
<tr><td>Likert scale question using a pre-defined anchor (skill)</td><td>In terms of internet skills, do you consider yourself to be:
○ Not at all skilled ○ Not very skilled ○ Fairly skilled
○ very skilled ○ Expert</td></tr>
</table>

Question design principles

- Wording matters
    - “usually” can be interpreted in 24 different ways
    - Variation gives incomparable data (I understand security as protecting my computer, for you it is protecting your password)
    - For Usable Security and privacy its worse (domain specific, technical language)
    - Respondents WILL ignore your instructions

A possible method

- Try to come up with higher level section guided by RQs
  - Can be steps of software use
  - Can be specific actions/events you have in mind
- Then for each section create high level things you want to know (as much as you can)
  - Two or more people working together helps
  - The more you know the better you are
- Create constructs for your questions
  - Might not be very good, so need iteration

6. Survey and question creation

Questions to ask

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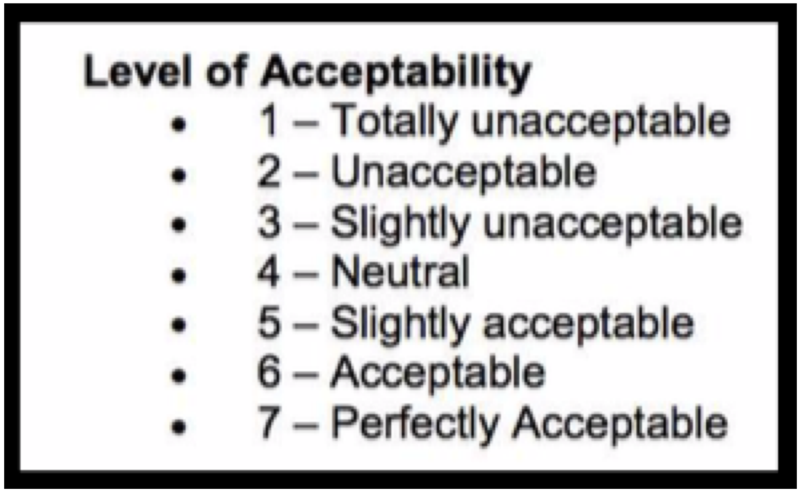
Using Likert scales in the right way

- Used to asses nuanced feelings (e.g., agreement)
  - Good scales are between 4 and 10 points
  - Even scales (4, 6 , 8 options) elicit stronger responses – no neutral option
  - Scaled should be balanced



Level of Acceptability

- 1 – Totally unacceptable
- 2 – Unacceptable
- 3 – Slightly unacceptable
- 4 – Neutral
- 5 – Slightly acceptable
- 6 – Acceptable
- 7 – Perfectly Acceptable

Avoid double barreled questions

- Do you believe that you should update your phone number to Google and change your password every three months?
    - Yes
    - No

Avoid double barreled questions

- Do you believe that you should update your phone number to Google and change your password every three months?
    - Yes
    - No

- Two/more questions: one answer
    - You end up not collecting answers to either

Avoid desirability bias

- Can be priming or leading
  - Question statement might force users likely give a specific answer
  - Question statement hints at a correct answer
- Asking questions so that they think have a correct or a societally correct answer
- Solution: soften the wording
  - People take many rules to create their password for ease of use, which of the following most closely matches a rule that you used or you know others use

Avoid order bias

- Ordering of questions change responses
  - Online survey: people pick top choice
  - On phone: they pick last choice

- Randomize questions and answers