U.S. Army Research, Development and Engineering Command

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Human-Robot Interaction (HRI): Achieving the Vision of Effective Soldier-Robot Teaming

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A Vision of the Future

"Give me a robot that acts like my bird dog"

--MG William Hix, Deputy Director, ARCIC

From this…

…to this

A Paradigm shift -
from Tool to Team Member

An Unmanned System that

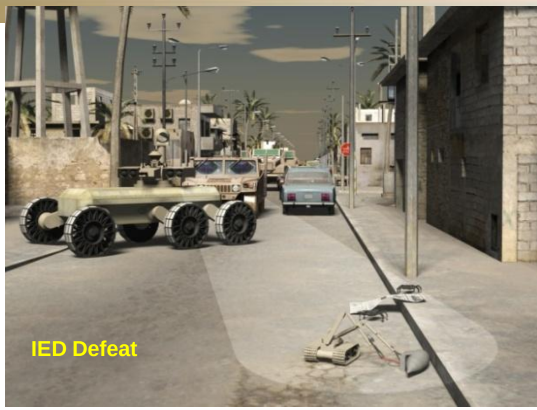
- ***Understands its environment***
- ***Conducts useful activity***
- ***Acts independently, but…***
- ***Acts within prescribed bounds***
- ***Learns from experience***
- ***Adapts to dynamic situations***
- ***Possesses a shared mental model***
- ***Communicates naturally***

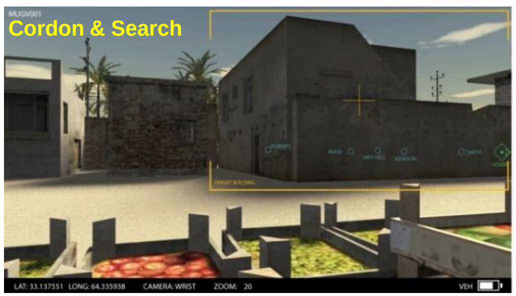
Expands the bubble of influence for a small unit

Human-Robot Interaction (HRI) Research supports transforming robots from ***Tools to Teammates***

- Humans
  - Transition from operators to teammates (or supervisors)
  - Devote less resources to managing the robot, resulting in more resources for situation awareness of the task-at-hand and greater team capabilities
- Robots
  - Process the complexity of the world
  - Aware of social dynamics within the operational environment
- HRI
  - Humans and robots as active collaborators
  - More natural ways for human-robot information exchanges (i.e., communication)

Multiple Missions Share Common Requirements





- ***Understand the mission****
  - Receive/interpret orders
  - React to changing situations
- ***Understand the environment****
  - Recognize “rubble pile by lamppost”
  - Observe person fleeing checkpoint
- ***Move in a tactically correct way****
  - Move downrange to IED – and return
  - Check intersection before manned units pass through it
- ***Communicate clearly & efficiently****
  - Ask for assistance when needed
  - Report salient activity – e.g., insurgent entering building, fleeing checkpoint
- ***Perform missions****
  - Monitor activity at checkpoint
  - Resupply combat outpost
  - Inspect and neutralize IED
  - Perform ISR in urban setting

* Equally true for Soldiers & robots

ARL Autonomous Systems Vision

Enable the teaming of autonomous systems with Soldiers

Expand the unit sphere of influence - provide technology to enable:

- *Greater level of autonomy for heterogeneous systems:*
  - *Ground, air, & surface vehicles*
  - *From micro-systems to combat vehicles*
- *Teaming capability*
  - *Increased intelligence, modular behaviors*
  - *Shared situational awareness & trust*

Focus on Army unique problem set

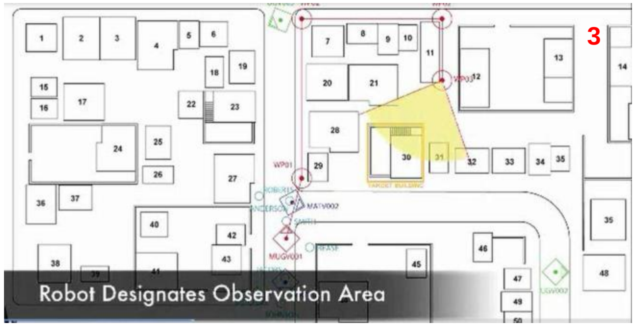
- *Dynamic, unstructured environments*
  - *Active opponent & non-combatants*
  - *Unknown & potentially hostile*
  - *High operational tempo*
- *Lack of similar commercial market*

Autumn 2014 Experiment
A Vision for Autonomous UGVs

-Mission order: “Watch the back of that building and report suspicious activity”

-Understand command
-Relate to perceived environment (“that building”)
-Demonstrate understanding (e.g., lase building)

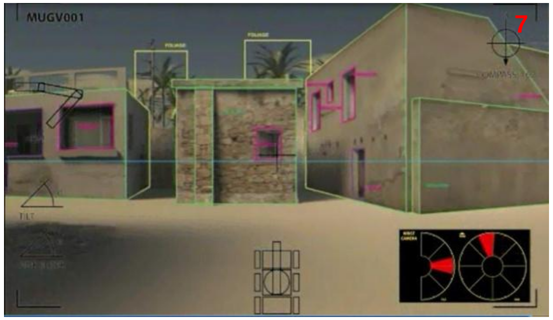
-Figure out where to go to surveil building
-Plan/execute path to move safely & securely
-Establish initial shared SA and Common Ground



-Approach OP cautiously -- along wall of building

-Move through cluttered environment to reach OP, overcome mobility challenges

-As needed, clear obstacles and get in advantageous position for surveillance



-Assess egress points, detect humans, update status

-Upon mission completion, rejoin unit, maintain SA, accept new missions

HRI for "Screen the Back Door" Scenario

1. Robot moves with Human-Robot Team to jumping-off point.
2. Robot accepts multimodal communications.
3. Robot understands & acknowledges orders.
4. Robot can apply mental model of the mission.
5. Robot and Human work collaboratively to disambiguate.
6. Robot moves in a tactically sound manner.
7. Robot selects suitable observation post.
8. Robot supports Human situation awareness.
9. Robot is aware of People around it.
10. Robot builds Human trust through predictable & reliable behaviors.
11. Robot has safe recovery behaviors or fails gracefully.

Human-Robot Interaction Thrusts

Naturalistic Interfaces
"Communicate"
-Multimodal displays and controls to reduce task burden
-Decrease Soldier cognitive & physical workload
-Human-like interaction with intelligent systems


Shared Cognition
"Think"
-Model human abilities (perception, learning, cognition)
-Develop "common ground"
-Collaborate on computational approaches to modeling shared mental models


Effective Soldier-Robot Teaming

Teaming
"Work together"
-Effective Soldier & robot teams
-Supervisory control
-Trust & transparency


Naturalistic Interfaces

OBJECTIVE: Utilize multimodal capabilities: Speech / Gesture / Haptics to alleviate visual workload (e.g., visual displays, handheld devices) and develop human engineering guidelines, address supervisory control issues, and evaluate advanced interfaces for HRI applications.

BENEFITS: More natural means of multi-modal communications (including voice, gesture and haptics); allows Soldiers to hold weapons rather than displays and to focus their visual attention on their local situation awareness.

RESULTS:

- Voice control is a promising, lightweight, hands-free solution, but still needs manual control for continuous processes
- Smartphone-sized interfaces are a possible solution for monitoring robots but poor controls make teleoperation difficult
- Autonomous small robot outperformed teleoperations for course deviation errors and mission completion time
- Using haptic glove for robot control and intra-squad communications via a tactile belt resulted in faster and easier communication performance

STATUS/SELECTED PUBLICATIONS:

- Current experiment with haptics
- Planned experimentation with combined speech and gesture

- Elliott, L., Mortimer, B., Cholewiak, R., Mort, G., Zets, G.,Pittman, R. (2013). Development of dual tactor capability for a Soldier multisensory navigation and communication system. Invited paper presented at the 2013 International HCI Conference (July, 2013).
- Hancock, P., Elliott, L., Cholewiak, R., van Erp, J., Mortimer, B., Rupert, A., Schmeisser, E. Redden, E. . Cross-modal multisensory cueing as an augmentation to Human Machine Interaction. Accepted for publication in Ergonomics (in review).
- Redden, E., Elliott, L., & Barnes, M. (2013). Robots: the New Team Members. In M. Coovert & L. Thompson (Eds.) The Psychology of Workplace Technology. Society of Industrial Organizational Psychology Frontiers Series. Routledge Press.
- Elliott L. & Redden, E. (2013). Reducing workload: A multisensory approach. In P. Savage-Knepshield (Ed.) Designing Soldier systems: Current issues in Human Factors. Ashgate

Human-Agent Teaming: RoboLeader

OBJECTIVE: Evaluate the effectiveness of RoboLeader, an intelligent agent capable of coordinating a team of robots, for enhancing the human-robot teaming performance in human-in-the-loop simulation experiments.

BENEFITS: Robot-to-robot interactions or capabilities similar to RoboLeader can potentially increase Soldiers' span of control, reduce their mental workload, and enable them to better focus on other tasks requiring their attention.

RoboLeader 3

STATUS/SELECTED PUBLICATIONS:

- Currently conducting a simulation experiment on human interaction with a route planning agent in dismounted navigation environments
- Two projects investigating visualization techniques for automation transparency and human trust in autonomous systems.
- Transparency and human trust in autonomous systems
- Review paper accepted in *IEEE Transactions on Human-Machine Systems*: Chen & Barnes (in press) "Human-Agent Teaming for Multi-Robot Control: A Review of Human Factors Issues"

RoboLeader 4

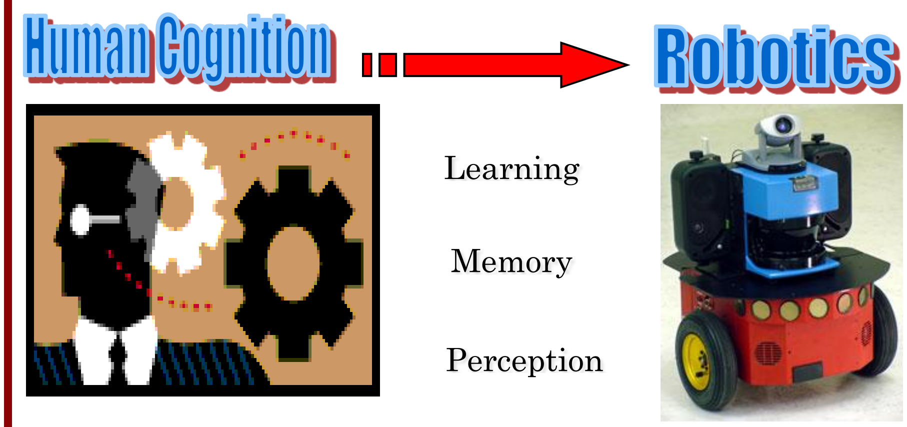
RoboLeader: Summary of Findings

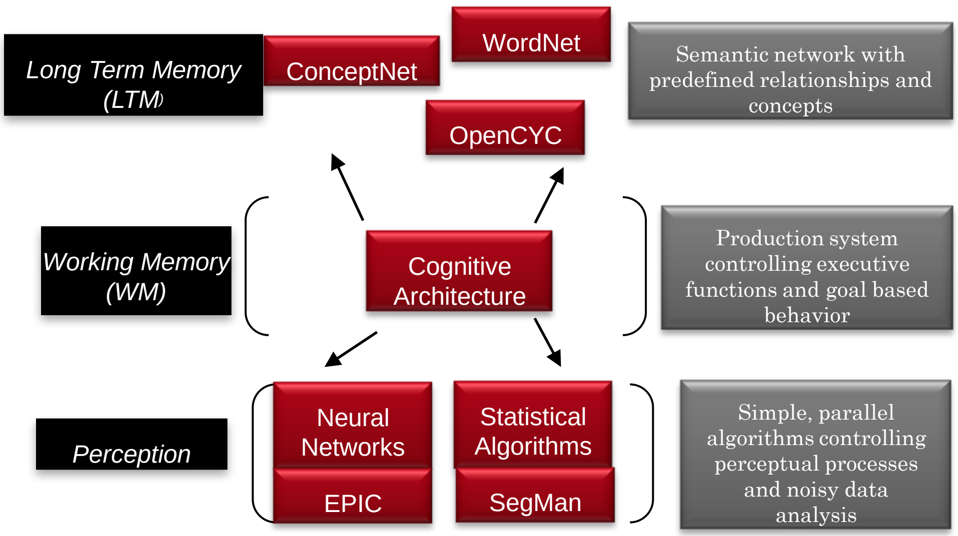
- **Effects of RoboLeader**
  - Benefited dynamic re-tasking: Participants' primary task (encapsulating a moving target) benefited from RoboLeader from all Level of Autonomy compared to manual performance (RoboLeader 3)
  - Benefited concurrent target detection (RoboLeader 4)
  - Participants' workload assessments were significantly lower when they were assisted by RoboLeader in both Exp. 3 and Exp. 4 .
- **Spatial Ability (SpA)**
  - Higher SpA participants:
    - Better task performance involving visual scanning (concurrent target detection, SA of the mission environment)
    - Consistent with some previous findings (e.g., Chen and Barnes, 2012).
- **Gaming Experience**
  - Frequent video game players
    - Better SA of the mission environments
    - Consistent with some previous findings (e.g., Chen & Barnes (2012)) that video game play is associated with greater visual short-term memory and faster information processing.
- **Implications**
  - Personnel selection
  - Training
    - Attention management
    - Spatial interpretations required for missions
  - User interface designs
    - Multi-modal cueing
    - Need for Transparency

Cognitive Robotics

OBJECTIVE: Transition lessons learned from cognitive architectures developed in the 90s to robotics control. Provide new approaches to traditional AI algorithms and augment existing algorithms

BENEFITS: Advances in automation are a force multiplier for the Army. Autonomous capabilities are applicable to a wide range of combat operations including reconnaissance, surveillance, and over watch

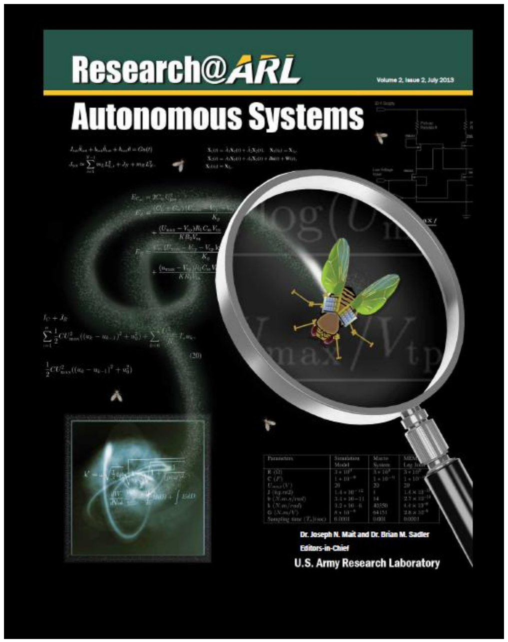




LESSONS LEARNED:

- From a psychological viewpoint, in order to have a complete cognitive system, at least three data structures are needed:
  - Working Memory, Long Term Memory, Perception
- Cognitive Architectures are good representations of WM
- Episodic Memory is needed to transfer information from WM to LTM
- Data structures in LTM need to account for instance based information
- Novelty can be used to highlight data that needs to be transferred to LTM

Human Robot Interaction: Selected Publications



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Featured Publication
Research@ARL
Volume 2 Issue 2

Barnes, M.J., Chen, J.Y.C. , Jentsch, F., Redden, E. and Light, K. (2013). An overview of humans and autonomy for military environments: Safety, types of autonomy, agents and users interfaces. In the *Proceedings of the 15th Annual Human Computer Interaction Internationa*l. Las Vegas, NV.

Barber, D., Lackey, S., Reinerman-Jones, L., & Hudson, I. (2013). Visual and Tactile Interfaces for Bi-Directional Human Robot Communication. In the proceedings of SPIE Defense, Security, and Sensing – Unmanned Systems Technology, Baltimore, MD.

Chen, J.Y.C., & Barnes, M.J. (2012). Supervisory control of multiple robots: Effects of imperfect automation and individual differences. *Human Factors, 54*(2), 157-174.

Chen, J.Y.C., Barnes, M.J., Harper-Sciarini, M. (2011). Supervisory control of multiple robots: Human performance issues and user interface design. *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Reviews, 41,* 435-454.

Chen, J.Y.C., & Barnes, M.J. (2012). Supervisory control of multiple robots in dynamic tasking environments. *Ergonomics,55*(9),1043-1058.

Edmondson, R, Light K, Bodenhamer, A, Bosscher P, Wilkinson ,L. (2012).Enhanced Operator Perception through 3D Vision and Haptic Feedback. In the *Proc. SPIE, Unmanned Systems Technology XIV*, vol. 8373, pp. 25-27. SPIE , Baltimore, MD

Redden, E. S. Elliott, L. R., Pettitt, R. A., & Carstens, C. B. (2011). Scaling robot systems for dismounted warfighters: Issues and experiments. *Journal of Cognitive Engineering and Decision Making: Special Issue on Improving Human-Robot Interaction in Complex Operational Environments: Translating Theory into Practice, Part II, 5,* 156-185.

Questions?

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