Mental Simulation

for a Robot Teammate

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A Good Teammate

- **Individual competency: StealthBot (Kennedy 2007) addressed a team members' core competencies:**
  - **Spatial reasoning**
  - **Perspective taking**
  - **Covert communications**

- **Working as a team: good team members have (Cannon-Bowers et al., 1993):**
  - **(1) Knowledge of own capabilities**
  - **(2) Knowledge of the task, and**
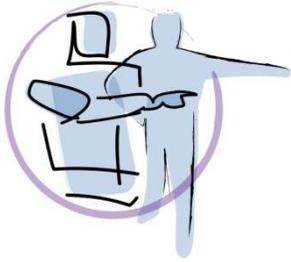 - **(3) Knowledge about the capabilities of their teammates.**
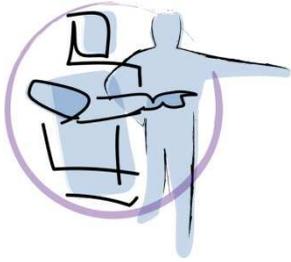
Security Team Scenario

- **Human + Robot team security team patrolling inside a warehouse**

- **Alarm => "man" the two guard stations ASAP**

- **If both go to the same guard station, one must go to the other to complete the team's response**
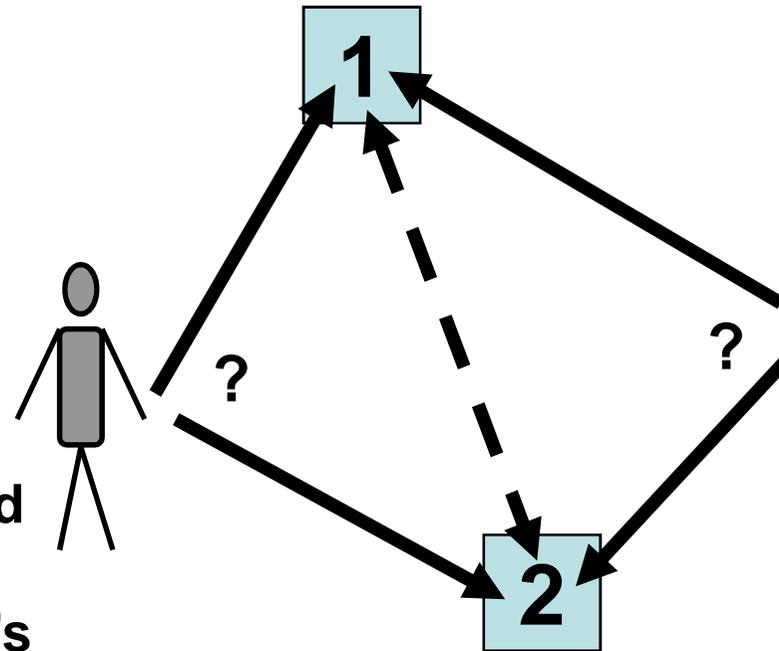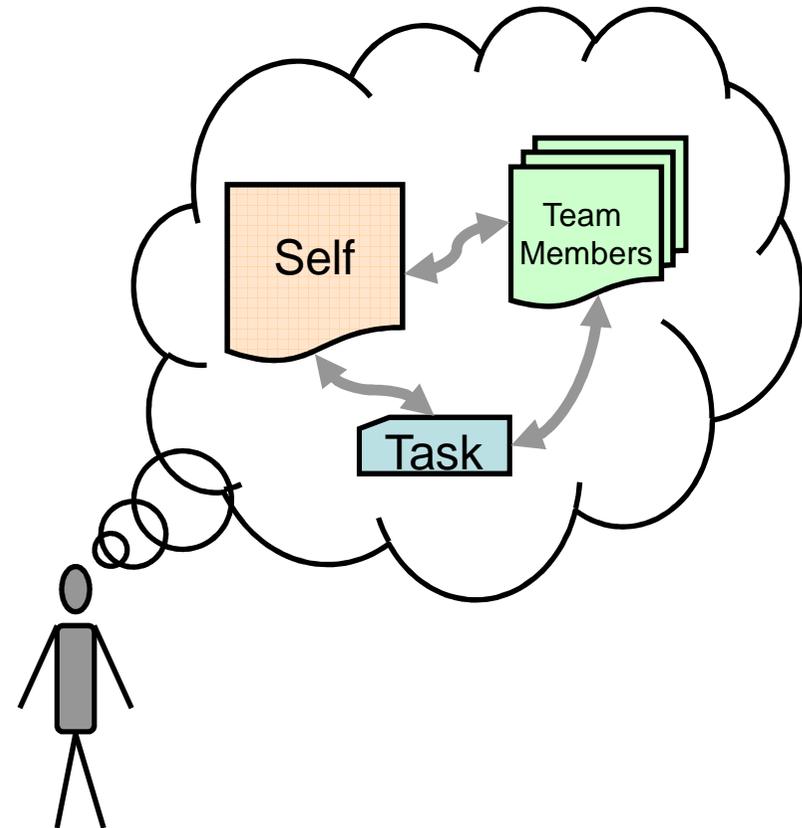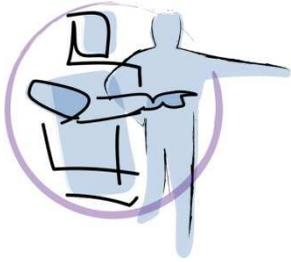
The Approach

- **Team members seem to be good at predicting what a teammate will do in different situations.**

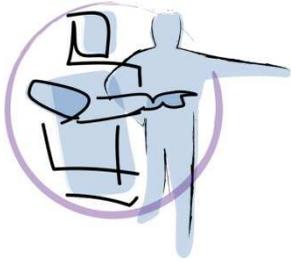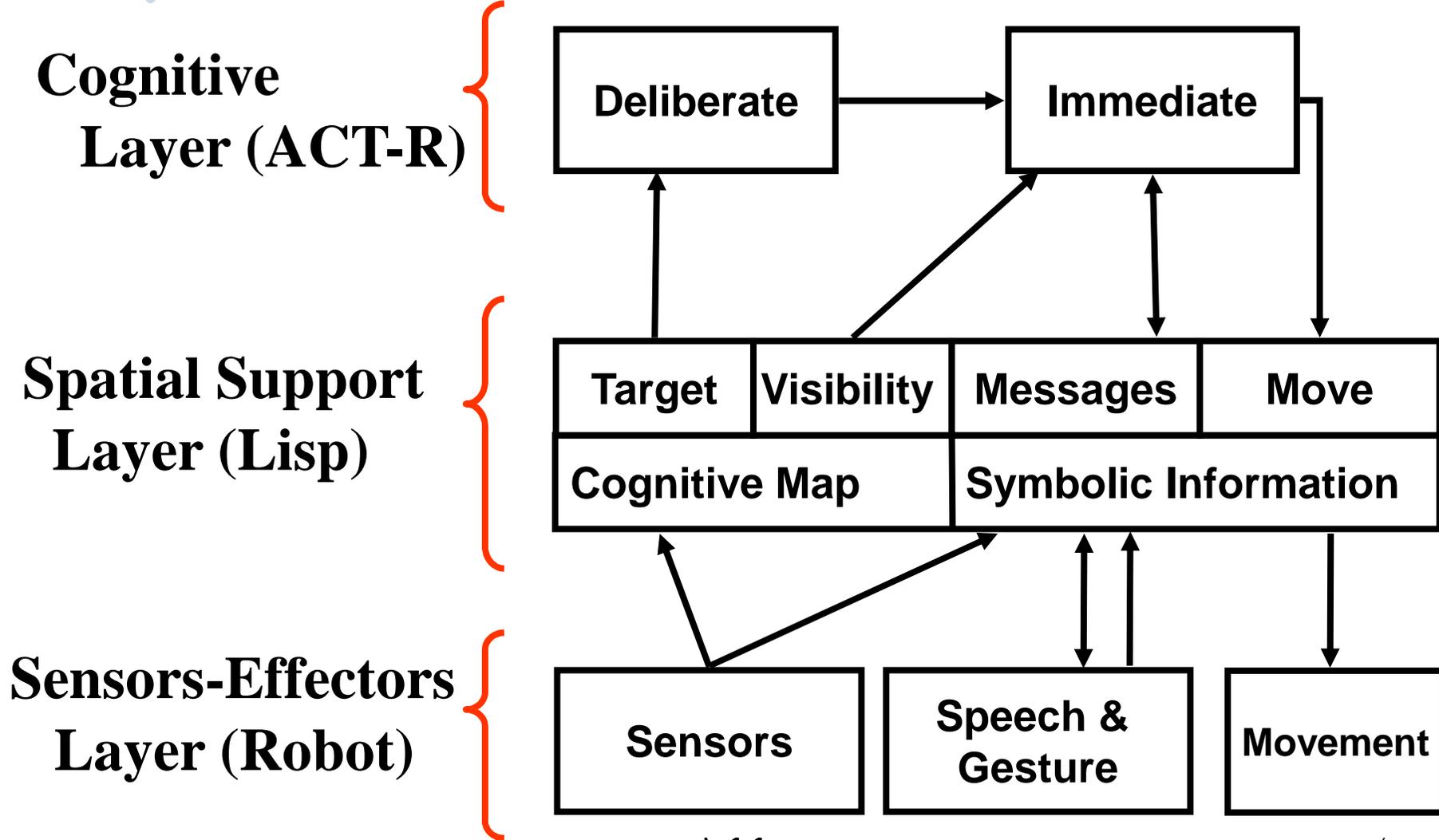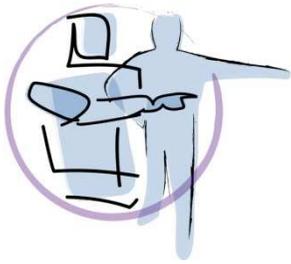- **First level mental simulation of others is base on ourselves.**

Capable Platform

- **Same robot platform as George (AAAI-2004), played hide & seek (Trafton et al 2006), and StealthBot (Kennedy et al 2007)**

- **Navigation & collision avoidance based on evidence grids (Schultz et al 1999)**

- **Object recognition & metrics was built on CMU's color blob (Bruce, Balch, & Veloso 2000) now using person tracking (Trafton et al 2008)**

- **Natural language recognition using our Nautilus system (Perzanowski et al 1998)**

- **Gesture recognition (Fransen et al 2007)**
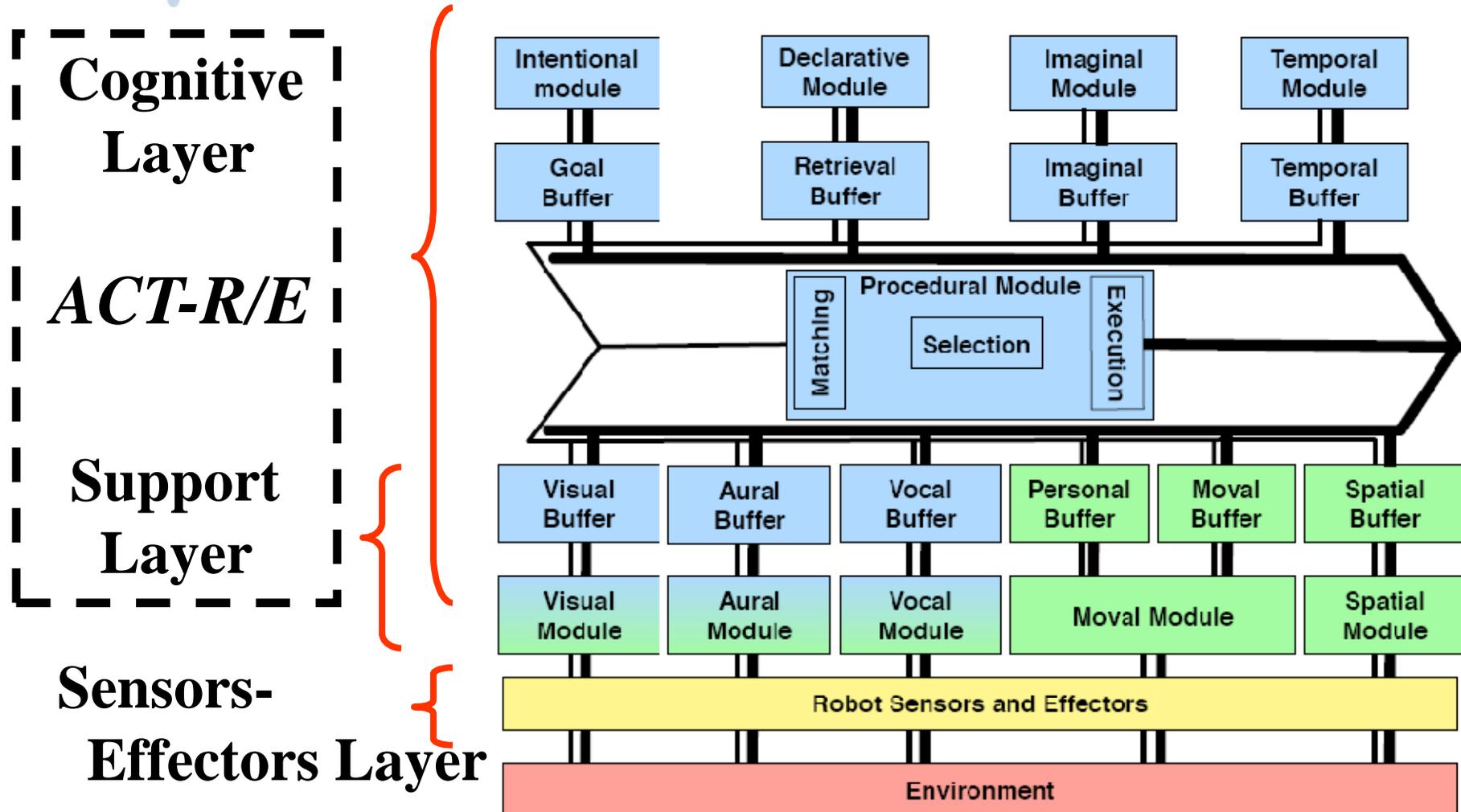
- **Generated speech output**

StealthBot's 3-Layer Architecture

Cognitive Layer (ACT-R)

| Deliberate | → | Immediate |

Spatial Support Layer (Lisp)

| Target | Visibility | Messages | Move |
| Cognitive Map | Symbolic Information | |

Sensors-Effectors Layer (Robot)

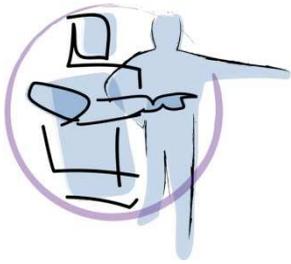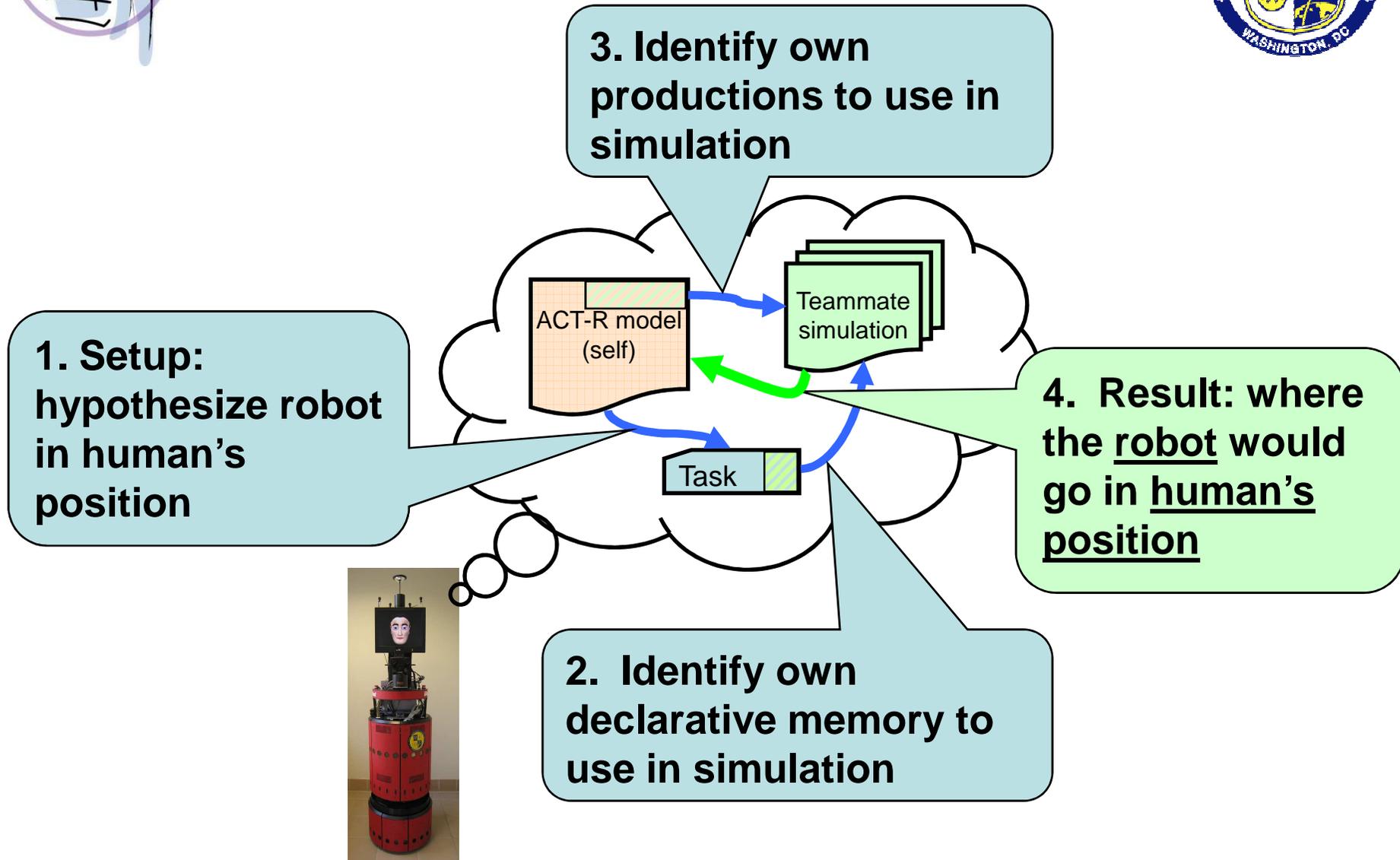| Sensors | Speech & Gesture | Movement |

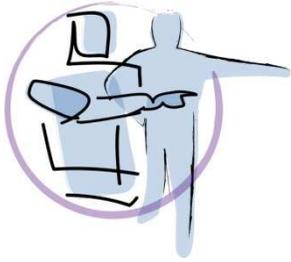# TeamBot's 2½-Layer Architecture
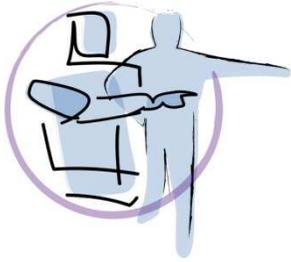
High-Level Reasoning

- **Routinely patrol warehouse and periodically check on teammate**

- **When alarm sounds, TeamBot must decide which guard station to go to and go there:**
  - **Closest to own location**

    OR

  - **Simulate where human will go and go to other**

- **If both arrive at the same guard station, someone (the robot) must go to other**

Mental Simulation

3. Identify own productions to use in simulation

1. Setup: hypothesize robot in human's position

ACT-R model (self)

Teammate simulation

Task

4. Result: where the robot would go in human's position

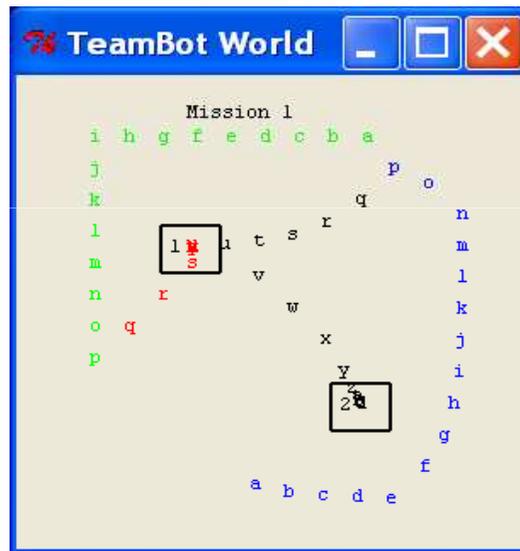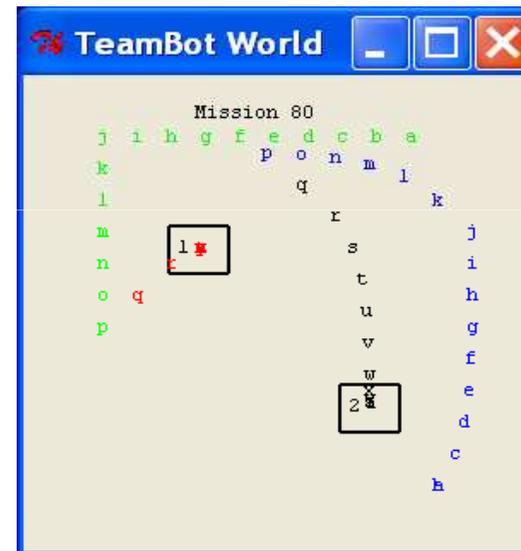**2. Identify own declarative memory to use in simulation**

Resulting Behavior

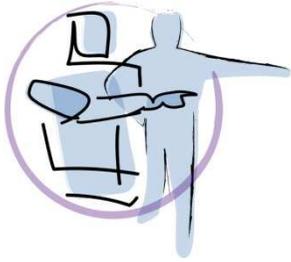Example tracks of runs with and without simulation of teammate
(Human starts at top in green, TeamBot starts at bottom in blue, alarm occurs at step "p")

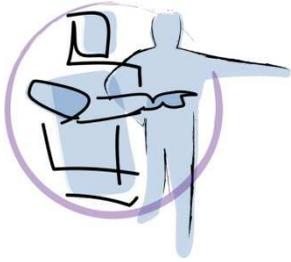**Without:** conflict & extra steps

With: fewer steps

Conclusions

Nuggets:

- Mental simulation is not as difficult as may be first assumed:
  - ✓ Mental simulation works in ACT-R out of the box
  - ✓ Should work similarly in Soar

Lumps of coal:

- "Like-me" simulation could be too powerful to be appropriate for some uses (others do not know everything you know)

Selected References

- Fransen, B.R., Morariu, V., Martinson, E., Blisard, S., Marge, M., Thomas, S., et al. 2007. *Using Vision, Acoustics, and Natural Language for Disambiguation*. Proceedings of the 2007 ACM Conference on Human-Robot Interaction, 73-80. Arlington, VA: ACM Press.

- Kennedy, W.G., Bugajska, M.D., Marge, M., Fransen, B.R., Adams, W., Perzanowski, D., et al. 2007. Spatial Representation and Reasoning for Human-Robot Collaboration. In *Proceedings of the National Conference of the Association for the Advancement of Artificial Intelligence*, 1554-1559. Vancouver, BC: AAAI Press.

- Kennedy, W.G., Bugajska, Adams, W., Schultz, A.C., and Trafton, J.G. (in press 2008). Mental Simulation for a More Effective Robot Teammate. In *Proceedings of the National Conference of the Association for the Advancement of Artificial Intelligence*. Chicago, IL: AAAI Press.

- Trafton, J. G., Bugajska, M. D., Fransen, B. R., and Ratwani, R. M. 2008. Integrating vision and audition within a cognitive architecture to track conversation. In *Proceedings of the 2008 ACM Conference on Human-Robot Interaction*, 201-208. Amsterdam, NL: ACM Press.