Human Cognition

SWE 632
Fall 2015

GEORGE MASON UNIVERSITY

In class exercise

- As you come in and take a seat
- What was the hardest bug you ever had to find?
- What did you do? What made it hard?

What makes debugging hard?

Administrivia

- HW0 and tech talk signup was due today
- HW1 out and due in 2 weeks
- Weekly readings
- Should look at HTML / CSS / JS tutorial if new to web programming
- How many have laptop or tablet?
    - If you do, bring it to class

$17 \times 24 =$

System 1

- Automatic (unconscious)
- Effortless
- “Fast” thinking
- Associative
- Heuristic
- Gullible
- Can’t be turned off

System 2

- Voluntary (conscious)
- Effortful
- “Slow” thinking
- Planning
- Logical
- Lazy
- Usually only partly on

Examples of System 1

- Detect that one object is more distant than another.
- Orient to the source of a sudden sound.
- Complete the phrase "bread and…"
- Make a "disgust face" when shown a horrible picture.
- Answer to 2 + 2 = ?
- Drive a car on an empty road.
- Understand simple sentences.

Examples of System 2

- When System 1 does not offer an answer (e.g., 17 x 24)
- When an event is detected that violates the model of the world that System 1 maintains (e.g., cat that barks)
- Continuous monitoring of behavior—(keeps you polite when you are angry)
- Normally has the last word

Attentional resources are fixed

- Demo

Attentional resources are fixed

- System 2 activity takes conscious attention
- Attentional resources are fixed
- Pupils dilate as mental effort increase
- If demands exceed max, tasks prioritized.

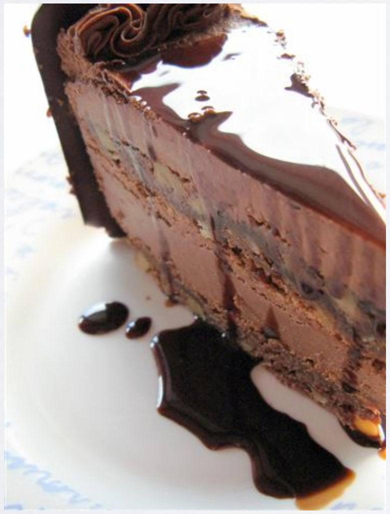
Examples of attention limitations

- Can walk and talk
- But not walk and compute 23 x 78
- Constructing complex argument better when still

Attention limitations - demo

- Remember the following digits:
- 8 3 5 2 1 9 0 5 1

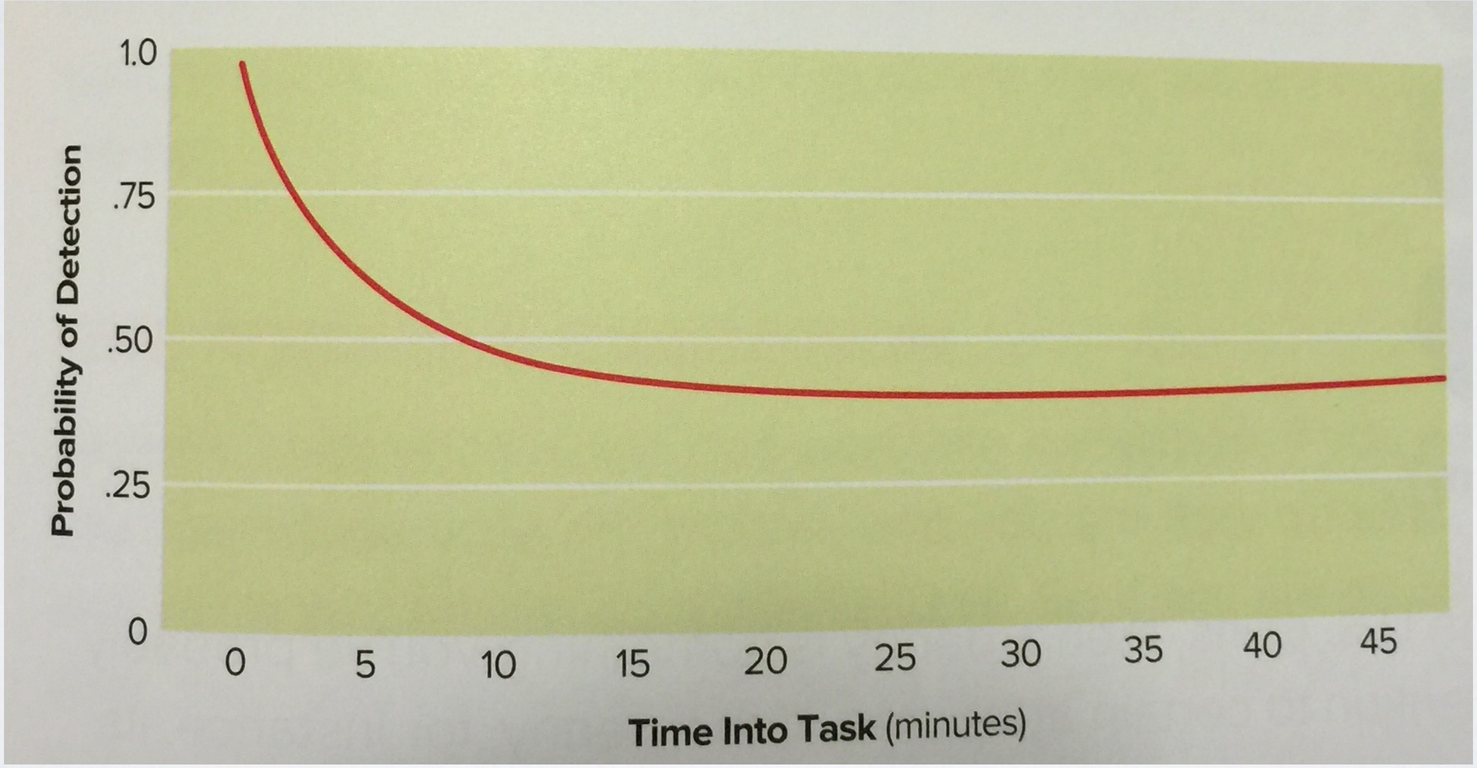
Attentional limitations - demo

- Would you prefer
- (a)  (b) 

Attentional resources - demo

- More likely to choose (a) when attentional resources are stressed
- Self control require attention and effort

Intense focus is unsustainable



Coexistence of Systems 1 and 2

- System 1 processes normal, everyday, expected activities at low cost.
- System 2 takes over when necessary, at higher cost.
- Law of least effort: pays for System 2 to be lazy.

Conflict - demo

Your first task is to go down both columns, calling out whether each word is printed in lowercase or in uppercase. When you are done with the first task, go down both columns again, saying whether each word is printed to the left or to the right of center by saying (or whispering to yourself) “LEFT” or “RIGHT.”

LEFT		upper	
	left	lower	
right			LOWER
RIGHT		upper	
	RIGHT	UPPER	
	left		lower
LEFT			LOWER
	right		upper

Conflict - examples

- Trying not to stare at oddly dressed couple
- Force attention on a boring book
- Following correct instructions when car skidding out of control on ice
- Not saying something negative to someone

Decision making

Anchoring heuristic - demo

- Split into two groups, A and B

Anchoring heuristic - demo

- In 5 seconds:
- what is 1 × 2 × 3 × 4 × 5 × 6 × 7 × 8 ?

Anchoring heuristic - demo

- In 5 seconds:
- what is 8 x 7 x 6 x 5 x 4 x 3 x 2 x 1?

Anchoring heuristic - demo

- Greater than 2000?
- Less than 2000?

Anchoring heuristic

- Actual answer: 40,320
- Estimate the number by looking at the first several numbers

Availability heuristic - demo

- Are you more likely to be bitten by a shark or hit by a falling airplane part?

Availability heuristic

- Ease of retrieving examples used as cue to estimate probability
- Greater reporting of shark attacks in media leads to conclusion that even is more frequent

Sunk costs - example

- You just spent $40 to see a concert. It's terrible. Do you stay or leave?

- vs.

- You just got free tickets to a concert. It's terrible. Do you stay or leave?

Sunk costs

- $40 or $0 has already been spent ("sunk cost") and has no (rational) bearing on future actions.
- Sunk costs influence behavior none the less.

Central route - demo

- Car A
  - 25 mpg
  - Excellent maintenance rating
  - Very good crash rating
  - Available in your favorite color

- Car B
  - 22 mpg
  - Very good maintenance rating
  - Fine crash rating
  - Available in your favorite color

Peripheral route - demo

- Car A

- Car B

Elaboration likelihood model

- Humans choose how much consideration and elaboration of arguments to make
- Peripheral route (System 1) - persuasion based on association with positive or negative stimuli
- Central route (System 2) - persuading based on appeal to logical arguments
- Central route requires more time and effort

Decision making summary

- System 1 vs. System 2
- Most decisions made by System 1 without System 2 involvement
- Even for central route, System 2 **biased** by information provided by System 1

Memory

Short term memory (STM)

- Primary, active memory used for holding current context for System 2
- Unless actively maintained (or encoded to long-term memory), decays after seconds
- Capacity ~ 4 items
  - (classic estimate of 7 +/- 2 is wrong)

Chunking - demo
What's easiest to remember?

- A lock combination with 8 numbers in order: 10, 20, 30, 40, 50, 60, 70, 80
- A lock combination with 8 numbers in order: 50, 30, 60, 20, 80, 10, 40, 70
- A string of 10 letter: R, P, L, B, V, Q, M, S, D, G
- A string of 52 letters: I pledge allegiance to the flag of the United State of America.

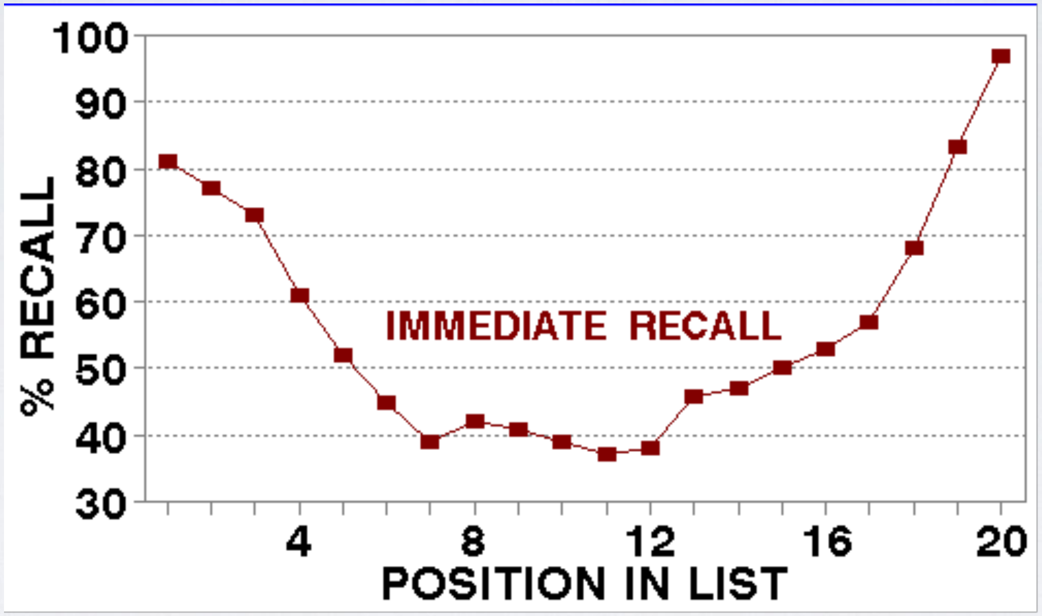
Chunking

- Items in memory encoded as **chunks**
- A chunk may be anything that has meaning
- # of chunks in STM fixed, but remembering bigger chunks lets you remember more
- Memory retention relative to the concepts you already have
- —> schemas & mental models (next time)

Long term memory (LTM)

- Items in short term memory may be encoded into storage in long term memory
- LTM capacity not limited
- Information must be retrieved from long term memory (i.e., through System 1)
- Many factors influence what is encoded into LTM and how it is encoded

Serial position effect



- Primacy effect - early items remembered better
- Recency effect - late items remembered better

Encoding specificity principle

- Match between context at encoding and at retrieval improves memory
- Context factors
    - Environment (e.g., studying in same room as exam)
    - Internal state (e.g., remember happy events when happy)

Memory is reconstructive - example

- How fast was the car going when it hit the other vehicle?

vs.

- How fast was the the car going when it smashed into the other vehicle?

- 2x more remember seeing broken glass

Memory is reconstructive

- Not stored files on a disk
- Encoded in brain, may be different every time retrieved
- Remember pieces, reconstruct other details based on expectations on what must have occurred
- Hard to distinguish similar memories

Vivid memories may be wrong

- What were you doing when you first learned about the Sept 11 attacks?
- **Flashbulb** memories vivid, but still reconstructed, and no more likely to be accurate
- Humans not effective at gauging accuracy of memories

Types of memory

- Semantic memory: facts, meanings, concepts
  - Paris is the capital of France; cats are animals
- Episodic memory: memory of events and sequences of events
  - Greeted by server, assigned seat, get menu, order drinks, order food, ask for check, pay, leave

Learning

Rehearsal

- Information may be repetitively experienced or actively repeated ("subvocalization")
- 232 535 487 235
- More times information is rehearsed, better memory

Depth of processing

- More time spent interacting with information, more likely it is to be remembered

Automaticity

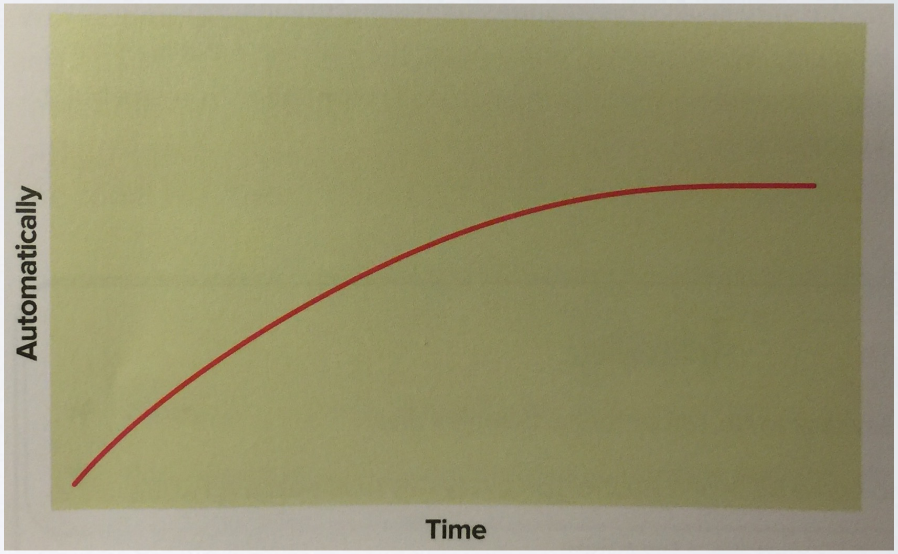
- This effect happens for sequences of actions ("**scripts**") as well.
  - Example: tying shoelaces
- More repetitions, faster, requires less conscious attention.
- Responsibility shifts from System 2 —> System 1

Habit formation takes time

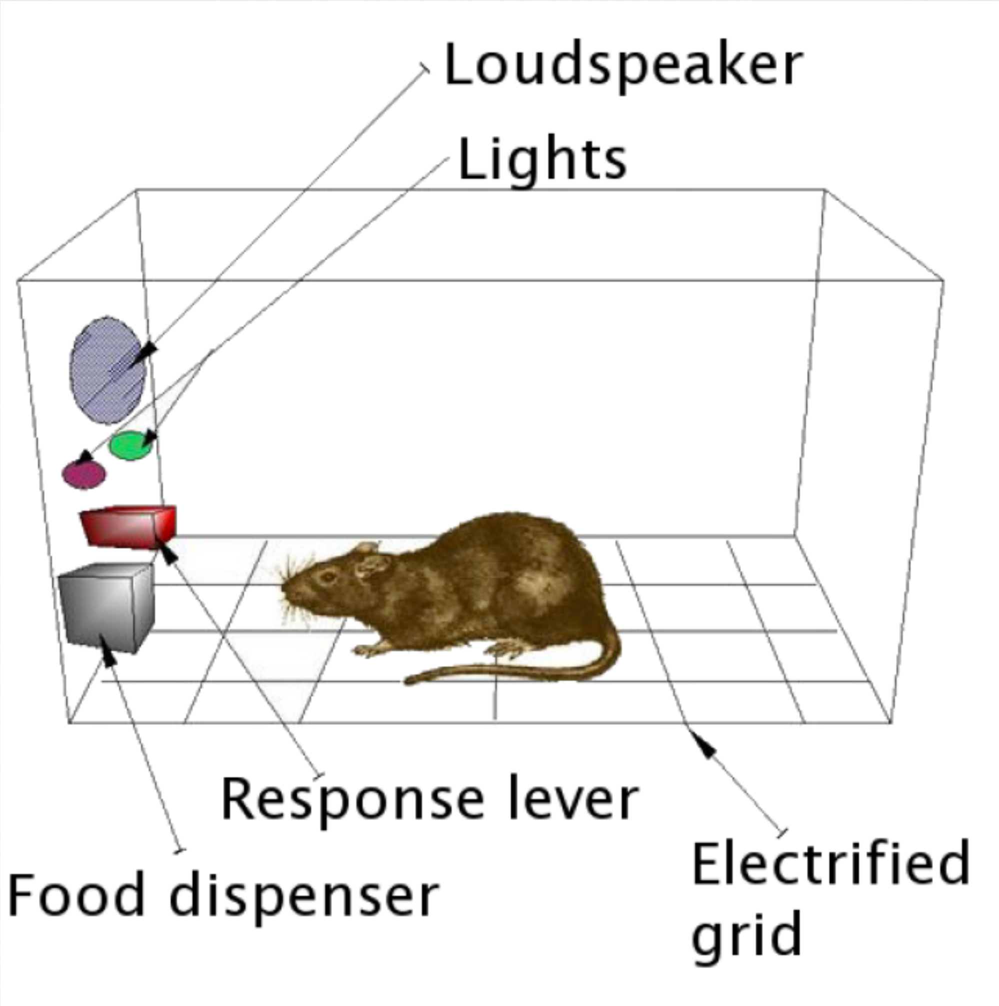
- How long does it take to form a eating, drinking, or activity habit?

- Mean: 66 days, Min: 18 days, Max: 254 days

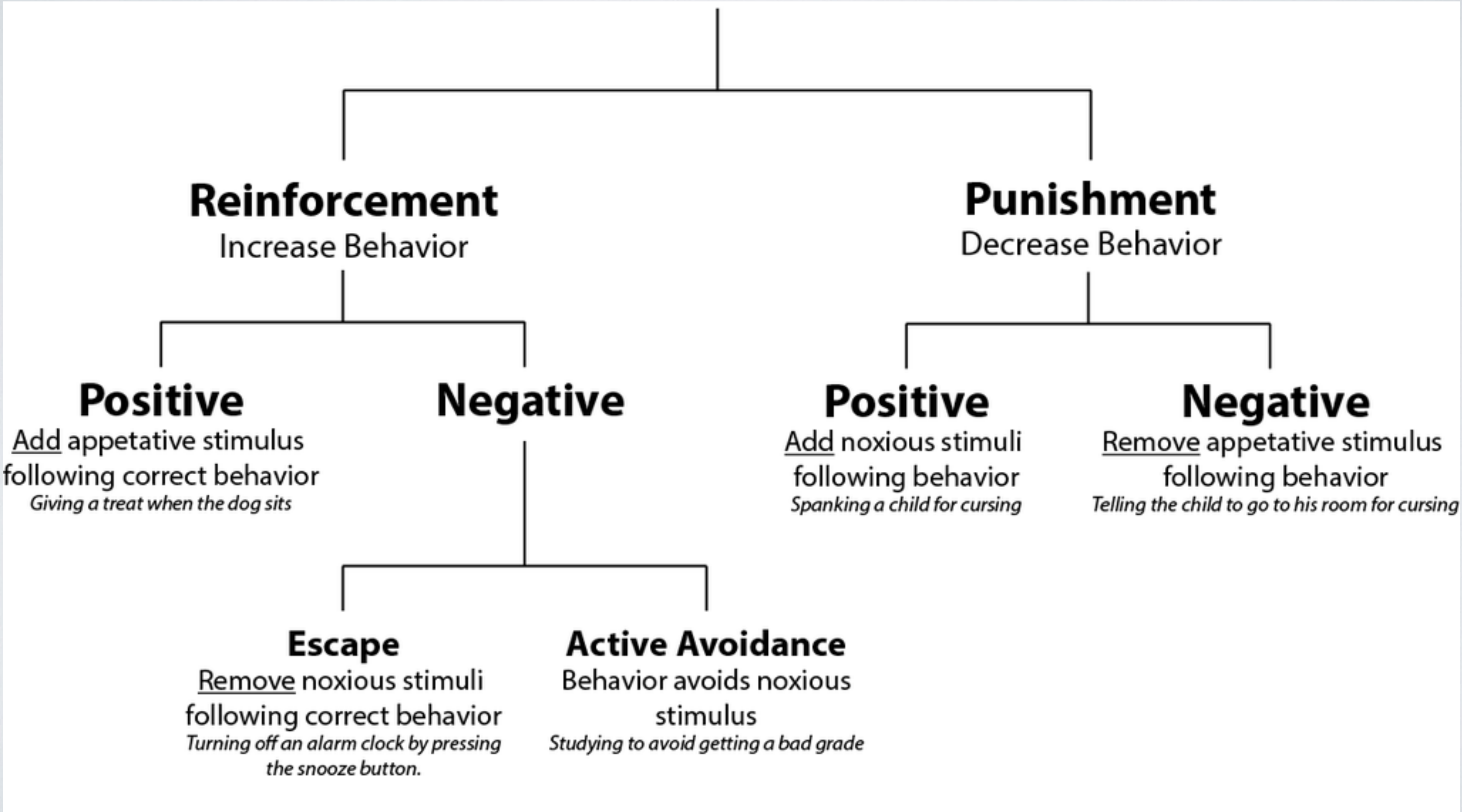
- More complex behaviors take longer to become habit



Skinner box


Loudspeaker
Lights
Response lever
Food dispenser
Electrified
grid

Operant conditioning
(a.k.a. reinforcement learning)



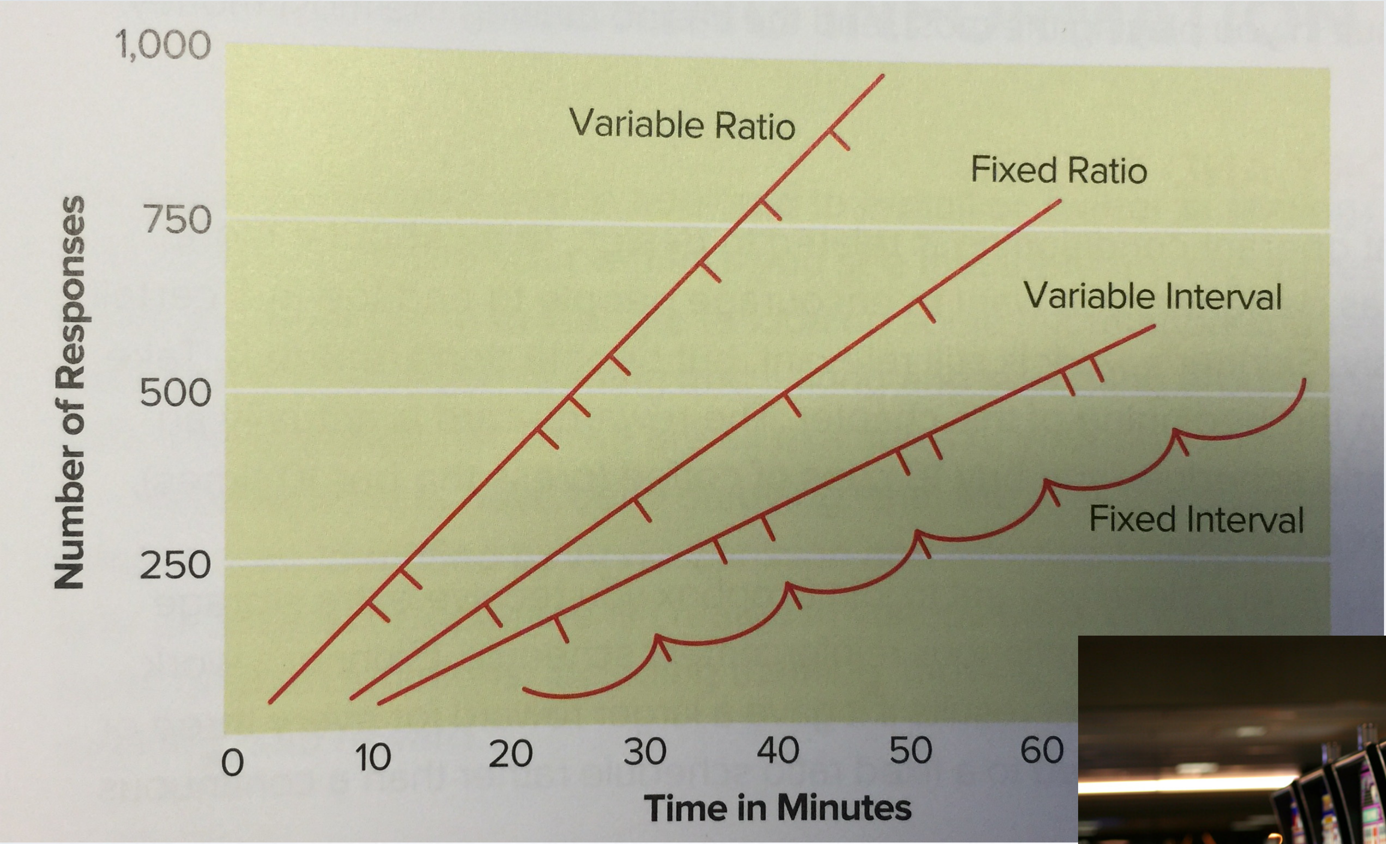
"Operant conditioning diagram" by Studentne

Motivation

Possible reinforcement schedules

- Fixed interval: reward proportional to fixed time passed
- Variable interval: reward proportional to time, but rewards given stochastically
- Fixed ratio: reward proportional to # actions taken
- Variable ratio: reward proportional to # actions taken, but rewards given stochastically

Variable rewards are powerful



Autonomy

- Humans motivated by perception of control to do things when and how they want to do them rather than controlled by others

- E.g., renew a drivers license online, online banking, online investment site, …

Surprises

- Unexpected, novel actions that are unexpected grab attention (engage System 2) and are enjoyable

Being busy

- You walk 2 minutes to get luggage carousel, and spend 10 minutes waiting for luggage.
- You walk 10 minutes to luggage carousel and spend 2 minutes waiting for luggage.
- Which do you prefer?
- Humans happier when they're busy

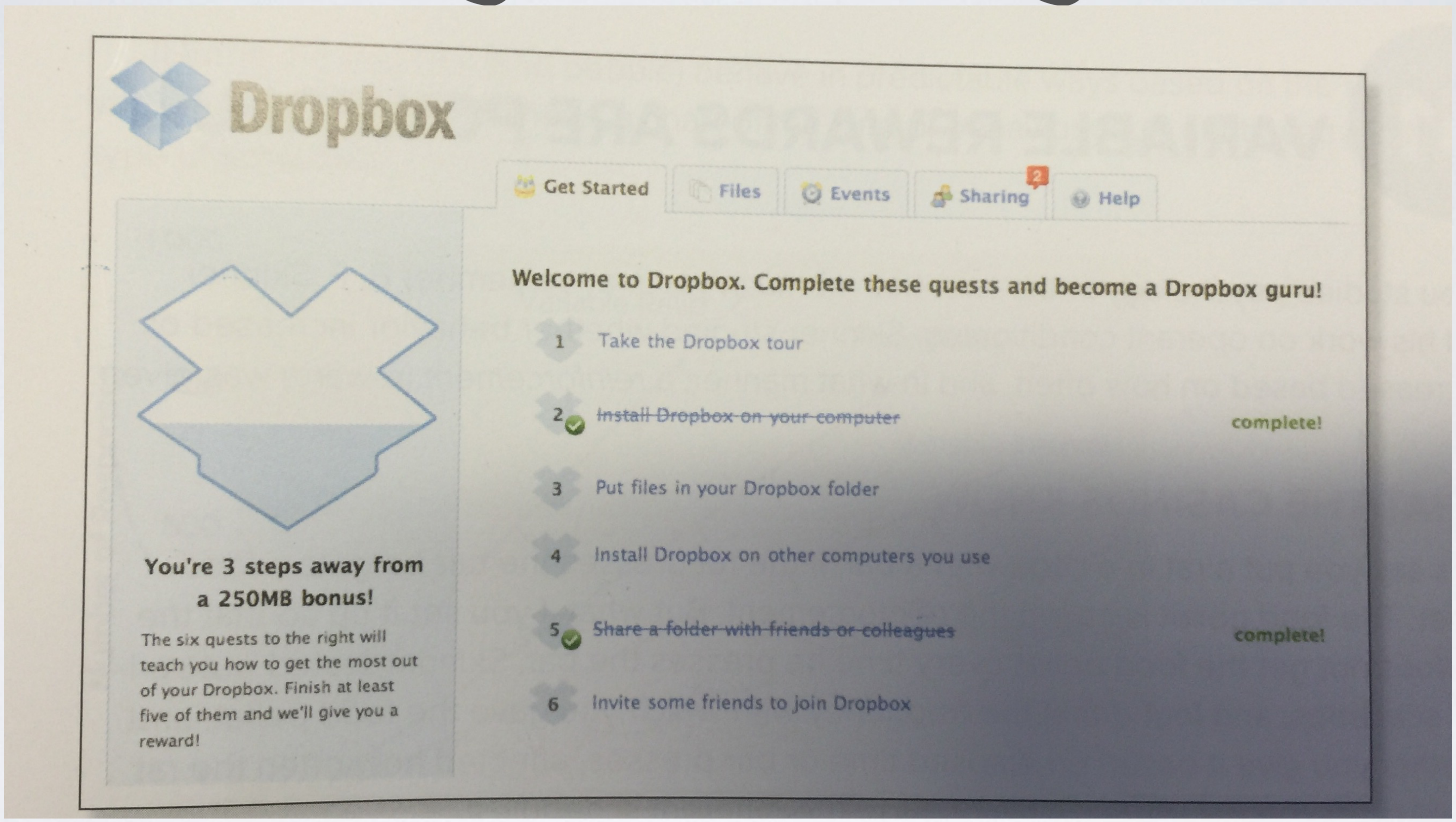
Pastoral scenes

- Experiencing images of nature
  - replenishes System 2 resources
  - reduces hospital stays
  - reduces required pain medication

Crave familiarity when scared

- Had a bad day. Will you get lunch at the place you always eat at or try something new?
- Preference for familiar when sad or scared.

Being close to goal



- Goal gradient effect: the shorter the distance to the goal, the more humans are motivated to reach it

Intrinsic vs. extrinsic motivation

- Intrinsic: motivated by properties of the task itself
  - e.g., doing a task to gain knowledge
- Extrinsic: motivated by the desire to obtain a desired outcome by completing the task
  - e.g., doing a task because you're paid to do it

Flow

- Humans experience flow when
  - A challenging activity that is neither too difficult nor too easy
  - The merging of action and awareness - complete occupation of System 2
  - Clear goals and feedback
  - Concentration on the task at hand
  - Paradox of control - perceive to be in control of situation, dictated by external events
  - Loss of self consciousness - no self scrutiny or judgements of self
  - Loss of sense of perceived time
  - Autotelic experience - intrinsically rewarding tasks

Affect

Affect

- Current emotional state
- Valence: positive or negative
- Arousal: strength of activation of sympathetic nervous system

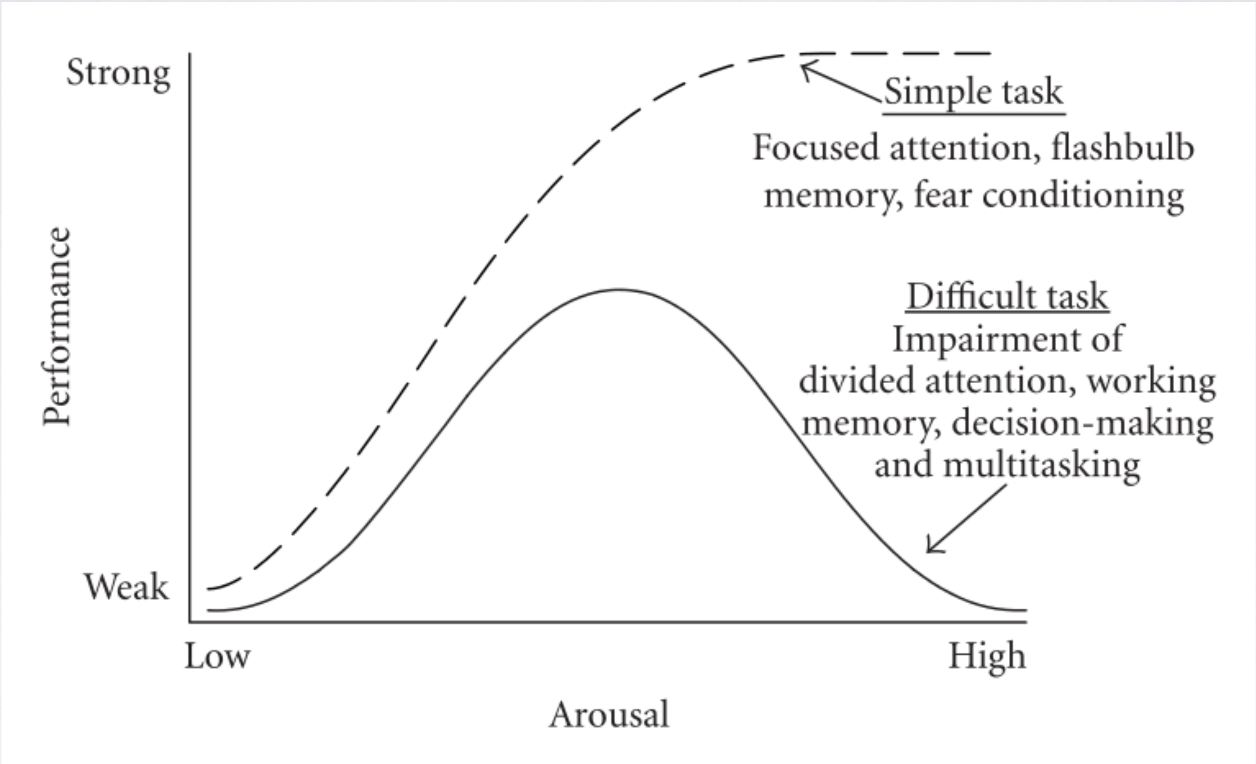
Affect affects focus and creativity

- Negative affect / high arousal
  - Escape from danger
  - Fire & door doesn’t open —> push harder
  - Neurotransmitted bias brain to focus on problem & ignore distractions
  - Tunnel vision on most salient aspects

Affect affects focus and creativity

- Positive affect / lower arousal
  - Better brainstorming and generating alternatives
    - More likely to work around minor difficulties —> better usability
    - See bigger picture, less focused

Performance / arousal curve



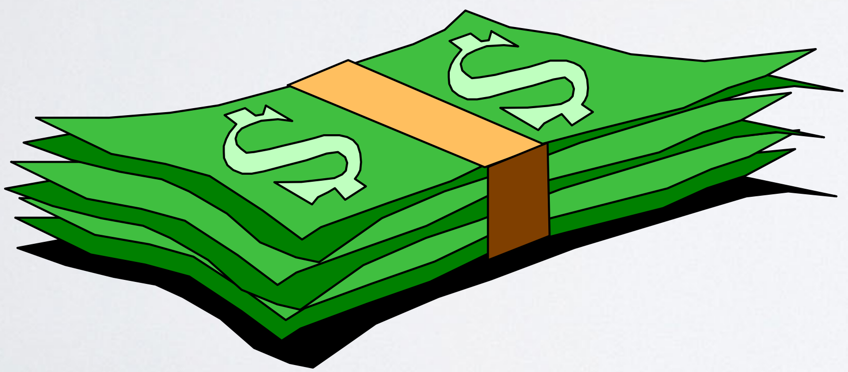
- Yerkes / Dodson law
- Arousal increasing performance for System 1 tasks, but only increases performance on System 2 tasks up to a threshold

Human performance modeling

Human performance modeling

- Predicts **skilled** performance **time** analytically from model
- Assumptions
    - Goals of accomplishing the task and doing so in as little time as possible
    - Known tasks
    - Known operators, of known time
    - Perceivable inputs
    - Complete knowledge of the task and environment

Example: IRS office automation system

- TMAC: procurement of office automation systems and software, maintenance and support
- Quantified factor in evaluation: Impact of software integration on user productivity
- 

  $1.4 billion contract awarded to AT&T over IBM and Lockheed

Enables efficiency to be predicted

B10 THE WALL STREET JOURNAL MONDAY, APRIL 19, 1993

TECHNOLOGY

INFORMATION AGE/ By WILLIAM M. BULKELEY

System Buyers Finally Value Productivity

People who buy computer systems for big organizations are finally trying to figure out whether a system actually makes their workers more productive.

Seem logical? Not in the wonderful world of computer procurement. For years, computer buyers based their decisions on the speed and the number of features in a system—without determining whether those things helped people work faster. Even today, many buyers just tally up bells and whistles. But "the next real boost in productivity will come from fitting the technology to the task – not the faster MIPS and bigger chips," says Judith Olson, who heads the computer studies department at the University of Michigan's business school.

Academic experts in the burgeoning field of human-computer interaction are trying to create methods to predict objectively whether one system will be more productive for people than another. Government and corporate buyers are trying to evaluate the real impact on productivity of new computer systems. Even influential trade magazines such as PC Week are changing their evaluation methods to do extensive tests with users, in addition to

John Segal

In another big contract dispute, a contract appeals board overturned a Navy award to Intergraph Corp. It said the Navy had claimed to make the decision on the basis of productivity, but had actually just counted features. The court noted: "The Navy never measured time. The Navy simply assumed a relationship between the number of productivity-enhancement tools and speed of operation."

Human factors in computing have been

precisely right. Ironically, she says, if Nynex had done the trials without the prediction, "when something counterintuitive happens, you say the trial was designed wrong."

John Carroll, manager of human interface theory and design at IBM, says he endorses Dr. John's efforts to bring scientific rigor to evaluating systems. However, he says, "higher-level concepts," such as the overall design and organization of the program, matter more than the time-and-motion studies she used for operators.

Human-factors researchers have established a variety of conceptual rules for designers. For example, the University of Michigan's Dr. Olson says that when software designers present users with more and more options, "you'll have memory overload." She adds that "creeping featurism can slow you down in your work. Each choice you make costs you at least two seconds."

Ben Shneiderman, head of the University of Maryland's human-computer interaction lab, says, "We try to understand basic principles. Eventually, you can make predictions in novel situations." He says that his research has established that

Keystroke-level model (KLM)

- Pre-defined level of detail:
  the keystroke-level

- No representation of goals, methods or selection-rules, just a sequence of operators that perform a task

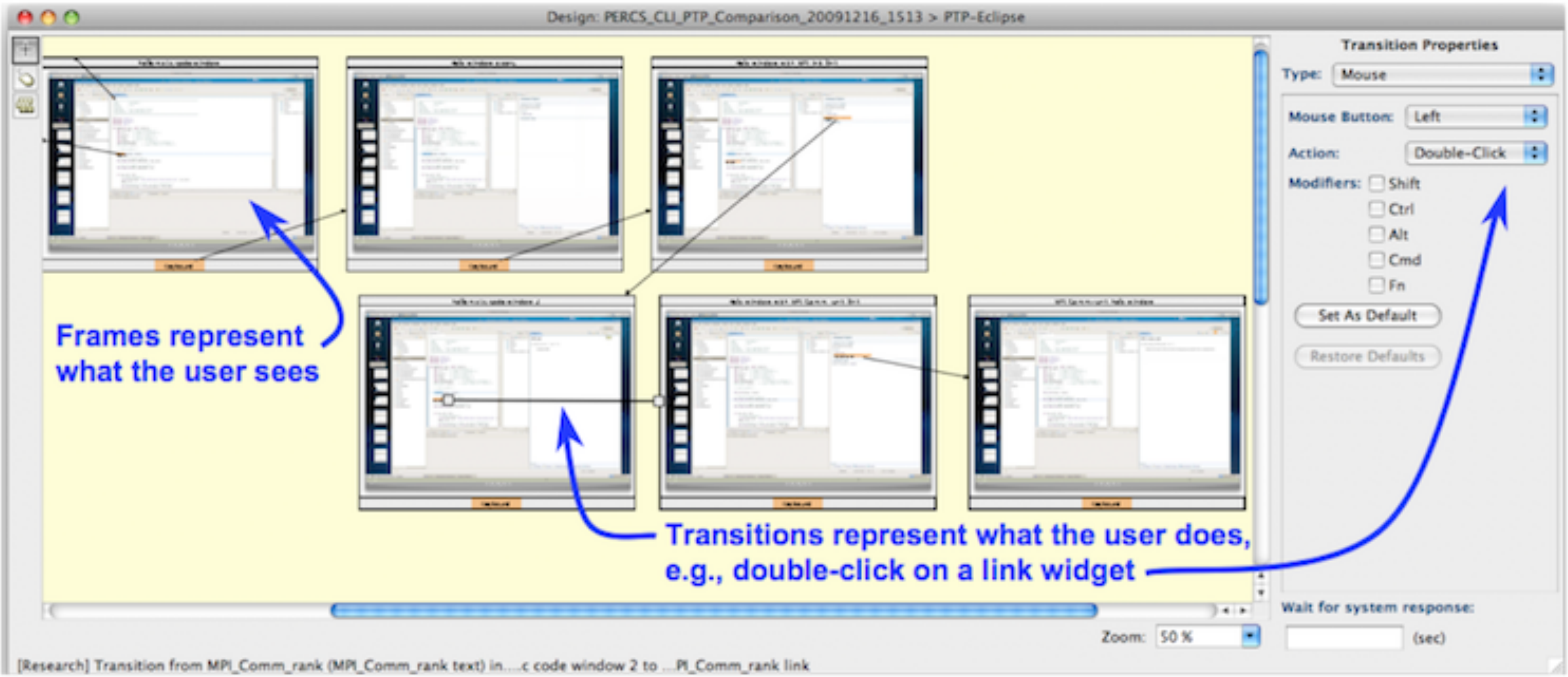
- Input: a suite of benchmark tasks that are important to your design or evaluation

- Output: the time it would take a skilled user to perform these benchmark tasks

Applying KLM by hand

- List the overt actions necessary to do the task
    - Keystrokes and button actions (K)
    - Mouse movements (P)
    - Hand movements from keyboard to mouse (H)
    - Also system response time (if user has to wait)
- Insert mental operators (M) by CMN's heuristics
- Assign execution times from previous research
    - K, M, H are straightforward
    - P often requires measuring D and S and calculating Fitts's Law time
- Add up the execution times

Automated KLM - CogTool



http://cogtool.com/

Implications for design

Some design implications

- Take advantage of System 1 where possible
- Don't confuse System 1 (e.g., consistent mapping in next lecture)
- Users can be stubborn (sunk cost investment in current strategy)
- People can get upset when have goals they cannot accomplish, as attentional resources exhausted solving problem and less self control
- Let users doing something else while waiting

Resources and further reading

- Thinking Fast and Slow. Daniel Kahneman. 2013.
- 100 things every designer needs to know about people. Susan M. Weinshenk. 2011.
- Cognitive Psychology. Douglas M. Medin, Brian H. Ross, Arthur B. Markman. 2001.
- Human Performance Modeling. Bonnie John.