Carleton University
Digital Security Seminar Series

Personal Choice and Challenge Questions: A Security and Usability Assessment

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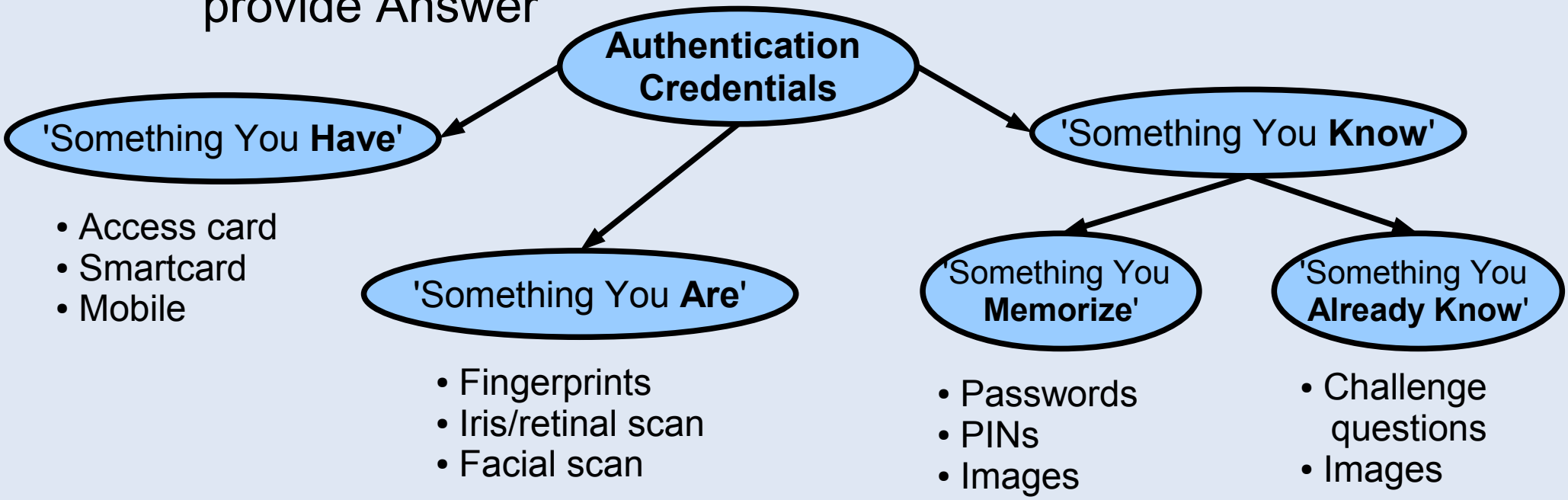
(joint work with David Aspinall)

What are Challenge Questions? (1 of 3)

- What are 'Challenge Questions?'
  - Type of 'authentication credential'
  - Users register Question & Answer
  - To authenticate later, user is posed Question and asked to provide Answer



What are Challenge Questions? (2 of 3)

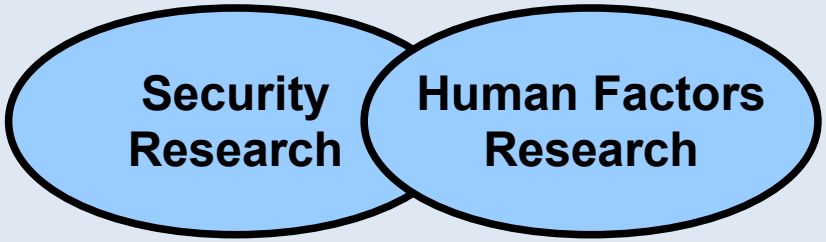
- Common Examples
  - 'What is my Mother's Maiden Name?'
  - 'What was the name of my first pet?'
  - 'What was the name of my primary school?'
- How do Challenge Questions support authentication?
  - The answers to the questions should be known only to the users that registered the questions, similar to how passwords should be uniquely known

What are Challenge Questions? (3 of 3)

- How and why do we use Challenge Questions?
  - Almost exclusively as secondary/fallback authentication in case of lost primary credential
  - Sometimes used to complement primary credential
  - Often driven by desire to avoid costly help-desk calls
  - In some cases, 're-registration' is possible, but not always
    - Too expensive or takes too much time
    - Not all sites have a registration phase (that includes user identification with shared secrets)
  - So, some form of secondary authentication is desireable
    - Challenge Questions are today's ubiqutous choice

Challenge Question Research

- What is studied w.r.t. Challenge Questions?
  1. Security (Attacker's Point-of-View)
     - How difficult is it to determine the answers to the questions?
     - Demonstration of security often involves *quantitative analysis*
  2. Usability (User's Point-of-View)
     - How easy is it to choose questions?
     - How easy is it to remember the answers?
     - Demonstration of usability often involves *qualitative research*



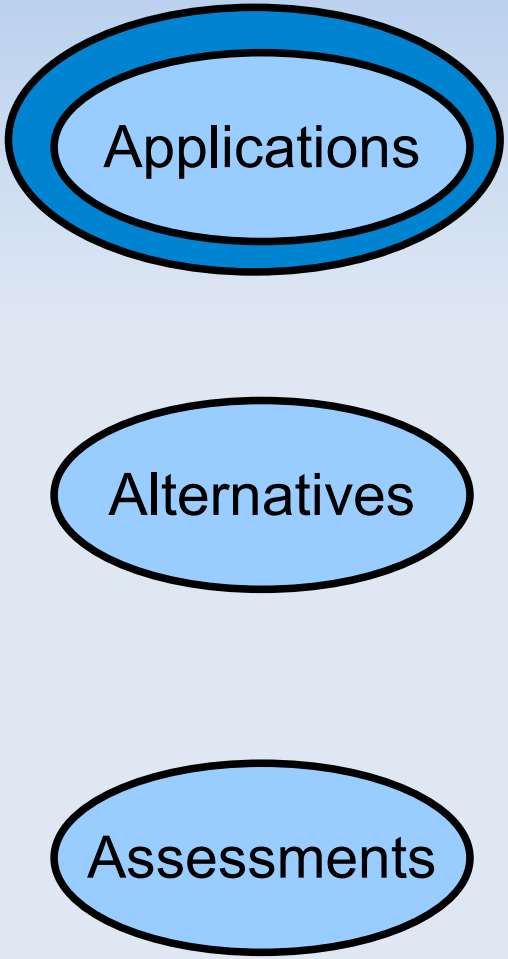
Related Work (1 of 5)

Applications — *Applications of challenge question authentication*

Alternatives — *Alternatives to traditional question-answer model*

Assessments — *Assessments of security and usability*

Related Work (2 of 5)

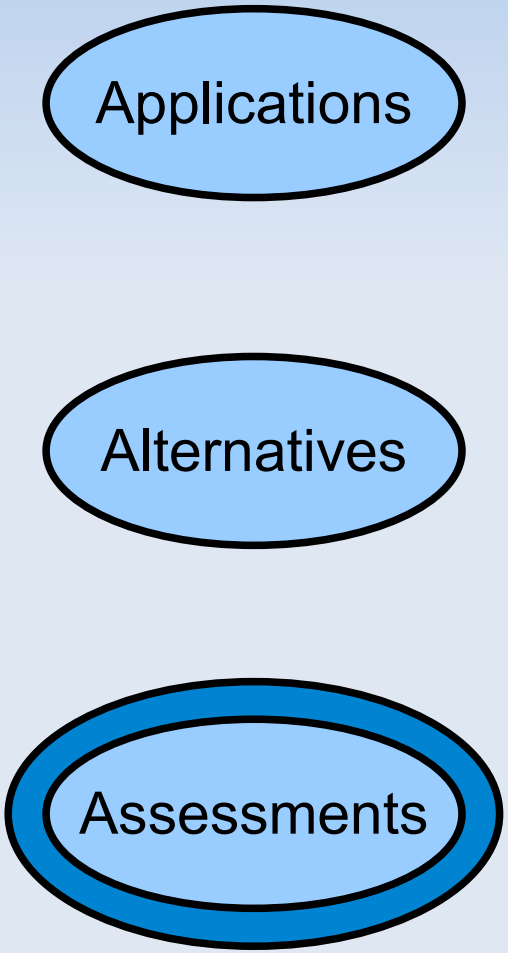


- Introduced as means of authentication of client to server (i.e., password replacement)
  - Haga and Zviran, *Info. Syst. 1991* (and others)
- Challenge questions to protect secret keys
  - Secret sharing to tolerate forgetfulness
  - Ellison *et al.*, *JFGCS 2000*
  - Frykholm and Juels, *ACM CCS 2001*
- Group authentication
  - Shared knowledge between two or more users
  - Toomim *et al.*, *CHI 2008*
  - Bonneau, *Security Protocols 2009.*

Related Work (3 of 5)

- User preferences
  - O'Gormann et al., *Financial Crypto. 2004*
  - Jakobsson et al., *DIM 2008*, *CHI 2008*
- Browsing history
  - Asgharpour and Jakobsson, *IWSSI 2007*
- Digital objects as passwords
  - Mannan and van Oorschot, *HotSec 2008*
- First two: *Something you (already) know*
- Last two: *Something you have (access to)*

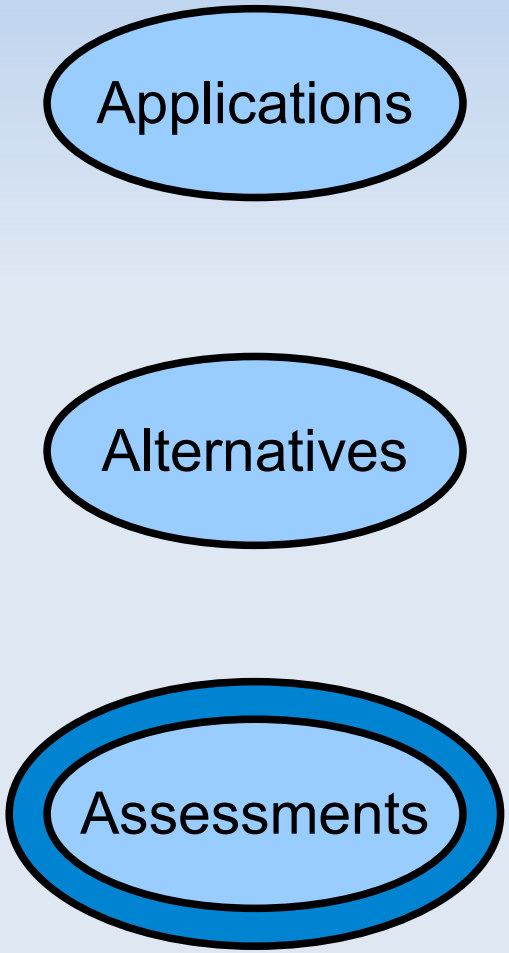
Related Work (4 of 5)



Usability

- Several studies of the applicability, memorability and repeatability of both system- and user-chosen questions
  - Haga, Zviran, *Info. Syst. 1991*
  - Pond *et al.*, *Comp. & Sec. 2000*
  - Rabkin, *SOUPS 2008* (Subjective assessment)
  - Just and Aspinall, *Trust 2009*
  - Schechter *et al.*, *IEEE S&P 2009*
- Results indicate that users have difficulty remembering or repeating their answers

Related Work (5 of 5)



Security

- Assessment using 'live' attacks by friend & family, acquaintances and strangers
  - Haga, Zviran, *Info. Syst. 1991*
  - Pond *et al.*, *Comp. & Sec. 2000*
  - Toomim *et al.*, *CHI 2008*
  - Schechter *et al.*, *IEEE S&P 2009*
- Assessment using 'likelihood' measures
  - Griffith and Jakobsson, *ACNS 2005*
  - Rabkin, *SOUPS 2008*
  - Bonneau, *Security Protocols 2009*
  - Just and Aspinall, *Trust 2009*
- Results indicate that many questions are at risk

Our Research (1 of 2)

- Recent research suggests significant problems with both the security and usability of challenge question authentication systems
  - How can we begin to improve?
- A systematic and repeatable way to analyze the security and usability of challenge questions
  - To continue to assess current systems
  - To allow assessment of future systems
- Our focus was on user-chosen questions ('personal choice')
- Along the way, we discovered an interesting experimental method

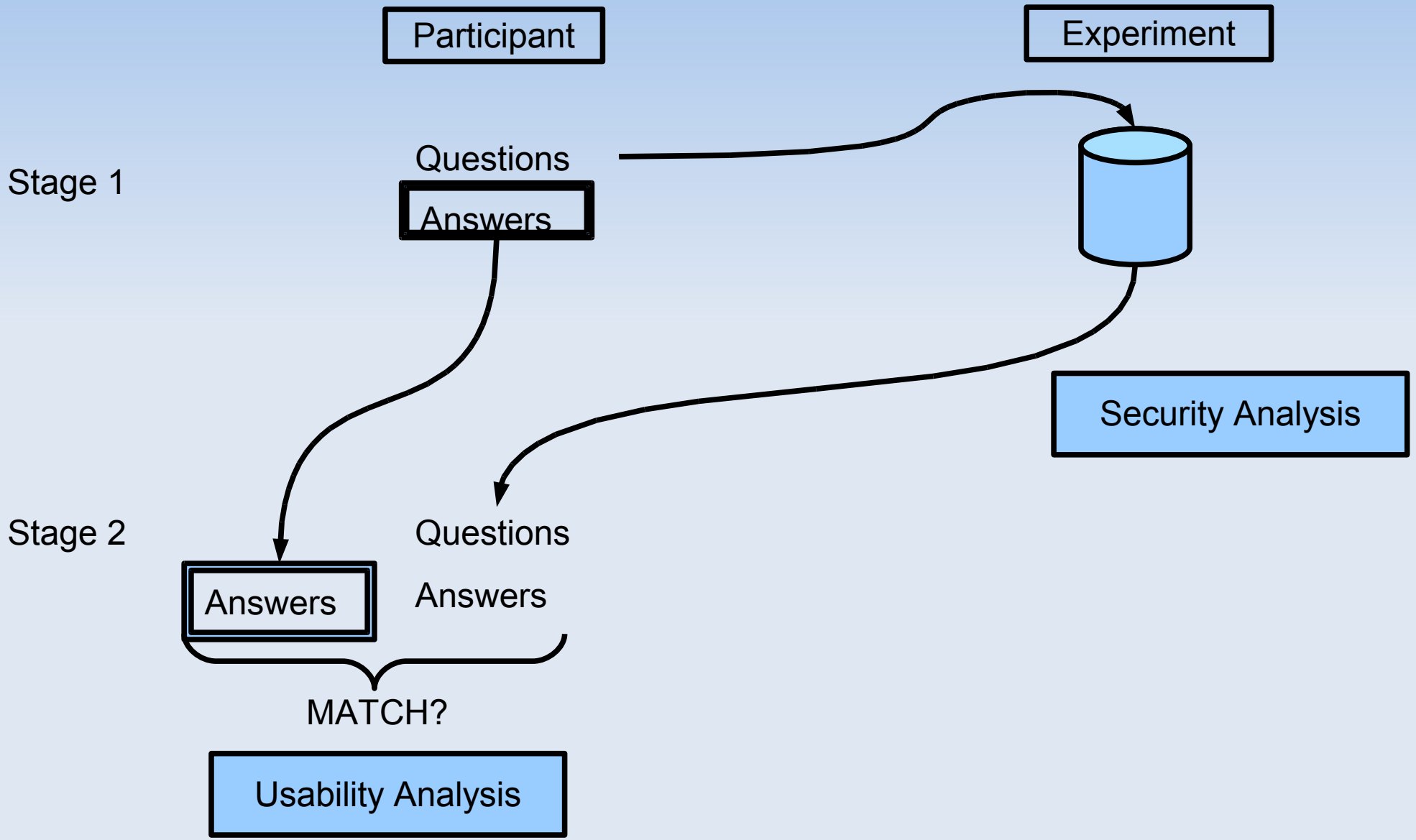
Our Research (2 of 2)

1. Devised novel experiment for collecting authentication information
2. Created a security model for question assessment
3. Assessed the security and usability of 180 user-chosen challenge questions
   - Experiment with 60 first-year Biology students at the University of Edinburgh

Collecting Data (1 of 3)

- Ethically challenging, but users readily submit
- Issues regarding participant behaviour
  - Equate credentials with other private information?
  - Contribute *real* information?
  - Degree of freedom with user-chosen questions
- Opportunities for improved Collector behaviour
  - Challenge to ourselves: Don't collect!
  - Avoid having to maintain information
  - Consistent message: Keep credentials to yourself!

Collecting Data (2 of 3)



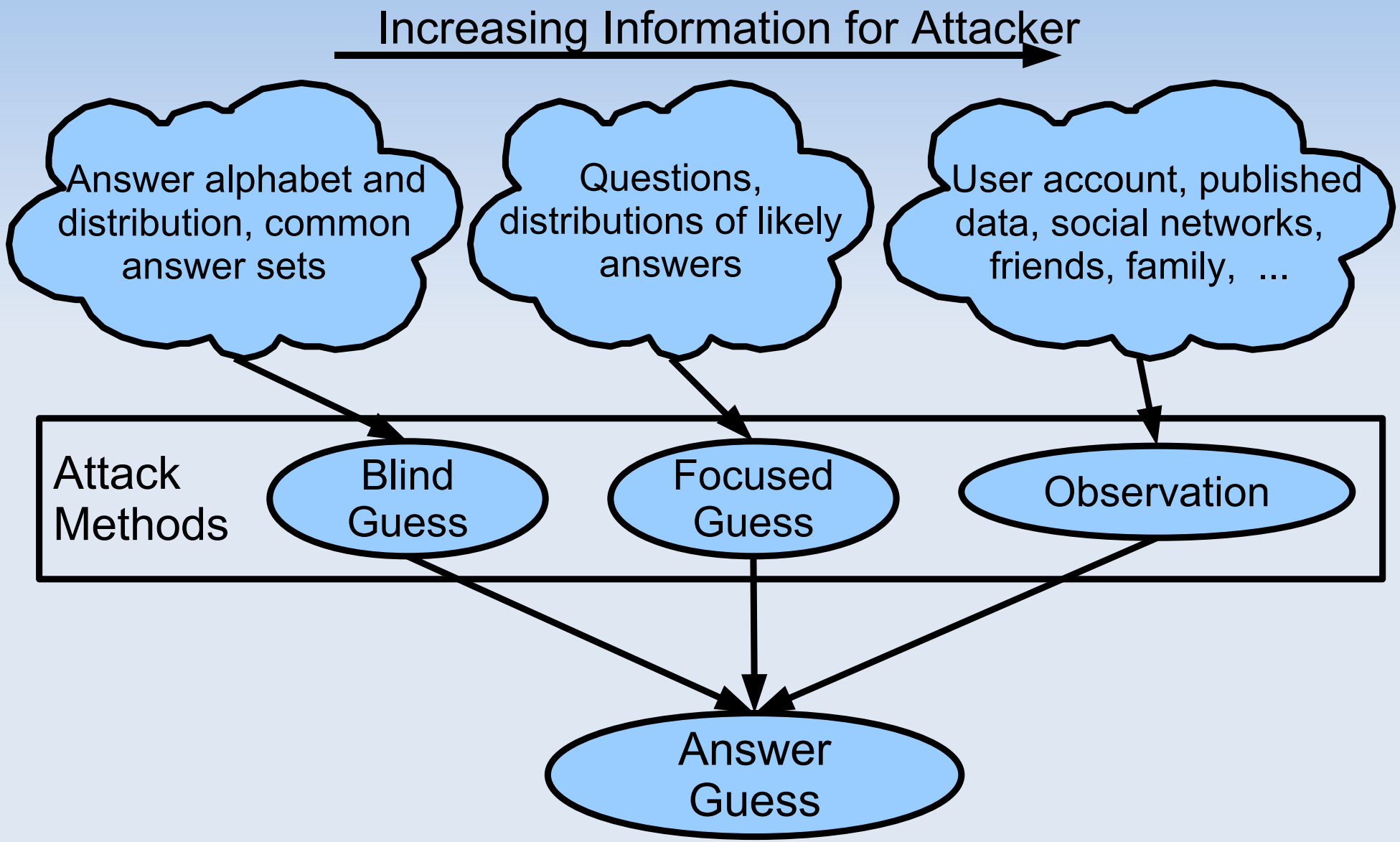
Collecting Data (3 of 3)

- Participants use of 'real' Questions and Answers
  - We asked if participants would use same Questions and Answers in real applications (e.g. Banking)
  - Of the respondents (94%) indicating that they would likely re-use their questions, 45% indicated some influence from not submitting their answers
- Participants and personal privacy
  - We asked participants if they would be concerned if their friends or family members knew their Questions and Answers
  - More than two-thirds of the questions raised 'no concern' at all for participants with < 10% meriting strong concern
- Results are similar to our earlier trials (*Trust 2009*)

Security Model (1 of 2)

- Existing security analysis of Challenge Questions is ad hoc
- There are no clear guidelines for choosing 'good' questions and answers
- We wanted a more systematic and repeatable approach that would
  - Provide some guidance for secure design
  - Allow continued assessment of new solutions
- We encourage further refinement of our model
- Assessment results depend upon context

Security Model (2 of 2)



Security Analysis – Blind Guess (1 of 6)

- Brute force attack
- Security Levels based on equivalence to passwords
  - 6-char alphabetic password (2^{34})
  - 8-char alphanumeric password (2^{48})

Low (2^{34}) Med (2^{48}) High

- Answer entropy: 2.3 bits (1st 8 chars), then 1.5 bits
- Results (by question)
  - Average answer length: 7.5 characters
  - 174 Low, 4 Medium, 2 High
- Results (by user)
  - Q1 – 59 Low, 1 Medium, 0 High
  - Q1, Q2 – 38 Low, 13 Medium, 9 High
  - Q1, Q2, Q3 – 5 Low, 19 Medium, 36 High

Security Analysis – Blind Guess (2 of 6)

- Blind Guess (cont'd)
  - Unlike passwords, the alphabet for answers is just 26 lowercase letters (plus 10 digits in some cases)
  - Use of a single question seems to provide insufficient protection against the simplest attack
  - But, multiple questions seem to help (only considering Blind Guess Attack)
  - Offline attacks would require more security (2^{80})
  - Might consider VeryLow and VeryHigh categories as well

Security Analysis – Focused Guess (3 of 6)

- Attacker knows the Challenge Questions
- Security Levels same as for Blind Guess
- Answer types and space →
- Results (by question)
  - 167 Low, 0 Medium, 13 High
- Results (by user)
  - Q1 – 58 Low, 0 Medium, 2 High
  - Q1, Q2 – 46 Low, 11 Medium, 3 High
  - Q1, Q2, Q3 – 5 Low, 28 Medium, 27 High
- Much room for refinement of 'Space'

Q Type	%	$\log_{10}$Space
Proper Name	50%	4 – 5
Place	20%	2 – 5
Name	18%	3 – 7
Number	3%	1 – 4
Time/Date	3%	2 – 5
Ambiguous	6%	8 – 15

Security Analysis – Observation (4 of 6)

- Attacker tries to obtain or observe the answer
- Security Levels defined qualitatively
  - Low – Answer publicly available
  - Medium – Answer not public, but known to F&F
  - High – Neither
- Levels assigned to questions by
  - Subjective analysis, and
  - Participant input (provided upper bound only)
- Results (by question)
  - 124 Low, 54 Medium, 2 High
- Results (by user)
  - 24 Low, 34 Medium, 2 High
  - Did not ”sum” levels (used max)
- Much room for refinement of levels and analysis

Security Analysis – Overall (5 of 6)

- Overall rating is a 3-tuple (Blind, Focused, Observation)
- Results
  - All Low – 1 participant
  - All High – 0 participants
  - No Lows – 31 participants (50%)
  - (H,M,M) or (M,H,M) – 15 participants (25%)
  - (H,H,M) – 11 participants (20%)
- Dependencies not (yet) considered
- Ability to perform observation attacks in parallel, and offline, is a significant advantage for attackers

Security Analysis – Overall (6 of 6)

- Perceived effort of Stranger to Discover Answers
  - Very difficult (47%)
  - Somewhat difficult (42%)
  - Not difficult at all (11%)
  - Users overestimate the difficulty of attack
- Perceived effort of Friend/Family to Discover Answers
  - Very difficult (11%)
  - Somewhat difficult (36%)
  - Not difficult at all (53%)
  - Users surprisingly aware of this risk

Usability Analysis (1 of 3)

- Usability often refers to 'usable interface design'
- For usable authentication, similar principles apply
  - The user should be able to understand and execute their task
  - We're dealing specifically with information
  - We're more concerned with mental capabilities, e.g., processing, memory

Usability Analysis (2 of 3)

- Applicability
  - Users have sufficient information to provide an answer to a question
  - E.g., 'What was my first pet's name?'
  - Relevant to administratively-chosen questions (not user-chosen)
- Memorability
  - Users can consistently recall the original answer to a question over time
  - Precise recall, 'blank'
- Repeatability
  - Users can consistently and accurately repeat the original answer to a question over time
  - E.g., 'Favourites' change over time, 'Street' versus 'Avenue'

Usability Analysis (3 of 3)

- Answer recall (180 questions)
  - 15 errors (8%)
  - Reduces to 7 errors (4%) if we exclude 'capitalization' errors
- Answer recall (60 users)
  - 11 users (18%) made at least one error
  - Reduces to 7 users (12%) if we exclude 'capitalization' errors
- Comments suggest that 'complicated answers' and allowance of free-form answers may be culprit
- Florêncio & Herley (2007) found that 4.28% of Yahoo! users forget their passwords
- Our results were after 23 days, with young students

What Does it All Mean? (1 of 2)

- Our results corroborate recent results regarding the security and usability of challenge questions
- But, before we write-off challenge questions ...
  - Multiple questions seem to help (security at least)
  - Current implementations are terribly boring
    - Little research of challenge question auth
    - Most has been to assess security and usability
    - Less research into new designs

What Does it All Mean? (2 of 2)

- Potential paths forward
  - Dynamic assessments of security and usability
  - New types of information for authentication (new questions, 5 W's)
  - Options of other methods: who you know, what you have access to, …
  - Users are different – customize to meet their strengths (no 'one-size-fits-all')
- But, how to improve usability ...
  - Fixed-form answers
  - Tolerance for < 100% accuracy

Further Information

- Project web site
  - http://homepages.inf.ed.ac.uk/mjust/KBA.html
- Email
  - mike.just@ed.ac.uk