Interaction with Machine Learning

ACS P230 / Part II unit / CDH - Alan Blackwell & Advait Sarkar

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Overview

- Practical experimental course
  - lectures provide overview and sample of current research
- This introduction
  - general principles, research approaches, current trends
- Specialist lectures:
  - six specialist topics
- Design and run your own study
  - discussion and feedback each week
- Final presentation of your results

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Course objective: deliver "4th wave" of AI

- Four waves of AI according to Google DeepMind founder Demis Hassabis:
  - First wave (GOFAI): Expert systems & symbolic reasoning
  - Second wave: Statistical inference
  - Third wave: Deep learning
  - Fourth wave: Intelligent tools
- Our approach:
  - Intelligent tools as advanced HCI
  - Including: Visualisation, Programming, Labelling, Explanation
- Practical HCI course:
  - Build, measure and observe
- For: Part III and MPhil ACS (research preparation), Part II (advanced HCI), Digital Humanities researchers (guided methods programme)

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Your background

- 1. Prior HCI experience
- 2. Prior ML/AI experience
- 3. What do you hope to get out of this course?

	None	Casual	Student	Professional
HCI	9	9	8	2
ML	6	9	12	1

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Target outcome

- This is a specialised and focused practical research training course.
- The expected outcome:
  - You will achieve research competence in a field such as Intelligent User Interfaces, Interactive Intelligent Systems etc
- ACS assessment will be relative to the international standard of graduate students working in these fields.
  - Written work will be graded relative to typical student publications in the field
  - Presentations will be expected to meet the standard of first-year PhD students in the field, for example at the Doctoral Consortium of a specialised conference.
- Part II assessment will demonstrate competence in delivering and reporting practical experimental work
  - Presentations will be optional
- Digital Humanities students will be briefed separately

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Lecture topics

- Week 2 - Mixed initiative interaction (AB)
  - information gain, cognitive ergonomics, agency & control
- Week 3 - Labelling (AS)
  - attribution, subjectivity, reliability, consistency
- Week 4 - Program synthesis (AB)
  - end-user programming, attention investment
- Week 5 - Visual analytics (AS)
  - visualisation, tool chains, design case studies
- Week 6 - Addressing data bias (Dr Daniela Massiceti, Microsoft Research)
- Week 7 - Interpretability (Prof Neil Lawrence)
- Week 8 – Your research presentations

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Practical work plan – for ACS and Part II

- Week 1 - select research question (part II select replication study)
- Week 2 - discuss potential study approaches (part II discuss preparations)
- Week 3 - review and feedback on study proposals (part II may start work)
- Week 4 & 5 - review logistical issues / practical progress
- Week 6 - discuss preliminary findings
- Week 7 - discuss research implications
- Week 8 - final presentation

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Assessment

- Everyone: final research report (80%)
  - Based on your practical work
  - Presented as a research paper
- Part II: phased submissions of work-in-progress drafts (20%)
  - Flat mark for each submission. *Text can be revised/reused in the final report!*
- ACS: optional (but recommended) work-in-progress drafts (0%)
  - Advisory grades will be provided as feedback, for revision in final report
- ACS: reflective diary (20%)
  - Summarise lectures
  - Document discussions
  - Record development of your own thinking
  - Make 8 weekly entries …
  - … plus a final summative review

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Common criteria for assessment

- Part II – will be marked to CST Part II unit standards
- ACS – will follow standard ACS criteria:
  - 90-100% - Original contribution
  - 80-89% - Significant insight or creativity
  - 75-79% - Demonstrates critical thought
  - 70-74% - Execution basically good
  - 60-69% - Adequate presentation
  - 50-59% - Some serious flaws
  - 40-49% - Work is poor
- All - preliminary feedback for guidance
  - A+ excellent - on target for 85-100
  - A very good - on target for 75-85
  - B good - on target for 70-80
  - C acceptable - on target for 60-70
  - D disappointing - risk of fail

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Continuous feedback

- Week 2 - Research question (200 words) + a sample diary entry for ACS
- Week 3 - Study design (400 words)
- Week 4 - Another sample diary entry for ACS
- Week 5 - Draft literature review for final report (400 words)
- Week 6 - Draft introduction to report (200 words)
- Week 7 - Draft results section for report (400 words)
- Week 8 - Draft discussion section for report (200 words)

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Continuous feedback – submit by noon each Tuesday

Week	Part II	ACS
2	Selection of study for replication, with summary of the key research question	Research question (200 words) + a sample diary entry
3	Detailed work plan for data collection and analysis	Study design (400 words)
4	Literature review (summary of original publication, and other work that cites it)	Another sample diary entry
5	Introduction to the replicated study	Draft literature review for final report (400 words)
6	Results and data analysis	Draft introduction to report (200 words)
7	Discussion of results and conclusion	Draft results section for report (400 words)
8		Draft discussion section for report (200 words)

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Reading suggestions

- Refresh undergraduate HCI
  - Cambridge notes online
  - Preece, Rogers and Sharp Interaction Design beyond HCI
- Cambridge guidance on human participants
  - https://www.tech.cam.ac.uk/research-ethics/school-technology-research-ethics-guidance
- Cairns and Cox (2008)
  - Research Methods for Human-Computer Interaction
- Carroll (2003)
  - HCI Models, Theories and Frameworks: Toward a multidisciplinary science
- **Mostly: Recent research literature**

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A note about the reading list

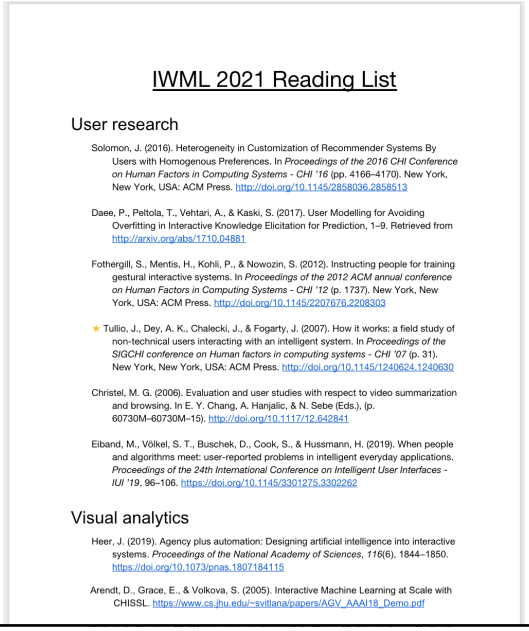
Available on course materials page.

Don't try to read all of it!

"Starred" entries are particularly good for one or more of the following reasons:
- Influential
- Well-executed research
- Interesting/unique angle

Read at least the abstracts of all of the starred entries.

Use as a basis for your own research question/study design.



IWML 2021 Reading List

User research

Solomon, J. (2016). Heterogeneity in Customization of Recommender Systems By Users with Homogenous Preferences. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16* (pp. 4166–4170). New York, New York, USA: ACM Press. http://doi.org/10.1145/2858036.2858513

Daee, P., Peltola, T., Vehtari, A., & Kaski, S. (2017). User Modelling for Avoiding Overfitting in Interactive Knowledge Elicitation for Prediction, 1–9. Retrieved from http://arxiv.org/abs/1710.04881

Fothergill, S., Mentis, H., Kohli, P., & Nowozin, S. (2012). Instructing people for training gestural interactive systems. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12* (p. 1737). New York, New York, USA: ACM Press. http://doi.org/10.1145/2207676.2208303

★ Tullio, J., Dey, A. K., Chalecki, J., & Fogarty, J. (2007). How it works: a field study of non-technical users interacting with an intelligent system. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07* (p. 31). New York, New York, USA: ACM Press. http://doi.org/10.1145/1240624.1240630

Christel, M. G. (2006). Evaluation and user studies with respect to video summarization and browsing. In E. Y. Chang, A. Hanjalic, & N. Sebe (Eds.), (p. 60730M–60730M–15). http://doi.org/10.1117/12.642841

Eiband, M., Völkel, S. T., Buschek, D., Cook, S., & Hussmann, H. (2019). When people and algorithms meet: user-reported problems in intelligent everyday applications. *Proceedings of the 24th International Conference on Intelligent User Interfaces - IUI '19*, 96–106. https://doi.org/10.1145/3301275.3302262

Visual analytics

Heer, J. (2019). Agency plus automation: Designing artificial intelligence into interactive systems. *Proceedings of the National Academy of Sciences*, *116*(6), 1844–1850. https://doi.org/10.1073/pnas.1807184115

Arendt, D., Grace, E., & Volkova, S. (2005). Interactive Machine Learning at Scale with CHISSL. https://www.cs.jhu.edu/~svitlana/papers/AGV_AAAI18_Demo.pdf

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Theories of interaction

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Human-Computer Interaction (HCI) - Three waves

- First wave (1980s):
  - Theory from Human Factors, Ergonomics and Cognitive Science
- Second wave (1990s):
  - Theory from Anthropology, Sociology and Work Psychology
- Third wave (2000s):
  - Theory from Art, Philosophy and Design

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First wave: HCI as engineering "human factors"

- The "user interface" (or MMI "man-machine interface") is a separate module, designed independently of the main system.
- Design goal is efficiency (speed and accuracy) for a human operator to achieve well-defined functions.
- Use methods from cognitive science to model users' perception, decision and action processes and predict usability
  - At this point, relatively closely aligned with AI

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Second wave: HCI as social system

- AI models did not result in more usable machines (see esp. Lucy Suchman)
  - Resulted in significant intellection challenge to cognitive science and AI
- The design of complex systems is a socio-technical experiment
  - Take account of other information factors including conversations, paper, and physical settings
- Study the context where people work
  - Use ethnography (or "Contextual Inquiry" or "Workplace Studies") to understand other ways of seeing the world and characterise social structures
- Other stakeholders are integrated into the design process
  - Prototyping and participatory workshops aim to empower users and acknowledge other value systems

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Third wave: HCI as culture and experience

- Ubiquitous computing affects every part of our lives
  - It mixes public (offices, lectures) and private (bedrooms, bathrooms)
- Outside the workplace, efficiency is not a priority
  - Usage is discretionary
  - User Experience (UX), includes aesthetics, affect,
- Design experiments are speculative and interpretive
  - Critical assessment of how this is meaningful
- Was until 2018 pretty much completely divorced from AI
  - But this is changing very rapidly, as critical AI studies mature!

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Summary of Cambridge HCI content

- Textbooks
  - Preece, Sharp & Rogers
  - Carroll
- Part 1a Interaction Design
  - Requirements analysis and design process, data collection (observation, interviews, focus groups) and analysis. Design and prototyping, personas, storyboards and task models. Principles of good design. Human cognition. Usability evaluation.
- Part 1b Further HCI
  - Theory driven approaches. Design of visual displays. Goal-oriented interaction. Designing smart systems. Designing efficient systems. Designing meaningful systems. Evaluating interactive system designs. Designing complex systems.
- Part 2/3
  - Affective Computing, Computer Music, Advanced Graphics …

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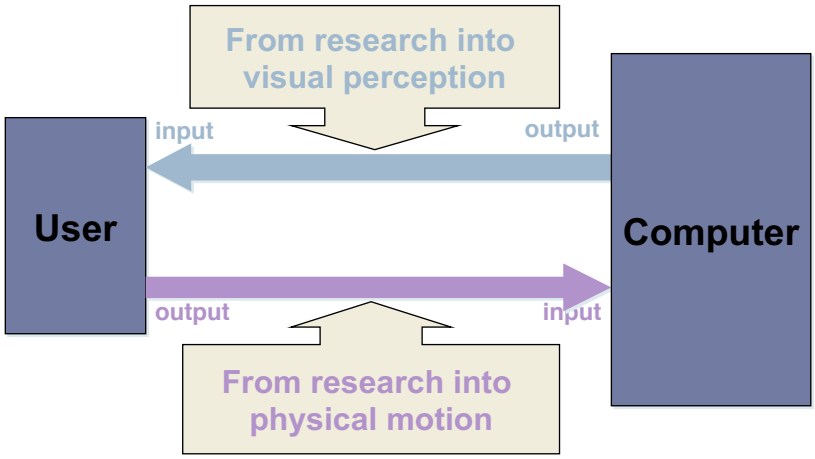
Classical cognitive science models of first-wave HCI



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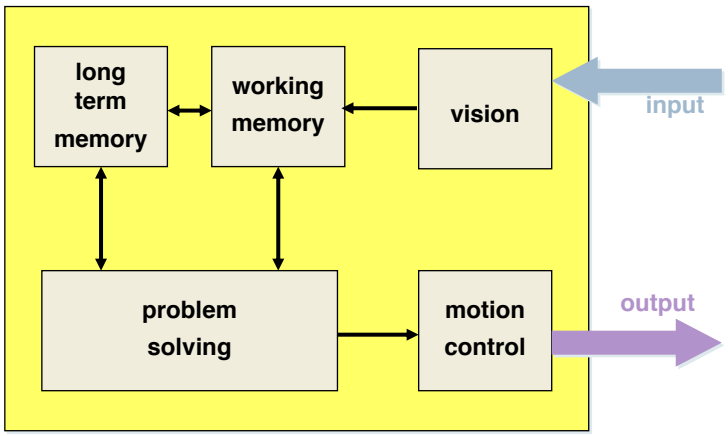
Classical cognitive science model of the user ('boxology')



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Engineering models of human I/O, memory, CPU

- Seeks "impedance match" of computer with computational user model
  - Extend principles of human factors and ergonomics
  - Psychophysical perception
  - Speed and accuracy of movement at keystroke level
  - Reaction and decision time
  - Include working memory capacity
    - 7 +/- 2 'chunks'
    - Single visual scene
  - GOFAI-planner style Goals Operators Methods Selection
- Is intelligent task design a matter of 'cognitive ergonomics'?

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The problem of learning (Clayton Lewis, Jack Carroll, Mary Beth Rosson …)

- Classical models assumed users would be made to read the manual
- In contrast, *discretionary usage* systems require exploratory learning models because users can (and do) walk away
  - Focus on minimal instruction, immediate progress toward user goals
  - Now taken for granted (but only after long battle with usability advocates)
- Cognitive walkthrough review methods allowed system designers to anticipate usability problems, based on model of situated learning rather than cognitive model of planning

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The sticky problem of viscosity (Thomas Green)

- Deciding what to do is often harder than doing it
  - But HCI models assume a 'correct' sequence of actions
- How do you change your mind if something goes wrong?
  - problem solving
  - planning
  - knowledge representation
- External representations are often required
  - But did the designers anticipate people making mistakes?
- Many systems and visual representations make it hard to change your mind

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Wicked problems (Rittel & Webber)

- Formulated in reaction to promotion of AI/cybernetic methods (e.g. optimization, goal-directed search) in business schools and public policy
- Wicked problems have:
  - no definitive formulation
  - no stopping rule
  - no true-or-false outcome: only good-or-bad
  - no ultimate test of a solution
  - no set of permissible operations
  - essentially unique

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Intelligent interaction

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Established paradigms of interacting with ML

- Perfect information games (toy worlds, chess, go, videogames)
  - Not considered particularly interesting
- Recommender systems
  - Once a major research area, now familiar - Amazon, Spotify etc etc
- Dialogue models: diagnostics, FAQ retrieval, interactive query refinement
  - An early example was "metaFAQ" from Cambridge company Transversal
  - But also familiar – consider usage of Google results, autocomplete, image search
- Programming by example / program synthesis
  - See Lieberman *Watch What I Do*, but also e.g. Microsoft Excel FlashFill
- Human-in-the-loop automation
  - Autopilots, remote-operation, "autonomous" vehicles
- Turing tests – but what is the (wicked?) objective function?

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Topics at 2021 Intelligent User Interfaces (IUI) conference

- Evaluations of intelligent user interfaces
  - experiments, studies, meta-analyses
- Modalities
  - agents, multi-modal (speech, gestural, gaze), conversational, tangible, visualization
- Interface paradigms
  - affective, collaborative, AR/VR, wearables/mobile, ubicomp
- Application areas
  - IoT, education, healthcare, social media, info retrieval/search, recommender systems

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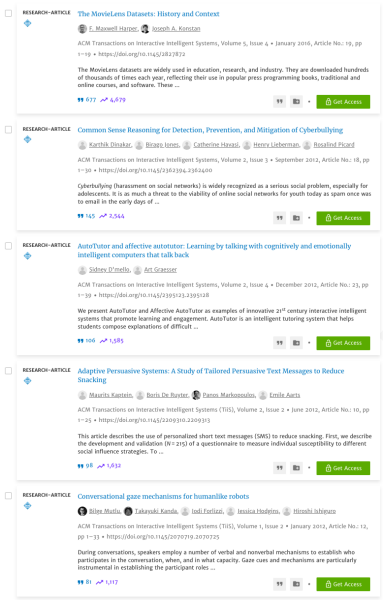
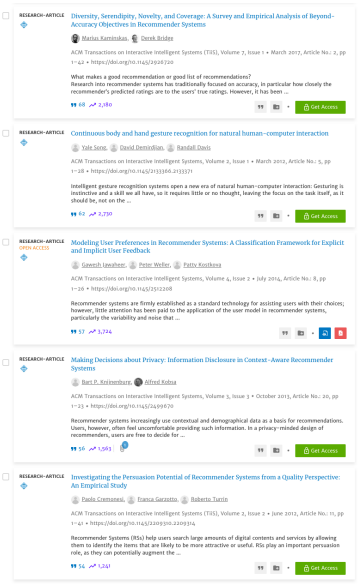
Top cited papers in ACM TIIS (Trans. Intelligent Interactive Systems)



Dataset	Evaluation methods; recommender systems; experiments
Social intervention; user modelling	Gestural interaction; ML model
Affective computing; education; controlled experiments	User modelling; recommender systems; human-in-the-loop learning
Conversational interaction; questionnaire; experiments	Trust/transparency; recommender systems; experiment
Gaze interaction; conversational interaction Human-robot interaction; controlled experiments	Trust/transparency; recommender systems; experiment



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TIIS Special Issues

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Recent papers at CHI (and elsewhere)

- Useful overview papers:
  - Dudley, J. J., & Kristensson, P. O. (2018). A Review of User Interface Design for Interactive Machine Learning. *ACM Transactions on Interactive Intelligent Systems*, *8*(2), 1–37. https://doi.org/10.1145/3185517
  - Abdul, A., Vermeulen, J., Wang, D., Lim, B. Y., & Kankanhalli, M. (2018). Trends and Trajectories for Explainable, Accountable and Intelligible Systems. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–18. https://doi.org/10.1145/3173574.3174156
- Ashktorab, Z., Jain, M., Liao, Q. V., & Weisz, J. D. (2019). Resilient Chatbots: Repair Strategy Preferences for Conversational Breakdowns. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–12. https://doi.org/10.1145/3290605.3300484
- Eiband, M., Völkel, S. T., Buschek, D., Cook, S., & Hussmann, H. (2019). When people and algorithms meet: User-reported Problems in Intelligent Everyday Applications. *Proceedings of the 24th International Conference on Intelligent User Interfaces*, *Part F1476*, 96–106. https://doi.org/10.1145/3301275.3302262
- Buolamwini, J., & Gebru, T. (2018). Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification. *Proceedings of Machine Learning Research*, *81*, 77–91. http://proceedings.mlr.press/v81/buolamwini18a.html
- Alvarado, O., & Waern, A. (2018). Towards Algorithmic Experience: Initial Efforts for Social Media Contexts. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–12. https://doi.org/10.1145/3173574.3173860
- Chen, N.-C., Suh, J., Verwey, J., Ramos, G., Drucker, S., & Simard, P. (2018). AnchorViz: Facilitating Classifier Error Discovery through Interactive Semantic Data Exploration. *Proceedings of the 2018 Conference on Human Information Interaction&Retrieval - IUI '18*, 269–280. https://doi.org/10.1145/3172944.3172950
- Yang, Q., Suh, J., Chen, N.-C., & Ramos, G. (2018). Grounding Interactive Machine Learning Tool Design in How Non-Experts Actually Build Models. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*, 573–584. https://doi.org/10.1145/3196709.3196729

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Research methods

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Ethical Issues in Research

- Review the Cambridge Technology Ethics guide
  - What kind of study are you planning?
  - What potential concerns might there be?
  - What will you do to address them?
- Submit a proposal to the Computer Science Ethics committee, giving above details.
  - https://dbwebserver.cl.cam.ac.uk/Administration/Ethics/EthicsRequest.aspx
  - (accessible from VPN – part II students send me details based on) https://www.cst.cam.ac.uk/local/policy/ethics/submission-read-only

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Controlled Experimental Methods

- ***Participants*** (subjects), potentially in ***groups***
- Experimental ***task***
- Performance ***measures*** (speed & accuracy)
- Trials
- ***Conditions*** / Treatments / Manipulations
  - modify the system
  - use alternative systems
  - Use different features of the system
- ***Effect*** of treatments on sample means
  - Within-subjects (each participant uses all versions)
  - Between-subjects (different groups use different versions)

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Controlled Experiments in HCI

- Based on a number of observations:
  - How long did Fred take to complete this task?
  - Did he get it right?
- But every observation is different.
- So we compare averages:
  - over a number of trials
  - over a range of people (experimental subjects)
- Results often have a normal distribution

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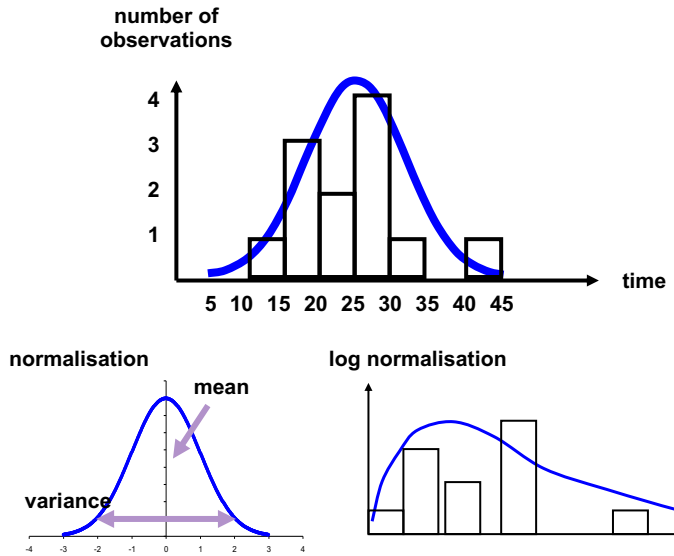
Sample Distribution



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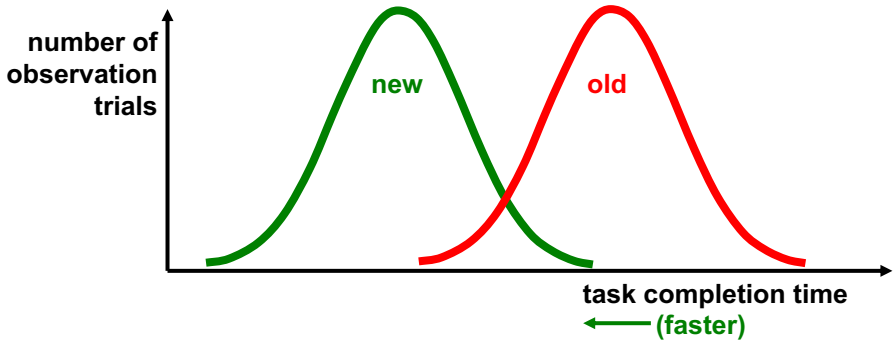
Effect Size



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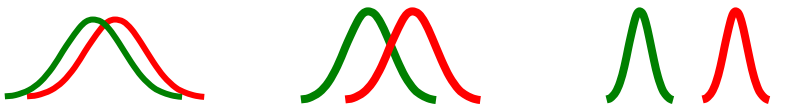
Significance testing

- What is the likelihood that this amount of difference in means could be random variation between samples (null hypothesis)?
- Hopefully very low ($p < 0.01$, or 1%)



only random variation observed

observed effect probably does result from treatment

very significant effect of treatment

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Experimental Manipulations

- Compare productivity gains (effect size) of version with new feature to one without?
  - Will system work without the new feature?
  - Will the experimental task be meaningful if the feature is disabled?
  - Must new feature be presented second in a within-subjects comparison (order effect)
  - Is your system sufficiently well-designed for external validity of productivity measure?
- Is full implementation necessary?
  - Can you simulate features with Wizard of Oz technique?

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Measurement

- Speed (classically 'reaction time')
  - Time to complete task
- Accuracy (number of (non)errors).
  - Is outcome as expected
- Trade-off between speed and accuracy?
  - Or poor performance on both?
  - Check correlation between them
- Task completion:
  - Stop after a fixed amount of time (ideally < 1 hour)
  - Measure proportion of the overall task completed

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Self-Report

- Did you find this easy to use? (Likert scale)
  - applied value: appeal to customers
  - theoretical value: estimate 'cognitive load'
- Danger of bias
  - Subjective impressions of performance inaccurate
  - Suffer from experimental demand
    - Participants want to be nice to the experimenter
    - Should disguise which manipulation is the novel one
- May be necessary to capture affect measures:
  - Did you enjoy it, feel creative/ enthusiastic?
- Alternative is to collect 'richer' data …

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Think-aloud

- "Tell me everything you are thinking"
  - 'concurrent verbalisation'
- Problems:
  - Hard tasks become even harder while speaking aloud
  - During the most intense (interesting) periods, participants simply stop talking,
- Alternative:
  - make video recording, or eye-tracking trace
  - playback for participant to narrate
  - 'retrospective verbal report'

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Qualitative Data

- Protocol analysis methods, e.g.
  - verbal protocol – transcript of recorded verbal data
  - video protocol – recording of actions
- Hypothesis-, or theory-driven
  - Create 'coding frame' for expected/hypothetical categories of behaviour
  - Segment the protocol into episodes, utterances, phrases etc
  - Classify these into relevant categories (considering inter-rater reliability)
  - Compare frequency or order statistically
- Grounded theory
  - Open coding, looking for patterns in the data
  - Stages of thematic grouping and generalization
  - Constant comparison of emerging framework to original data
  - More interpretive, danger of subjective bias

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Experiment Design

- Arrangement of participants, groups, tasks, trials, conditions, measures, and hypothesized effects of treatments
- Within-subjects designs are preferred
  - because so much variation between individuals
- This leads to order effects:
  - first condition may seem worse, because of learning effect
  - last condition may suffer from fatigue effect
  - task familiarity – can't use the same task twice
- Precautions:
  - Prior training to reduce learning effects
  - Minimise experimental session length to reduce fatigue effects
  - Use different tasks in each condition, but 'balance' with treatment and order
- These are typically combined in a 'latin square' where each participant gets a different combination

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Analysis

- For an easy life, plan your analysis before collecting data!
- Will quantitative data be normally distributed?
  - t-test to compare two groups
  - ANOVA to compare effect of multiple conditions (which include latin square of task and order)
  - Pearson correlation to compare relationship between measures
- Distributions of task times are often skewed:
  - a small number of individuals complete the task quite slowly
  - don't exclude 'outliers' who have difficulty with your system
  - log transform of time is usually found to be normally distributed
- Subjective ratings are seldom normally distributed
  - chi-square test of categories
  - non-parametric comparison of means

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Evaluation

- Rather than testing hypothesis, or comparing treatments
  - ask 'is my system usable'?
- More typical of commercial practice, for short-term goals, rather than general understanding
  - Formative evaluation assesses options early in design process
  - Summative evaluation identifies usability problems in a system you have built
  - Repeated for iterative refinement in user-centred design
- Weaker research, because no direct contribution to theory
  - However applied research venues require evidence of any claims made for new tools

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Field Study Methods

- Laboratory studies are not adequate for:
  - organizational context of system deployment
  - interaction within a user community
- Typical methods:
  - 'contextual inquiry' interviews
  - 'focus group' discussions
  - 'case studies' of projects or organisations
  - 'ethnographic' field work as participant-observer
- All result in qualitative data, often transcribed, and analysed using grounded theory approaches

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Planning your study

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Candidate interactive systems / intelligent tools

- your own personal research
  - e.g. MPhil dissertation
- other research
  - other research in Cambridge
  - recent product releases
  - research prototypes developed elsewhere
- theoretical models
  - including topics introduced in our specialist lectures
  - is there a (well-articulated) user model to challenge?
- applications research
  - who is the intended user?
  - what will they be trying to achieve?

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Representative tasks and measures

- Identify user activities you plan to observe
  - assigned tasks (controlled experiment)
  - or user's goal (observational study)
- Will these explore an interesting research question?
- What measures are relevant to that question?
- Will qualitative data analysis be necessary?
- Will there be a threat to external validity?
  - From task, measure or analysis

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Review of study design options

- Do you wish to carry out a comparison, an evaluation, or an open exploratory study?
- If you plan to conduct a controlled experiment, will it be possible to use a within-subjects design?
- What data analysis method will you use?
- What would you need to do in order to complete a pilot study?
- What ethical issues are raised by your planned research?

- A good starting point is to choose a published study that you would like to emulate / replicate

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Theoretical goal

- What do you expect to learn from conducting your study?
- What contribution will it make to the research literature in interaction with machine learning?
- Where would you publish the results?

- A good starting point is to review contributions that were made in published studies you would like to emulate
  - Warning – be careful of studies done without prior training in HCI, and not published in peer-reviewed HCI venues.

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Techniques for remote studies

- Surveys and questionnaires
- Interviews
- Instrumented remote prototypes (i.e., telemetry)
- Diary studies & experience sampling (see https://www.microsoft.com/en-us/research/project/meetings-during-covid-19/ for a recent example)
- Things that don't work well:
  - prototypes requiring a complicated software setup
- Paid recruitment tools: UserTesting.com, Amazon Mechanical Turk, Microworkers, Prolific.
- Free recruitment tools: r/SampleSize, friends and family, this class (beware bias)!
- Survey/questionnaire deployment tools: Microsoft Forms, Google Forms, Survey Monkey

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Review of feedback timetable (submit by noon each Tuesday)

Week	Part II	ACS
2	Selection of study for replication, with summary of the key research question	Research question (200 words) + a sample diary entry
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+ don't forget diary entries every week

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