Strategies Large & Micro

wk11

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What is a Strategy?

- **"Any procedure that is nonobligatory and goal directed" (Siegler and Jenkins, 1989, p. 11)**
  - **There are many ways of accomplishing the same task**
  - **Individual differences in strategy usage have important implications for understanding general abilities**
  - **Psychometric tests assume that all people use same strategies to solve the test, but these tests are never strategically pure**

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What are the prerequisites to using a strategy?

- **Gray & Boehm-Davis**
  - **Set of possible strategies is limited by design of interactive objects**
- **Roberts & Newton**
  - **"The first conclusion to be drawn from these studies is that accounts of strategy selection, whether ability or stylistically based, are incomplete without accounts of strategy possession: strategies can only be chosen from those that are available."**
  - Roberts, M. J., & Newton, E. J. (2001). Understanding strategy selection. *International Journal of Human-Computer Studies, 54*(1), 137-154.

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Why do some people discover new strategies while others do not?

- **Folk Psychology -- Strategy discovery is failure driven.**
  - **We might think that people who fail at applying a particular strategy to accomplish a particular task will be those people who search and discover new strategies.**
- **But Roberts & Newton suggest that there is a Catch-22 to strategy discovery**
  - **"Those people who are best equipped to use a strategy are often those who are most likely to dispense with it and turn to other, more effective methods"**
  - **"Strategy discovery depends upon what a person can learn from a task while performing it, and the more effectively a task is performed, the more that can be learnt. Hence, the most successful people learn the most" p. 150.**
- **So . . . is strategy discovery driven by success, not failure?**

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How are New Strategies Discovered?

- Are strategies discovered and then used? Or
- Used and then discovered?
  - Siegler, R. S., & Stern, E. (1998). Conscious and unconscious strategy discoveries: A microgenetic analysis. Journal of Experimental Psychology-General, 127(4), 377-397.

Enduring issues in strategy discovery

- **Relationship between conscious insight and strategy discovery**
  - **Discovery of new problem-solving techniques often viewed as implying a prior conscious insight**
  - **In other accounts, strategy discovery has been viewed as first arising at an implicit, unconscious, procedural level and only later at an explicit, conscious, metaprocedural one**
  - **By this latter view, conscious insight should follow, rather than precede, discovery of new strategies**

Enduring issues in strategy discovery

- **Are discoveries made abruptly or gradually?**
  - **Typically, theorists who emphasize unconscious processes view discovery as a gradual process,**
  - **whereas those who emphasize conscious processes tend to view it as abrupt.**

How to Study Strategy Acquisition and Change?

- **Siegler favors *Microgenetic* methods: three properties:**
  - **(a) Observations span as large a portion as possible of the period in which rapid change in the competence occurs;**
  - **(b) the density of observations within this period is high relative to the rate of change in the phenomenon; and**
  - **(c) observations are examined on an intensive trial-by-trial basis, with the goal of understanding in detail the process of change.**

Five Dimensions of Cognitive Change

- The detailed data yielded by microgenetic studies suggest a conceptual framework for thinking about changes in children's thinking
- Within this framework, distinctions are made among five dimensions of change (Siegler, 1995)
  - the path
  - rate
  - breadth
  - variability
  - sources of change

Source of Change

- "Having" a strategy viewed as either/or
  - Either the kid has it or does not
  - But activation of many cognitive entities varies continuously and that degree of activation influences the reportability, accessibility, and transfer of knowledge
  - It seemed likely that the same holds true for strategy discovery
- If so, then should be possible to increase activation of the shortcut strategy by presenting blocks of shortcut problems versus mixing shortcut problems with standard problems

The Task: The Inversion Problem

- Subjects are German 2nd graders, mean age 8.75yr
- Inversion: the principle that adding and subtracting the same number leaves the result unchanged
- 28 + 36 - 36 = ??
- a + b - a; a + b - b; versus standard problems; a + b - c

Blocks versus Mixed

- Blocked problems set should lead to
  - (a) more rapid discovery of the shortcut strategy at both nonverbalizable and verbalizable levels,
  - (b) fewer inversion problems separating the two levels of discovery,
  - (c) a higher percentage of use of the shortcut strategy once it is discovered,
  - (d) a higher percentage of appropriate generalization of the shortcut strategy to novel types of problems in which the strategy is applicable (e.g., a + b - a), and
  - (e) a higher percentage of inappropriate generalization of the shortcut strategy to novel types of problems in which it is inapplicable (e.g., a + b + b).

Main Inversion Strategies

- Five strategies ordered from least to most advanced (24 + 36 - 36) (a + b - b)
  - computation: 24 + 36 = 60; 60 - 36 = 24
  - negation: 24 + 36 = 60; 24 (should take longer when b is larger, but should be shorter than computation)
  - shortcut: = 24

Intermediate Inversion Strategies

- Siegler had children verbalize the strategy they used after each trial
- *unconscious shortcut*
  - If solution time was 4-s or less, & verbal report indicated computational strategy
  - This strategy would emerge if kids used the shortcut strategy but were unaware they did so -- would expect the unconscious shortcut strategy to appear very soon before kids begin verbalizing the shortcut strategy

Intermediate Inversion Strategies

- *computation-shortcut*
  - If solution time was > 4-s, & verbal report indicated use of the shortcut strategy
  - This strategy would emerge if kids began using the computation strategy but after beginning it, they realized that they did not need to add or subtract. Answers should ALWAYS be correct.

Path of Change

- The sequence of understandings (e.g., strategies, theories, or rules) that lead to mastery of a given concept or skill
- Five strategies ordered from least to most advanced (24 + 36 - 36) (a + b - b)
  - computation --> negation --> unconscious shortcut --> computation-shortcut --> shortcut
  - If strategy discoveries reflect gradually increasing activation of the new strategy, and if lower levels of activation are needed for nonreportable uses of a new strategy than for reportable ones, then children should use the unconscious shortcut, which does not involve reporting the shortcut, before they use either the computation—shortcut or the shortcut strategy, both of which require explicit recognition of its use

Experimental Method

- **8 sessions -- two different groups**
- **Pretest (session 1) - mixed set of 20 inversion problems and 20 standard problems (same for both groups)**
- **Practice (session 2-7) (different for each group)**
  - **mixed group -- 10 inversion problems and 10 standard problems (randomly mixed) in each session**
  - **blocked group -- 20 inversion problems (no standard problems) in sessions 2, 3, 4, and 6. Same as mixed gp for session 5 & 7**
- **Transfer (session 8) (same for both groups)**
  - **48 problems, 8 each of six types**
  - **a + b - b; a - b + b; a + b □ a , a □ b □ b , a + b + b , and a □ b + a**

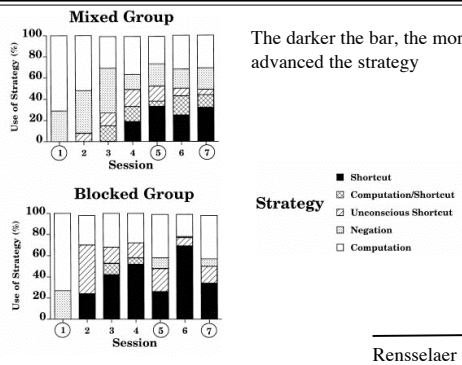
Results

- **Overview**
  - (a) Children in both groups used all five hypothesized strategies;
  - (b) frequency of use of the strategies differed between the groups; and
  - (c) each strategy's accuracy, speed, and likelihood of being accompanied by overt behavior were highly similar for the two groups.
- Experimental manipulation influence
  - how often strategies were used,
  - but not whether they were used,
  - and not how they were executed

Results (2)

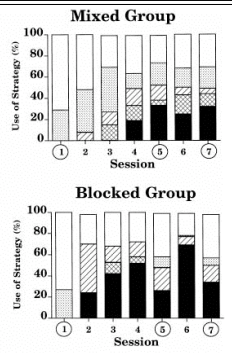
- Children in the blocked problems condition tended more often to use the more advanced strategies, and children in the mixed problems condition tended more often to use the less advanced strategies

Path of Change Changes over sessions in frequency of use of strategies



The darker the bar, the more advanced the strategy

Path of Change Changes over sessions in frequency of use of strategies



Children in the blocked problems condition learned to use the shortcut strategy quite consistently when only inversion problems were presented, but they did not use it nearly as often when standard problems were presented on half of the trials (blocks 5 & 7)

Order of Discovery

- **Blocked 80% of kids**
  - **computation --> negation --> unconscious shortcut --> shortcut**
  - **Half later used computation-shortcut; half did not**
- **Mixed 80% of kids**
  - **computation --> negation --> unconscious shortcut**
  - **2/3's used the computation-shortcut before the shortcut**
- **Thus -- most children in both groups discovered the strategies in an order that closely paralleled their hypothesized order of sophistication**

Conscious versus Unconscious

- **Across conditions 27/31 of the kids (88%) used the unconscious shortcut before either the computation—shortcut or shortcut strategy**

Strategy use just before and just after discovery of the shortcut strategy

- **Blocked Condition:**
  - **80% of children in the blocked problems condition** used the unconscious shortcut strategy **on each of the three trials preceding their discovery of the shortcut strategy**
  - **After children in this condition first used the shortcut strategy, about 80% of them continued to use it on the next three trials**
- **Mixed Condition**
  - **the first use of the unconscious shortcut strategy by children in the mixed problems group was an isolated event**
  - **Both before and after that first use, the large majority of children used the computation or the negation strategy. Neither the unconscious shortcut nor the shortcut strategy was used often on the trials immediately after the first use of the unconscious shortcut.**

Conscious and Unconscious Strategy Discoveries

- These data indicate that strategy discoveries can be unconscious
- What is the mechanism through which unconscious discoveries contribute to conscious ones?
- The data are consistent with at least two accounts.
  - A. Differing thresholds: Unconscious discoveries reflect a lower level of activation than conscious ones, enough activation to surpass one threshold but not the other. Consistent with short period between unconscious and conscious discovery in the blocked condition.
  - B. conscious version of the shortcut may have arisen through children observing their own execution of the unconscious shortcut strategy and drawing inferences about it.
  - But, the two explanations are not exclusive; both differing thresholds and inferences from self-observations may be involved in the relation between unconscious and conscious discoveries.

How do we choose between strategies?

- Siegler (e.g. 1996) suggests that strategies can be selected more or less automatically without the need to invoke a metacognitive homunculus

Microstrategies

- Gray & Boehm-Davis
- More complex interactions of cognitive, perception, and action than those studied by Siegler
- (But, our emphasis was not on discovery and change!)

CPM-GOMS: The Embodied Cognition level

Analyzing activities into microstrategies

Scale (sec)	Time Units	System	Analysis	World (theory)
[illegible]	[illegible]	[illegible]	[illegible]	Social & Organizational
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	Task	Microstrategy Task Analysis	Situated Rationality
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
1	1 sec	Activities	Microstrategy Analysis	Cognitive Band (symbolic)
	1/3 sec	Embodied Activities (Basic units of embodied cognition)	Production Rules	
0.1	100 ms	Production Rule	Elements (DME-MA-VA)	
0.01	10 ms	Elements	Architectural	Biological Band (subsymbolic)
0.001	1 ms	Parameters		

CPM-GOMS Extension to GOMS

- Critical Path Method (or Cognitive Perceptual Motor) - GOMS
- Control structure: Relaxed hierarchy, can be interrupted and continued based on new information in the world
- Serial or Parallel: Parallel
- Level of Analysis: Primarily elementary perceptual, cognitive and motor operators

CPM-GOMS - why?

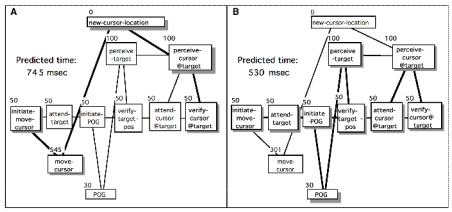
- Need for analysis suitable for parallel activities
- Human cognition is embodied cognition
  - In some cases we need to understand the interleaving and interdependencies between elementary cognitive, perceptual, and motor operations

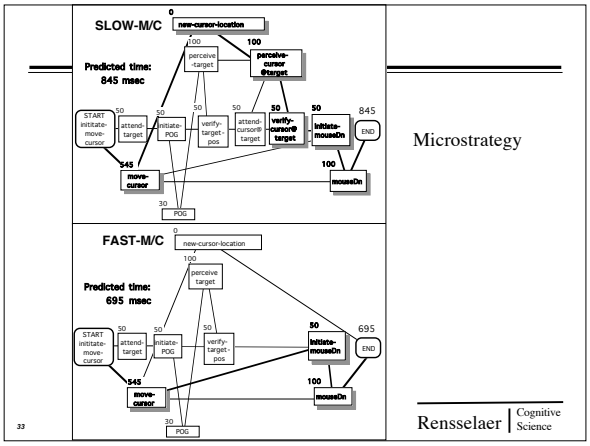
CPM-GOMS models are composites of simpler, basic-level activities

- Embodied Activities
- Activities/Microstrategies
- Unit Tasks

We will illustrate these in the context of moving and clicking a mouse

Activity





Microstrategy

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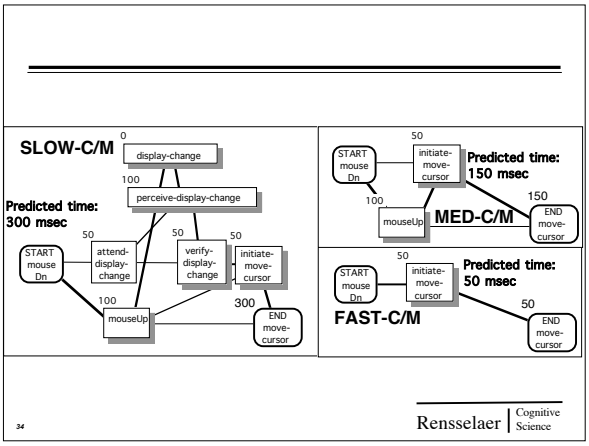

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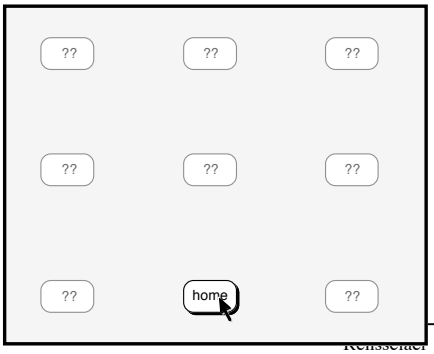
The Button Study



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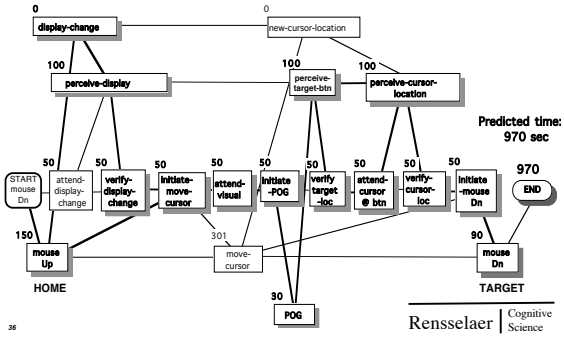
Home to Target



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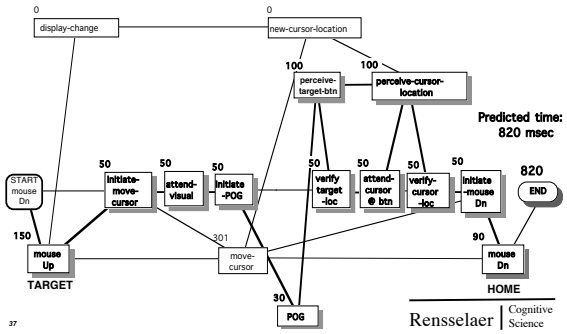
Target to Home



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Experimental Data

	HOME-to-TARGET	TARGET-to-HOME	Difference
Predicted	**970 msec**	**820 msec**	**150 msec**
Found	**994 msec (19.7)**	**840 msec (19.7)**	**154 msec**
Absolute Difference	**2.41%**	**2.38%**	

Data and examples are from: Gray, W. D., & Boehm-Davis, D. A. (2000). Milliseconds Matter: An introduction to microstrategies and to their use in describing and predicting interactive behavior. *Journal of Experiment Psychology: Applied.*

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Uses of CPM-GOMS in Design

- **Project Ernestine emphasized**
  - **Quantitative comparisons between alternative systems**
  - **Qualitative explanations for differences between alternative systems**

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Uses of CPM-GOMS in Design

- **CPM-GOMS can also be used to**
  - **Direct design effort**
  - **Bracketing, Profiling, and Diagnosis**

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Directing Design Effort

- Designing telephone operator workstations: Should we redesign
  - keyboards?
  - screens?
  - system response times?

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One use of Profiling

- How much of the time is each
- activity on the critical path?

Call Cat.	Sys RT	Talking	Keying	Reading	Ring/Coin
cc01	25%	40%	1%	3%	31%
cc02	3%	93%	0%	4%	0%
cc03	20%	71%	2%	6%	0%
cco4	25%	31%	6%	4%	35%
cc05	19%	44%	3%	2%	22%
cc06	12%	79%	2%	6%	0%
cc07	30%	57%	8%	3%	0%
cc08	26%	41%	23%	10%	0%
...	...	...	...	...	...
Average	16%	64%	6%	5%	8%

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Directing Design Effort

- Bracketing
- Profiling
- Diagnosis

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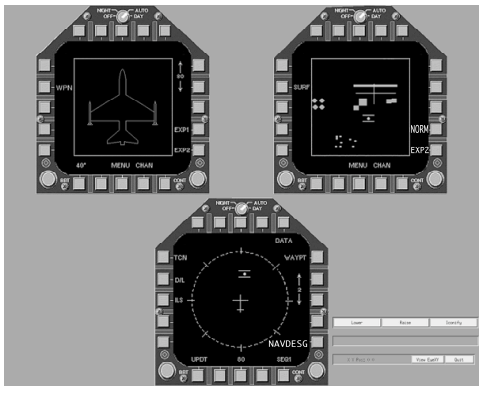
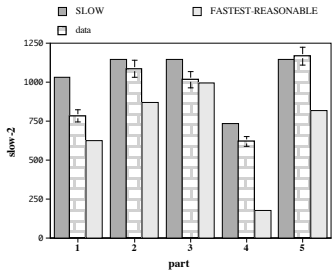


Bracketing: Slow & Fastest Reasonable

Description	Microstrategy	SLOW	BEST FIT	FASTEST REASONABLE
Part 1: K3 to mDn@zoomPt				
from keypress to move cursor	KEYPRESS-MOVE	SLOW-KP/M	P1 FAST-KP/M P2 MED-KP/M	FAST-KP/M
mouse down on zoom-point	MOVE-CLICK	SLOW-M/C	SLOW-M/C	SLOW-M/C
Part 2: mDn@zoomPt to mDn@EXP2 btn				
move from zoom-point to EXP2 button	CLICK-MOVE	SLOW-C/M	P1 SLOW-C/M P2 MED-C/M	FAST-C/M
mouse down on EXP2 button	MOVE-CLICK	SLOW-M/C	SLOW-M/C	SLOW-M/C
Part 3: mDn @ EXP2 btn to mDn @ trgt				
move from EXP2 button to way-point	CLICK-MOVE	SLOW-C/M	P1 MED-C/M P2 SLOW-C/M	MED-C/M
mouse down on way-point	MOVE-CLICK	SLOW-M/C	SLOW-M/C	SLOW-M/C
Part 4: mDn @ trgt to K2				
keypress to select NAV-his display	CLICK-KEYPRESS	SLOW-C/KP	P1 SLOW-C/KP P2 MED-C/KP	FAST-C/KP
Part 5: K2 to mDn @ NavDesg Btn				
move from center to NAVDESG button	KEYPRESS-MOVE	SLOW-KP/M	P1 SLOW-KP/M P2 MED-KP/M	FAST-KP/M
mouse down on NAVDESG button	MOVE-CLICK	SLOW-M/C	SLOW-M/C	SLOW-M/C

Bracketing



Profiling

- When a model mismatches performance, a common way to increase its fit is to change one or more of its parameters.
- The microstrategy approach constrains the set of possible model changes in several important ways
- In building a BEST FIT model:
  - The parameters must be constant: the SLOW, BEST FIT, and FASTEST REASONABLE models must all use the same parameter set;
  - Corresponding parts of the SLOW, BEST FIT, and FASTEST REASONABLE models must use members of the same microstrategy family; and
  - Improving the fit of the BEST FIT model can only be accomplished by swapping microstrategies in and out from the same family.

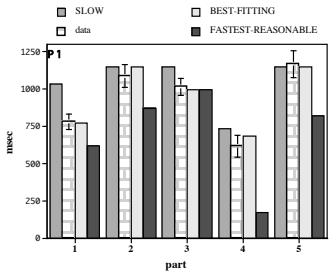
Profiling: BEST FIT models

Description	Microstrategy	SLOW	BEST FIT	FASTEST REASONABLE
Part 1: K3 to mDn@zoomPt				
from keypress to move cursor	KEYPRESS-MOVE	SLOW-KP/M	**P1 FAST-KP/M P2 MED-KP/M**	FAST-KP/M
mouse down on zoom-point	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C
Part 2: mDn@zoomPt to mDn@EXP2 btn				
move from zoom-point to EXP2 button	CLICK-MOVE	SLOW-C/M	**P1 SLOW-C/M P2 MED-C/M**	FAST-C/M
mouse down on EXP2 button	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C
Part 3: mDn @ EXP2 btn to mDn @ trgt				
move from EXP2 button to way-point	CLICK-MOVE	SLOW-C/M	**P1 MED-C/M P2 SLOW-C/M**	MED-C/M
mouse down on way-point	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C
Part 4: mDn @ trgt to K2				
keypress to select NAV-his display	CLICK-KEYPRESS	SLOW-C/KP	**P1 SLOW-C/KP P2 MED-C/KP**	FAST-C/KP
Part 5: K2 to mDn @ NavDesg Btn				
move from center to NAVDESG button	KEYPRESS-MOVE	SLOW-KP/M	**P1 SLOW-KP/M P2 MED-KP/M**	FAST-KP/M
mouse down on NAVDESG button	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C

Profiling

- **BEST FIT models are post hoc, but not ad hoc**
- **As with the mouse-button example, the set of microstrategies for any given interactive technology is small, constrained, and determinable**

Profiling



Diagnosis

- **Places where the microstrategy used in the BEST FIT model differs from that used in the FASTEST REASONABLE model indicate less than optimal performance**
- **The BEST FIT models identify what people are doing instead of the optimal and may lead to insights regarding why they are doing it**

Diagnosis: Example of CLICK-MOVE

Description	Microstrategy	SLOW	BEST FIT	FASTEST REASONABLE
Part 1: K3 to mDn@zoomPt				
from keypress to move cursor	KEYPRESS-MOVE	SLOW-KP/M	**P1 FAST-KP/M P2 MED-KP/M**	FAST-KP/M
mouse down on zoom-point	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C
Part 2: mDn@zoomPt to mDn@EXP2 btn				
move from zoom-point to EXP2 button	CLICK-MOVE	SLOW-C/M	**P1 SLOW-C/M P2 MED-C/M**	FAST-C/M
mouse down on EXP2 button	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C
Part 3: mDn @ EXP2 btn to mDn @ trgt				
move from EXP2 button to way-point	CLICK-MOVE	SLOW-C/M	**P1 MED-C/M P2 SLOW-C/M**	MED-C/M
mouse down on way-point	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C
Part 4: mDn @ trgt to K2				
keypress to select NAV-his display	CLICK-KEYPRESS	SLOW-C/KP	**P1 SLOW-C/KP P2 MED-C/KP**	FAST-C/KP
Part 5: K2 to mDn @ NavDesg Btn				
move from center to NAVDESG button	KEYPRESS-MOVE	SLOW-KP/M	**P1 SLOW-KP/M P2 MED-KP/M**	FAST-KP/M
mouse down on NAVDESG button	MOVE-CLICK	SLOW-M/C	**SLOW-M/C**	SLOW-M/C

Diagnosis: example

- CLICK-MOVE
  - Used in part 2 and part 3
  - Use of slower microstrategies may reflect a confusion among the three unit tasks
    - Not perceptually distinct
  - Participants might have had to rely more on memory than is usual for interactive behavior with current interactive technology

Summary of CPM-GOMS

- Predicts expert performance time and provides qualitative explanations for tasks involving parallel activities
- Once the models are built, schedule charts allow designers to rapidly play what-if games with design ideas and parameters
- Not intended to predict the occurrence of learning time, or errors - other forms of GOMS models are more helpful there
- Subject to the limitations of GOMS models in general (no casual use, fatigue, etc.)

Summary of Microstrategies

- Different members of the same microstrategy family may be deployed in the same context
- Microstrategy selection is non-deliberate
- Faster microstrategies require elimination of explicit verifications
  - Use of explicit verifications may indicate lack of distinctive perceptual cues in interface (users unsure)
  - Novices require more explicit verifications than do experts -- in ambiguous situations explicit verifications may be the norm regardless of expertise
  - Explicit verifications may be a design goal in situations where the cost of an error is high (real-time safety critical tasks)

Where do Strategies come from?

- Performance will not be faster than the fastest reasonable strategy permitted by the design of the system
- Hence, if performance criteria fall outside the brackets predicted by SLOW and FASTEST-REASONABLE models, redesign may be the answer
- Design can eliminate feedback and therefore eliminate use of strategies that require explicit verification -- but this may meet the time criterion but not meet the error rate criterion

Where do Strategies come from?

- Is each critical path a different strategy?
- If so, then we have a lot to account for!!!
- Implications from Schweikert, Fisher, and Proctor

Why Milliseconds Matter

- Decisions made by designers who focus on higher level design issues affect strategies adopted at the millisecond level
- The cost of milliseconds, compared to the fastest, the slowest microstrategy added:
  - 22% to M/C
  - 179% to C/KP
  - 500% to C/M
  - 560% to KP/M

Why Milliseconds Matter

- Use of slow microstrategy when faster one is available may make interface seem sluggish
- Attempts by user to avoid slow microstrategy may result in higher workload or increased errors
- User acceptance of new interactive technologies