The Design of Interactive Computational Media

Class 10: 18 Mar. 2003

System and Interface Evaluation 2 *

* Some material adapted from J. Tombaugh and R. Dillon, *A Practical Introduction to Experimental Design in CHI Research*, CHI Tutorial Notes, 1992

Second Hour of Last Class

- Usefulness and usability
- Empirical evaluation, and its use in the design process
- Observing scenarios and prototypes
- User testing with thinking aloud
- Data capture and analysis
- Asking users as well as testing them
- Ethical issues

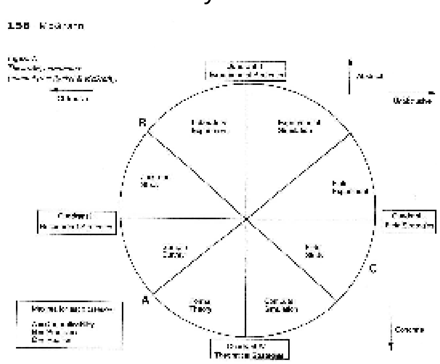
Outline

- Goals for research in HCI
- McGrath's taxonomy of research methods
  - Field strategies
  - Experimental strategies
  - Respondent strategies
  - Theroretical strategies
- Demonstrations (a respondent strategy)
- Usability inspection (a respondent strategy)
- Controlled experiments
- Quasi-experiments
- Tradeoffs among empirical methods
- Research methods in the development process

Goals for Research in HCI

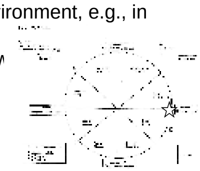
- Evaluate or compare existing systems/features/interfaces
- Invent or design new systems/features/interfaces
- Discover and test useful scientific principles
- Establish benchmarks/standards/guidelines

McGrath's Taxonomy of Research Methods



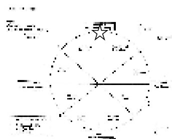
Quadrant 1 — Field Strategies

- Study systems in real use on real tasks in real work environments, i.e., observe under settings with conditions as natural as possible
- Field studies — Study systems in situ, disturbing as little as possible, e.g., with ethnography and interaction analysis (Class 3), contextual inquiry
- Field experiments — Observe impact of changing (ideally) one aspect of a work environment, e.g., in beta testing, studies of technological change and new technology introduction



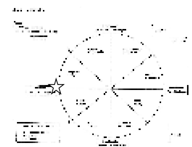
Quadrant 2 — Experimental Strategies

- Study systems in a lab under controlled conditions, i.,e., conditions concocted for research purposes
- Laboratory experiments — Carry out controlled experiments studying impacts of (ideally) one (or two) interface parameter(s) (later this class)
- Experimental simulations — Create in lab for experimental purposes a real system that is used by real users on (usually) artificially simplified tasks, e.g., user testing (last class), usability engineering



Quadrant 3 — Respondent Strategies

- Ask informants to tell us something about themselves and/or their work or about an interface, i.e., where the setting in which questions are asked plays no role
- Judgment studies — Ask respondents about an interface, e.g., in a demonstration (later this class), or with usability inspection (later this class)
- Sample surveys — Ask respondents about themselves and/or their work, i.e., with questionnaires, surveys, interviews (class 3)



Quadrant 4 — Theoretical Strategies

- Ask a theory to tell us something about people's work and/or about an interface, i.,e., no observation of behaviour, experiments, or questions are required
- Formal theory — Use a qualitative theory or some equations, e.g., design theory such as Norman's 7 stages (classes 6 and 7), or behavioural theory, such as colour vision or Fitts' Law (next week)
- Computer simulation — Use and run a computer model, e.g., human information processing theory (CSC 428F)

Respondent Strategies

- Judgment studies
  - Demonstrations
  - Usability inspection
    - Heuristic evaluation
    - Cognitive walkthroughs
- "Sample surveys" (Class 3)
  - Questionnaires
  - Surveys
  - Interviews

Demonstrations

- Method
  - Demonstrate system to:
    - Any warm body you can capture
    - Management, potential investors, journalists
    - Potential customers
    - Potential users
    - Potential business partners
  - Take detailed notes
- Role
  - Elicit reactions to user's model, functionality, interface

Demonstrations

- Advantages
  - Get feedback early in prototype or system construction
  - You're going to have to give demos anyway — why not learn from them?
- Disadvantages
  - System still rough, which introduces noise into process
- Examples
  - Happens on all projects

Usability Inspection

- Methods
  - *Heuristic evaluation* — Judgments by a panel of evaluators (e.g, 3 to 5) of the degree to which an interface satisfies a set of usability guidelines, followed by discussion and analysis
  - *Cognitive walkthroughs* (CSC428)
- Roles
  - Evaluation without users (contrast to usability tests, etc.)
  - Elicit *expert opinions* about the user's model, functionality, look & feel, etc.

Usability Inspection

- Advantages
  - Structured method of using accumulated wisdom of experts
- Disadvantages
  - Doesn't take advantage of real insights from real users
- Example — Heuristic evaluation with 10 usability guidelines (Nielsen, BGBG, Fig. 2.7, p. 83)
  - Visibility of system status
  - Match between system and the real world
  - User control and freedom
  - Consistency and standards
  - Error prevention
  - Recognition rather than recall
  - Flexibility and efficiency of ue
  - Aesthetic and minimalist design
  - Help users recognize, diagnose, and recover from errors
  - Help and documentation

Questions and Discussion

Break

Controlled Experiments

- Method
  - Manipulate *independent variables*,system characteristics
  - Control for other variables
  - Measure *dependent variables*, user behaviour
- Roles
  - Understanding causes of user behaviour
  - Understanding factors influencing interface quality

Controlled Experiments

- Advantages
  - Strong statements about causality
  - Many experimental designs suitable for varying situations
- Disadvantages
  - Requires time, planning, may be expensive
  - Complex designs (more than 3 or 4 independent variables) are often difficult to interpret
  - May legitimize trivial research, and generate results of weak generalization (*external validity*)

Examples of Real Experiments

- Egan et al. study of searching with print text and electronic text (SuperBook), as a function of whether or not the search term appears in the document heading structure and/or the document text (BGBG, pp. 843-848)
- Myers and Buxton study of impact of using two hands for input on speed of carrying out tasks
- Baecker et al. study of impact of new method of presenting computer program source text on program reading comprehension

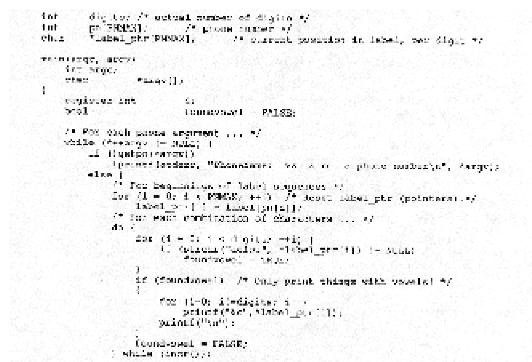
Tasks to Design and Run an Experiment

- Design
  - Choose independent variables
  - Choose dependent variables
  - Develop hypothesis
  - Choose design paradigm
  - Choose control procedures
  - Choose a sample size
- Pilot experiment
- Run experiment
- Analyze data
- Interpret results

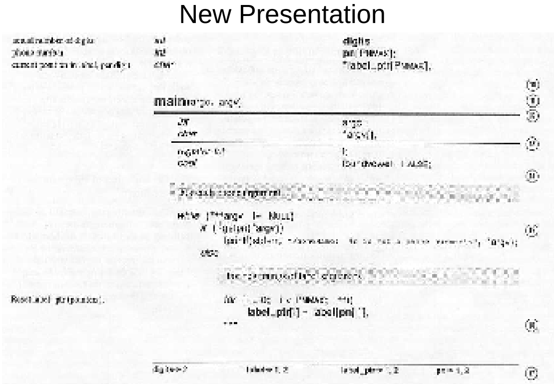
The Problem: Effectiveness of New Method of Source Code Presentation

- Source code appearance makes inadequate use of capabilities of digital typography
- Potential to make code more readable, more comprehensible with new and "enhanced" presentation format
- See book by Baecker and Marcus, *Human Factors and Typography for More Readable Programs*, Addison-Wesley, 1990
- On following slides, bullet points that refer to an experimental study of our new presentation format indicated by **

Conventional Presentation



New Presentation



Independent Variables

- Definition
  - Factor or treatment
  - The variable manipulated by the experimenter
- Options in experiment design
  - One independent variable: single factor design
  - Two or more independent variables: factorial design
- Characteristics of independent variables
  - Number of levels (2 or more)
  - Quantitative (length of menu) or qualitative (letter vs. number, mouse vs. trackball)
- ** In our example: single factor — new typesetting format or traditional presentation format

Dependent Variables

- Definition
  - Outcome measure
  - Variable measured by experimenter
  - Variable which should depend on the independent variable
- Examples
  - Accuracy
  - Number of subtasks completed in a given time period
- Criteria for judging
  - Sensitivity: Responsiveness to changes in independent variable
  - Reliability and consistency: Similar outputs for similar inputs
  - Validity: Measuring what you really want to measure
- ** In our example, ability to comprehend program as measured by # of questions answered in given time

Hypotheses

- Statement of hypothesized relationship between independent and dependent variables
- Statement of how relationship is to be examined or tested
- ** Hypothesis in our example: reading comprehension as defined above is improved by new method of source code presentation
- Typical paradigm for testing the hypothesis
  - Single factor randomized group design with two groups
  - More on next slide

Experimental Design Paradigms

- Between subjects or within subjects manipulation
- Example: designs with one independent variable
  - Between subjects (randomized group) design
    - One independent variable with 2 or more levels
    - Subjects randomly assigned to groups
    - Each subject tested under only 1 condition
  - Within subject (repeated measures) design
    - One independent variable with 2 or more levels
    - Each subject tested under all conditions
    - Order of conditions randomized or counterbalanced
- **In our example, within subjects chosen with two conditions, i.e., two sample programs

Control Procedures

- Goal is to eliminate *confound hypothesis*, i.e., that there are alternative explanation(s), and thereby to increase *internal validity*
- To do this: Make sure there are no systematic differences between conditions other than the independent variable
- What to control (next slide)
- How to control (slide after next)
- ** In our example, ensure that two sample programs are “identical” in length, complexity, difficulty

What To Control

- Subject characteristics
  - Gender
  - Ability
  - Experience
- Task variables
  - Instructions
  - Materials used
- Environmental variables
  - Setting
  - Noise, light, etc.
- Order effects
  - Practice
  - Fatigue

How to Control

- Hold constant
  - ** Use males only, or students from same class only
- Randomize
  - ** Subjects to groups
- Balance
  - Same number of novices and experts
- Counterbalance
  - ** Half (chosen randomly) get new presentation format first
- Match
  - Subjects on ability, e.g., programming ability
  - ** Materials (programs) on length, difficulty
- Eliminate
  - ** Experience, by using novices only

Sample Size Selection

- More subjects --> more confidence in results. i.e., greater statistical significance
- But this can be very expensive
- Many methods to reduce the required number of subjects
- Most HCI experiments: 4 to 25 subjects per group
- ** In our example, 44 subjects chosen from an 3rd year programming course

Designing and Running the Experiment and Collecting the Data

- Run pilot studies
  - Check experimental design
  - Test and improve:
    - Task definition
    - Experimental materials (often the most difficult)
    - Instructions
    - Practice tasks
  - Develop experimenter skills
  - Identify and deal with special problems
- Run actual experiment
  - Record data
  - Observe behaviour

** The Presentation Format Experiment

- Within-subjects design, 44 subjects from 3rd year programming course
- Two “similar” short C programs, roughly 200 lines of code, 4 to 5 pages
- 40 minutes to skim first program and attempt to answer 18 questions, half in familiar format and half in new format
- Then each group given other program in other format

Data Analysis and Hypothesis Testing

- Describe data
  - Descriptive statistics (means, medians, standard deviations)
  - Graphs and tables
- Perform statistical analysis of results
  - Are results due to chance? (That is, with what probability)
- **In our example, mean percentage of correct answers with new format = 44%, with conventional format = 35%
- **Analysis of variance showed that effect of presentation format in increasing “program readability” was significant, $F(1,42)=18.25$, $p<0.0001$.

Interpretation of Results

- Consider plausible causes of differences. i.e., *internal validity*
  - The independent variable *or* confounding variables
- Describe limits to generalization *(external validity)*
  - Variables held constant
    - **200 line programs
  - Task limitations
    - **Skimming programs, answering simple questions
  - Subject characteristics
    - **3rd year computer science students

Quasi-experiments

- Experiments that lack statistical significance (i.e., not enough subjects or individual variability too great for statistical significance) or that lack controls, lacks *internal validity*
- Typical method
  - Measure change of subjects' behaviour as system changes
  - E.g., study system as it evolves over time, measure performance of group of subjects *both* before and after experimental treatment such as modification of interface, icons, input devices

Quasi-experiments

- But this is not a controlled experiment
  - Same people used: learning is a *confound*
  - Subjects know system's been refined: expectation is a confound
  - Multiple factors changed from v. *n* to *n* +1: these are confounds
- Roles
  - Understanding effects of system change on user behaviour
  - Evaluation at far lower cost than controlled experiments

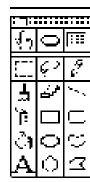
Examples of Quasi-experiments

- Bewley et al. tests on Star "graphics" (line drawing) functionality (B&B, pp. 662-667)
- Perkins et al. iterative design of Freestyle user interface plus tutorial (BGBG, pp. 881-885) — Confound is changing the interface plus the tutorial Baecker, Small, Mander tests on "animated icons" (BGBG, pp. 444-449) — Confound is learning from test of static icons to test of animated icons

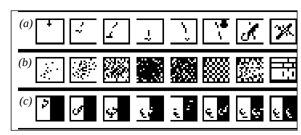
Animated Icons (Baecker Small Mander 1991)

- Icons
  - Strengths
    - Compact
    - Quickly recognizable
    - "Universal" because language "not needed"
  - Weaknesses
    - Non-obvious
    - Hard to scale to deal with large numbers
  - Typically, now, both word and image
- Animated icons: a way to improve the comprehensibility of static icons
  - Dynamic visual representations of functions

Animated Icons



Browse	Button	Field
Selection	Lasso	Pencil
Paint Brush	Eraser	Line
Spray Can	Rectangle	Rounded Rectangle
Paint Bucket	Oval	Curve
Text	Regular Polygon	Irregular Polygon



Animated Icons

QuickTime™ and a Sorenson Video decompressor are needed to see this picture.

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User Comprehension of Static & Animated Icons

	Novice (3)		Familiar (4)		Expert (1)	
	Static	Anim.	Static	Anim.	Static	Anim.
	1	**All**	All	All	All	All
	All	All	All	All	All	All
	All	All	All	All	All	All
	All	All	All	All	All	All
	All	All	**3**	**All**	All	All
	2	**All**	All	All	All	All
	All	All	All	All	All	All
	2	**All**	All	All	All	All
	2	**All**	All	All	All	All
	0	**All**	**1**	**All**	All	All
	2	**All**	All	All	All	All
	0	**All**	**1**	**All**	**0**	**All**
	All	All	All	All	All	All
	0	**All**	**0**	**All**	All	All
	1	**All**	**1**	**All**	All	All

Evaluation of Animated Icons

- 8 subjects with varying degrees of familiarity with paint tools
- Asked to explain static icons, then asked again after viewing animations
- Animations helpful in explaining Selection, Lasso, Paint, Curve, both Polygon tools (where users had trouble with static icons)
- Sound compelling, but not tested

Internal Validity

- Degree of confidence that we've found "the" explanation for our results, that is, we know of no other confounding explanations
- Achieve by increasing precision and direct control over the experiment

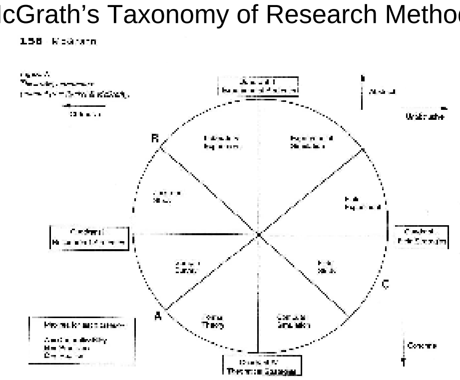
External Validity

- Degree to which our research applies to other phenomena than just the "experiment"
- Achieve this by increasing range, scope, of phenomena studied

Tradeoffs among Empirical Methods

- Tradeoff between internal validity (soundness) and external validity (generalizability, relevance, realism)
  - Controlled experiments for internal validity
  - Breadth of naturalistic observation for external validity
- "Credible empirical knowledge requires consistency or convergence of evidence across studies based on different methods." (McGrath, in BGBG, p. 155)
- Different strategies and methods have different advantages and disadvantages — cannot simultaneously maximize:
  - *Generalizability* of evidence over *populations* of actors (A)
  - *Precision* of measurement of the *behaviours* (B)
  - *Realism* of the situation or *context* (C)

McGrath's Taxonomy of Research Methods



BGBG Design Process in Tabular Form

	DESIGN	IMPLEMENT	ANALYZE AND EVALUATE
Information collection and requirements analysis	Questionnaires, interviews, observation of potential users	Task analyses, artifact analyses, "day in the life" "problem" scenarios	e.g., interviews with users about scenarios
Activity, information, and interaction design	Initial design concepts	Design mockups, prototypes, activity scenarios	e.g., interviews with users about prototypes, heuristic evaluations, quasi-experiments
Prototyping and prototype system	System functionality and look-&-feel	"Smoke and mirrors" prototype, partially working system	e.g., usability tests
Production prototype and its evolution	Complete system, incorporating evaluation insights	Real working system, implemented and installed	e.g., heuristic evaluation, usability tests, beta tests
Production system and its evolution	Deliverable system, monitoring and feedback system	Production system, including monitoring and feedback system	e.g., interviews, surveys of real users

Research and Evaluation Methods in the Design and Development Process

- Information collection
  - Interviews and questionnaires
  - Contextual inquiry
  - Ethnography and interaction analysis
- Concept design
  - Interviews
  - Heuristic evaluation
  - Usability testing
  - Controlled experiments
- Functionality (activity) and interface (information & interaction) design
  - Heuristic evaluation
  - Usability testing
  - Quasi-experiments
  - Theory-based evaluations
  - Human information processing simulations

Research and Evaluation Methods in the Design and Development Process

- Prototype implementation
  - Usability testing
  - Heuristic evaluation
- Deliverable system implementation
  - Usability testing
  - Quasi-experiments
- System enhancement and evolution
  - Interaction analysis
  - Interviews and questionnaires
  - Field experiments

Questions and Discussion