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Day 2: Cognition

ELEC-D7011 Human Factors Engineering
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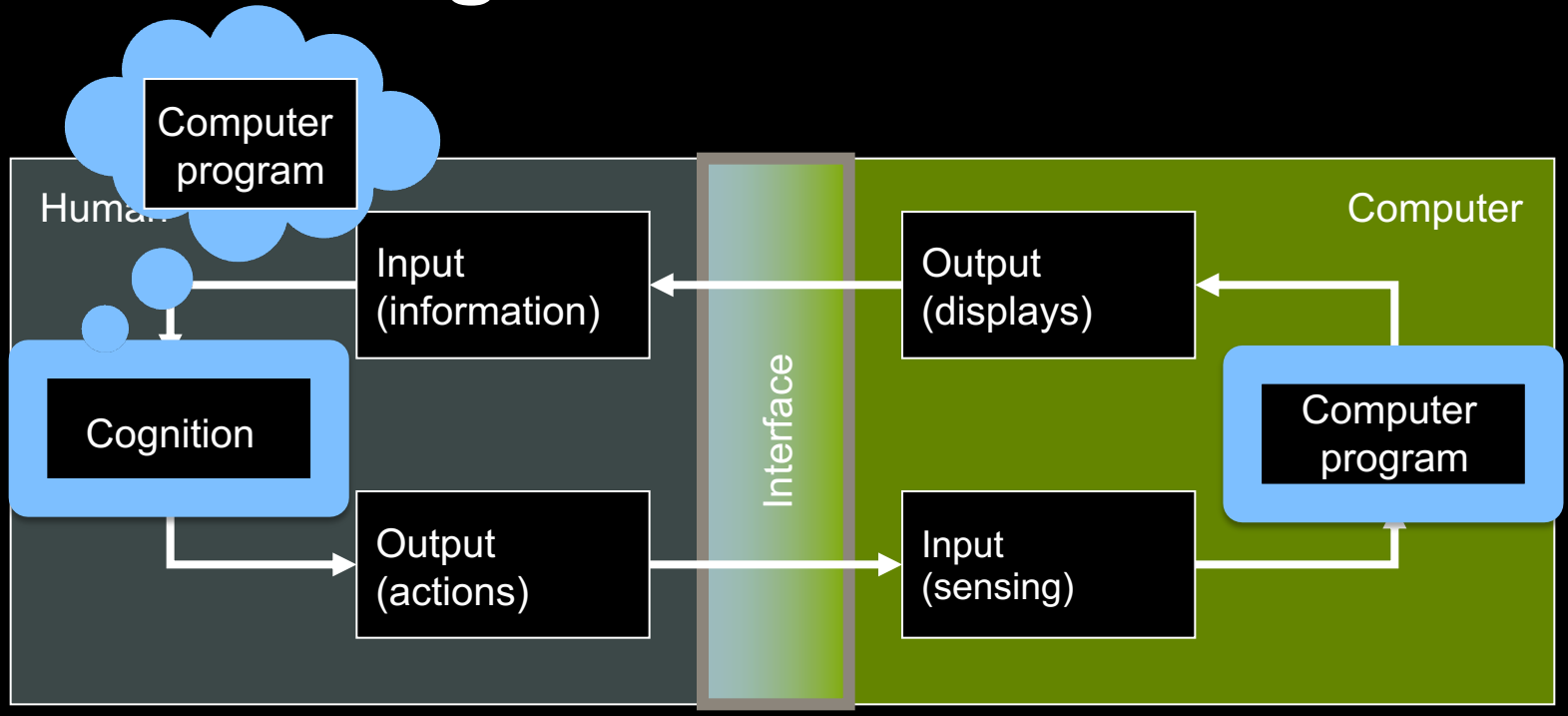
Aalto University

Cognition comes from the Latin word ’cognoscere’, which means knowing or learning.

As a scientific term, it refers to mental activities involved in thinking and doing.

Cognition is needed when interacting with machines



Elementary cognitive capabilities

Memory

"Oh, Powerpoint does have image editing capabilities!"

Control

"What should I press now to edit a photo?"

Reasoning

"Could I edit the photo in Powerpoint and take a screencapture to store it?"

Decision-making

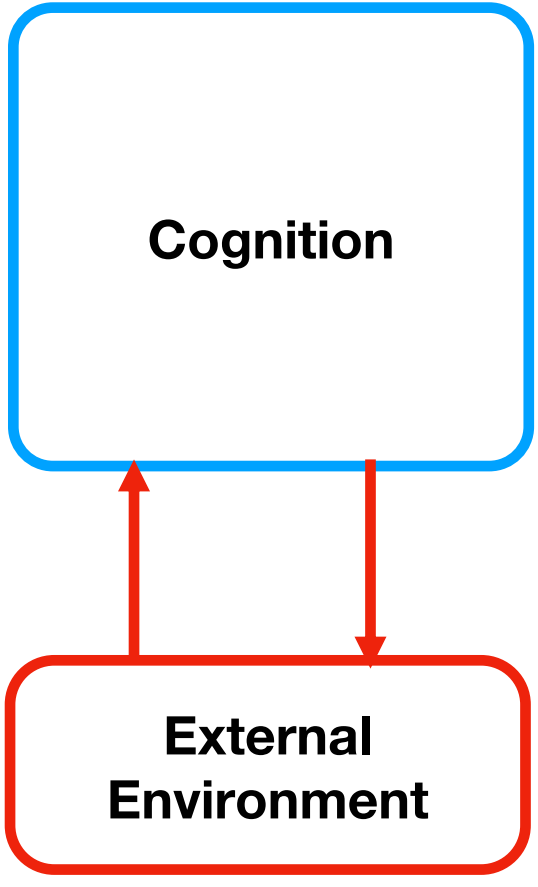
"I don't have time to learn Powerpoint, I'll just send this to Mary and ask her to do it."

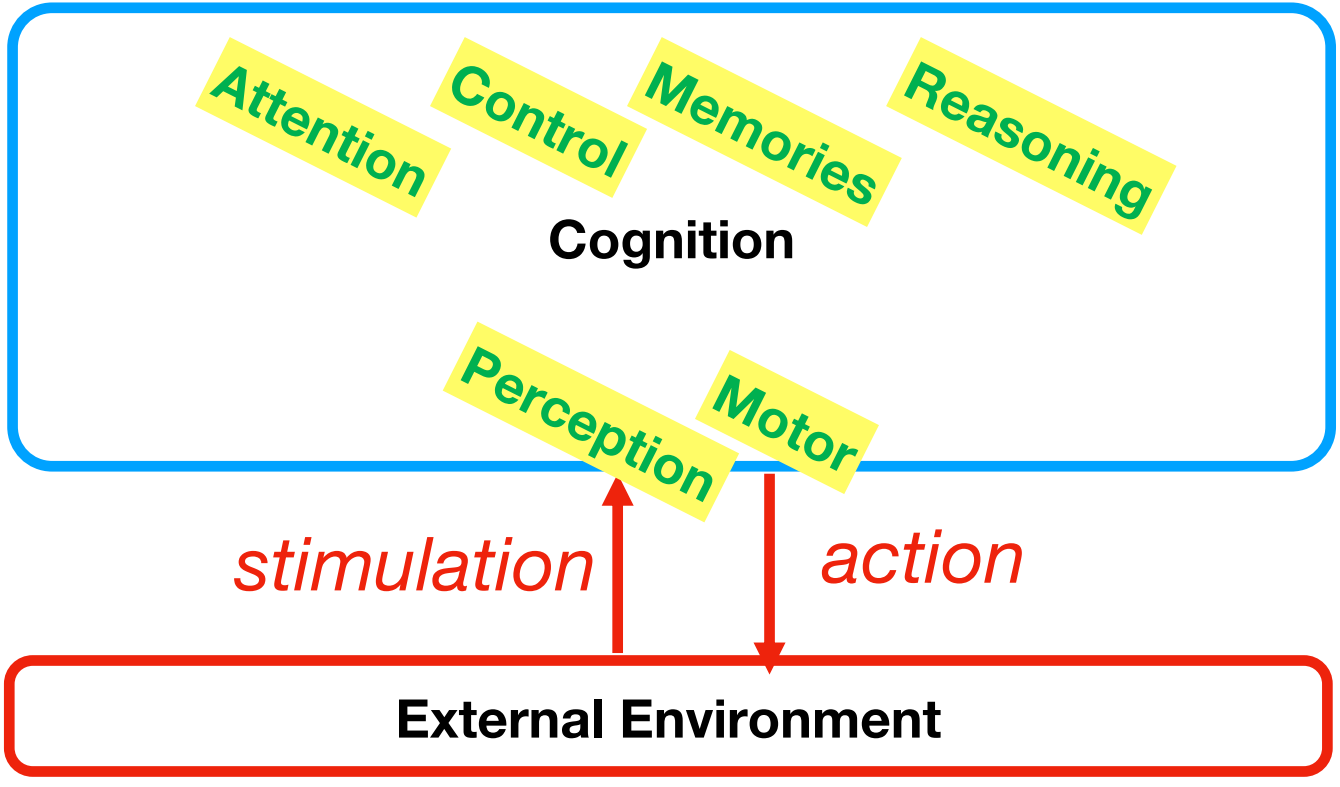
What is cognition?

Cognition centers on internal representations.

Five points about cognition:

1. **It is limited.**
2. **It learns.**
3. **It adapts.**
4. **It serves the control of action.**
5. **It carries out computations on representations.**




Attention
Control
Memories
Reasoning
Cognition
Perception
Motor
stimulation
action
External Environment

Our case today

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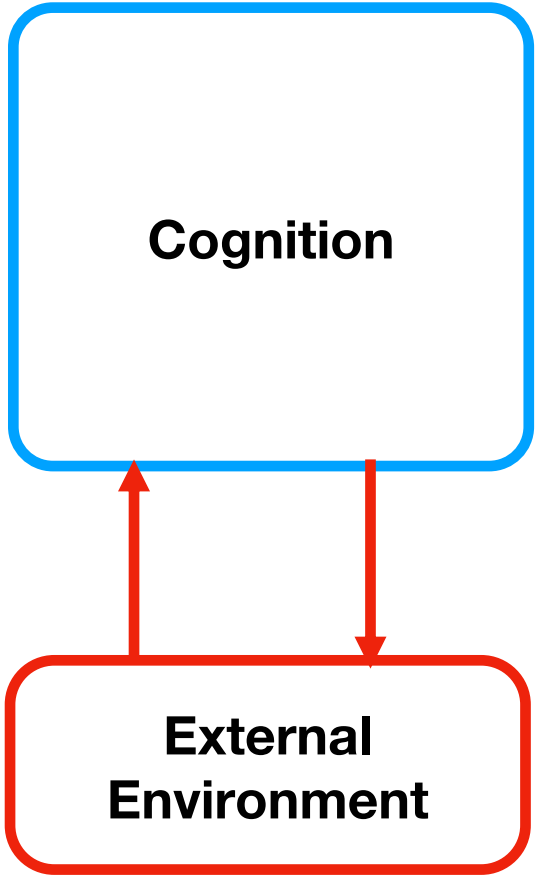
1. Cognition

What is cognition?

Cognition is about sensing, representing, and acting in the world.

1. **It is limited.**
2. **It learns.**
3. **It adapts.**
4. **It serves the control of action.**
5. **It carries out computations on representations.**



1. Cognition is limited

1. **Visual attention is spatially limited**
   - We can extract more information from the foveal region and less so from the periphery.
2. **Working memory is capacity limited**
   - We can only keep active in mind a mental representations for use in thought and action. According to latest research, we can only hold in mind 2-4 ideas actively.
3. **Long-term memory forgets**
   - We quickly forget details of things we have attended.
4. **Our ability for abstract reasoning (using symbols) and planning is limited.**
   - We often resort to external aids like calculators and notes to help us go beyond the limits posed by our cognition.

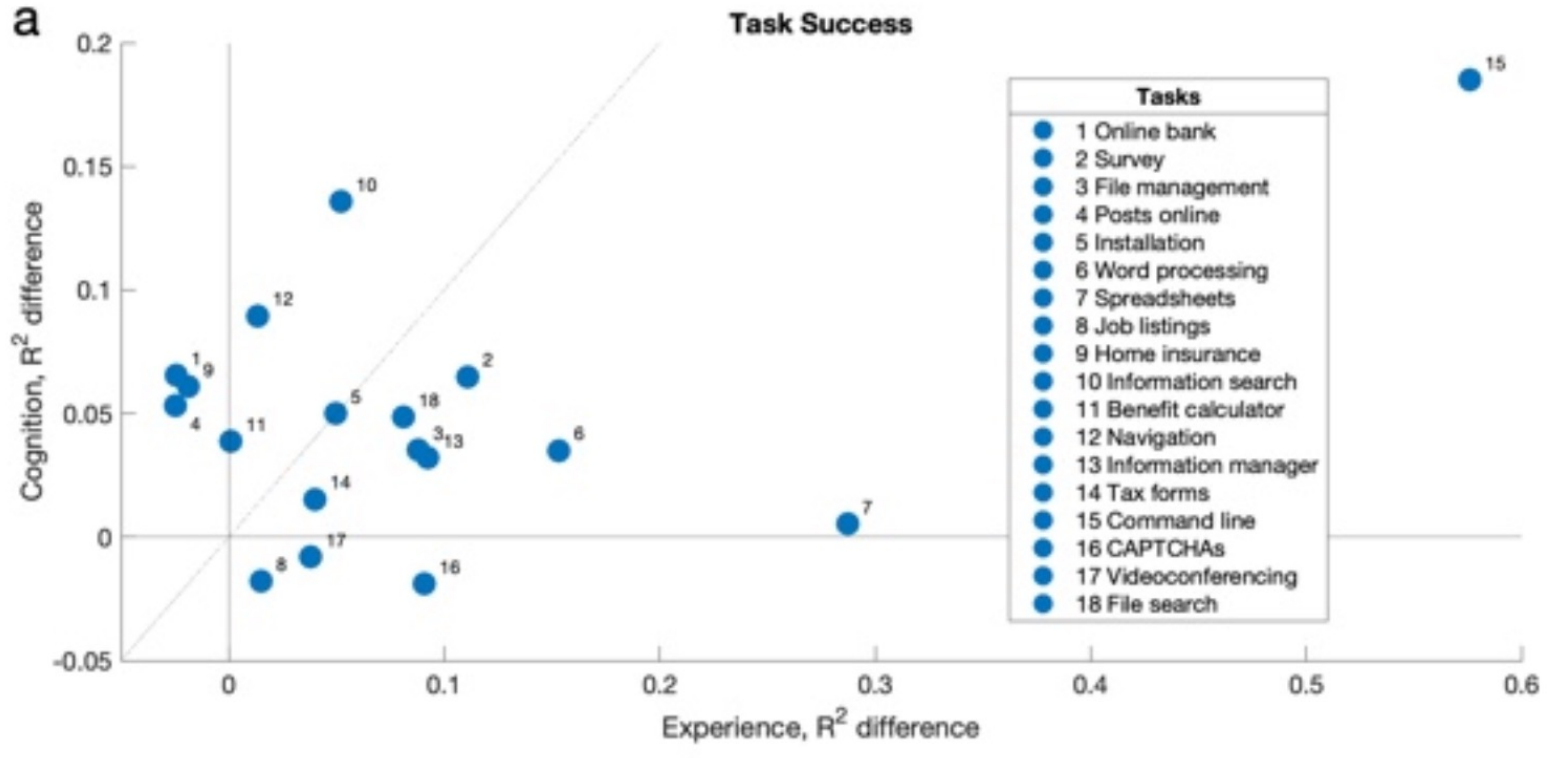
Lab-based cognitive assessment

https://d68b3152cf5d08c2f050-97c828cc9502c69ac5af7576c62d48d6.ssl.cf3.rackcdn.com/includes/img/cms/site-images/orig/kingston-university-c9ab23e-.jpg

2.A. Psytoolkit (20 mins)

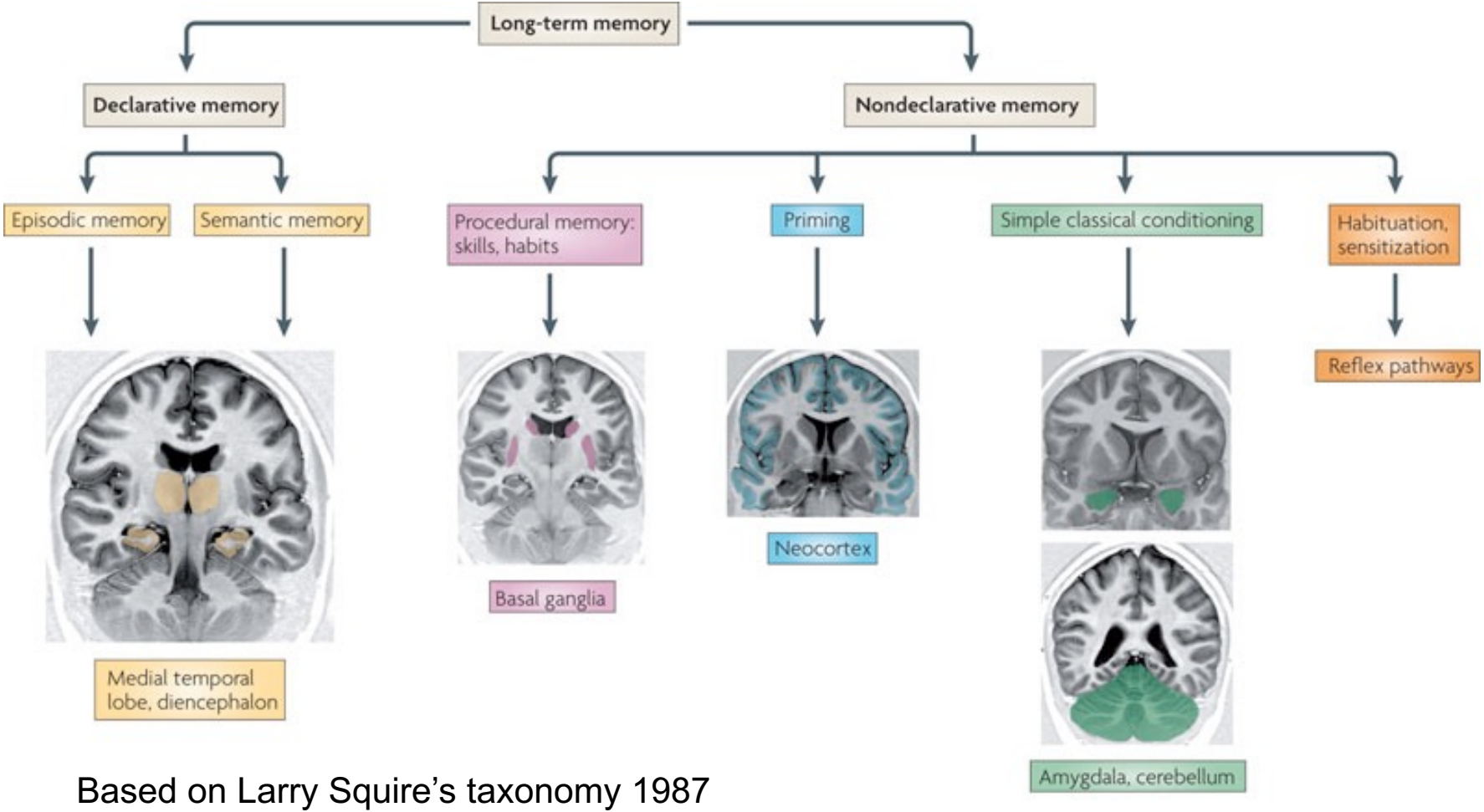
1. Take your laptop
2. Open https://www.psytoolkit.org/experiment-library/
3. Identify all tests that are related to ”multitasking” -> **list them**
4. Pick 1 to focus on
5. Conduct the experiment
6. **Report** the results

Cognitive functioning is predictive of one's ability to use computer



Lintunen et al. in review

2. Cognition learns (here: 6 systems)



Based on Larry Squire's taxonomy 1987

Direct manipulation

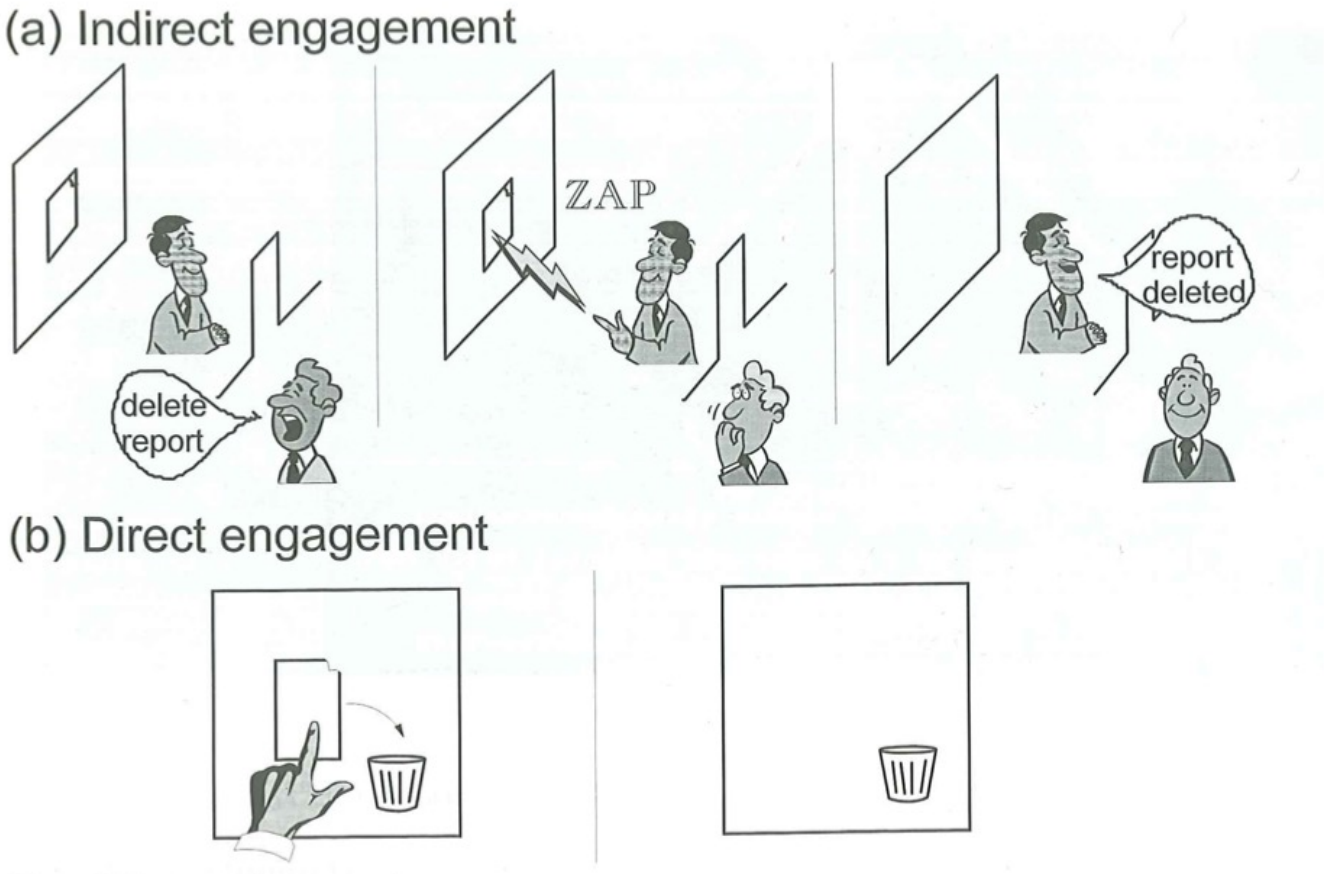
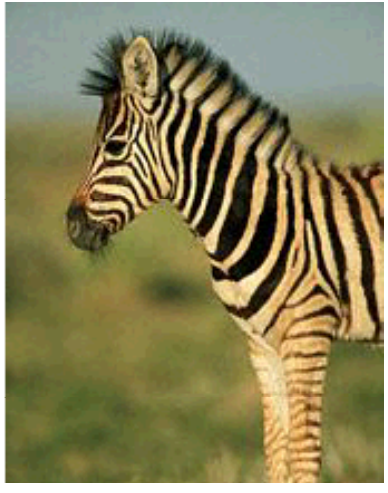


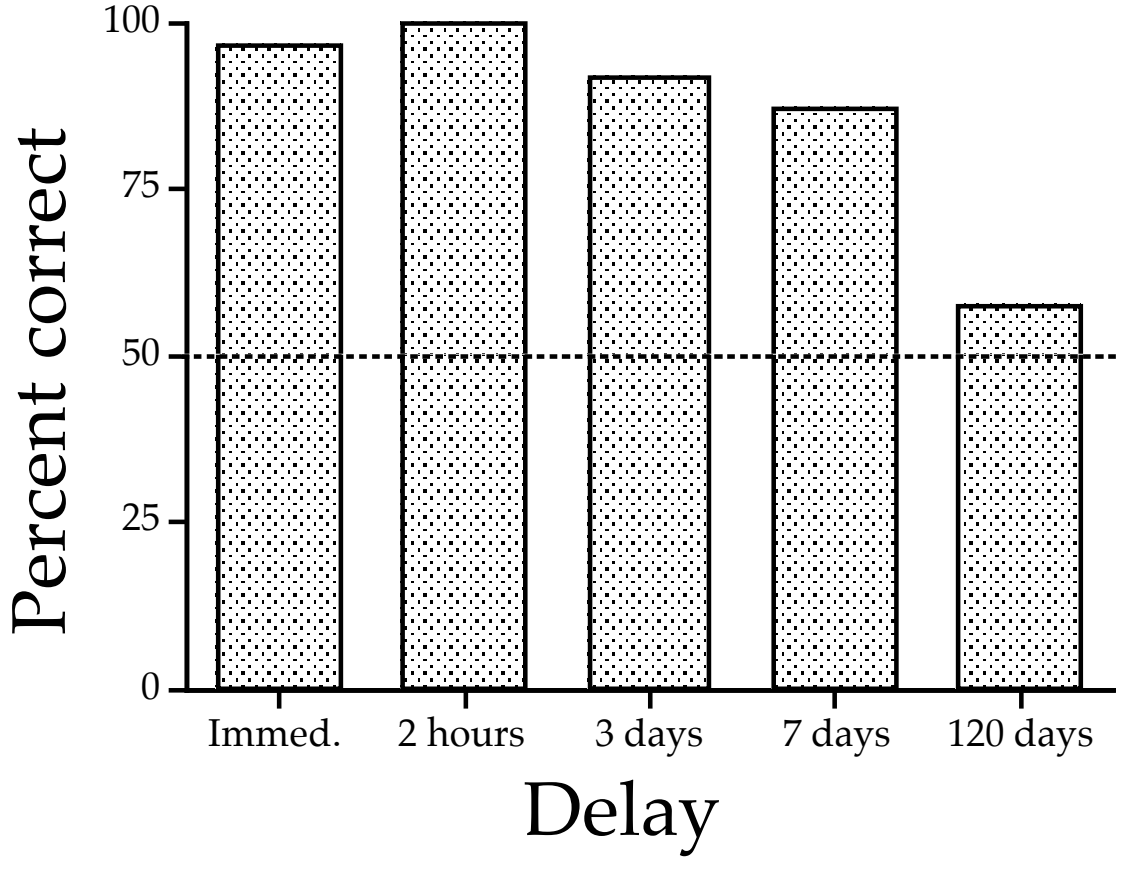
Figure 2. Two types of engagement.

Phase 1: Learn

Phase 2: Test

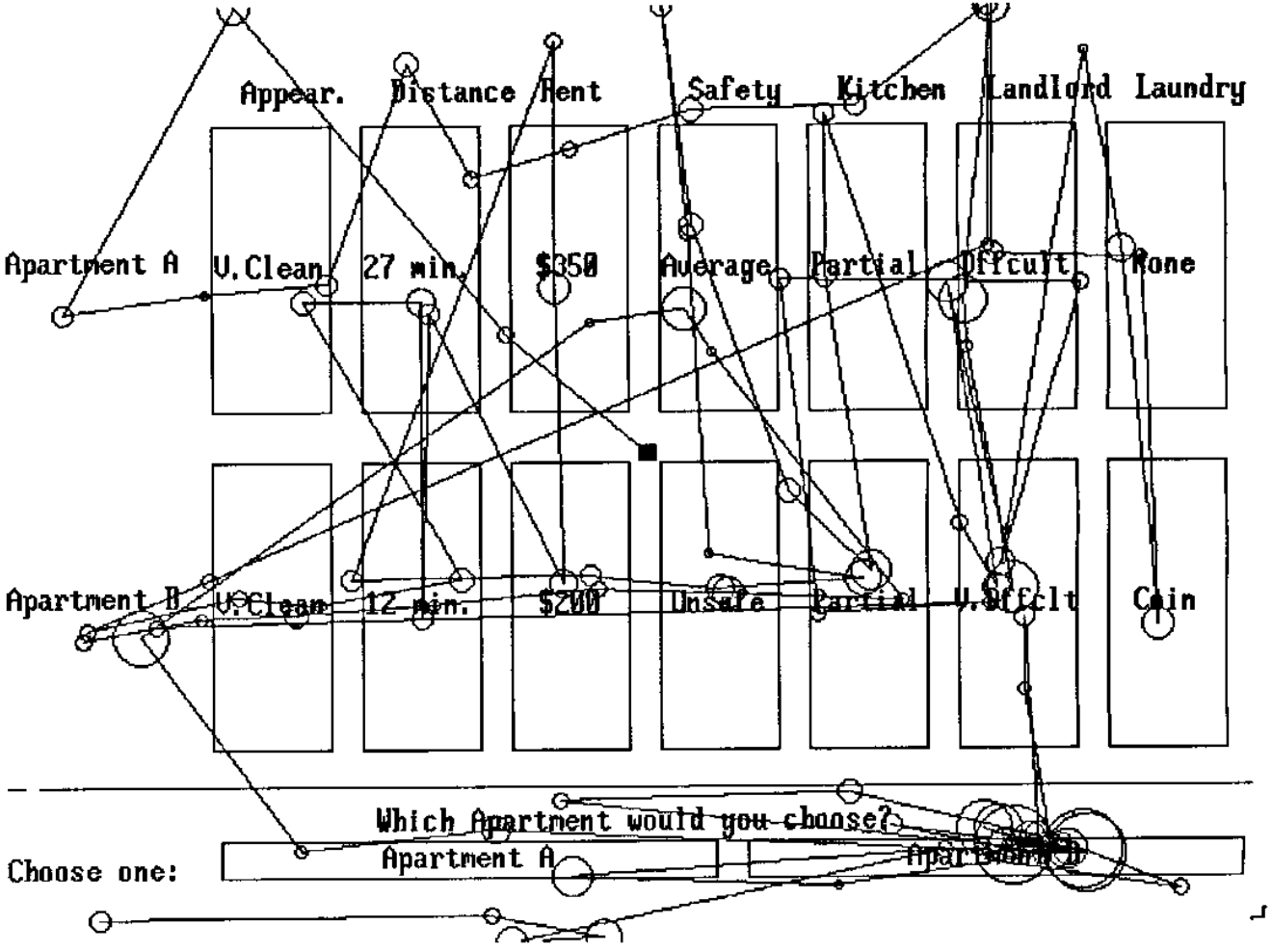


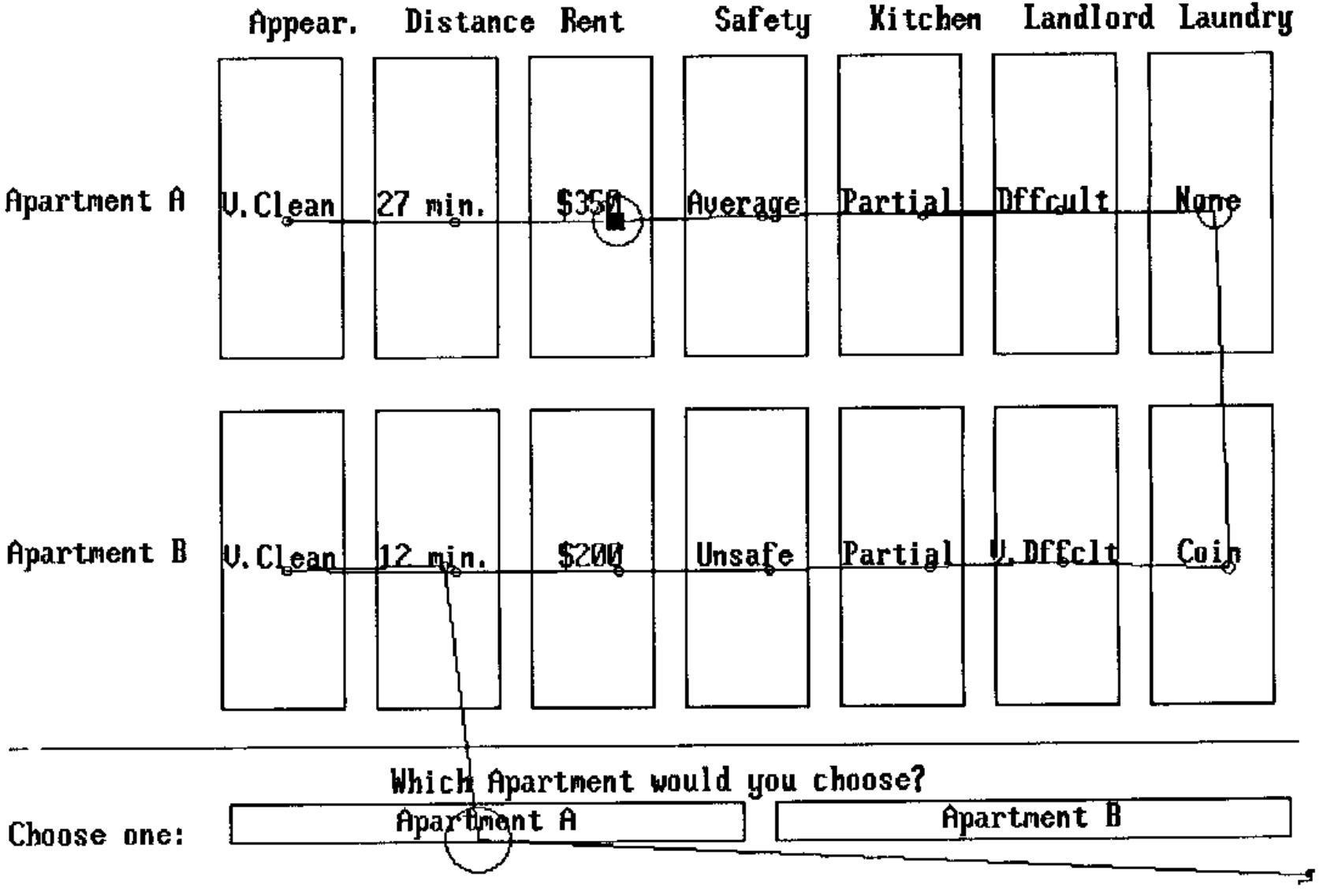
Shepard's results



3. Cognition adapts

Lohse & Johnson 1986




Appear.
Distance
Rent
Safety
Kitchen
Landlord
Laundry
Apartment A
V.Clean
27 min.
$350
Average
Partial
Dffcult
None
Apartment B
V.Clean
12 min.
$200
Unsafe
Partial
V.Dffclt
Coin
Which Apartment would you choose?
Choose one:
Apartment A
Apartment B

4. Cognition serves the control of action

Problem: *At any given time, there are several stimuli barraging our senses and several options on how to share attention and other limited resources to them.*

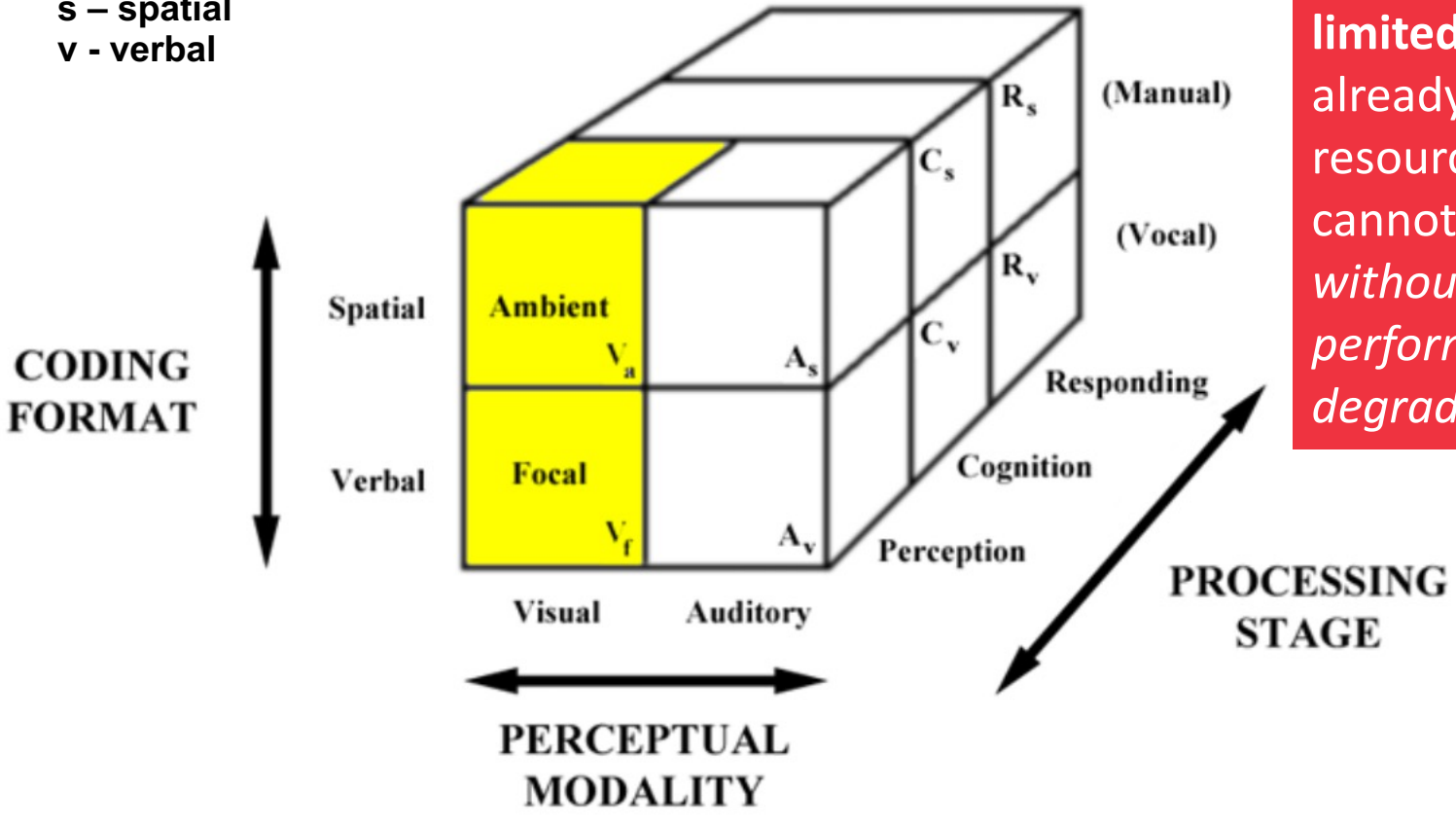
Cognitive control refers to our ability to direct thinking and action toward some goal.

- Setting goals
- Directing resources and attention
- Multitasking
- Task-switching
- Inhibiting distracting ideas

Cognitive control is effortful. Workload increases

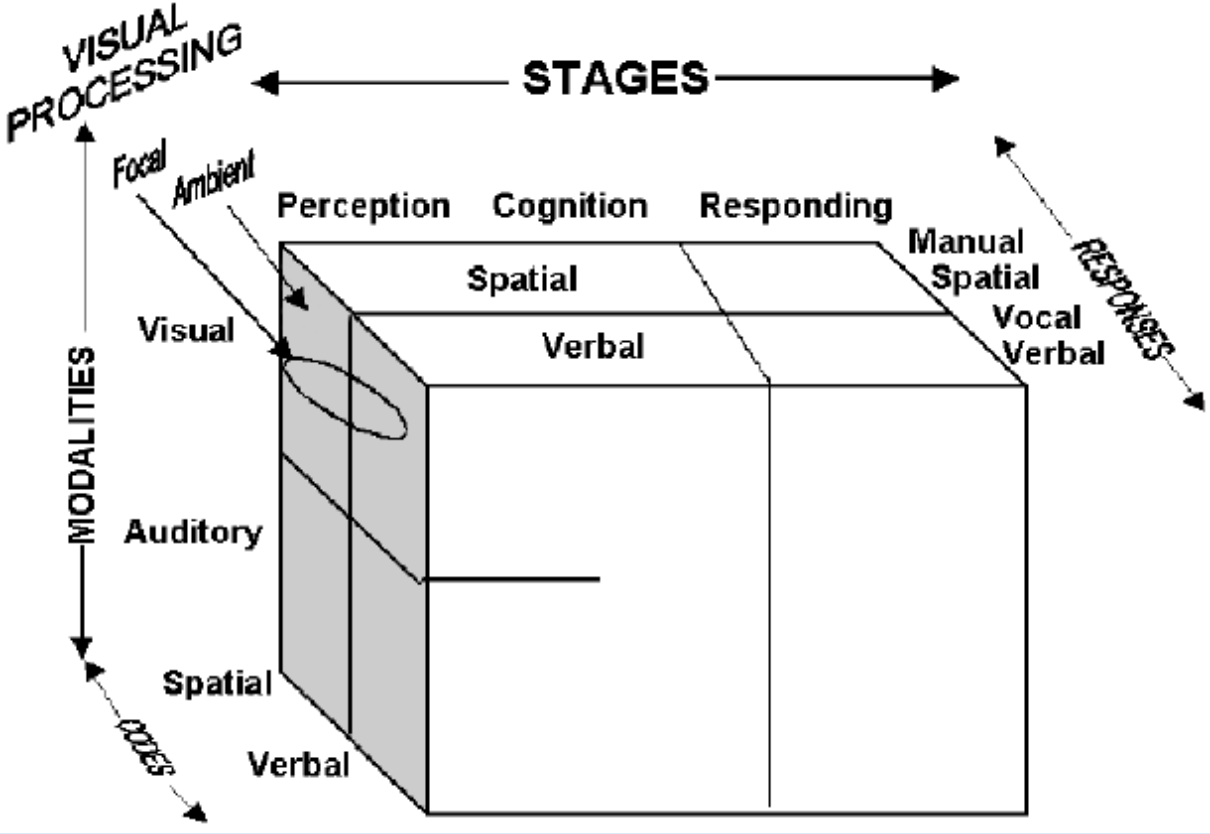
Wickens' Multiple Resources Theory

s – spatial
v - verbal



Resource-sharing is limited: If Task A already recruits a resource, Task B cannot share it *without causing performance-degradation.*

Another perspective



Estimation of distractabil

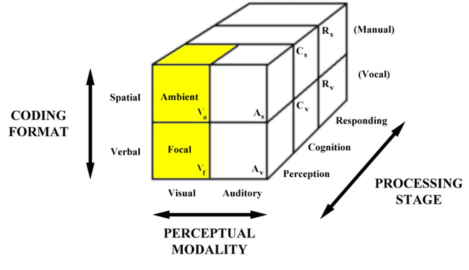
MRT can be used to assess HOW distracting two tasks are

Task A Resources

		Perceptual				Cognitive		Response	
		VS	VV	AS	AV	CS	CV	RS	RV
	VS	0.8	0.6	0.6	0.4	0.7	0.5	0.4	0.2
	VV		0.8	0.4	0.6	0.5	0.7	0.2	0.4
	AS			0.8	0.4	0.7	0.5	0.4	0.2
Task B	AV			0	.8	0.5	0.7	0.2	0.4
Resources	CS			0		.8	0.6	0.6	0.4
	CV						0.8	0.4	0.6
	RS							0.8	0.6
	RV							0.6	1.0

2.B. MRT (20 mins)

1. Pick a task that should **not** be done when driving (other than texting!)
2. Draw the MRT cube
3. Ideate a UI that would be less distracting
   - Which modalities to use?
4. Show the two designs and their MRT cubes
5. Bonus: do the distractability calculation



5. Cognition carries out computations on representations

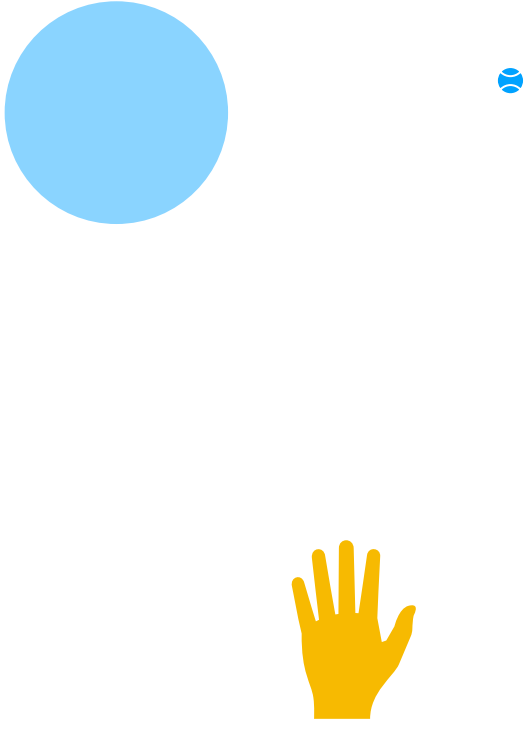
Computations alter existing and produce new representations

Case: Cognition adapts in a Bayesian fashion to noisy perceptions


Tavernjers :: Anuttea was disconnected due to high ping!

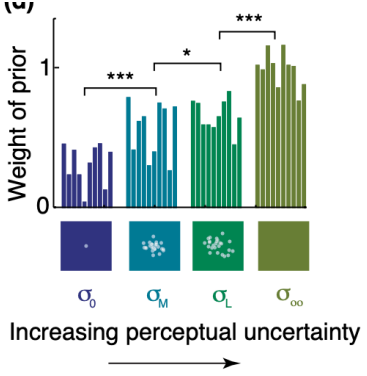
Example

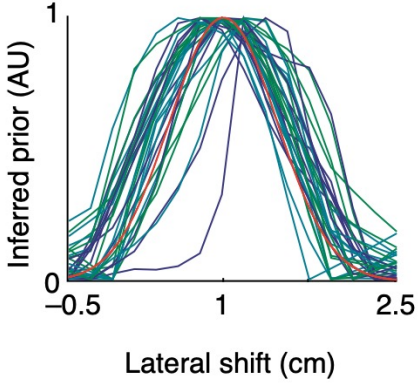
- Kording and Wolpert (2004)
- Subjects had to estimate the position of a cursor relative to their hand.
- Subjects could use two sources of information:
  - The distribution of displacements over the course of many trials (prior),
  - as well as what they see during the current trial (giving a likelihood).
- The quality of the visual feedback was also varied, in some cases a ball was shown at the position of the cursor giving precise feedback whereas in other trials a large cloud was shown at the position of the cursor thereby increasing the variability (noise) in the sensory input.



Results

- The Bayesian estimation process predicts that with increasing noise in the sensory feedback subjects should increase the weight of the prior and decrease the weight of their sensory feedback in their final estimate of the location.
- People used a prior that was very close to the optimal one. From the data it is possible to infer the prior that people are using – assuming that they use an optimal Bayesian strategy.





Summary

Cognition is about sensing, representing, and acting in the world.

1. **It is limited.**
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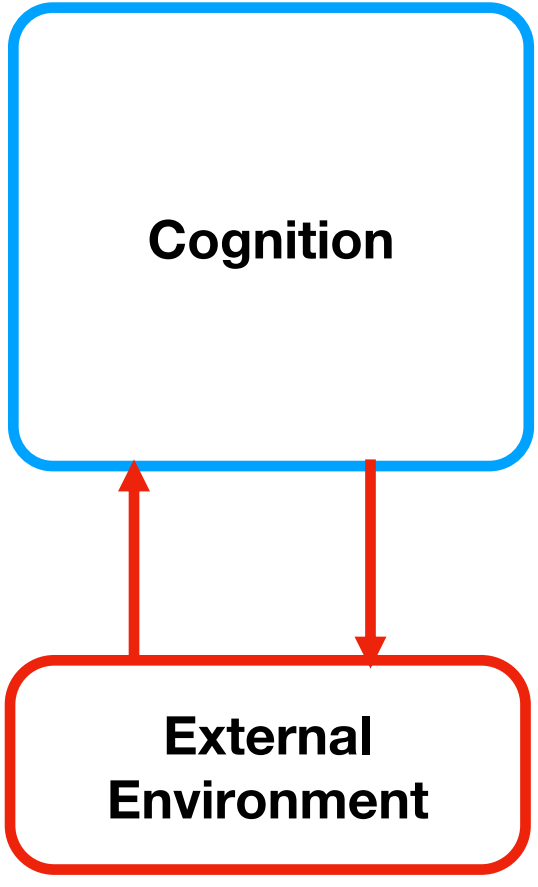

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Distract-R

A multitasking simulator built on ACT-R

https://www.cs.drexel.edu/~dds26/cog/distract-r/download.php

Texting and driving

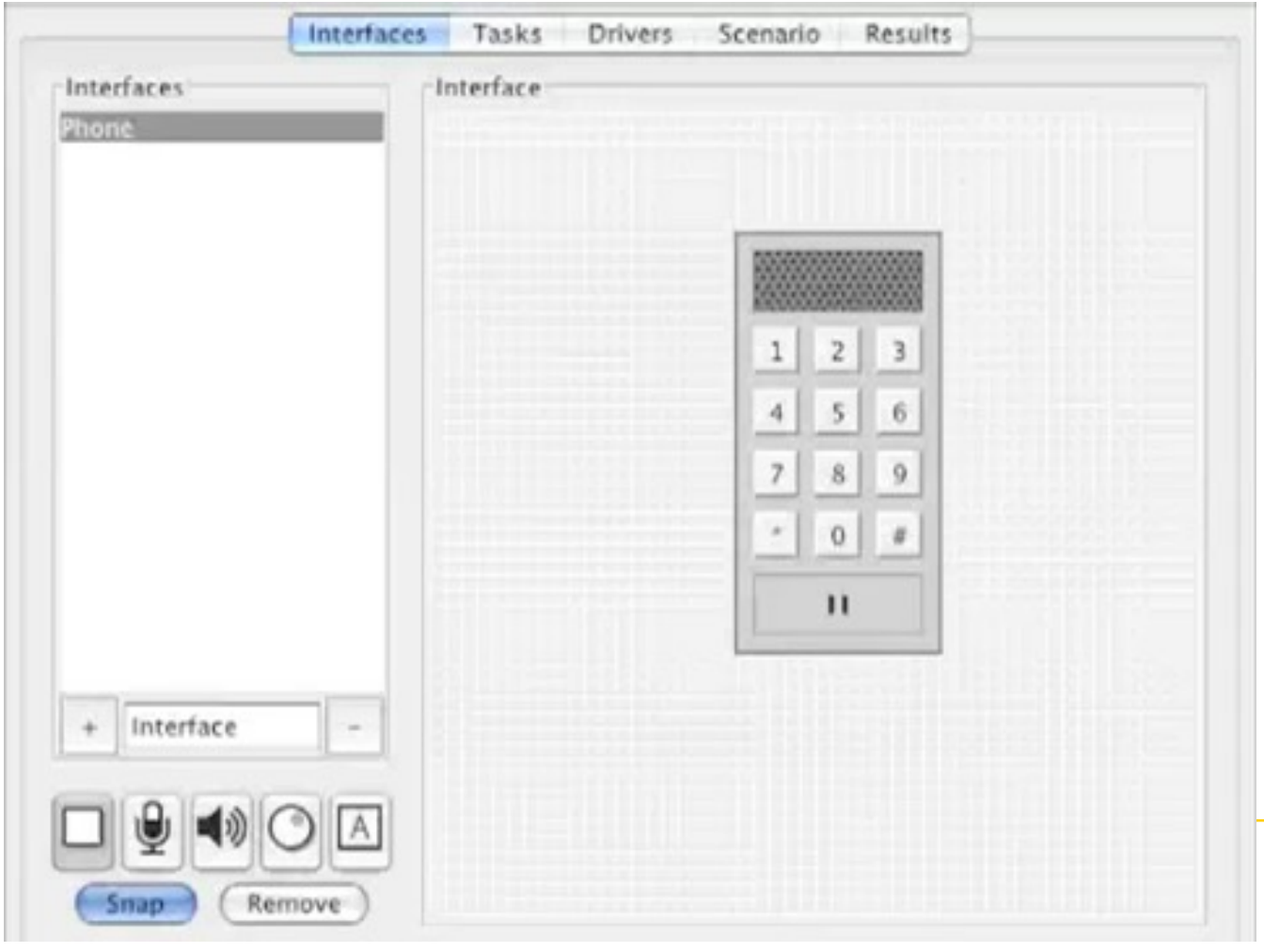
RAC Foundation (2008, UK): 45% of drivers admit to texting while driving.

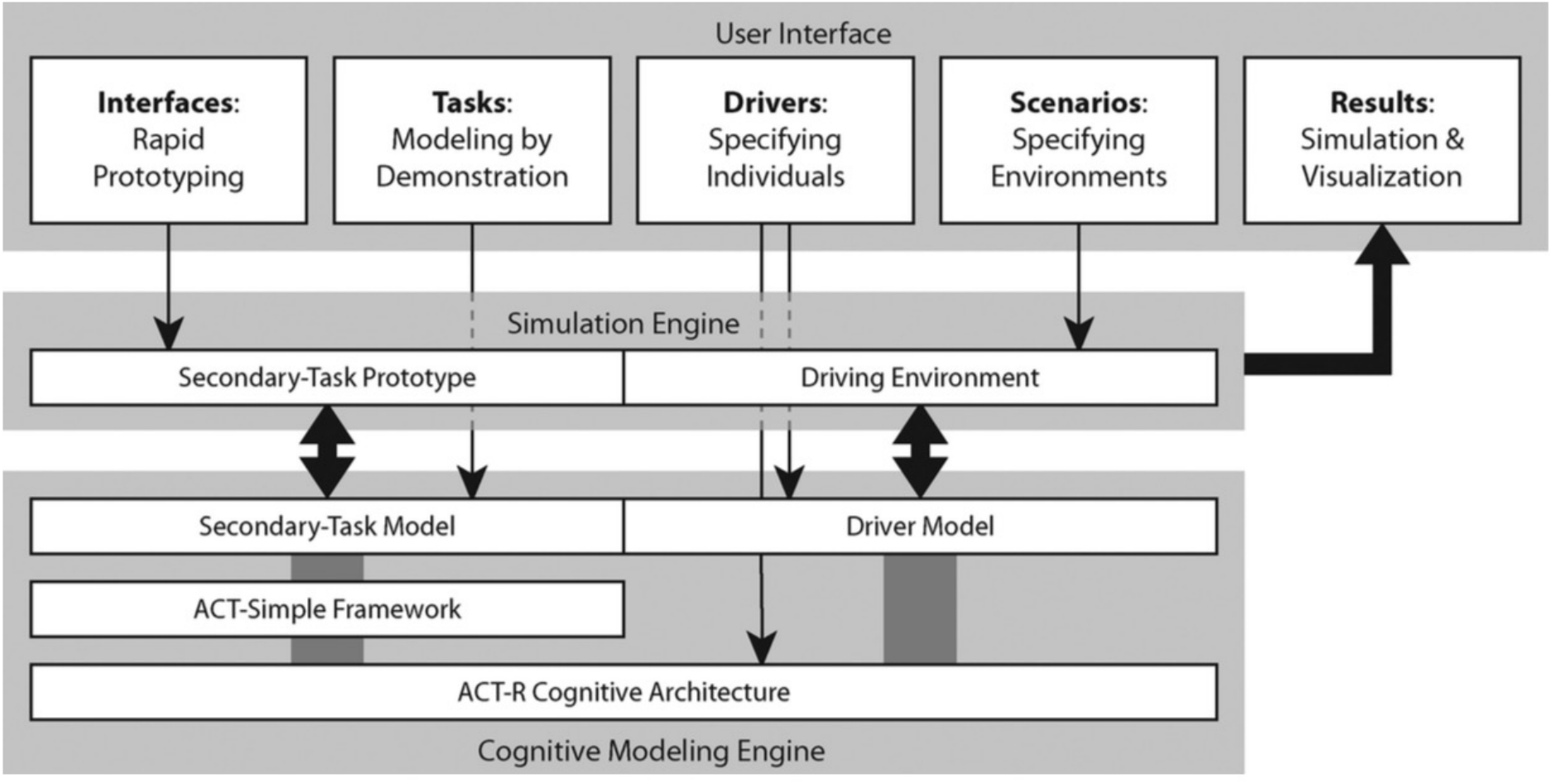
Pennay (2006, Australia): 75% of 18-25 year olds text while driving (36% of over-25 year olds).

Harrison (2011, US), Atchley et al (2011, US): 90% of college students text while driving.

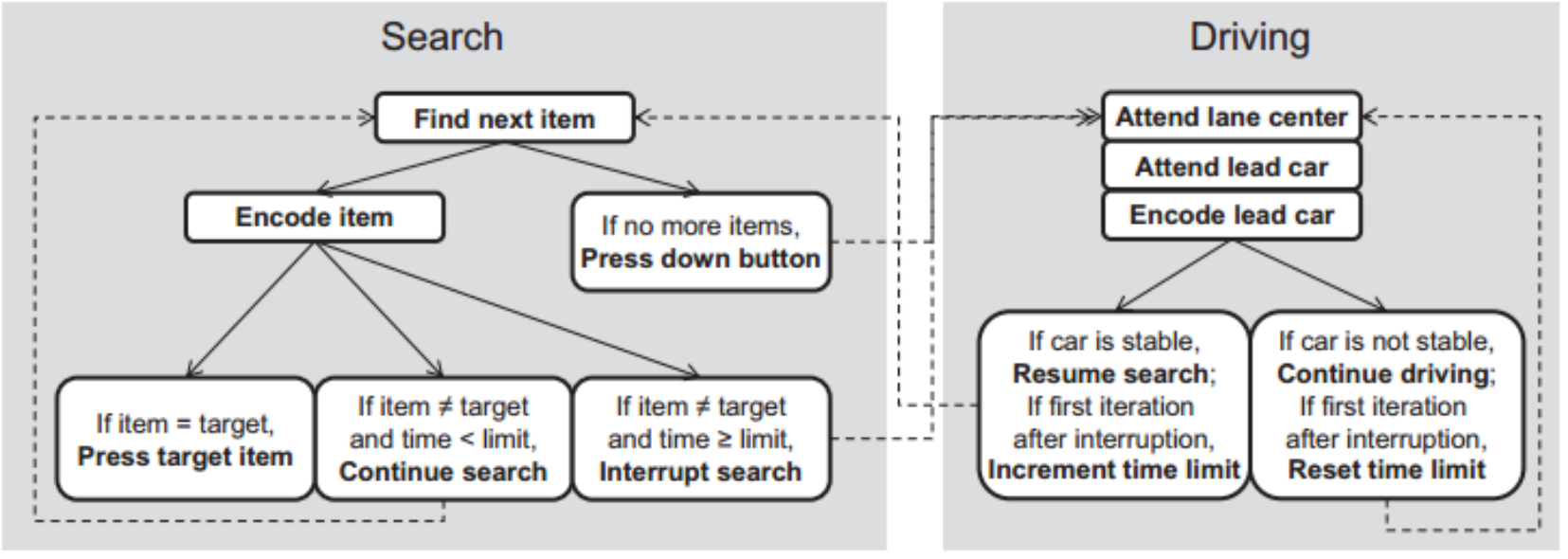
IAM/TRL (2012, UK): 8% of drivers use smartphones while driving (24% of 17-24 year olds).

Demo: Distract-r




User Interface
Interfaces: Rapid Prototyping
Tasks: Modeling by Demonstration
Drivers: Specifying Individuals
Scenarios: Specifying Environments
Results: Simulation & Visualization
Simulation Engine
Secondary-Task Prototype
Driving Environment
Secondary-Task Model
Driver Model
ACT-Simple Framework
ACT-R Cognitive Architecture
Cognitive Modeling Engine

Modeling the two tasks in Distract-R



Brumby et al. 2018 in Computational Interaction, OUP

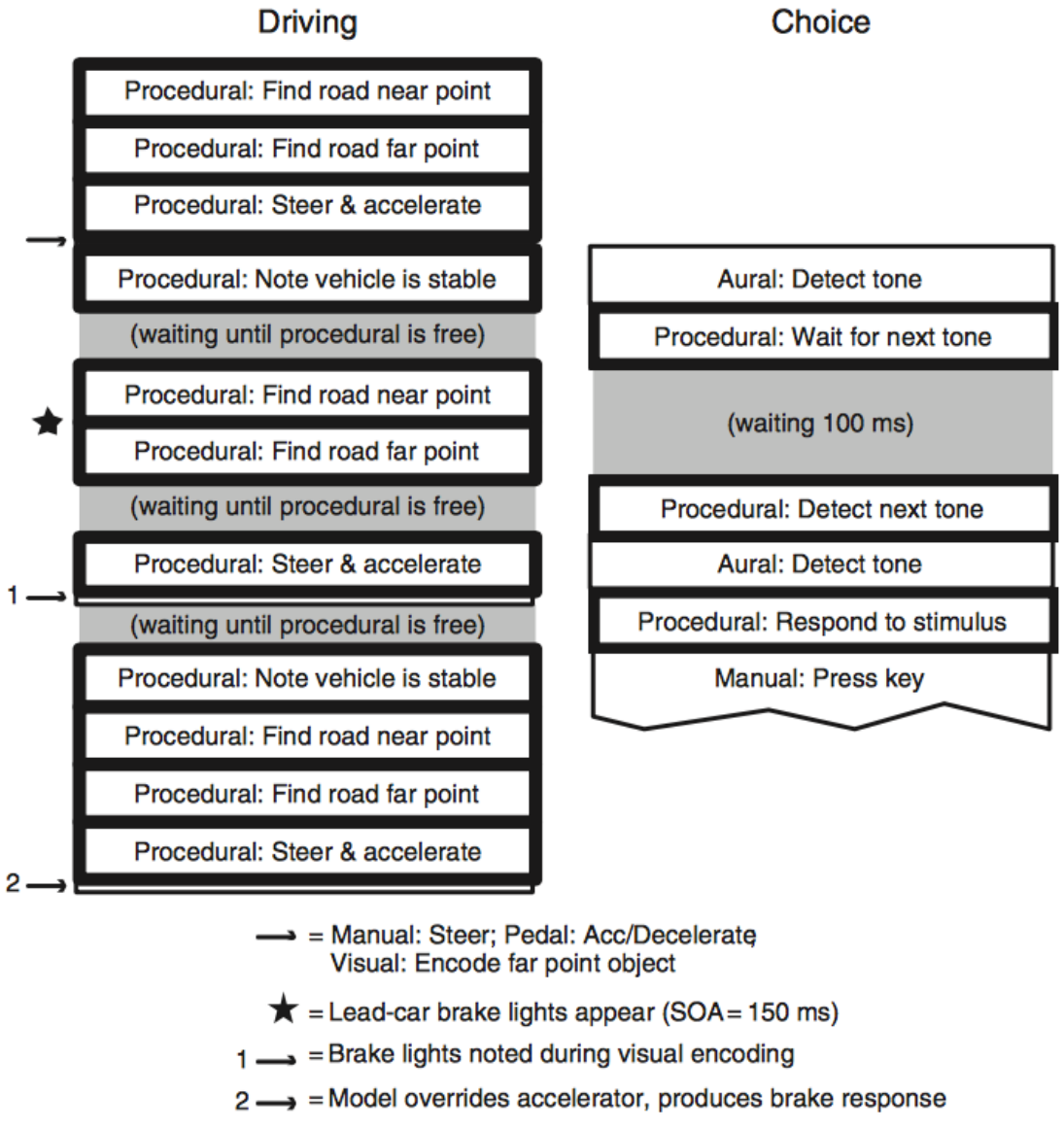
An architecture for multitasking

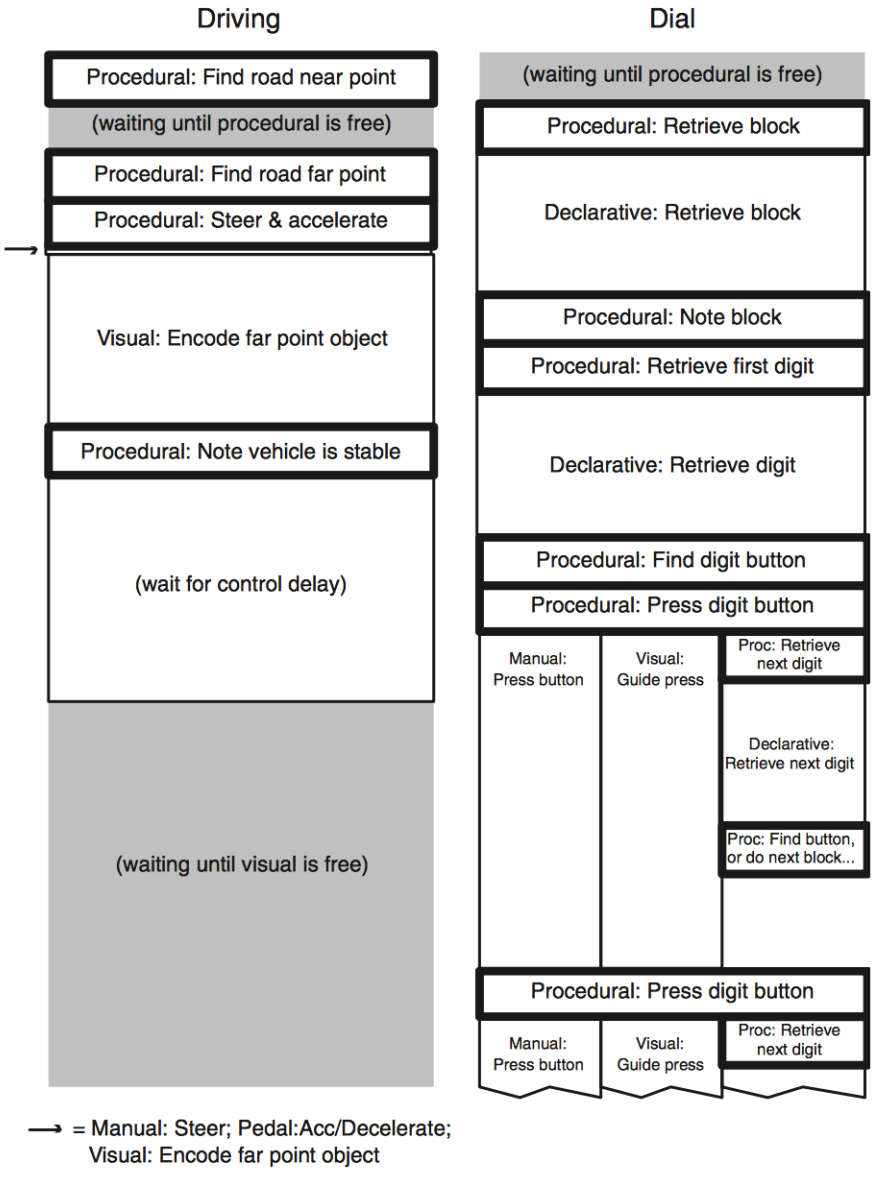
The theory of threaded cognition is a general mechanism for multitask interleaving:

Threaded cognition posits that multitasking is achieved by cognitive “threads,” each of which performs the cognitive processing for one particular task; as this processing spreads across multiple cognitive resources (vision, declarative memory, etc.), multiple threads can interleave and result in efficient multitasking behavior

Brumby et al. 2018 in Computational Interaction, OUP

Threaded cognition




Driving
Dial
Procedural: Find road near point
(waiting until procedural is free)
Procedural: Find road far point
Procedural: Steer & accelerate
Visual: Encode far point object
Procedural: Note vehicle is stable
(wait for control delay)
(waiting until visual is free)
(waiting until procedural is free)
Procedural: Retrieve block
Declarative: Retrieve block
Procedural: Note block
Procedural: Retrieve first digit
Declarative: Retrieve digit
Procedural: Find digit button
Procedural: Press digit button
Manual: Press button
Visual: Guide press
Proc: Retrieve next digit
Declarative: Retrieve next digit
Proc: Find button, or do next block...
Procedural: Press digit button
Manual: Press button
Visual: Guide press
Proc: Retrieve next digit
= Manual: Steer; Pedal:Acc/Decelerate;
Visual: Encode far point object

2.C. Distract-R (15 mins)

1. Download Distract-R
    1. https://www.cs.drexel.edu/~dds26/cog/distract-r/download.php
2. Modify a UI in the car to make distractions better/worse
3. Show the UI and the results before/after

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Pairwork topics

Compare two designs (baseline & better) using MRT

Topics and models

Topics

1. Takeover requests in L2/L3 driving
2. Authentication with a PIN while driving
3. Accessible pop-up notifications for cars
4. Media selector for drivers
5. Route instructions while driving
6. Your own task*

* Risk of failing to pick a good case

Models

- MRT (Wickens' cube)
- Distractability score

Optionally

- Distract-R

Task A Resources

Task B Resources		Perceptual				Cognitive		Response	
		VS	VV	AS	AV	CS	CV	RS	RV
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	AV			0	.8	0.5	0.7	0.2	0.4
	CS			0		.8	0.6	0.6	0.4
	CV						0.8	0.4	0.6
	RS							0.8	0.6
	RV							0.6	1.0

Presentation

Content

1. Problem introduction
2. Baseline design
3. Better design
4. MRT-based comparison
5. Conclusion

Note: You can compare existing designs OR create your own design

Guidelines

- Annotate your visuals
- No “walls of text”
- Show evidence
- Explicate your assumptions!
- Argue for your design decisions
- Discuss limitations

Tips

Lessons from yesterday

- Scope your work in advance
- You can take ideas from existing designs
- Only focus on those aspects of design your model can affect, don’t overdo it
- Use the Wickens cube to think through different modalities