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# (Re)introducing Cognitive Modeling to Robotics

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Drexel University

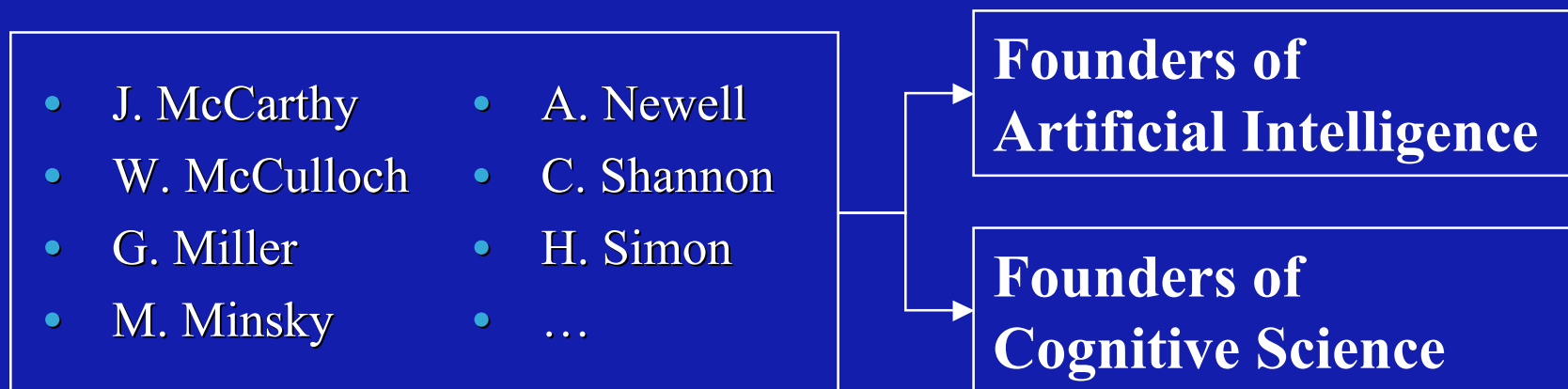
# The Goal

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“ An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves.”

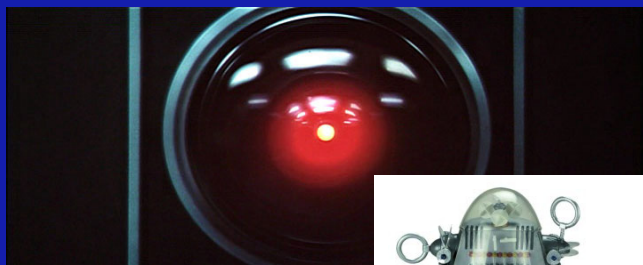
From McCarthy, Minsky, Rochester, Shannon (1955)

*A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence*



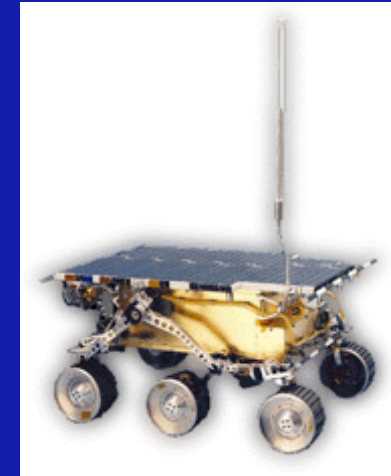
# The Dream

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# The Reality

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# Schism

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~~Internal  
Representations~~

**Representation-based ==> Behavior-based**

## Examples

- Subsumption Architecture (Brooks 1997)
- Universal Plans (ref)
- Situated Action (ref)

# Cognitive Science

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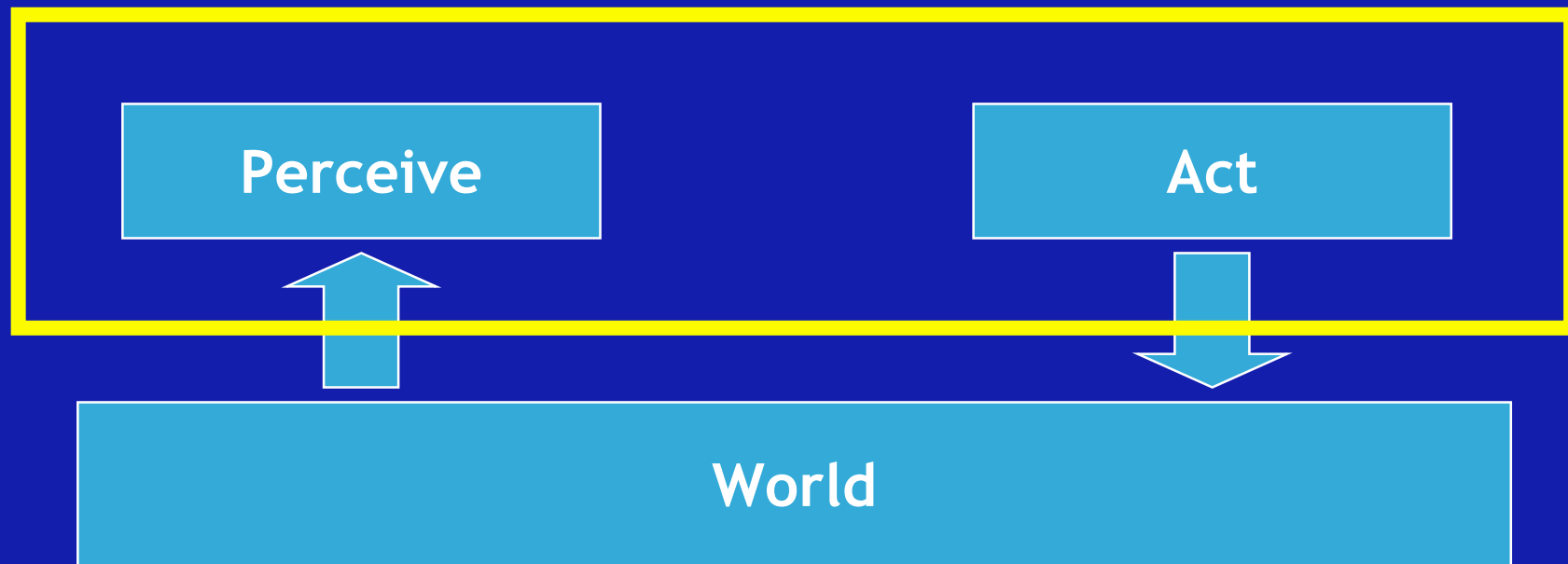


*In general have been focused on higher-level cognition, such as decision making, problem solving, learning.*

# Robotics

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*In general have been focused on basic perception and motor action and the direct mapping between them!*





# Cognitive Modeling

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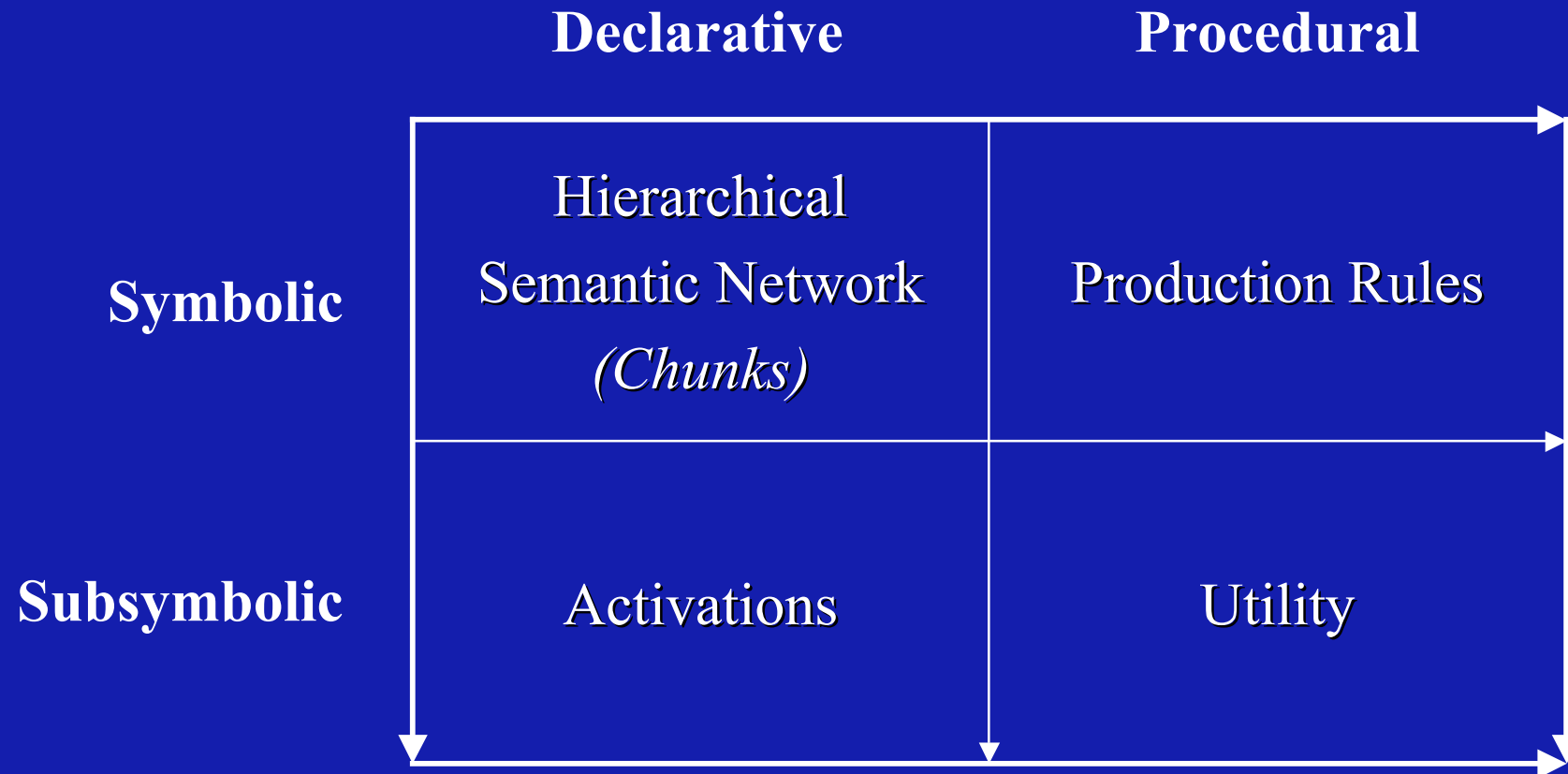
# Cognitive Architectures

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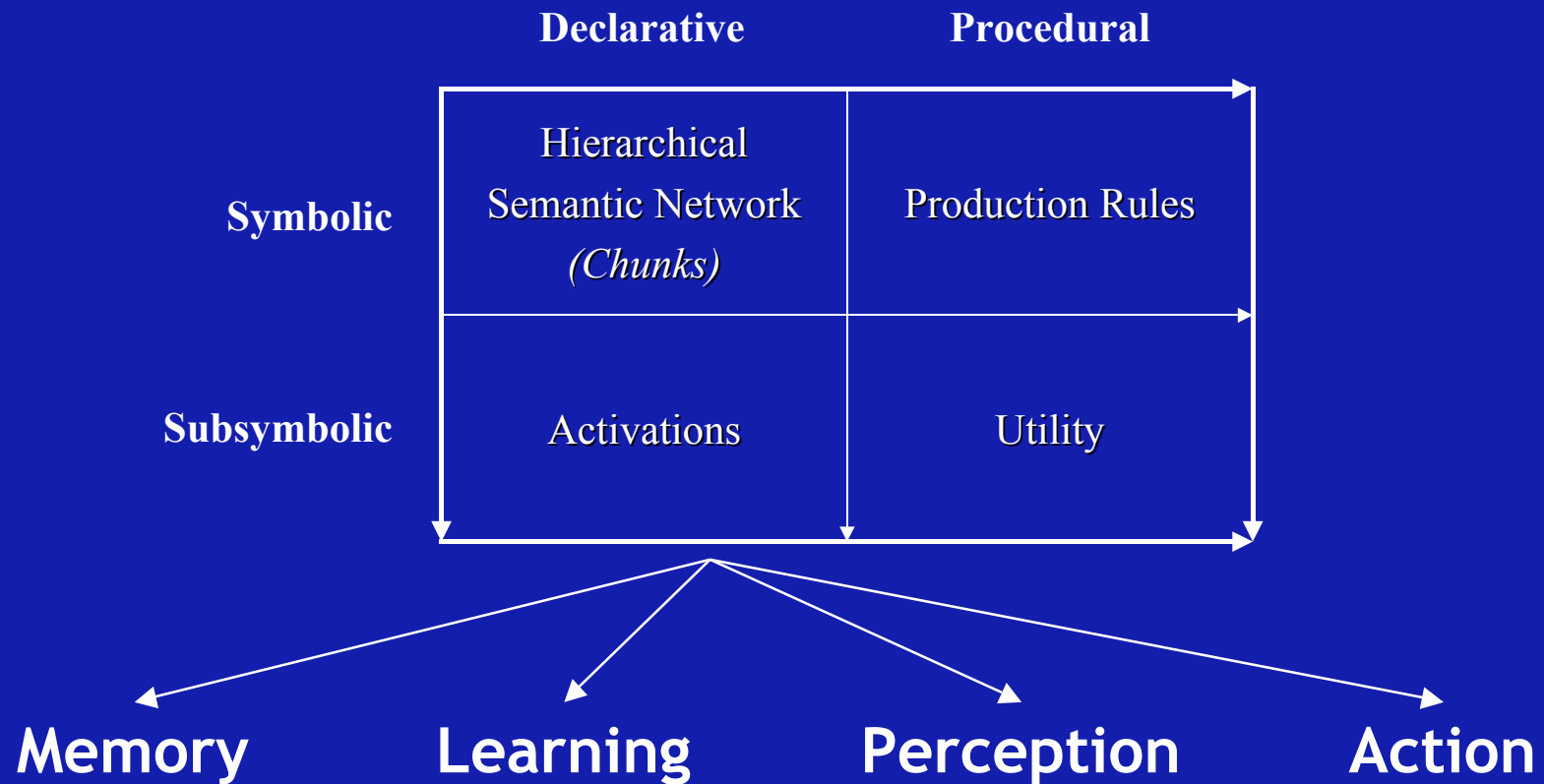
- Cognitive architecture = psychological theory + computational framework
  - models are constrained within larger theory
  - models are more psychologically plausible
- ACT-R (Anderson & Lebiere, 1998)
  - declarative memory: facts, goals, ...
  - production rules: manipulate memory, world
  - some important features...
    - performance parameters
    - individual variability
    - learning mechanisms
    - perceptual-motor modules

# ACT-R Assumptions and Representations

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# ACT-R Assumptions and Representations



# Air-Traffic Control Example

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Lee & Anderson (2001)

Taatgen & Lee (2003)

# Kanfer-Ackerman ATC Task

```

      FLT#      TYPE      FUEL      POS.
      ----      ----      ----      ----
      342      DC10       5       3 n
      148       727       6       3 s
      -> 692      747       4       3 e
      2 n
      2 s
      428      prop       * 3       2 e
      2 w
      259      727       4       1 n
      1 s
      840      prop       4       1 e
      190      DC10       5       1 w
  
```

(a)

```

      n ===== s #1
  
```

(b)

```

      n ===== s #2
  
```

```

      w ||||| e #3
  
```

(c)

```

      Score : 380
      Landing Pts: 400 Penalty Pts: -20
      Runways : DRY
      Wind : 0 - 20 knots from SOUTH
  
```

(d)

```

      Flts in Queue: .....
      <F1> to accept
  
```

(e)

(f)

```

      w ||||| e #4
  
```

(g)

(h)

- (a) Hold Positions (in 3 levels)
- (b) Runways
- (c) Performance Feedback
- (d) Weather Information

- (e) Queue
- (f) Weather Change Message
- (g) Error Message
- (h) Rule Message

# Land at Trial 1

FLT#	TYPE	FUEL	POS.	
171	prop	* 4	3 n	
631	727	5	3 s	
319	747	6	3 e	
369	747	5	2 n	
659	DC10	6	2 s	
536	DC10	6	2 e	
561	747	* 4	2 w	
917	727	* 4	1 n	
			1 s	
975	DC10	5	1 e	
269	prop	5	1 w	

Score :0  
Landing Pts:0      Penalty Pts: 0  
Runways : WET  
Wind : 0 - 20 knots from SOUTH

Flts in Queue:  
<F1> to accept

```

n ===== s #1
n ===== s #2
w ||||| e #3
w ||||| e #4
    
```

# Land at Trial 18

```

      FLT#      TYPE      FUEL      POS.
      ----      ----      ----      ----
->  533      prop      * 4      3 n
    604      727      5      3 s
    147      747      6      3 e
                                3 w
    834      747      5      2 n
    661      DC10      6      2 s
    247      DC10      6      2 e
    530      747      * 4      2 w
    116      727      * 4      1 n
                                1 s
    773      DC10      5      1 e
    300      prop      5      1 w
.
n ===== s #1
n ===== s #2
w ||||| e #3
w ||||| e #4

```

Score :0  
Landing Pts:0      Penalty Pts: 0  
Runways : WET  
Wind : 0 - 20 knots from SOUTH

Flts in Queue:  
 <F1> to accept

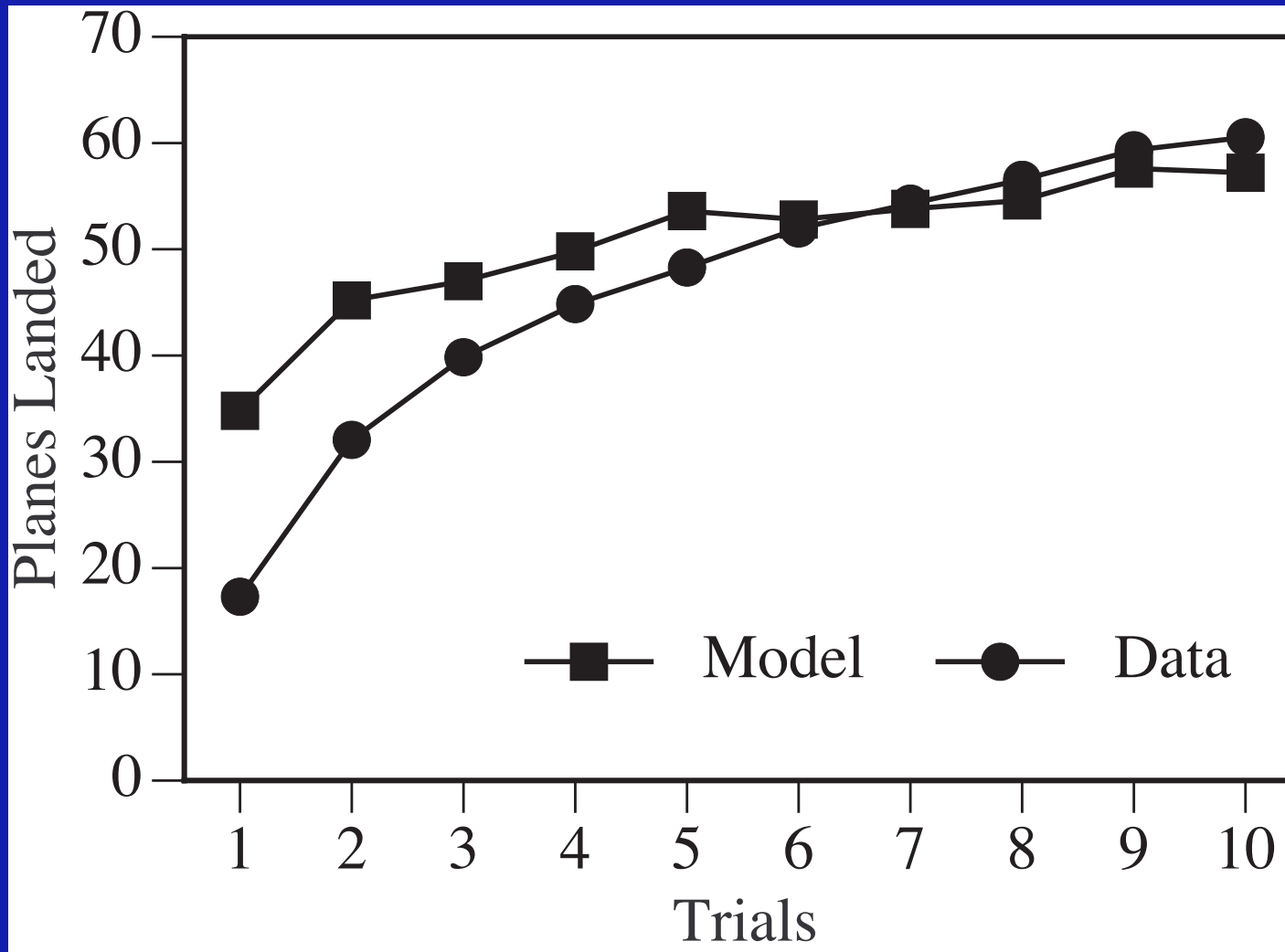


# Our Computational Work (so far)

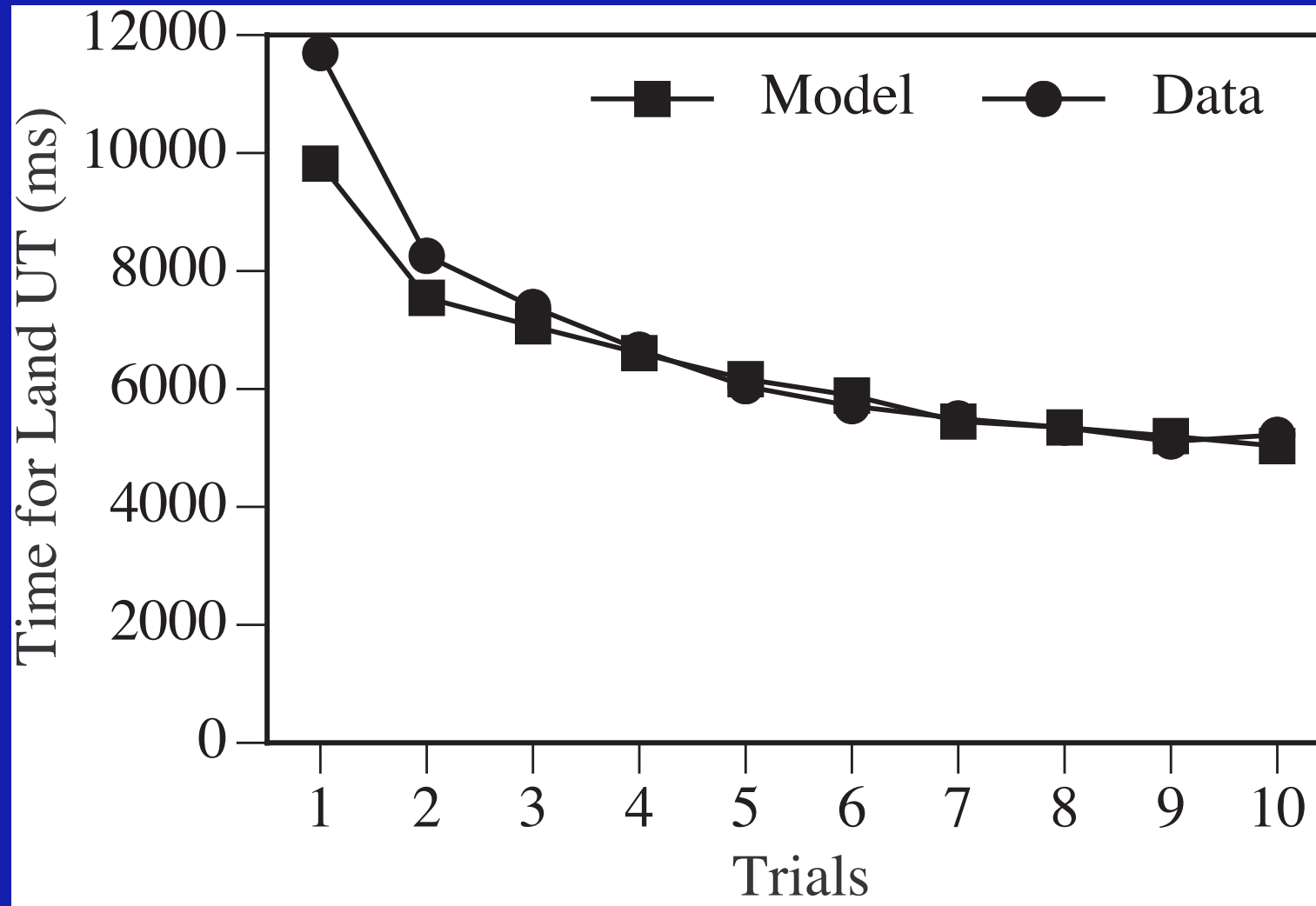
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- Collectively, we have developed cognitive models of
  - Expert Performance (Lee & Anderson, 2000)
  - Individual Differences (Taatgen, 2000)
  - Multitasking (Lee & Taatgen, 2002)
  - Learning from Instructions (Taatgen & Lee, in press)

# Model Performance: Overall



# Model Performance: Land UT



# Driving Example

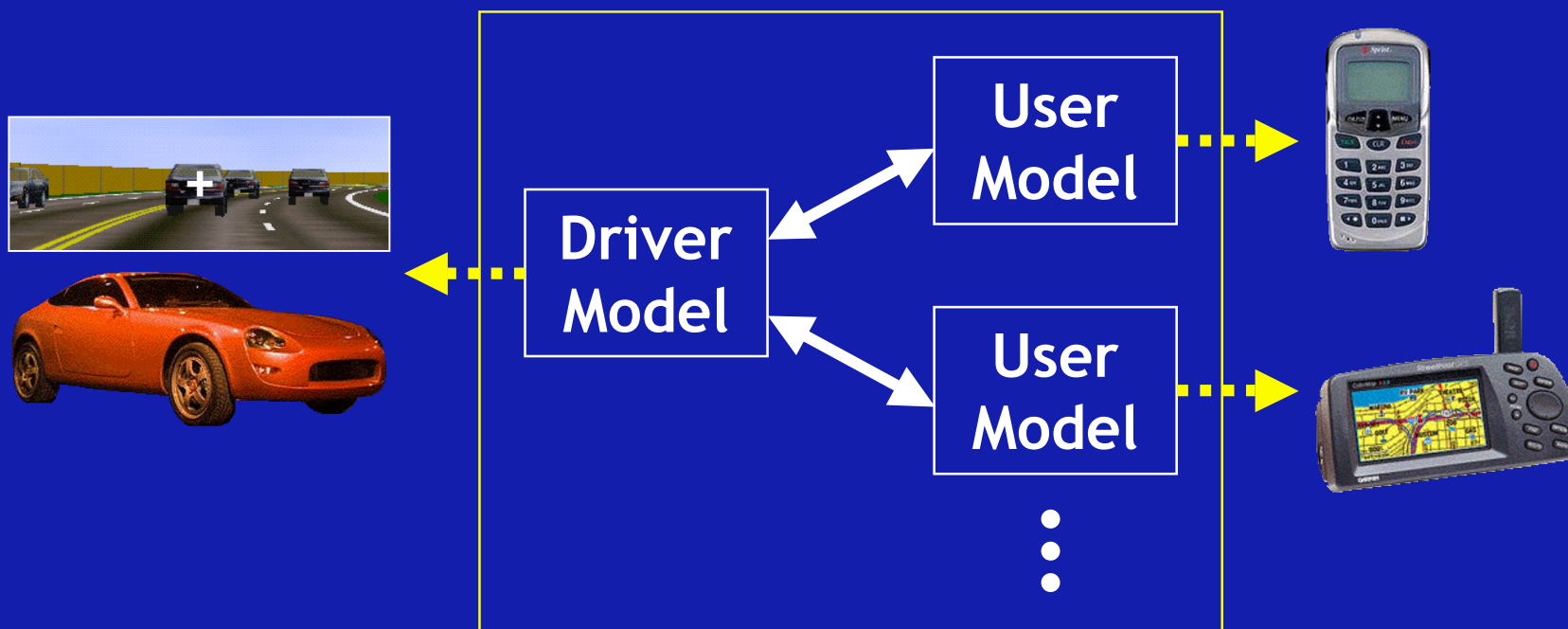
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Salvucci, Boer, & Liu (2001)

Salvucci, Chavez, & Lee (2004)

# Integrated Cognitive Models

- Cognitive model = computational process that thinks/acts like a person
- Integrating driver and user models...



# Cell-Phone Dialing Task

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- Commercial cell phone, hands-free mounting
  - example: call Jenny @ 867-5309

## Manual Dialing

Press 8, 6, 7, 5, 3, 0, 9  
Press *Talk*

## Speed Dialing

Press 2 (speed number)  
Press *Talk*

## Menu Dialing

Press *Up-Arrow*  
Press *Down-Arrow*  
until number reached  
Press *Talk*

## Voice Dialing

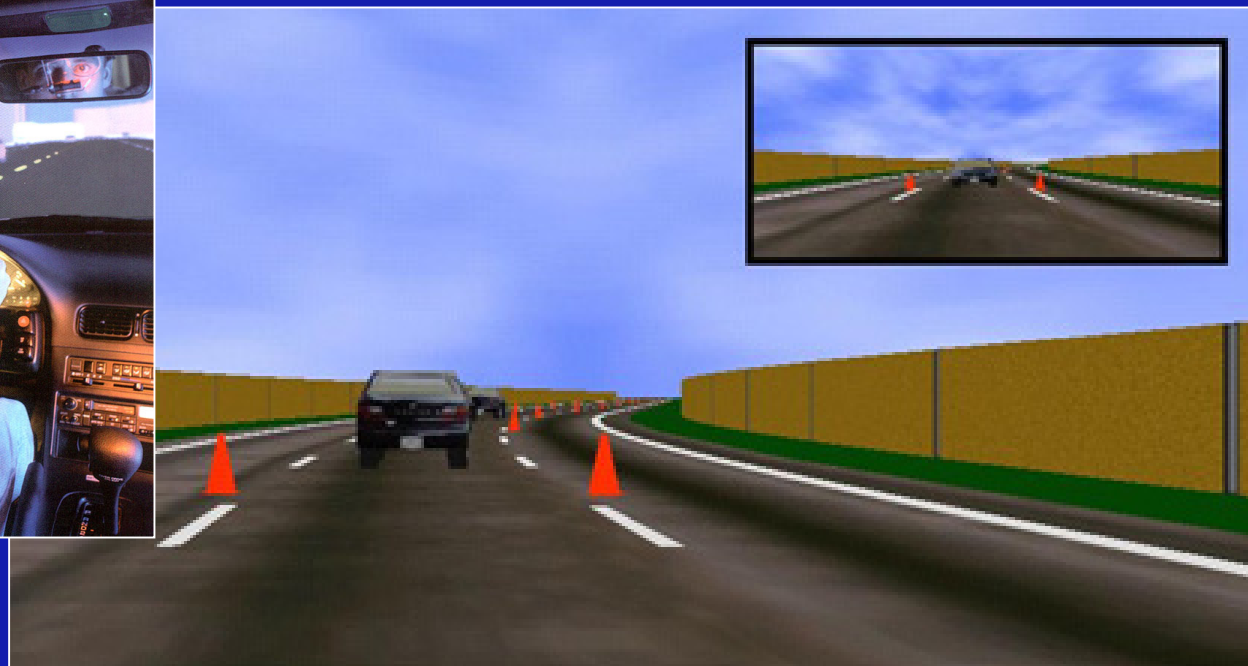
Press, hold *Talk*  
Hear "What number?"  
Say "Jenny"  
Hear "Jenny"  
Hear "Connecting..."



# Driving Task

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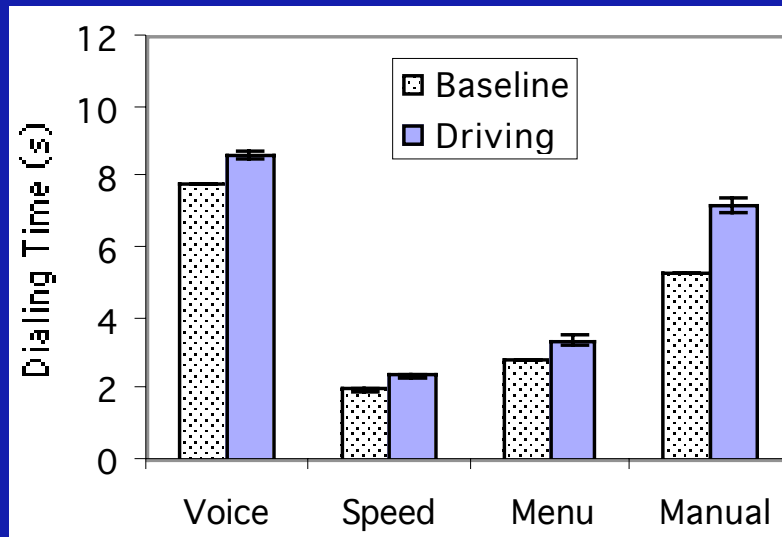
- Car-following task: steering & speed control
  - construction zone environment



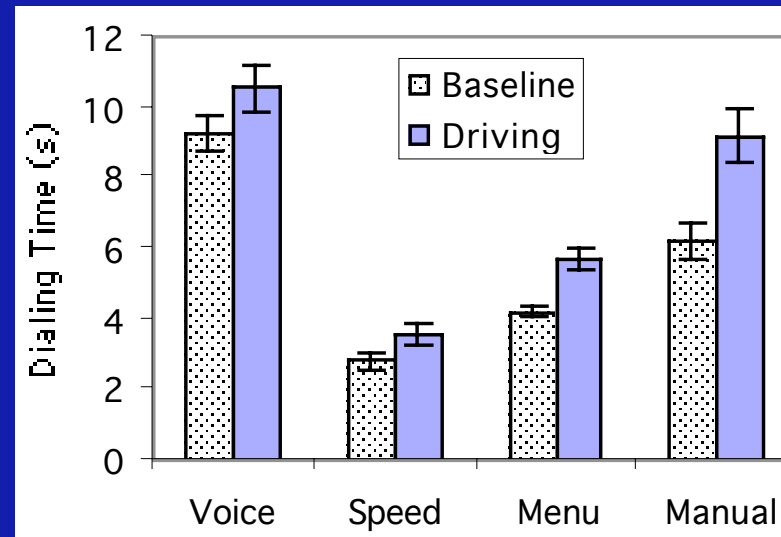
# Dialing Times

- Time needed to dial the phone, per call (s)

Model Predictions



Human Data





# Game Example: Synthetic Characters

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Lee & Gamard (2003)

# Unreal Tournament

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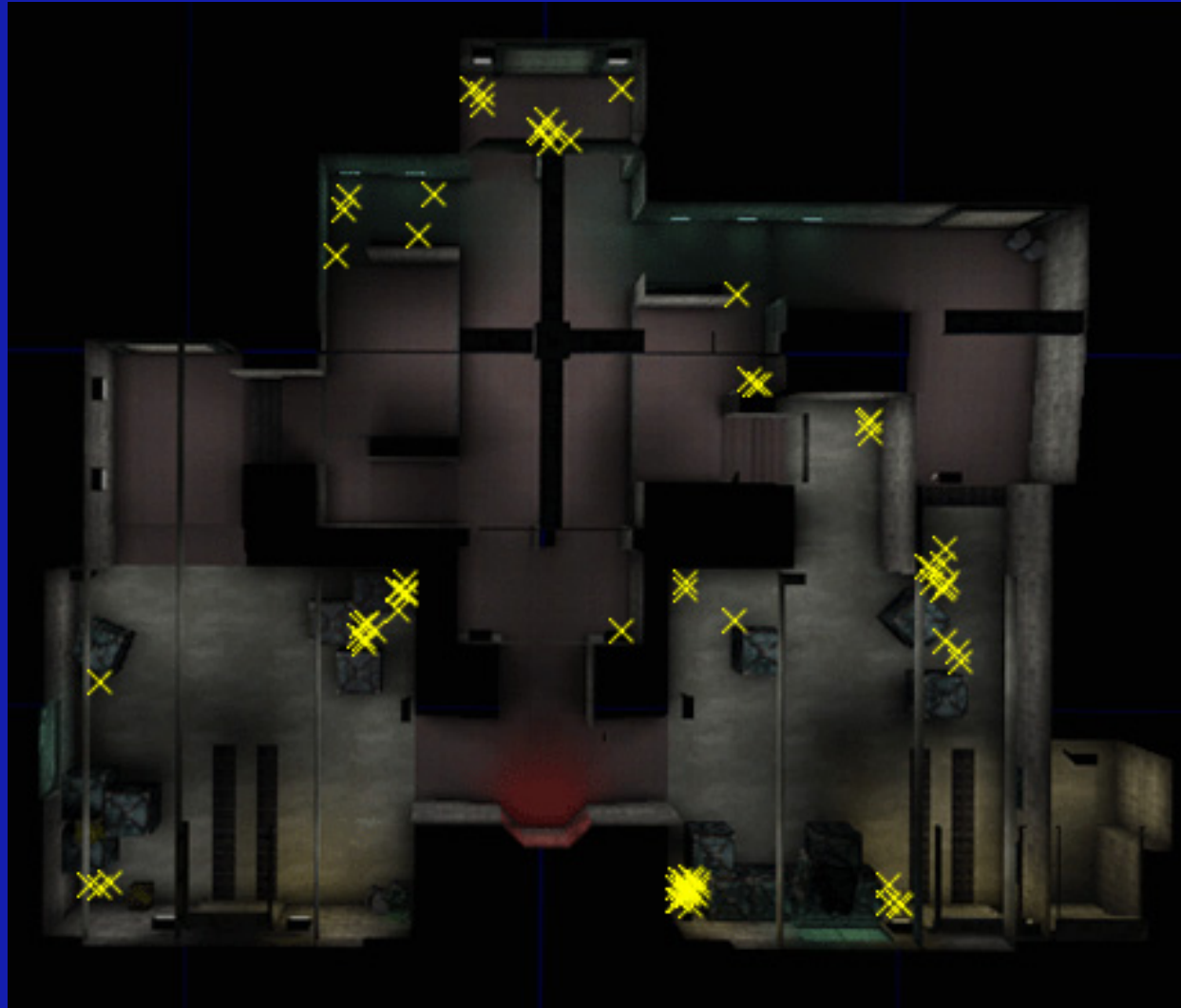
# The Task: Hide and Seek

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1. Player 1 and 2 at start location
2. Player 2 is told to hide
3. After 100 seconds, Player 1 is go told to find Player 2
4. Player 1 has 100 seconds to find Player 2
5. If Player 1 finds Player 2 in time or the time runs out, both players are asked to return to the start location
6. Repeat 1-5 with Players switching roles

# Human Hiding Places

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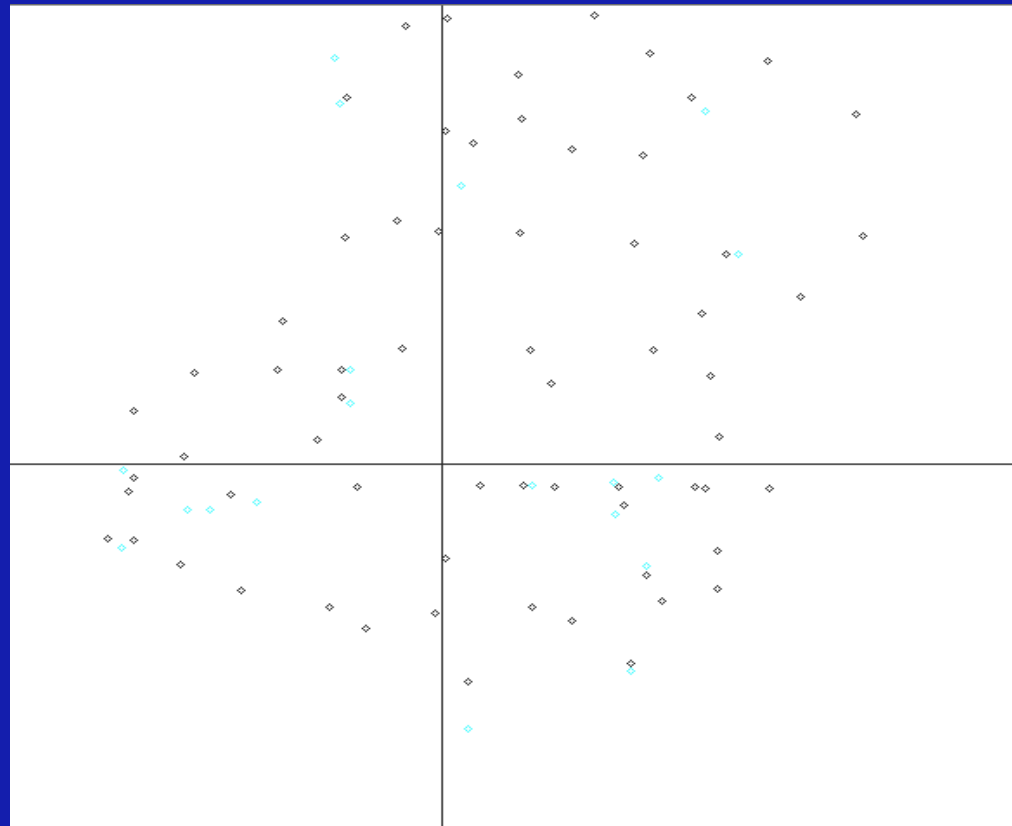
# Model Hiding Places

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# Perceptual Limitations in UT

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# Re(introducing) Cognitive Modeling

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- Why should robotics be interested in cognition?
  - Certainly behavior-based systems have had remarkable success
- My conjecture is that it will become critical as systems are deployed in social situations
  - in many such domains, internal representation of other people, of their beliefs, goals, and desires, will become critical to the goal of the system.

# Thanks! Questions?

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