CS 380: Artificial Intelligence

Lecture 18: Cognitive Models II

Overview

- Last time, we looked at *cognitive models* — simulation models of human thought and behavior
- Most of the work on these models has focused on smaller, experimental domains
- But how are cognitive models useful in the real world?
- Let's look at two examples…
  - Intelligent tutoring
  - Driving

Observation

- The "Two-Sigma" Effect

Students who receive one-on-one instruction perform two standard deviations better than students who receive traditional classroom instruction.

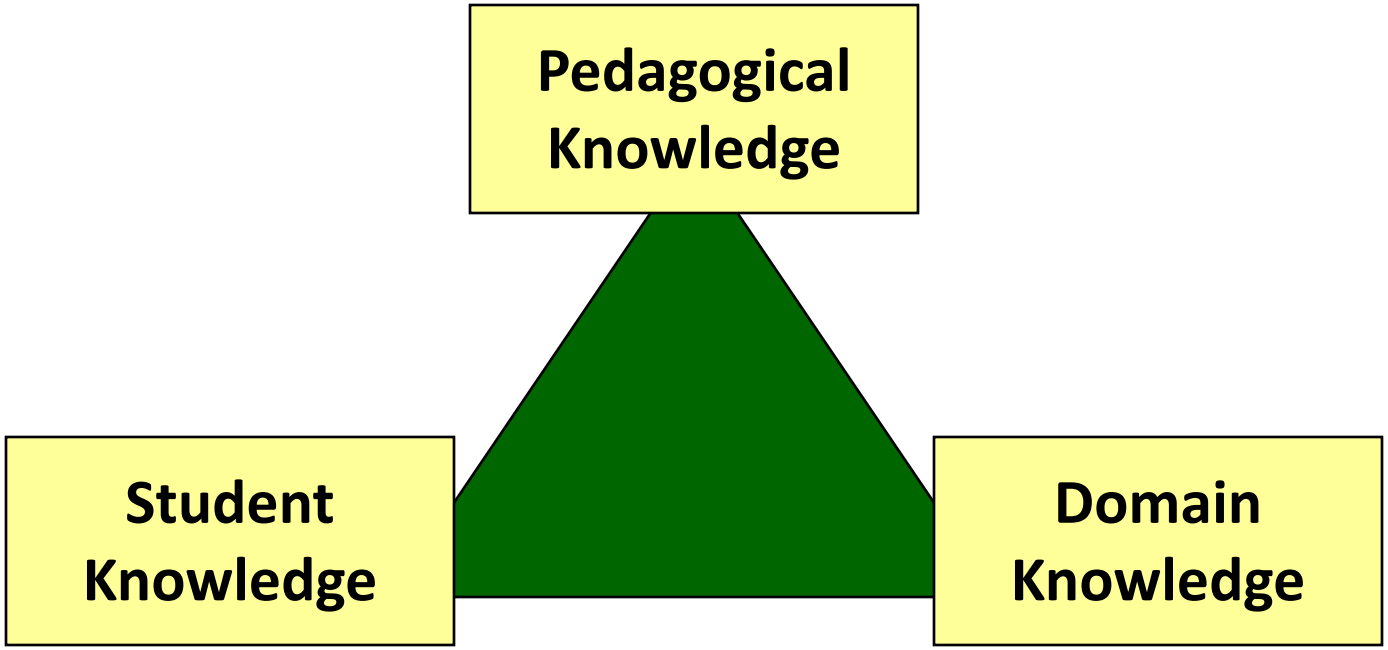
  - i.e., the average tutored student does as well as the top 2 percent of classroom-taught students

Intelligent Tutoring Systems

- Computer tutors that recognize and respond to student behavior and their inferred knowledge
- Advantages
  - a teacher for every student? not feasible.
    a computer tutor for every student? sure!
  - facilitates "human-like", personalized instruction
  - enables practice, practice, practice on possibly large (or infinite) database of problems
  - but also can answer questions, provide guidance

ITS components

- What makes up an ITS?



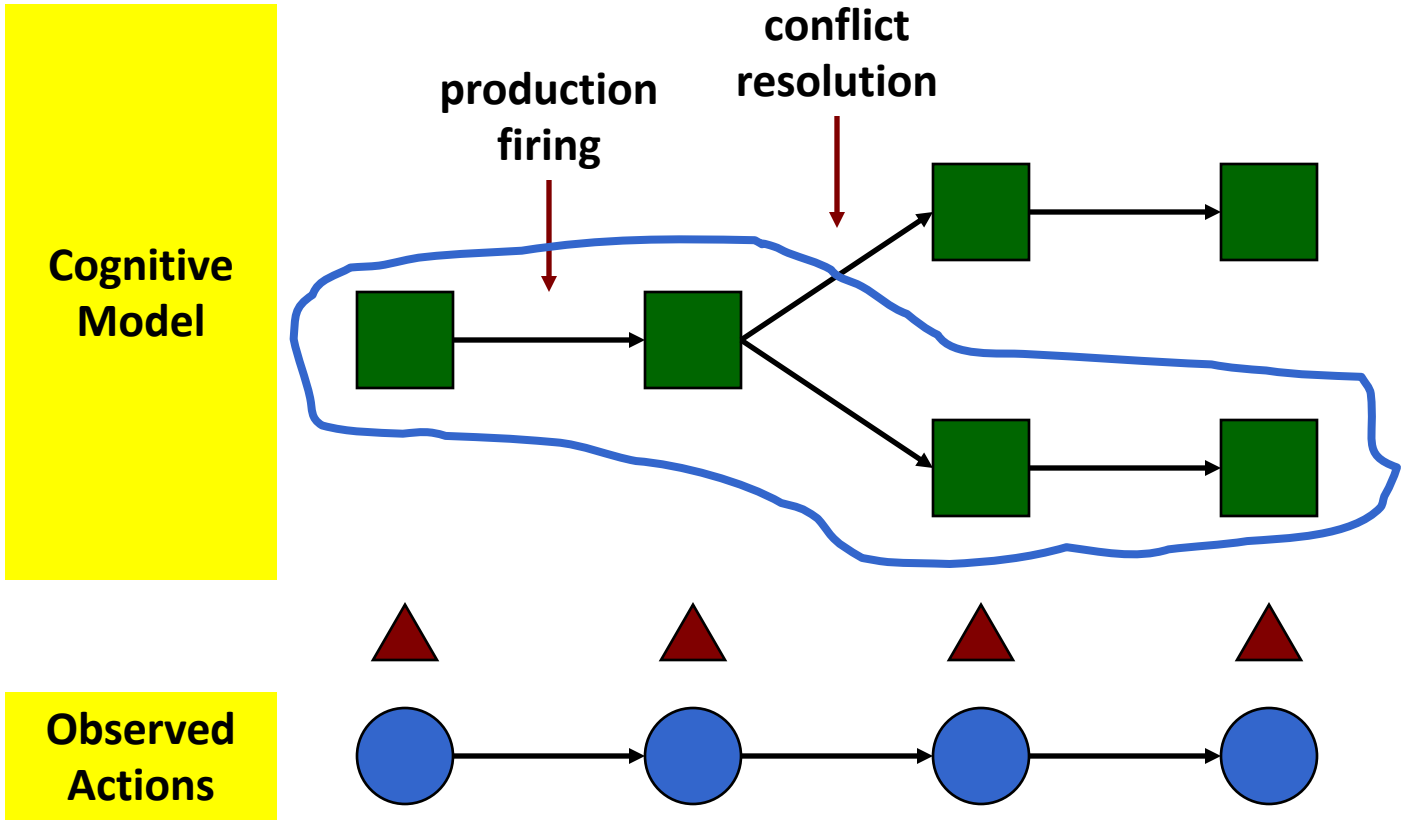
Model Tracing

- Model tracing = relating observed actions with hidden cognitive states
- In essence, "think" along with the student and keep track of cognitive state
- From a given point in time...
  - simulate all possible "thought" sequences (i.e., all possible firings for productions)
  - determine which sequence best matches the actions observed from the student
  - make the best matching sequence the current "estimated" cognitive state

Model Tracing

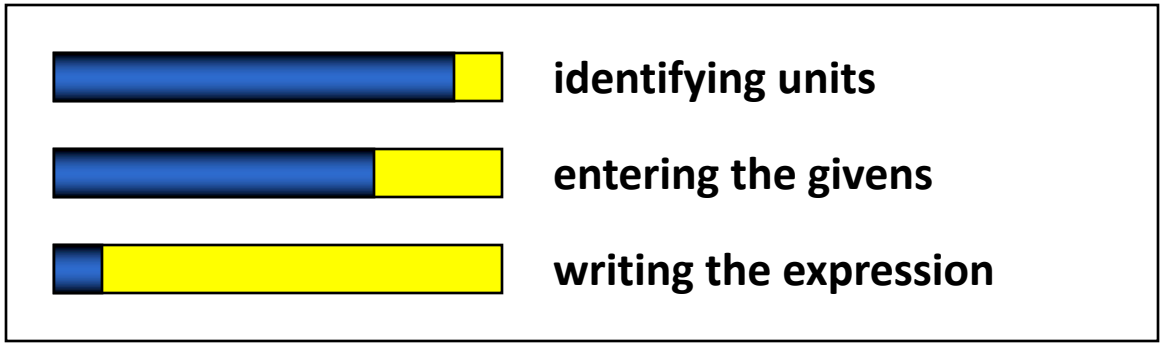
- Main components of the approach...
  - Student model: a production system that represents the necessary skills
  - On-path actions: recognize correct actions by the student based on the student model
  - Off-path actions: if student performs an off-path action, steer back to solution path
  - Error feedback: provide student with bug and help messages to steer toward a solution
- Each component embodies certain assumptions & is non-trivial to build

Model Tracing



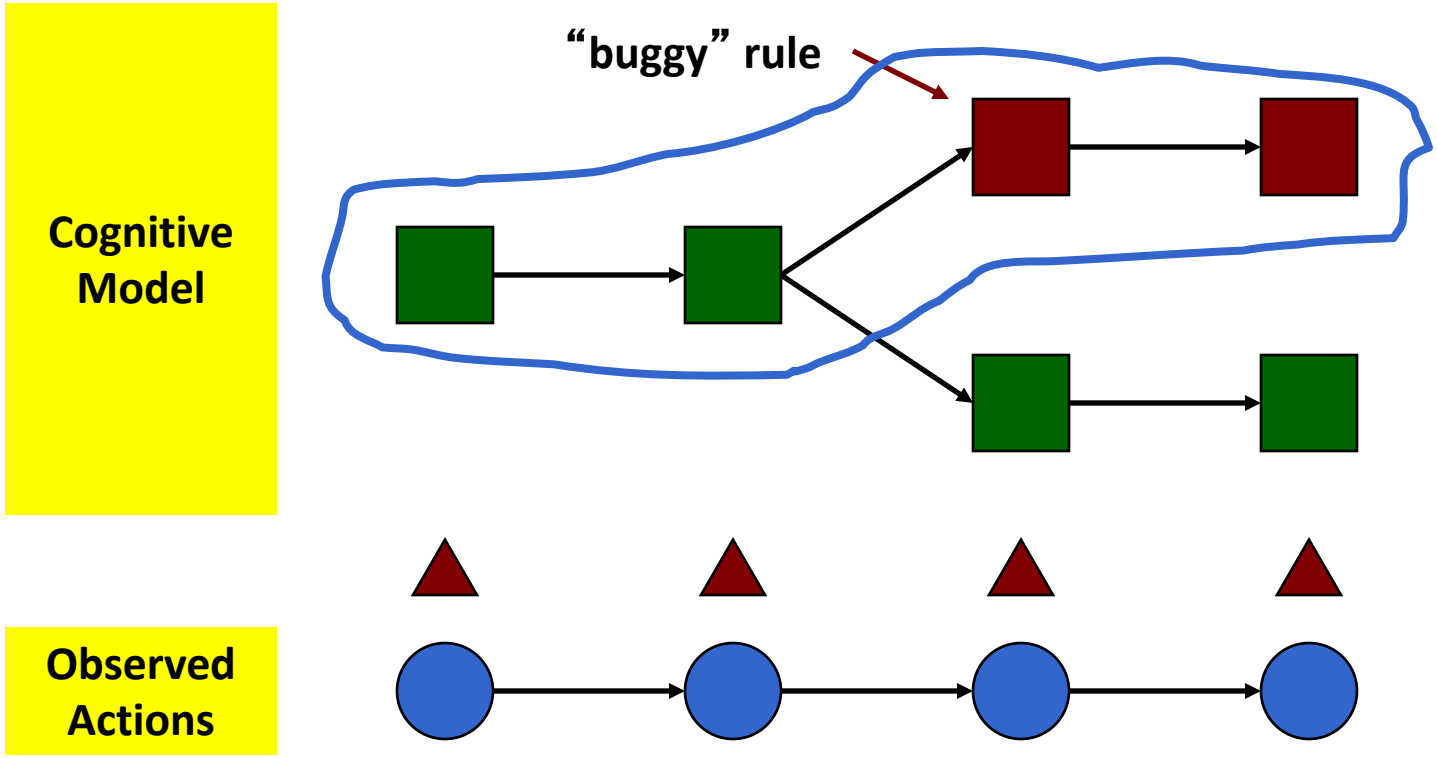
Knowledge Tracing

- Sounds similar, but very different than model tracing
- Knowledge tracing = maintaining estimates on how well students know certain skills
  - the "skill-o-meter"
  - example: algebra word problems



Handling errors

- Include “buggy” rules in our model
- Include help to go with these rules if fired



Field tests: LISP tutor

- Step-by-step tutor with "structured editor"
  - top-down approach to coding

```
(defun create-list (num)
  <<BODY>>)
```

```
(defun create-list (num)
  (let (<<INITIALIZATIONS>>)
    <<BODY>>))
```

```
(defun create-list (num)
  (let ((count 1))
    <<BODY>>))
```

```
... etc.
```

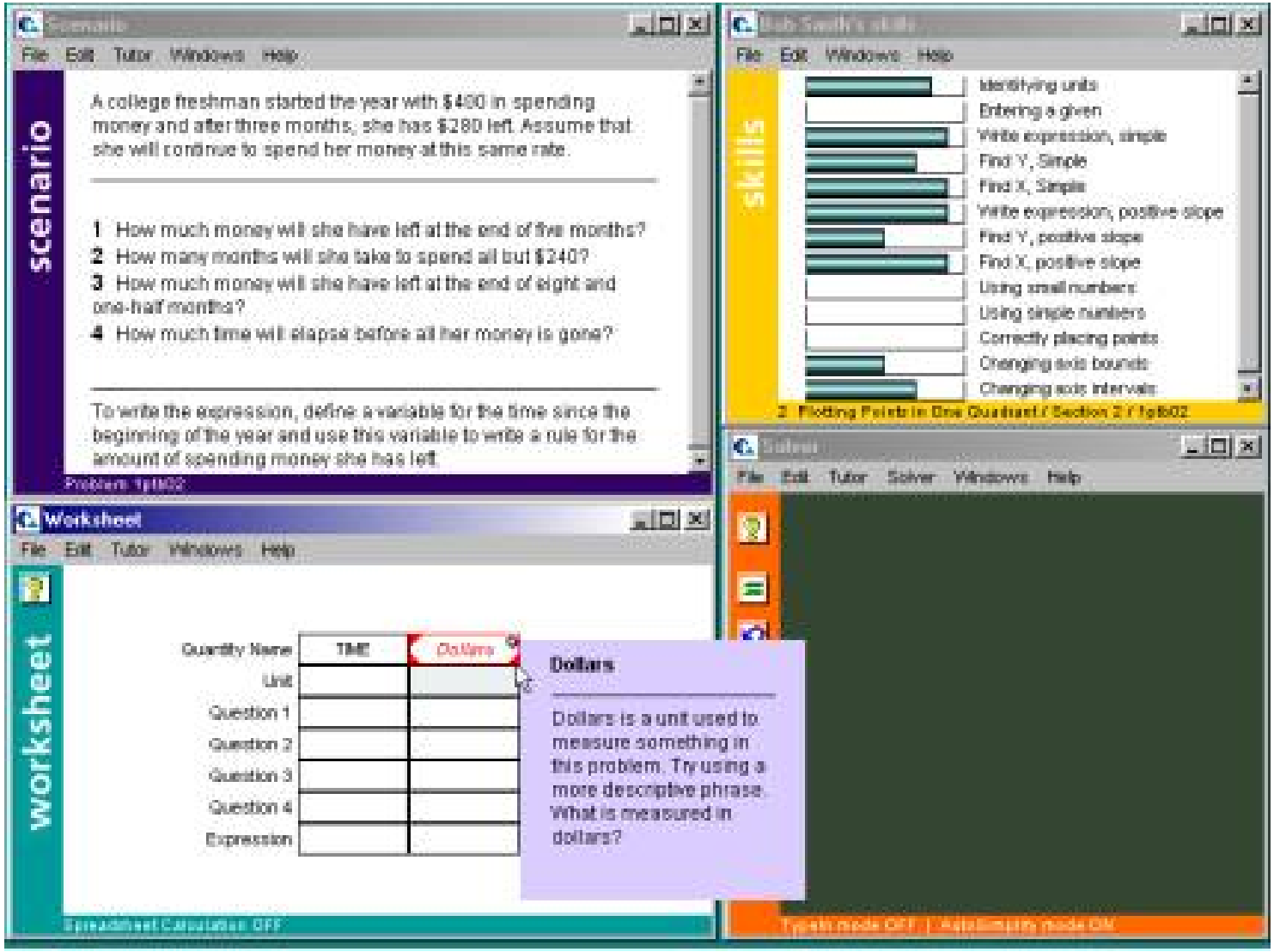
Field tests: LISP tutor

- Results
  - mini-course at CMU with LISP tutor
  - two groups in course, with & without tutor
  - group with tutor took 30% less time to complete a sequence of prescribed lessons
  - AND group with tutor scored 43% = 1 std dev higher on the post-test!
    - learned faster, *and* the knowledge stayed with them!

More tutors in the field

- Algebra tutor (PUMP)
  - 1.2 sigma for Representations test, lower for other tests/domains
  - (truancy was also a problem)
- Geometry tutor
  - 14 extra points (out of 100) for tutored students
  - actually, only 1-on-1 tutoring; 2-on-1, only 4 pts
- Carnegie Learning
  - company spun-off from this and other research
  - tutors in several (mostly mathematical) areas with integrated curriculum (textbooks, etc.)
  - now serving 845 school districts = 340,000 students nationwide!

Algebra word problem tutor



Driving & Driver Distraction

- Driver distraction is one of today's hot topics
- There are many layers to this discussion...
  - a scientific understanding of driving & distraction
    - theoretical developments -- our primary focus
    - experiments that quantify distraction -- our secondary focus
  - legislative efforts
    - e.g., bans on handheld cell phones?
  - public-relations efforts
    - how can we get people to stop being distracted?

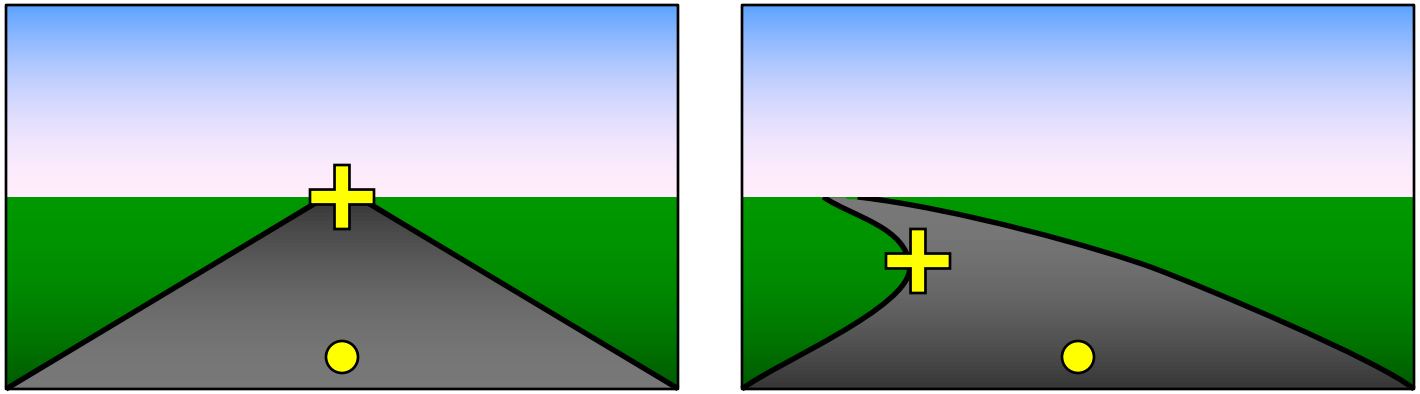
Driving & Driver Distraction

- How can cognitive models help?
  - contribute to the scientific knowledge base
    - generally: multitasking behavior
    - specifically: driver behavior under distraction
    - more specifically: particular devices
  - serve as core simulation engines for computational design tools
    - e.g., rapid prototyping & evaluation for new devices
    - e.g., inferring and tracking driver intentions

Driving as a Single Task

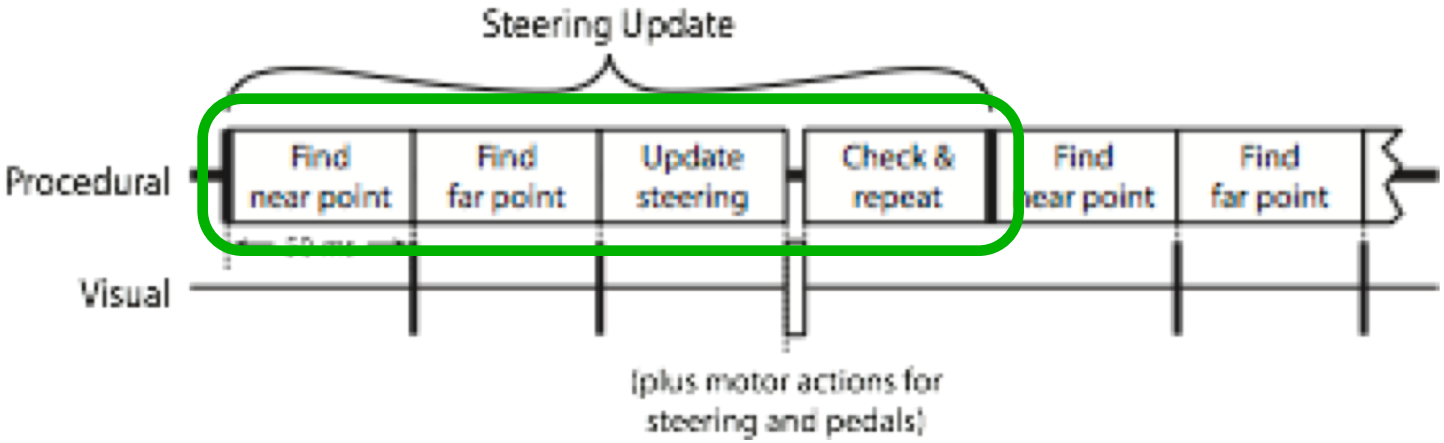
- Two-level steering with near & far points

$$\dot{\varphi}_{steer} = k_f \dot{\theta}_{far} + k_n \dot{\theta}_{near} + k_I \theta_{near}$$



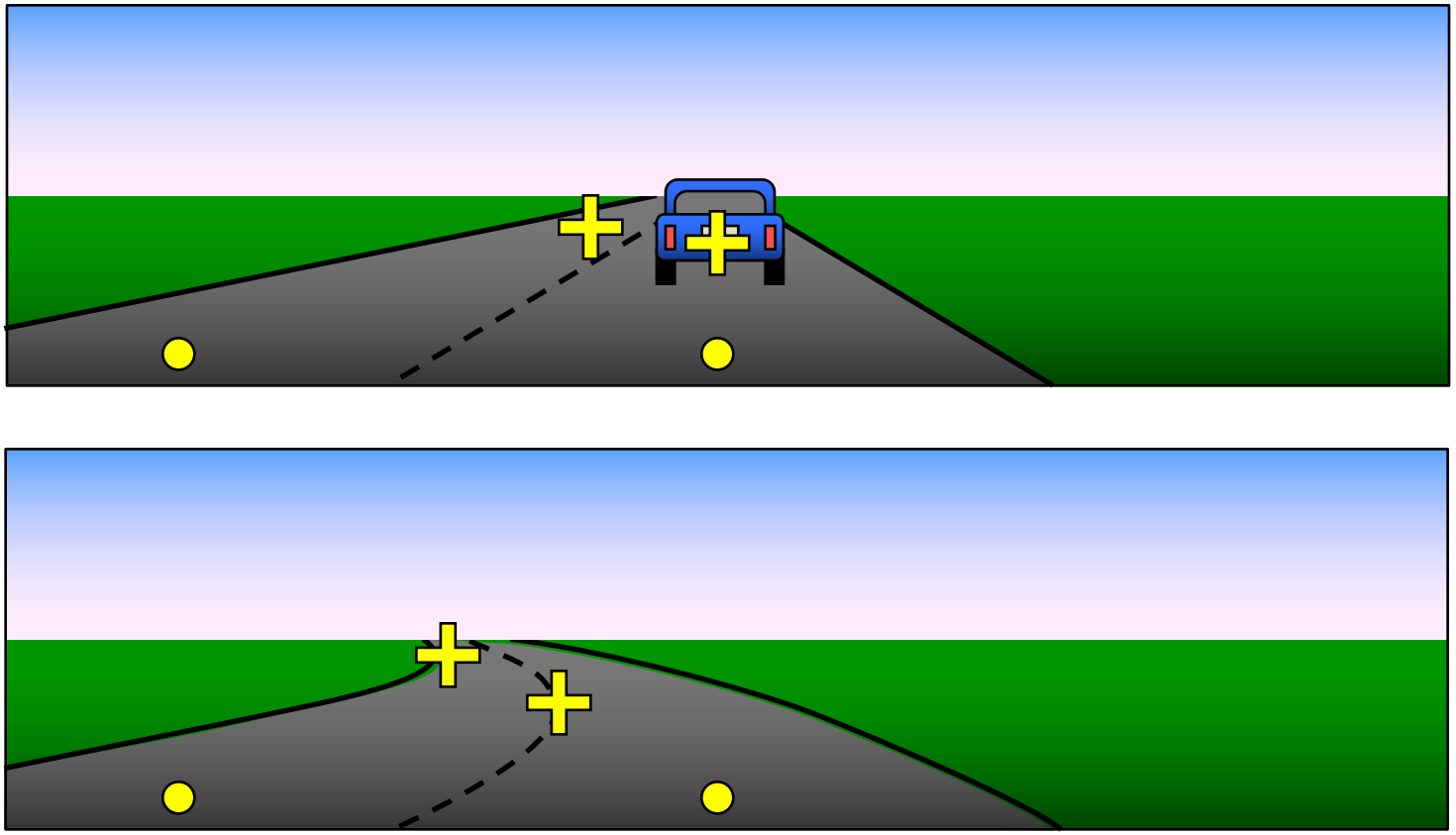
Driving as a Single Task

- Cognitive model of driving as 4 x 50-ms steps…

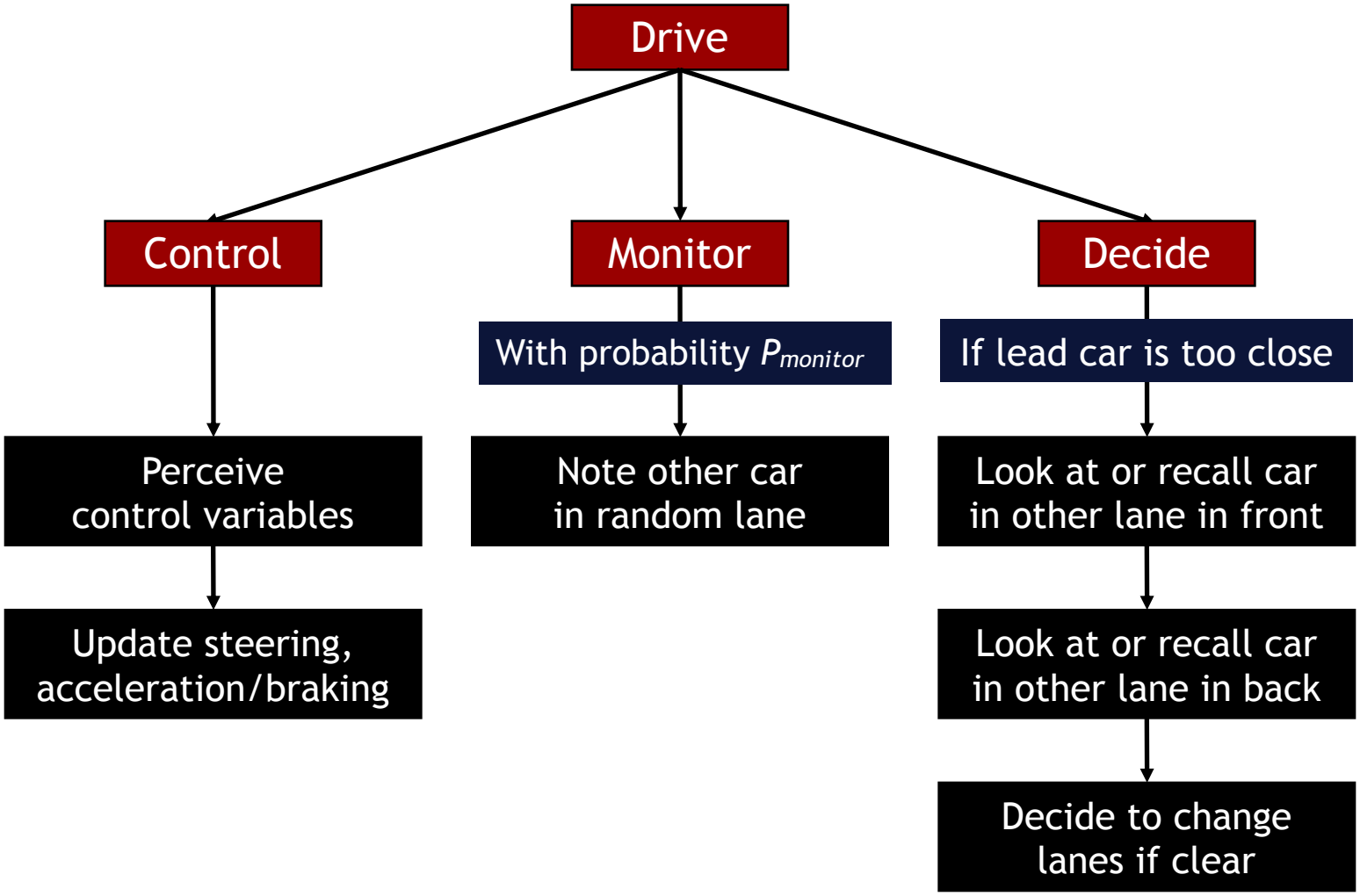


Driving as a Single Task

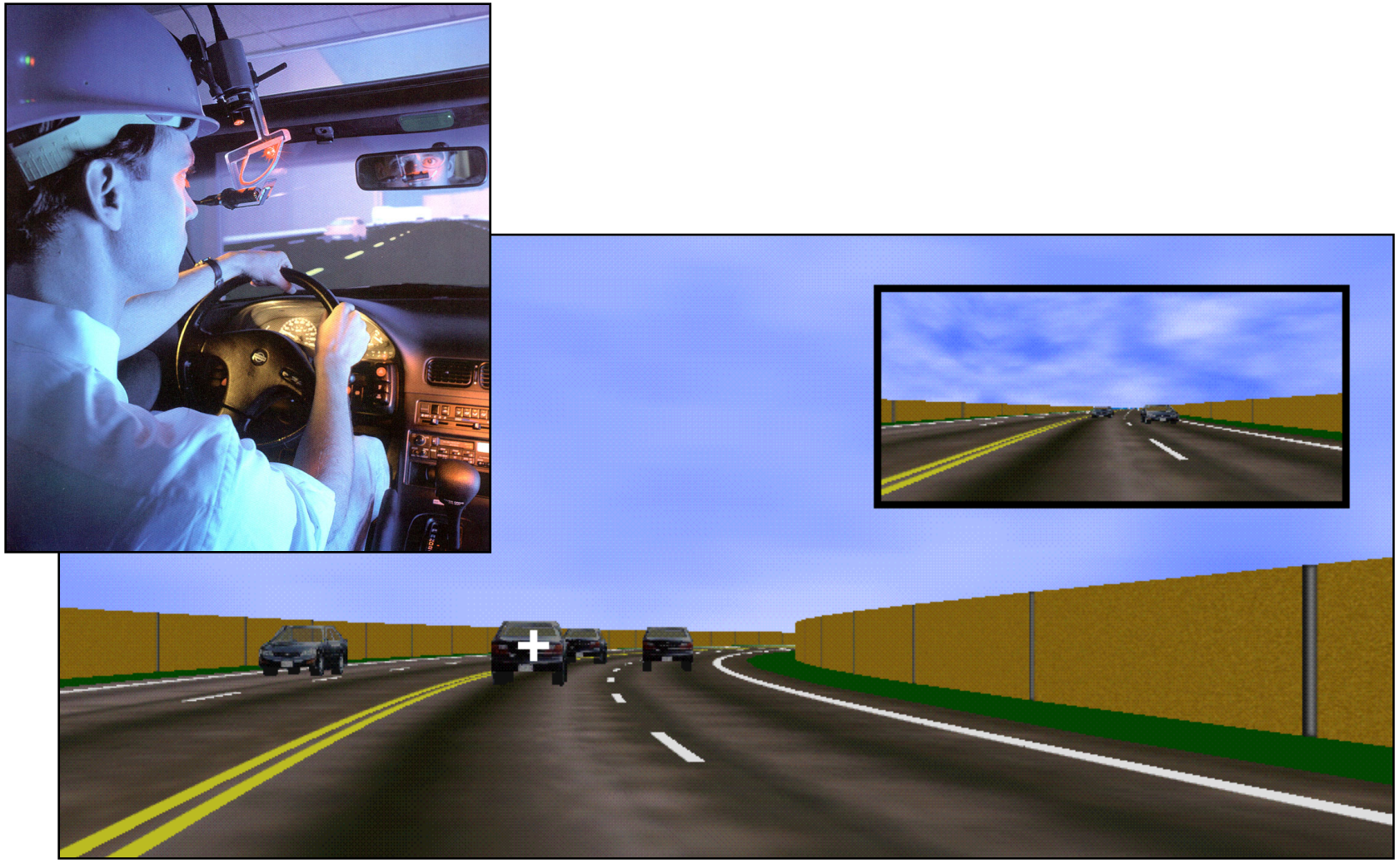
- Lane change: Switch, start → end lane



Driving as a Single Task

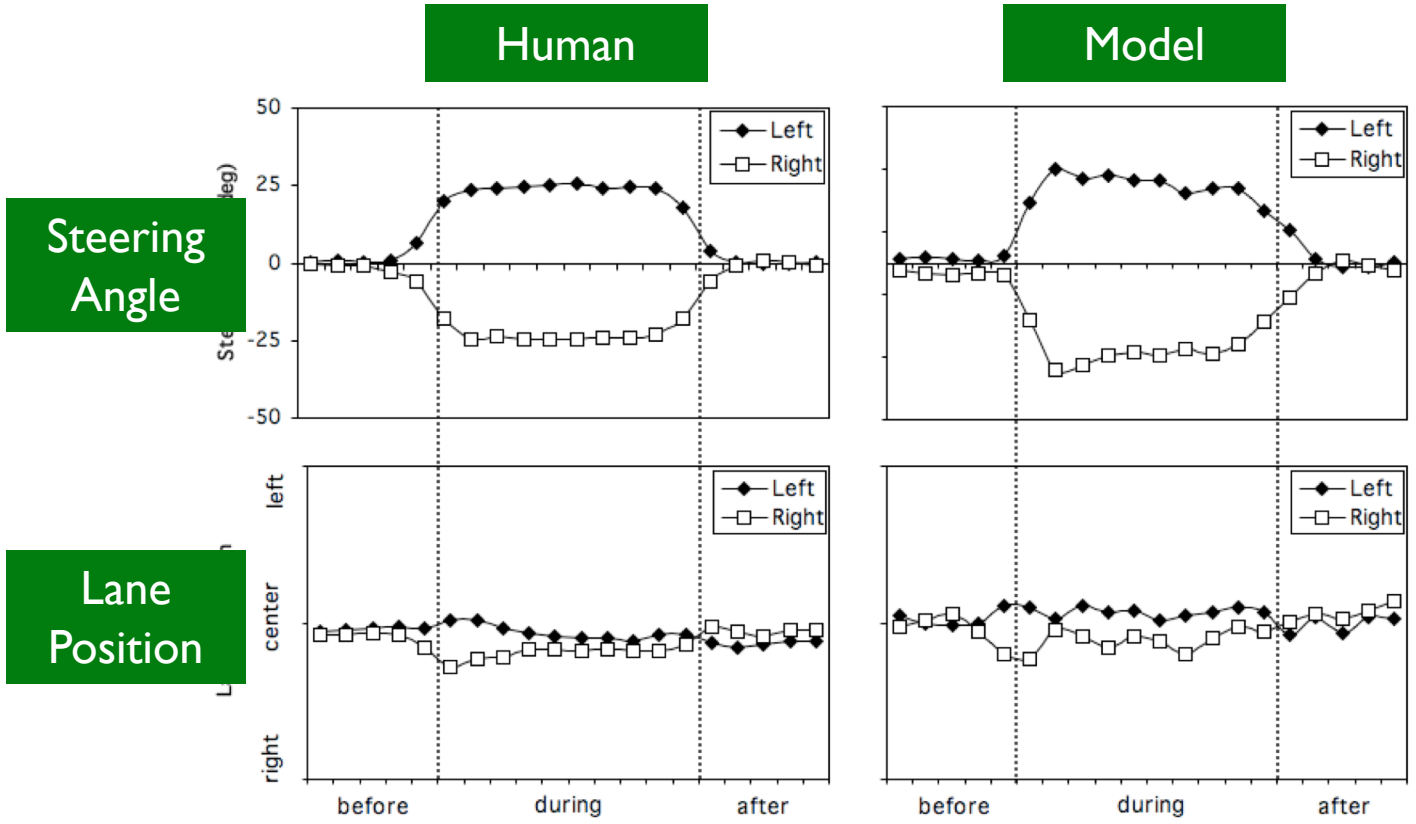


Driving as a Single Task



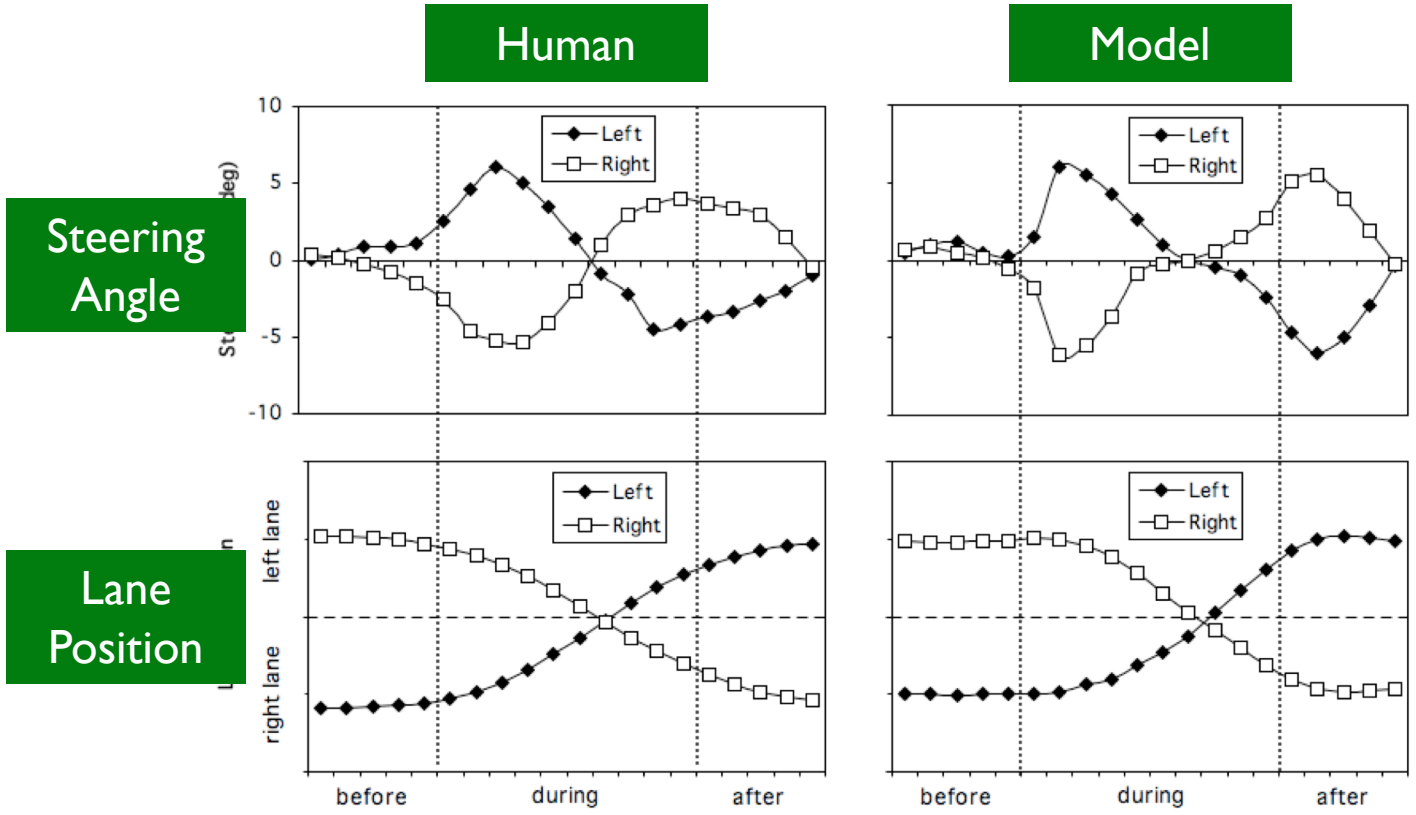
Driving as a Single Task

- Curve negotiation



Driving as a Single Task

- Lane changing

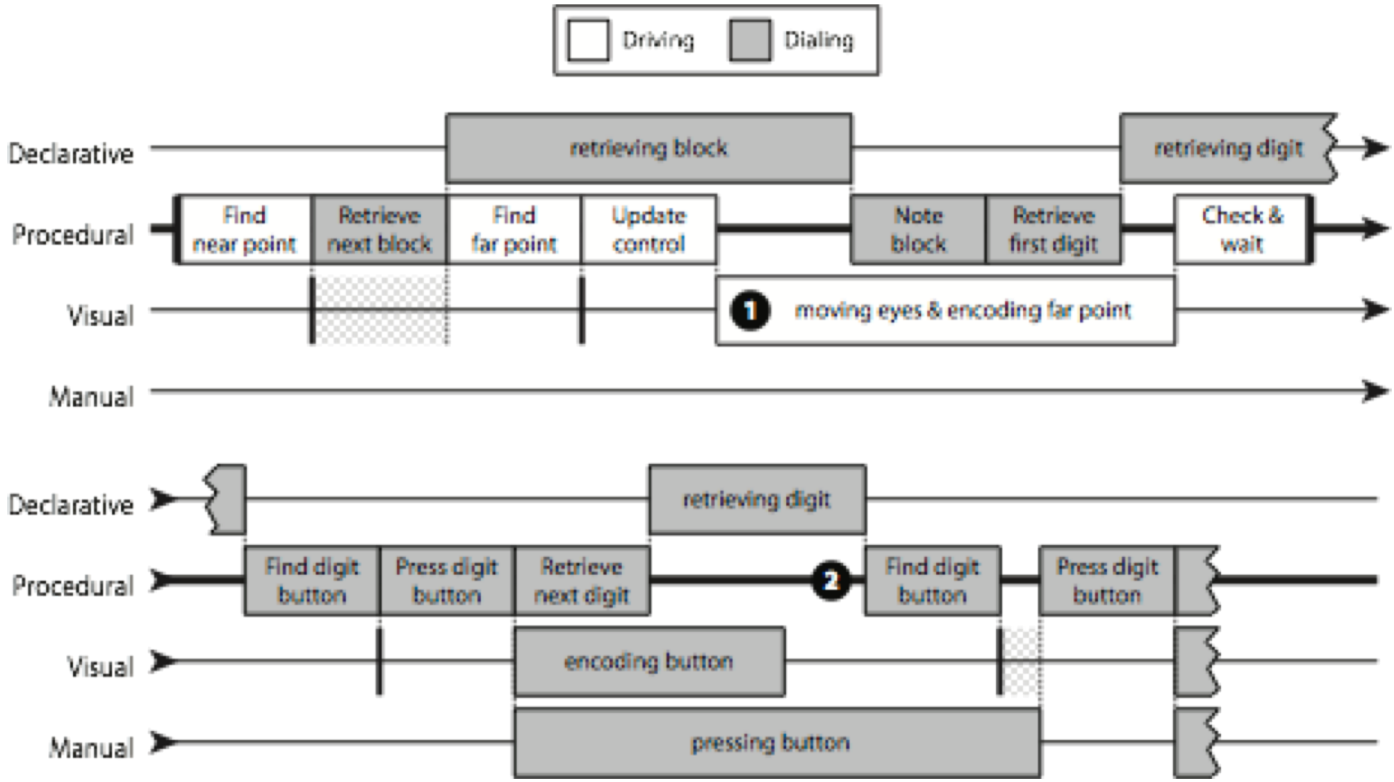


Driving & Dialing

- Cell-phone use can affect…
  - lane keeping: ability to maintain central position
  - speed control: ability to maintain safe distance
  - general attention: ability to see/react to hazards
- Driving & dialing a phone
  - four dialing conditions
    - full-manual: ON + 7 digits as xxx-xxxx + SEND
    - speed-manual: ON + speed number + SEND
    - full-voice: ON + say 7 digits + repeat + END
    - speed-voice: ON + say phrase + repeat + END
  - interference of manual vs. voice dialing?

Driving & Dialing

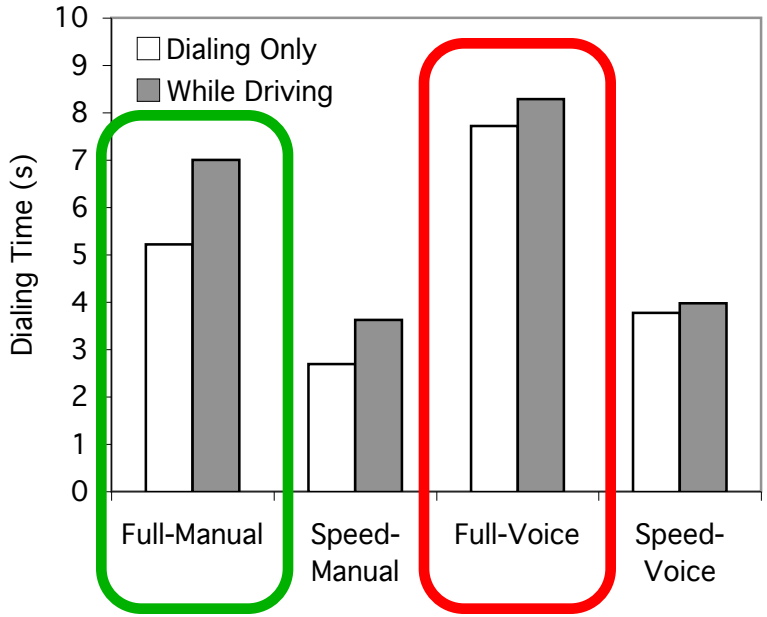
- Model (full-manual dialing)



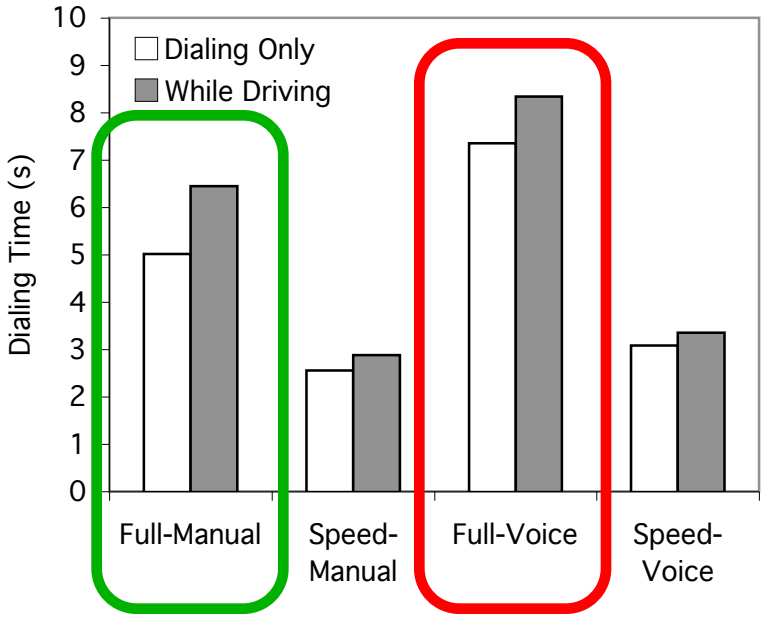
Driving & Dialing

- Time to dial a phone number

Human



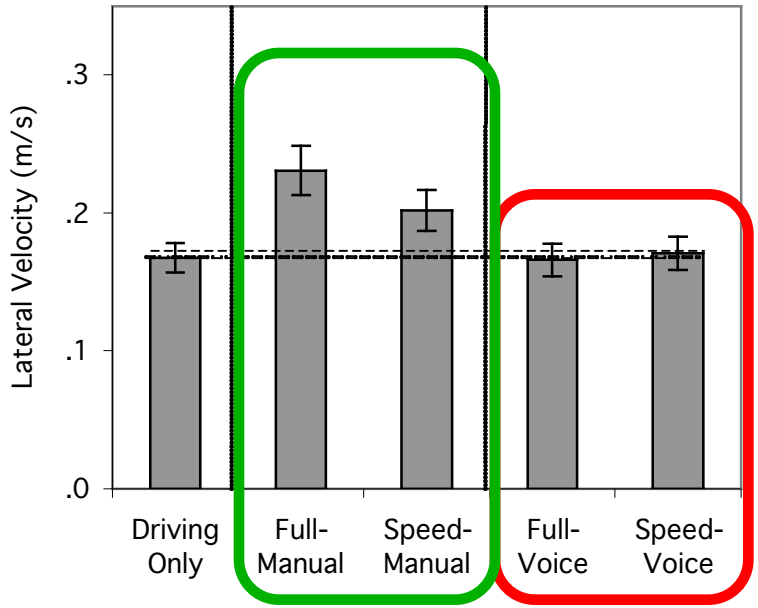
Model



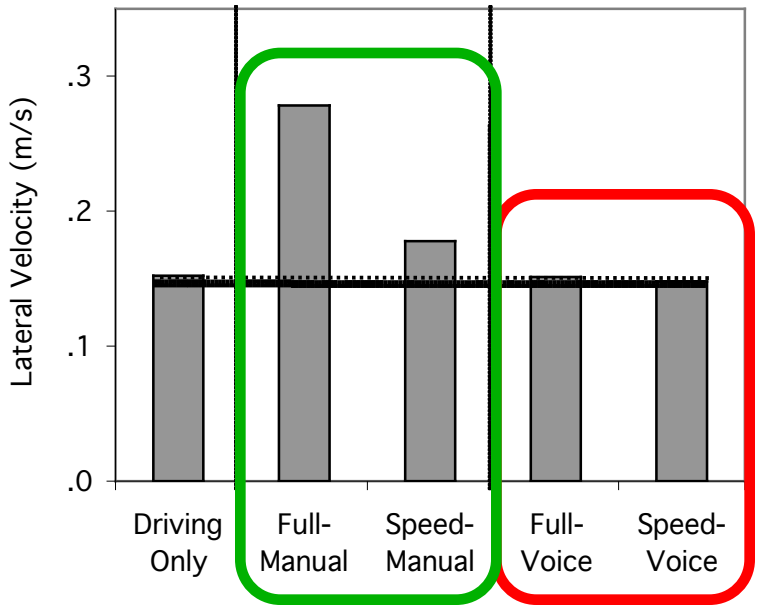
Driving & Dialing

- Lateral velocity (vehicle stability)

Human

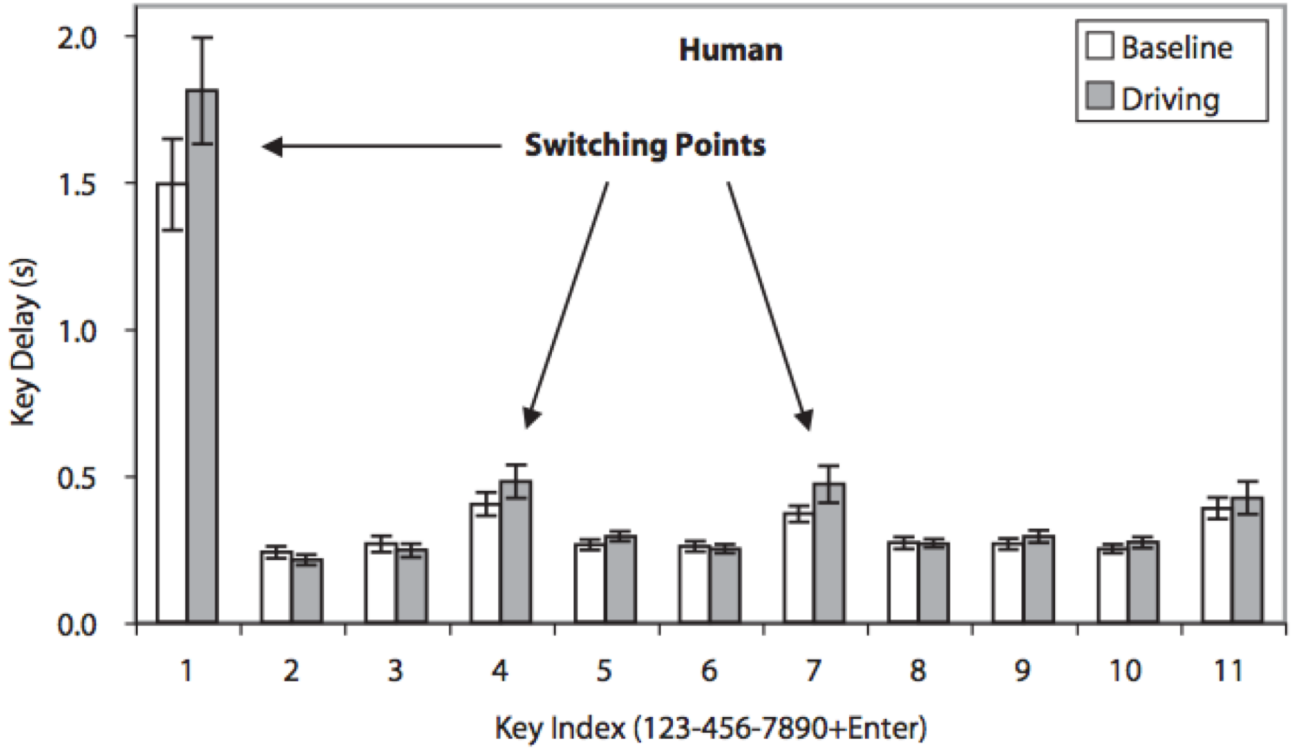


Model



Driving & Dialing

- When exactly do drivers switch tasks?
  - more data from a study of 10-digit dialing...



Driving & Dialing

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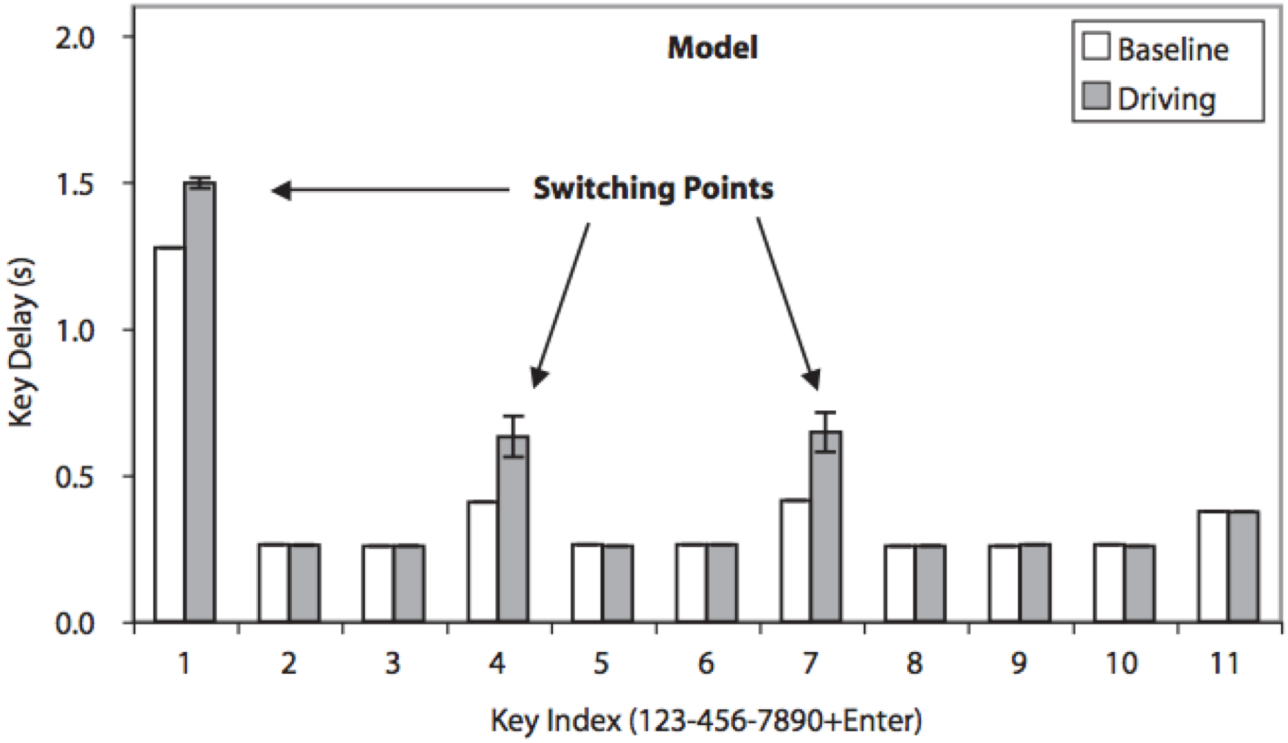
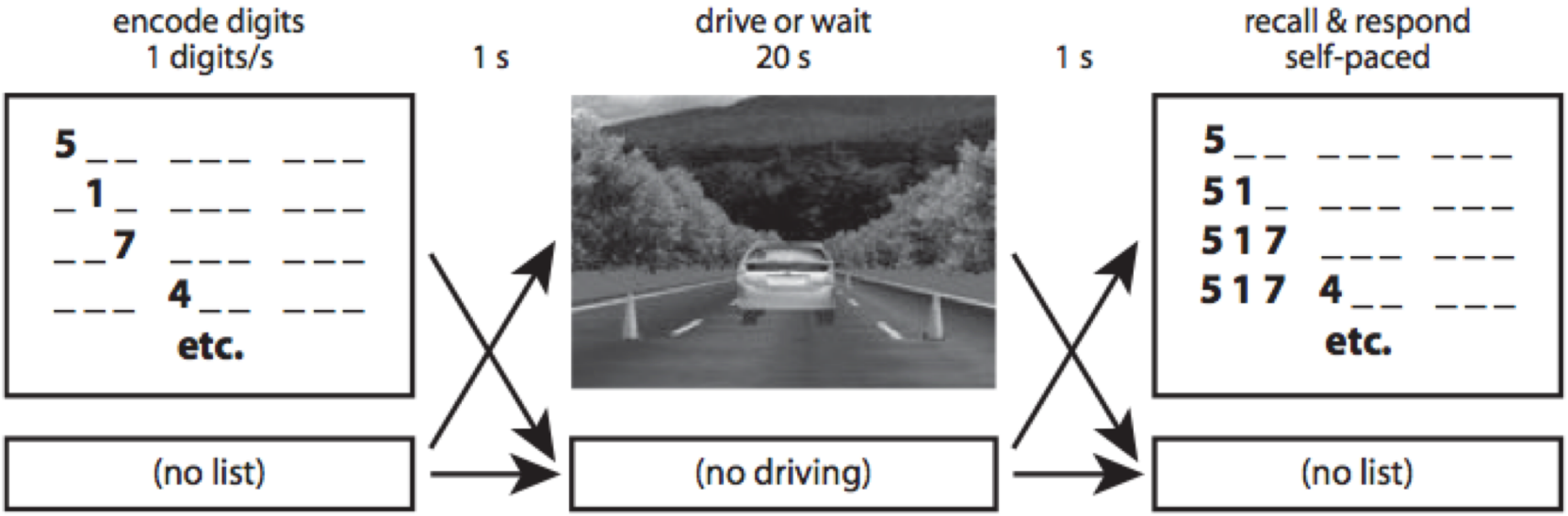


Driving & Memory Rehearsal

- Eliminating visual and/or motor demands does not eliminate effects on driving!
  - e.g., conversation can affect performance
  - but such tasks still use aural/vocal resources
- What about a "purely" cognitive task?: Driving & memory rehearsal
  - memory task: encode, rehearse, recall 5/9 digits
  - driving task: drive for 20 sec
    - drive during the rehearsal phase only!
  - braking task: brake when lead car brakes

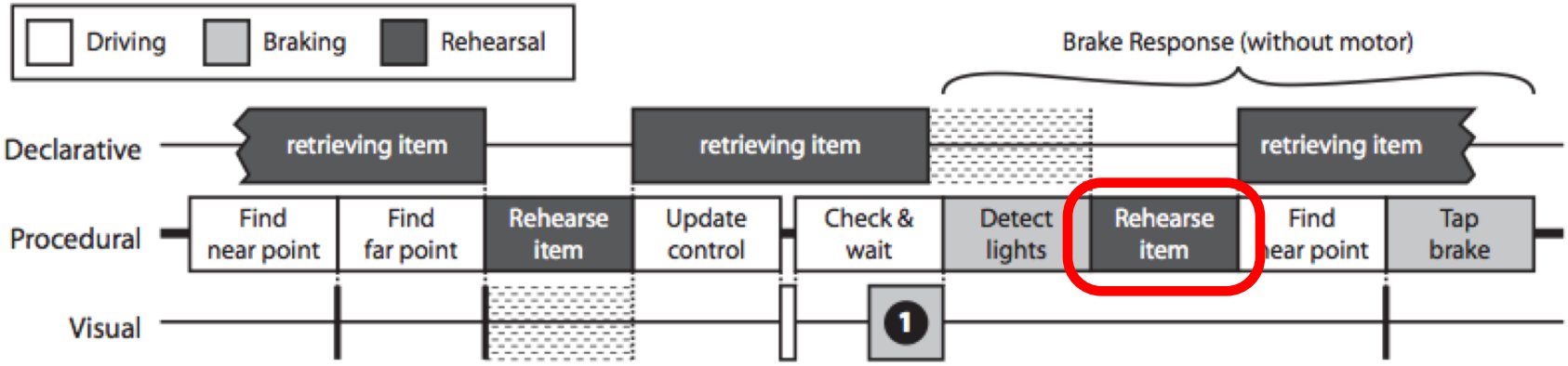
Driving & Memory Rehearsal

- Experiment structure



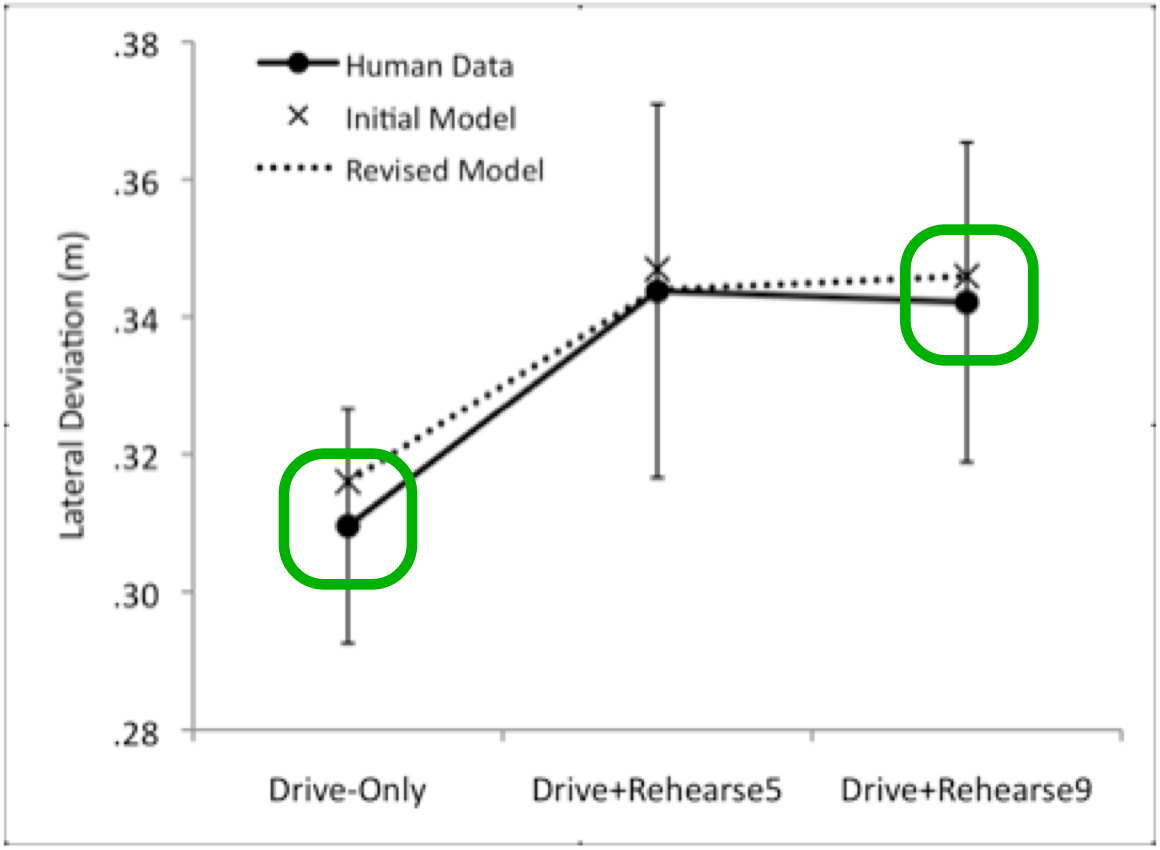
Driving & Memory Rehearsal

- Model



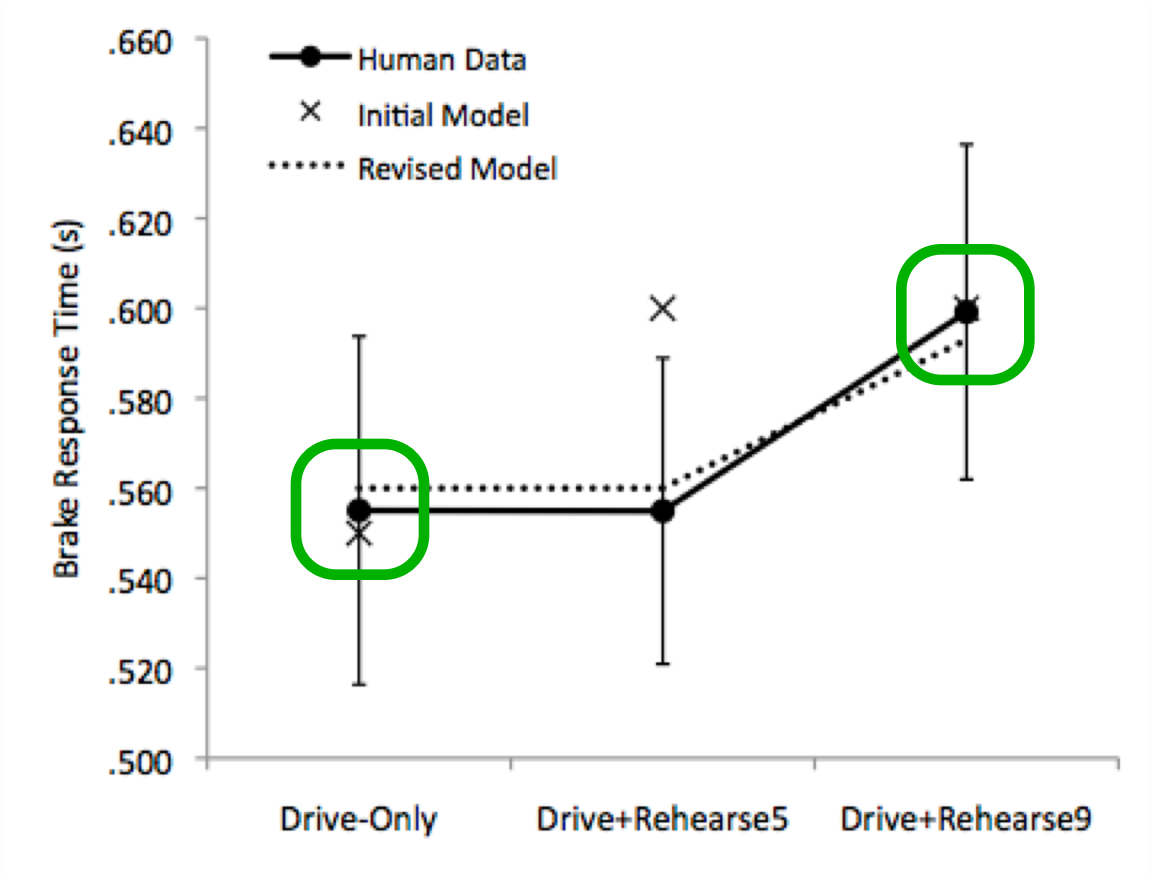
Driving & Memory Rehearsal

- Lane deviation (distance from center)



Driving & Memory Rehearsal

- Brake response time

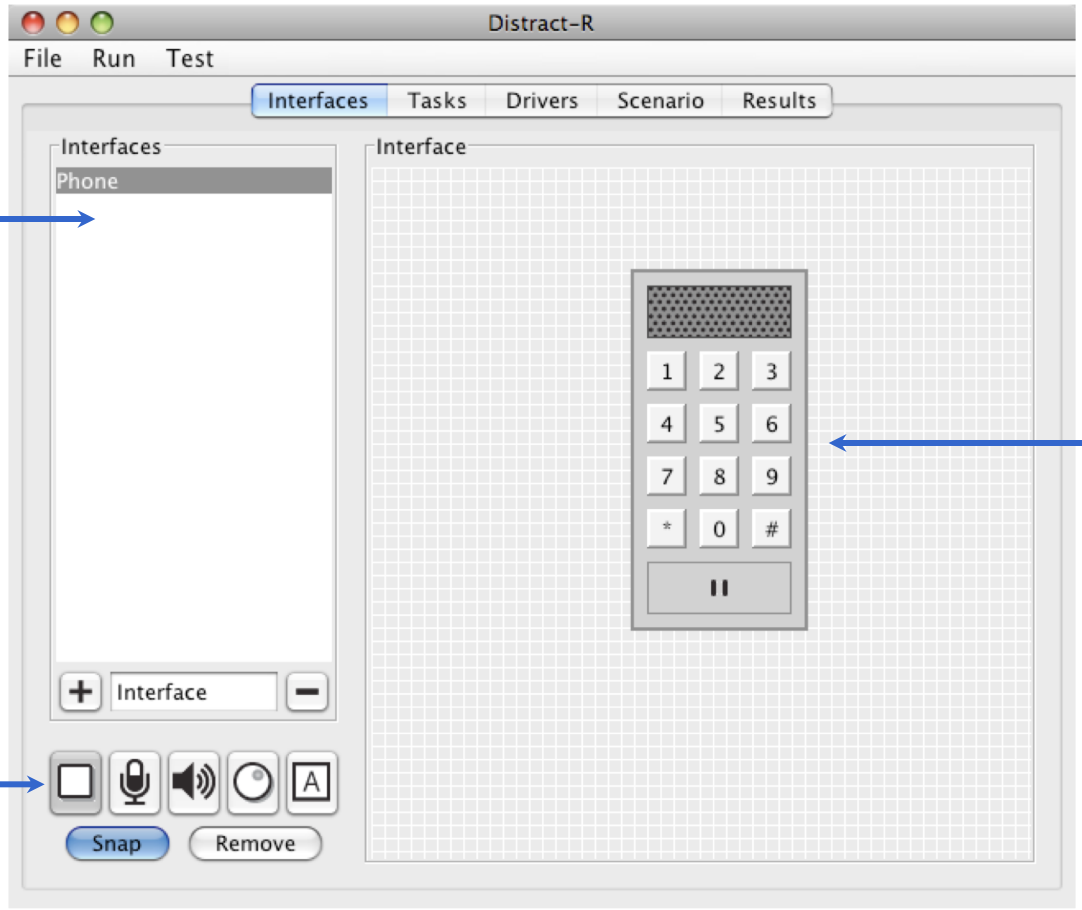


The Engineering Side of Distraction

- Engineering questions on our plate…
  - how can we design less distracting devices?
  - how can we evaluate devices w.r.t. distraction?
- One attempt: Distract-R
  - Idea to Evaluation in four steps…
    - (1) Prototype Interfaces
    - (2) Demonstrate Tasks
    - (3) Specify Drivers
    - (4) Analyze Results

Distract-R: Interfaces

- Create interface mock-up on simple grid



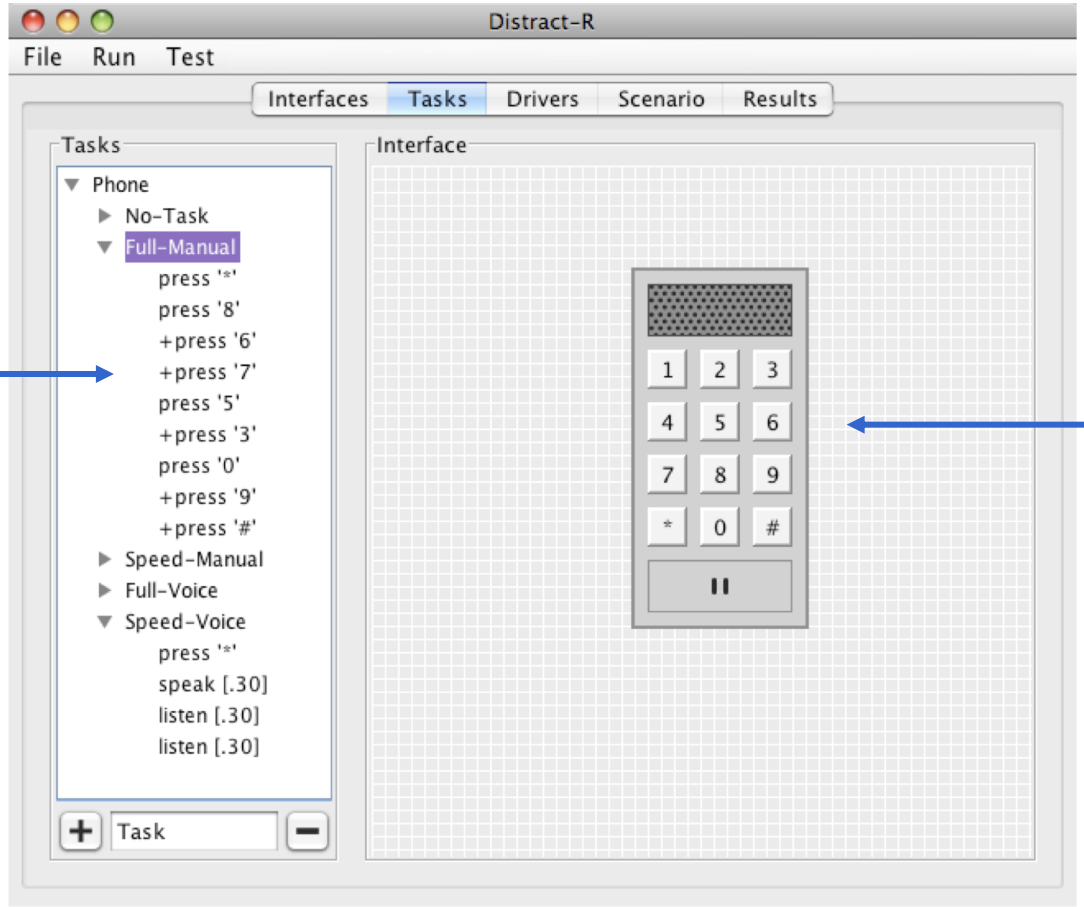
list of prototyped interfaces

button, microphone, speaker, dial, display

phone interface prototype

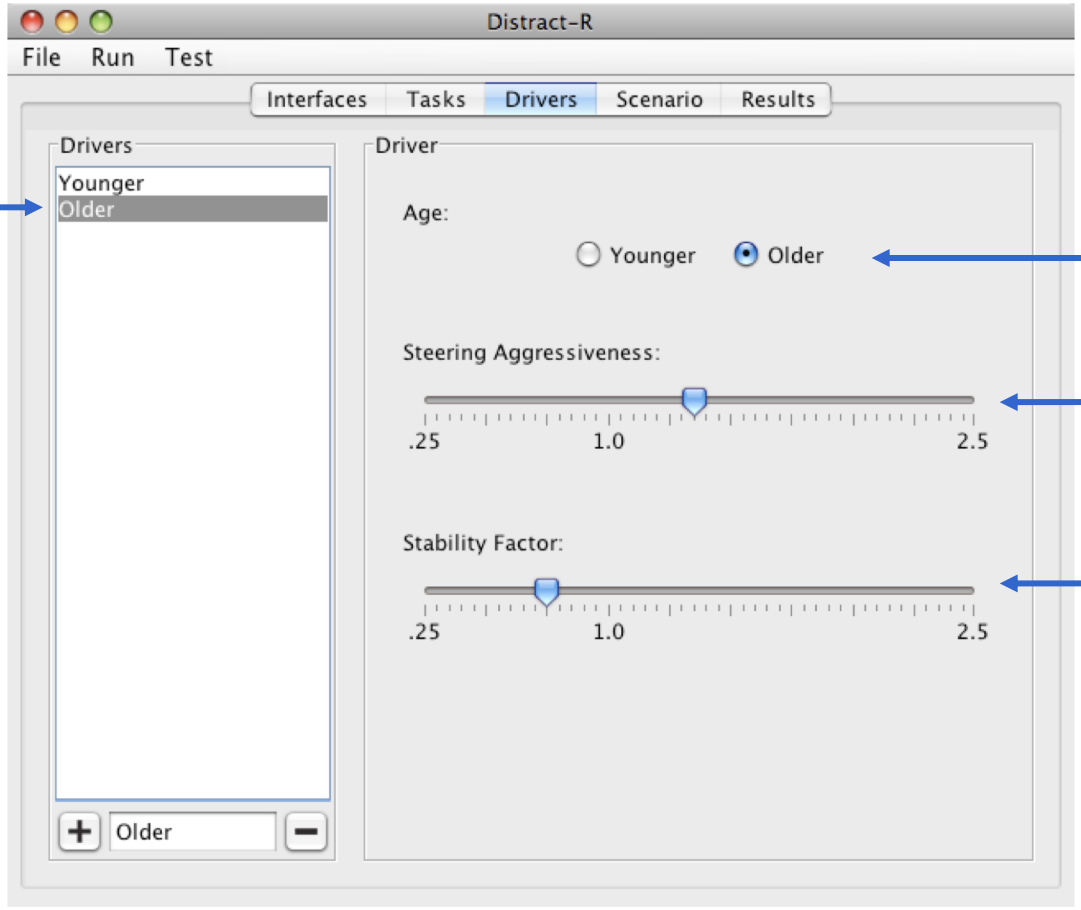
Distract-R: Tasks

- Specify tasks through demonstration



Distract-R: Drivers

- Select driver age, steering aggressiveness



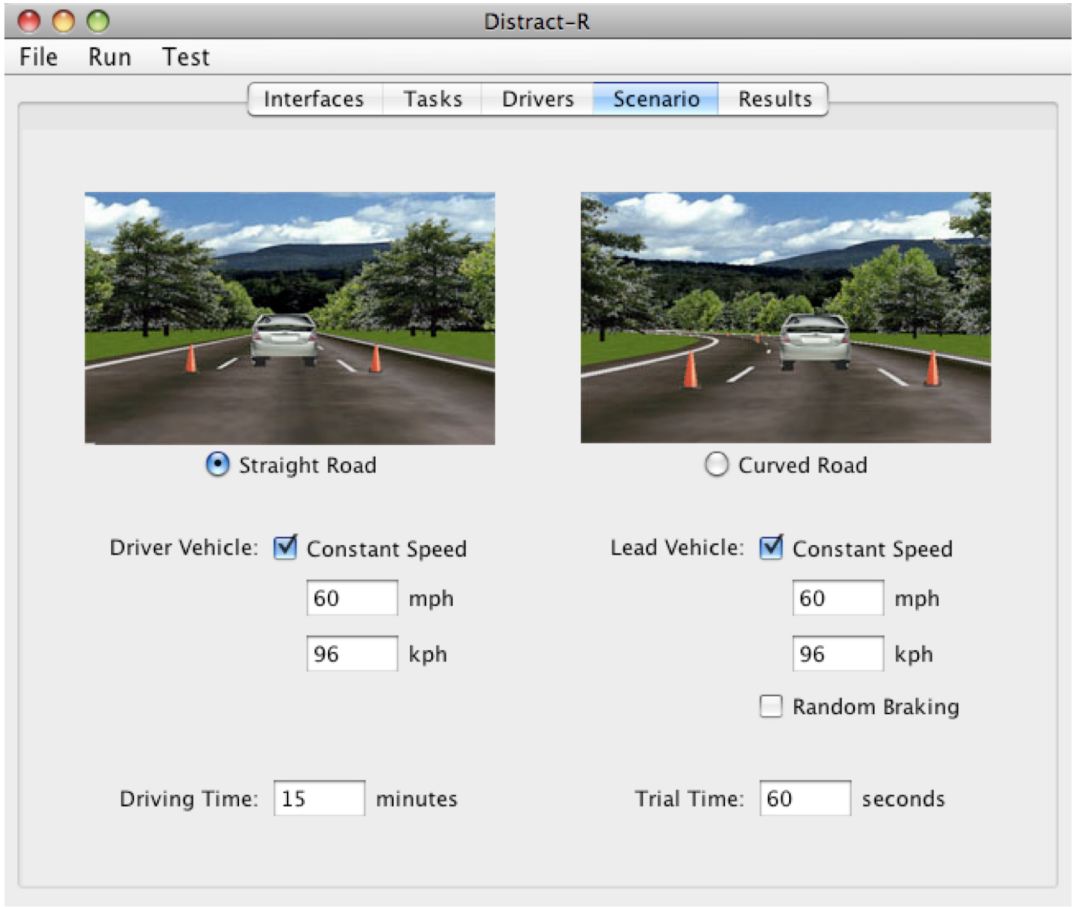
E.g., younger & older drivers

age

steering parameters

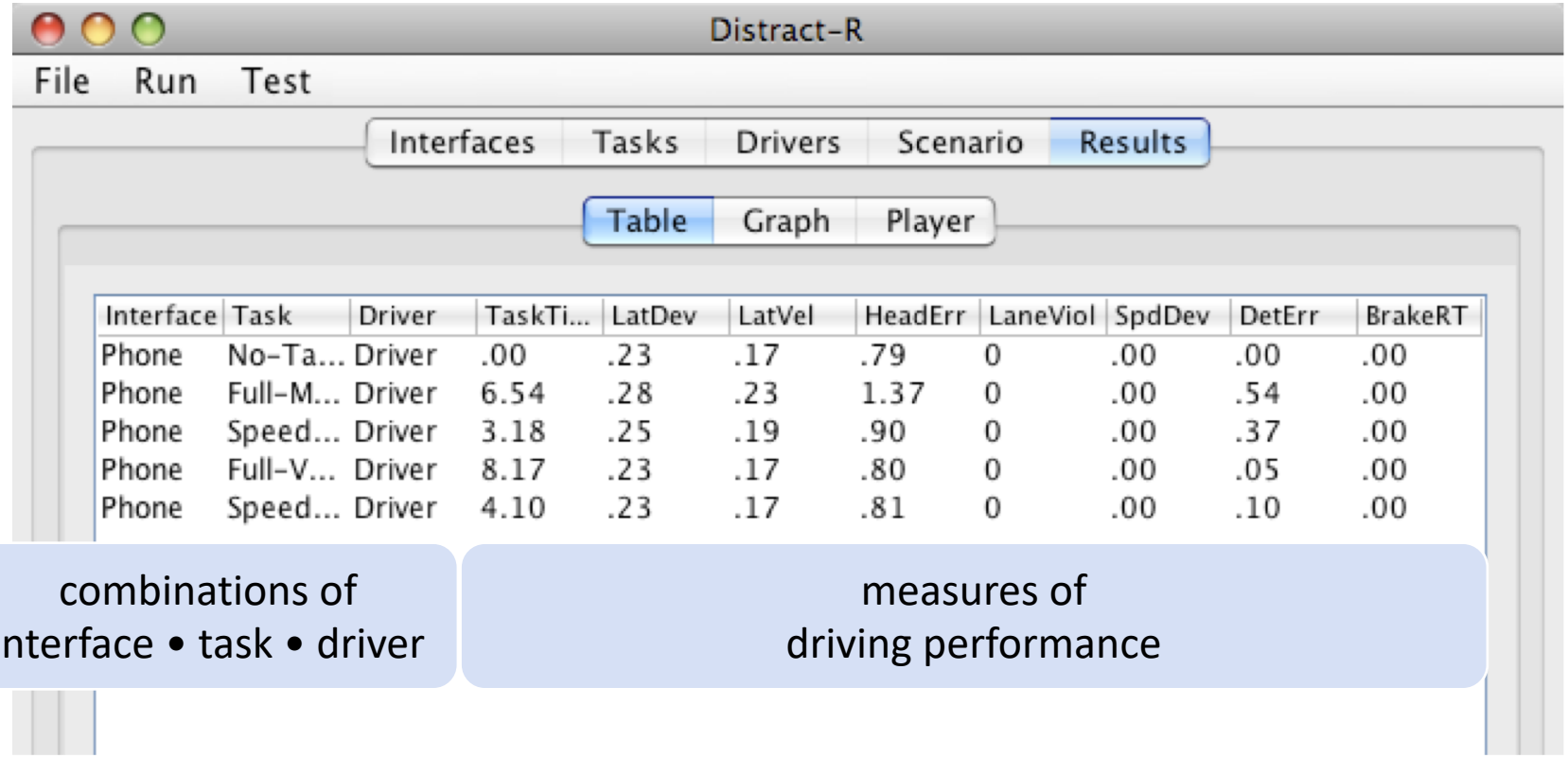
Distract-R: Scenario

- Select aspects of driving environment



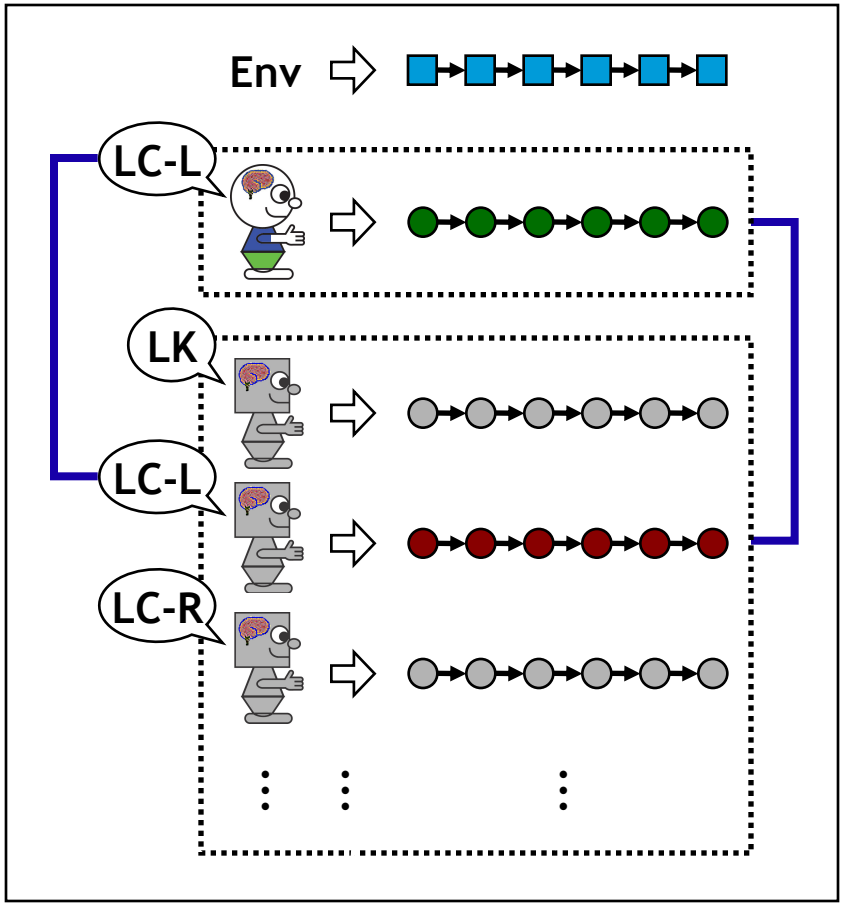
Distract-R: Results

- Run simulations, see results...



Related: Driver Intentions

- Instead of prediction, do the complement: recognize behavior
- Focus: Inference of **driver intentions**
  - Just like model tracing in intelligent tutors!



That's It!

- AI touches just about every area of Computer Science today
  - Not to mention many areas of science, engineering, even arts and humanities, …
- We've only skimmed the surface of AI in this course — there's a vast world of AI out there to explore!