Agent Based Aiding of Human Teams

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Talk Outline

- **Motivation**
- **Types of Agent Aiding**
- **Benefits of Agent Aiding**
- **Roles of Agent in Aiding Human Teams**
- **Examples**
- **Conclusions**

Motivation

- Teamwork is characterized by shared goals and activity inter-dependence
- *Distributed* Human Collaboration
  - Planning
  - Execution
- Large amounts of information
- Environment changes unpredictably
- Decreasing Time for Decisions
  - But need for optimized decisions
- Cognitive overload

Agents to the Rescue

- Agents can provide support to human teams for different aspects of teamwork
  - Find and filter needed information
  - Provide decision support
    - (Re)Planning and (Re)scheduling of joint tasks
    - Resource (re)allocation
  - Aid in synchronization of team activity
  - Route and present the right information to the right person at the right time
    - Aid in shared understanding of team members
- Adapt to user, task and situation

Cognitive Model of Human-Agent Team Collaboration

COLLABORATION SYSTEM CHARACTERISTICS

Synchronous /asynchronous collaboration

Proximal / distributed collaboration

TEAM CHARACTERISTICS

Agent capacity / involvement

Participant command structure (hierarchical/flat)

Homogeneity /heterogeneity of knowledge

Deliberation / Course of Action

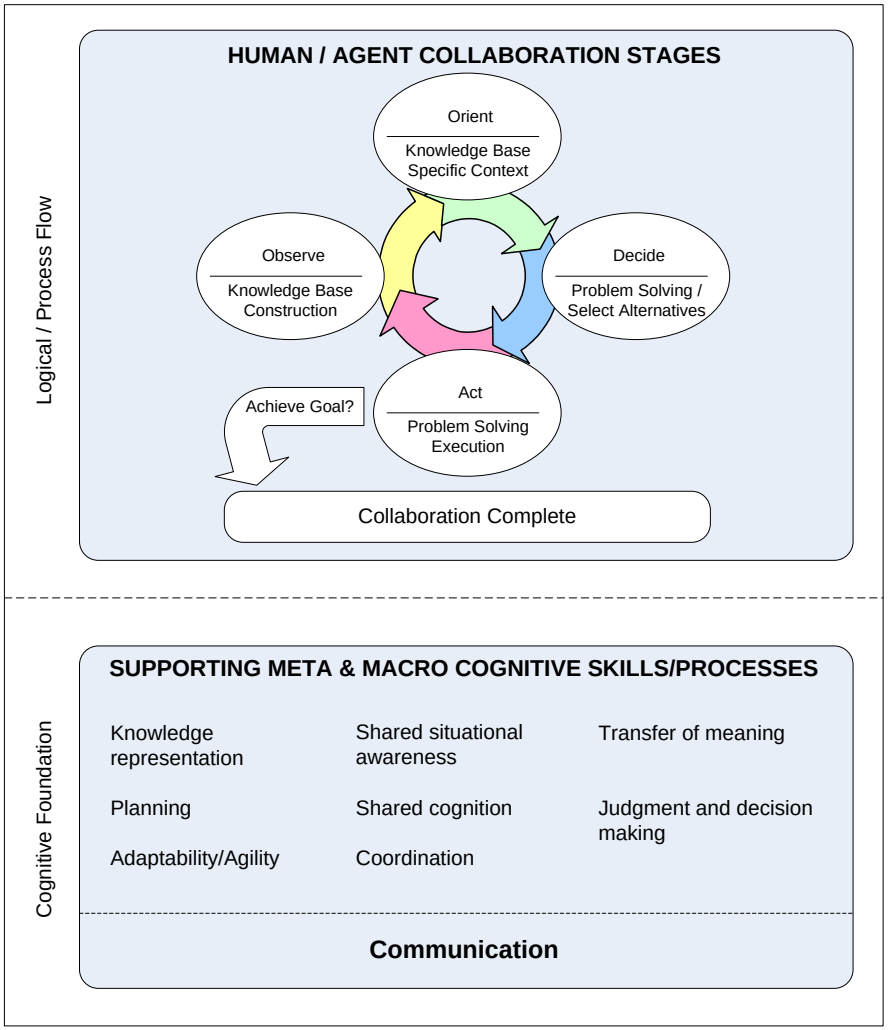
Team size

TASK DIMENSIONS

Task load (complexity, time pressure)

Frequency of task (recurring/ one-off)

Nature of Task
- Planning
- Creative
- Intellective
- Decision-making
- Cognitive-conflict
- Mixed-motive
- Contests/competitive
- Performances



OUTCOMES

Performance (task and team)
- Efficiency
- Accuracy
- Agility

Social Judgment
- Credibility
- Trust

Team Consensus

Dimensions of Agent Aiding

Agents can provide support

- Reactively
  - Agent needs to understand user's request
- Proactively
  - Agent needs to monitor and recognize user activity
  - Agent needs to infer user intentions
  - Agent needs to understand task context
  - Agent needs to understand time constraints of the user

Dimensions of Agent Aiding

Agent Support can be:

- Single shot
- Continuously throughout a task

- Support can be provided by
  - Single agent
  - Multiple agents
    - Acting independently
    - Cooperating
      - Develop schemes for autonomous agent coordination
      - Multi-agent discovery and interoperation

Agents in Teams: Expected Improvements

- Reduce time for human teams to arrive at a decision
- Allow teams to consider a broader range of alternatives
- Enable teams to flexibly manage contingencies (replan, repair)
- Reduce individual and team errors
- Increase overall team performance

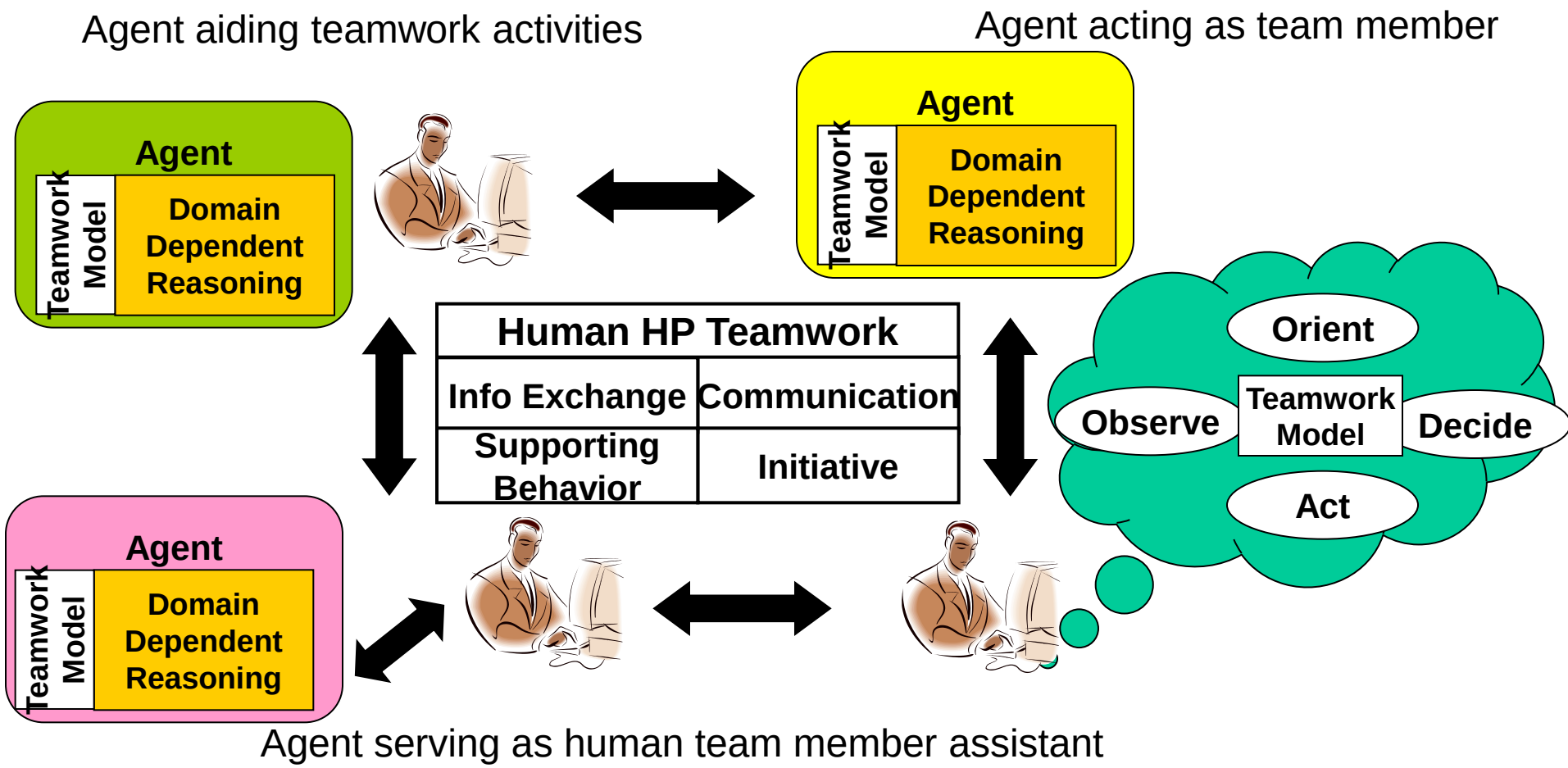
Models of Human Teamwork

- Teamwork (Cannon-Bowers et al, 1995) is composed of:
  - Cognitions: information about the task such as team mission, objectives, norms, problem models, and resources
  - Skills: adaptability, performance monitoring, leadership, communication patterns, interpersonal communication
  - Attitudes: team cohesion, mutual trust, importance of teamwork
- Experienced teams develop *shared mental models; c*ongruence of team cognition is associated with higher team performance
- In a team there are two types of models used:
  - Individual competence model for the task
  - Team model
- ATOM model (Smith-Jentsch et al, 1998) for high performing teams emphasizes importance of domain independent team expertise

ATOM Human Teamwork Dimensions

Information Exchange •Seeking information from all available sources •Passing information to the appropriate persons before being asked •Providing "big picture" situation updates	**Communication** •Using proper phraseology •Providing complete internal and external reports •Avoiding excess chatter
Supporting Behavior •Correcting team errors •Providing and requesting backup or assistance when needed	**Team Initiative/Leadership** •Providing guidance or suggestions to team members •Stating clear team and individual priorities.

Models of Agent Aiding



Principle: By equipping software agents with domain-independent models of teamwork, agents are 1) able to assume the role of full team members 2) more capable of recognizing, monitoring and aiding teamwork activities between human teammates.

Supporting Individual Team Members

- Software agent aids a single human and does not directly interact with other humans.
- Humans can be supported by:
  - a single agent
  - team of agents
- Research challenges:
  - Human-agent intelligibility
  - Modeling user preferences
  - Determining optimal transfer-of-control policies for adjustable autonomy
  - Considering the user's attention when timing services

Supporting Human Teams

- Agent facilitates teamwork between humans involved in a group task by aiding communication, coordination, and focus of attention.
- This can be more effective than having the agents aid in task completion.
- Example applications:
  - TANDEM target-identification control task
  - Cooperative route and resource planning (MokSAF)
  - Aiding teams with different policies and plan constraints
- Research challenges:
  - Identifying information that needs to be communicated
  - Automatically prioritizing tasks for human team members
  - Maintaining shared task information in a way that is useful for human team members

Acting as Team Members

- The software agent acts as an equal team member, sometimes replacing missing team members
- Research challenges:
  - Achieving task proficiency comparable to a human
  - Critiquing team performance
  - Suggesting alternate courses of action

Aiding & Cognitive Resources

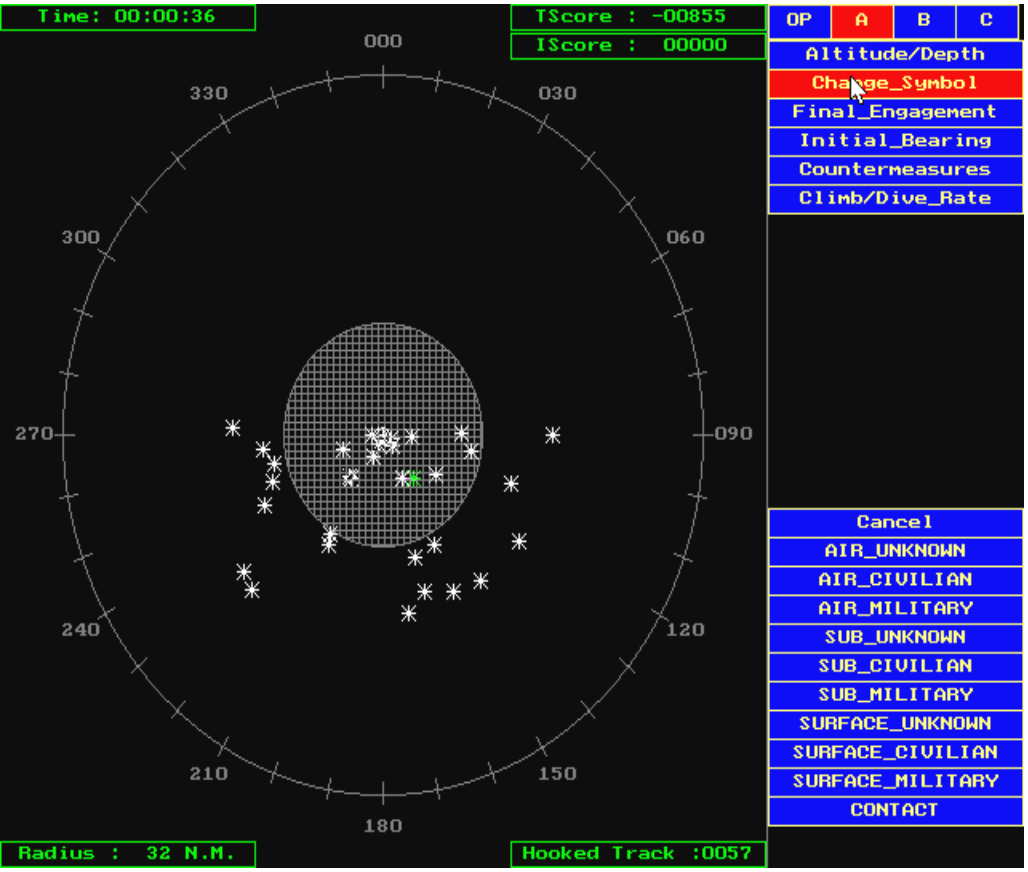
We might improve team performance by:

1. Making individual tasks easier freeing cognitive resources for team coordination tasks
2. Aiding aspects of individual task exercised in coordination activities
3. Supporting team coordination tasks directly

TANDEM Synthetic Radar Task

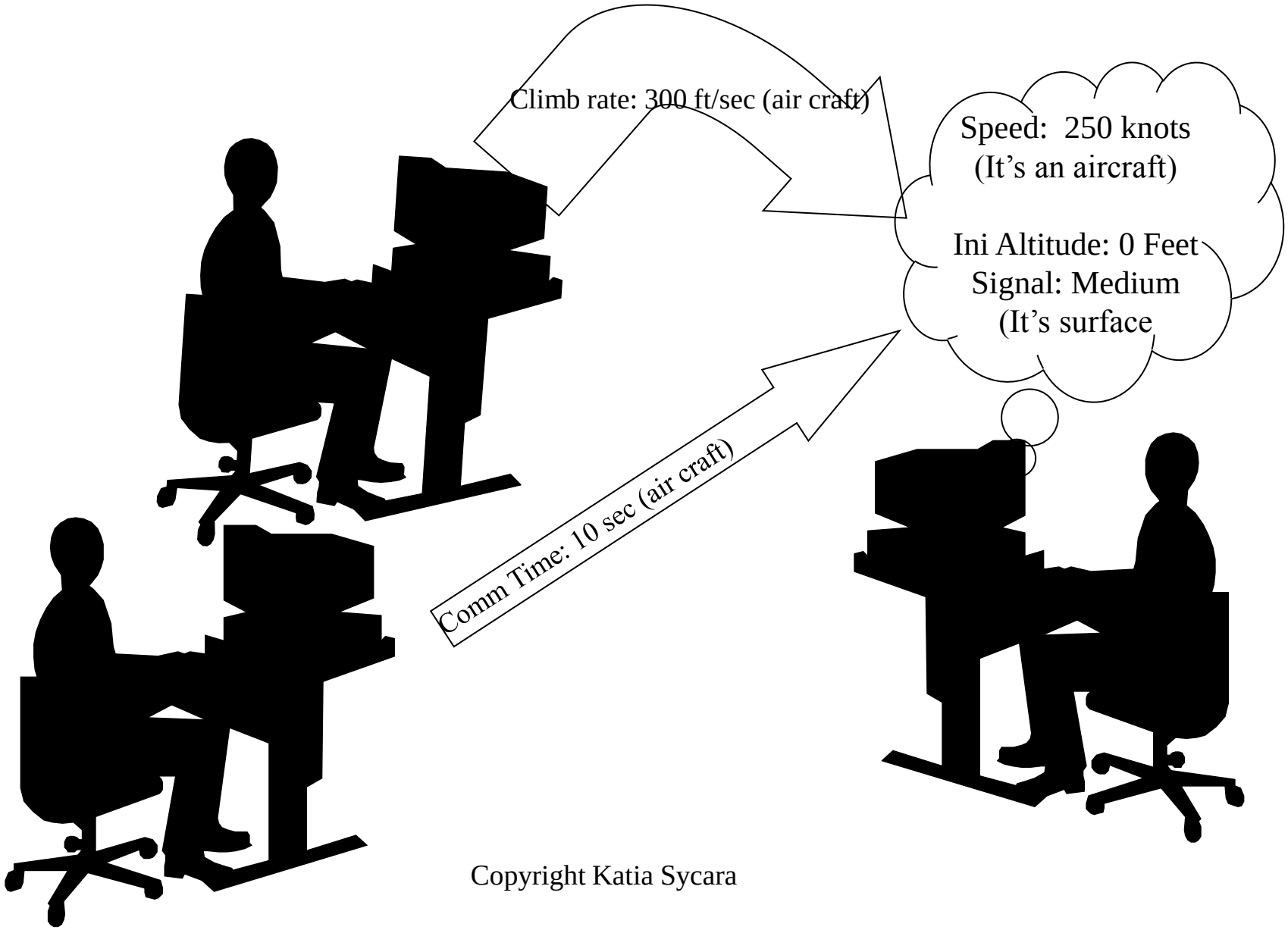
- Lab Simulation : moderate fidelity Aegis-based simulation
- Characteristics : Real-time, reactive & inflexible
- Cognitive task analysis:
- Task : Forced Pace, High Workload, Highly Dependent on Cooperation, Shared Information, Individual Action
- Cognitive Demands: High working memory load..
  - Subjects must access from menus or obtain from teammates five parameter values and their classifications in order to reach each of their individual targeting decisions
- Studies : contrasted agent aiding for reducing memory load with assistance in communication and cooperation

Tandem Experiments



- Three team members (Alpha, Bravo, & Charlie) each responsible for a different decision (type, classify, intent)
- Each team member has 3 menus each accessing 3 parameters
- Each team member has 3 pieces of data for his task, but the remaining two items must be obtained from teammates

User may need information from teammates



Agent Aiding Strategies

	Supports Individual's Task	Supports Team Work
Registry	• Shows who has what data	• **Facilitates coordination**
Persistent Memory	• **Preserves accessed values for own decision**	• Preserves accessed values for communication to team
Information Push	• Accumulates values for own task	**Pushes accessed values to teammates** • Reduces verbal communication • Reduces communication errors

Impact of Agents on Team Performance

- Between subject design with 4 conditions
  - Individual *Memory* agent
  - Team *Push* agent
  - Team *Registry* agent
  - Control (no agent)
- Three team members (Alpha, Bravo, & Charlie) each responsible for a different decision (type, classify, intent)
- Each team member has 3 menus each accessing 3 parameters
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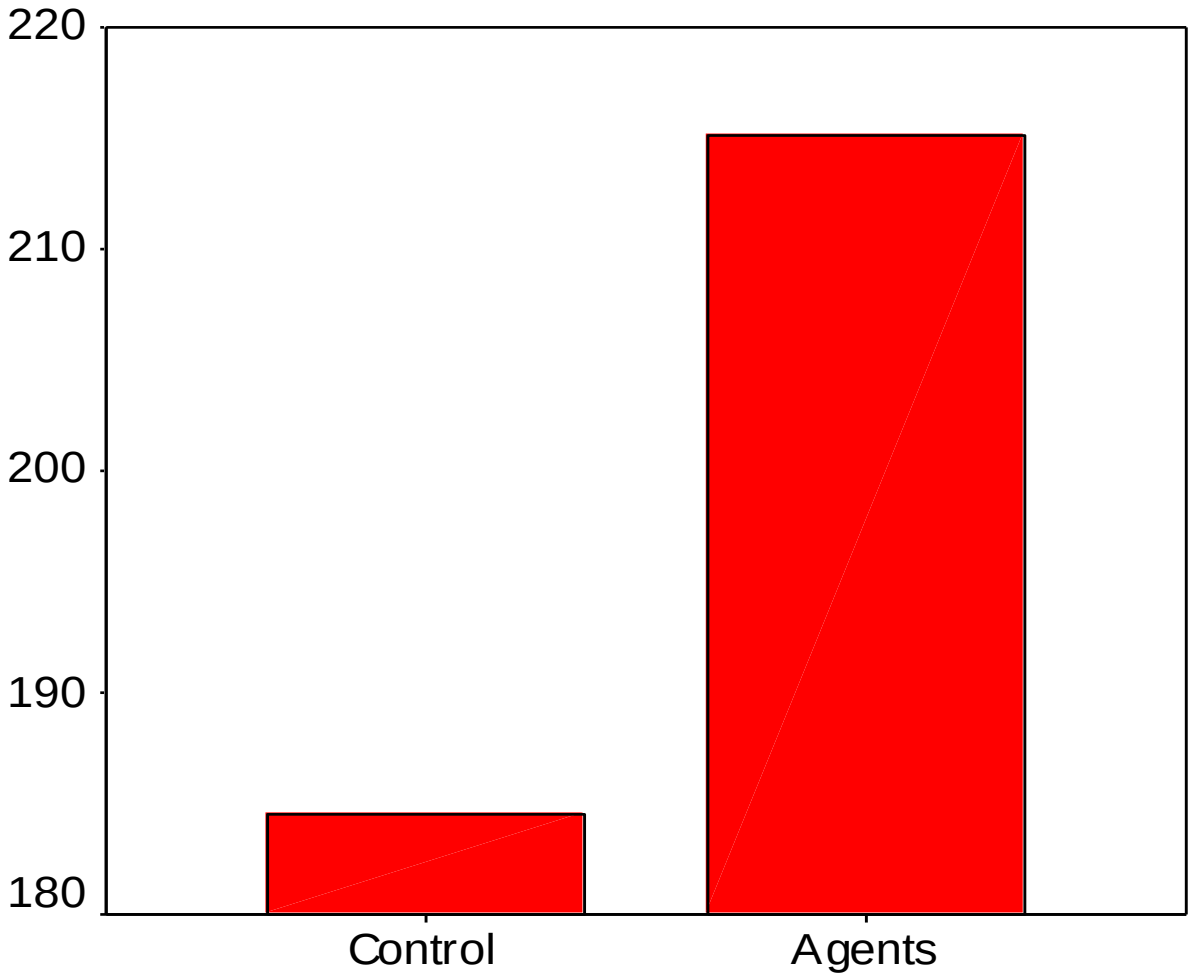
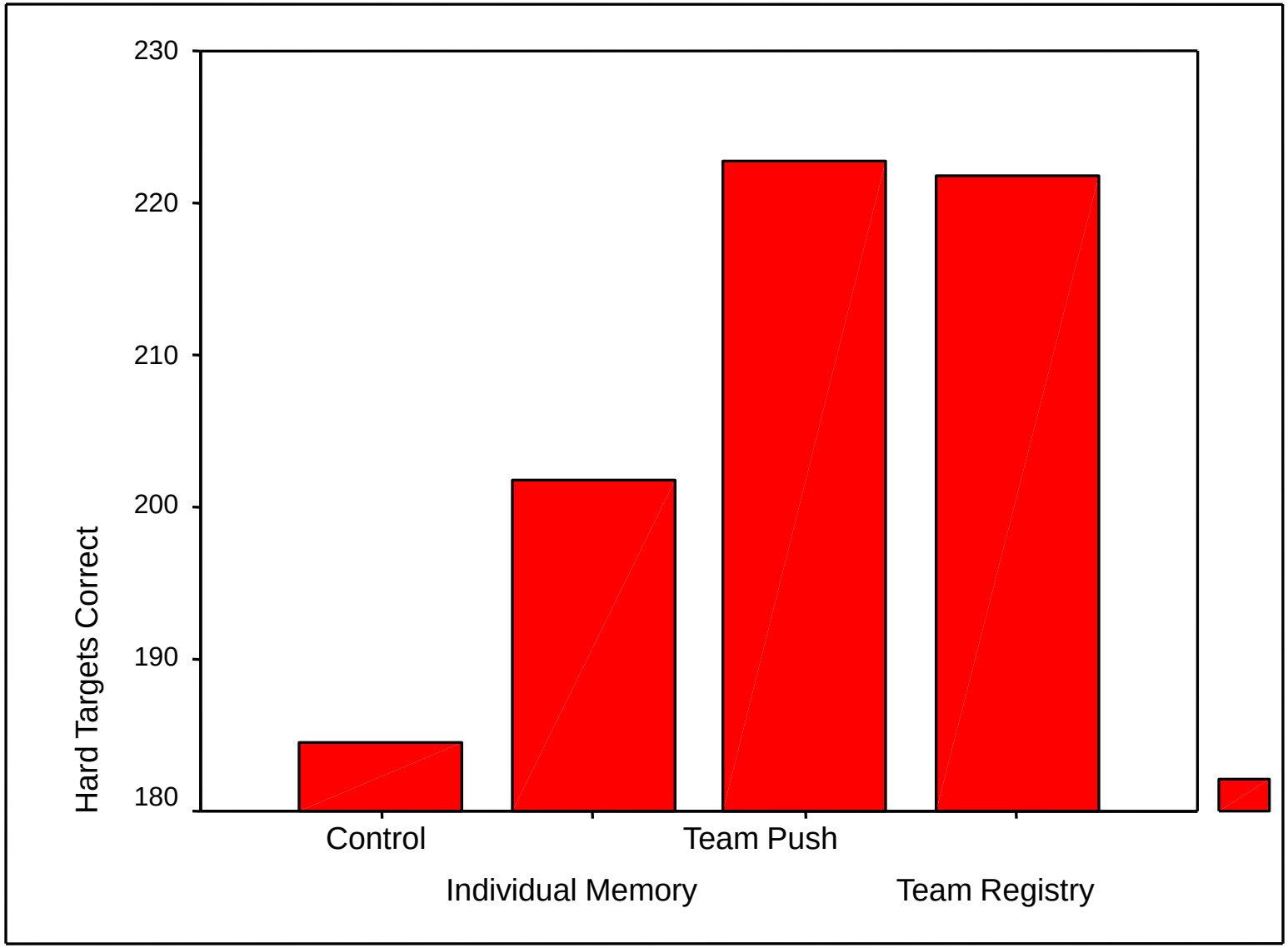
Team vs. Task (cont)

- 10 teams of 3 subjects in each condition (120 subjects)
- Each session contained 3 trials, 15 minutes each
- Each trial included 75 targets with 3 levels of target difficulty
- Target difficulty : hard (25 targets), medium (25 targets) & easy (25 targets)

Identification of Hard Targets



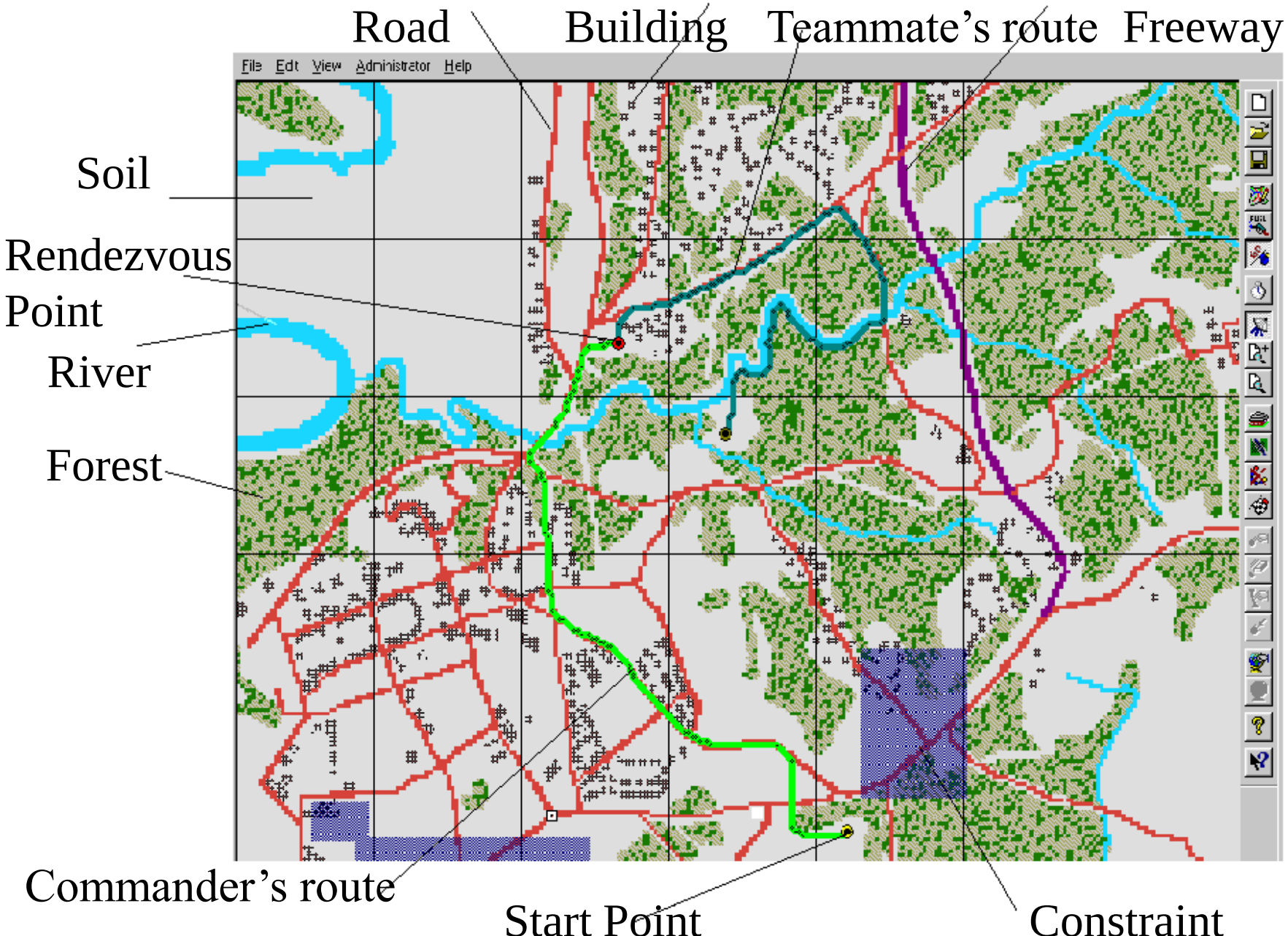
Aiding Teams Helps more than Aiding Individuals for Hard Targets



MokSAF Collaborative Planning Task

- Lab Simulation : MokSAF lightweight agent-based planning environment using ModSAF terrain database and automated planner
- Characteristics : Deliberative, iterative & multiattribute
- Task : Self-Paced, Complex, Highly Dependent on Cooperation, Shared Information, Team Action
- Cognitive Demands: Complex problem-solving, requires multi-attribute negotiation among subjects
- Studies : Comparisons between autonomous, cooperative, and critiquing route planning agents

MokSAF Display



Humans & Agents

Agents:

- have access to digital information in the infosphere
- cannot consider intangible objectives which are not part of that digital infosphere

Humans:

- Understand Idiosyncratic and situation-specific factors
  - local politics, non-quantified information, complex or vaguely specified mission objectives
- Dynamically changing situations
  - Information, obstacles, enemy actions

Problem:

- To share and combine human and agent information and resources

Experiments

- Map planning environment
- Teams of three subjects
- Three conditions
  - Control (route critic) Agent
  - Autonomous Planning Agent
  - Cooperative Planning Agent
- Capability to express intangible constraints via physical artifacts on the map

Sharing Plans

- Subjects create individual routes to rendezvous point by
  - drawing them
  - asking agent to draw them
- When ready, subjects can share plans with other team mates
  - all routes will appear on screen
- Can communicate with each other via typing into a comm program
  - messages go to one team mate or all team mates
  - categorized by subject

Mission Objectives (Performance Measures)

- All platoons arrive at the specified rendezvous point within some agreed time frame
- Create an optimal route in terms of path length
- The route should not violate any physical constraints
- The route should not violate any social constraints (e.g., avoid this area because the roads are under construction)
- The route should pass through areas designated as “go-bys”
- Minimize sharing paths with other teammates
- The team should take the total number and types of units specified by the mission briefing.
  - Too few units is worse than too many units.
  - An exact match is best.

Results

For path selection: aided teams did much better than un-aided teams

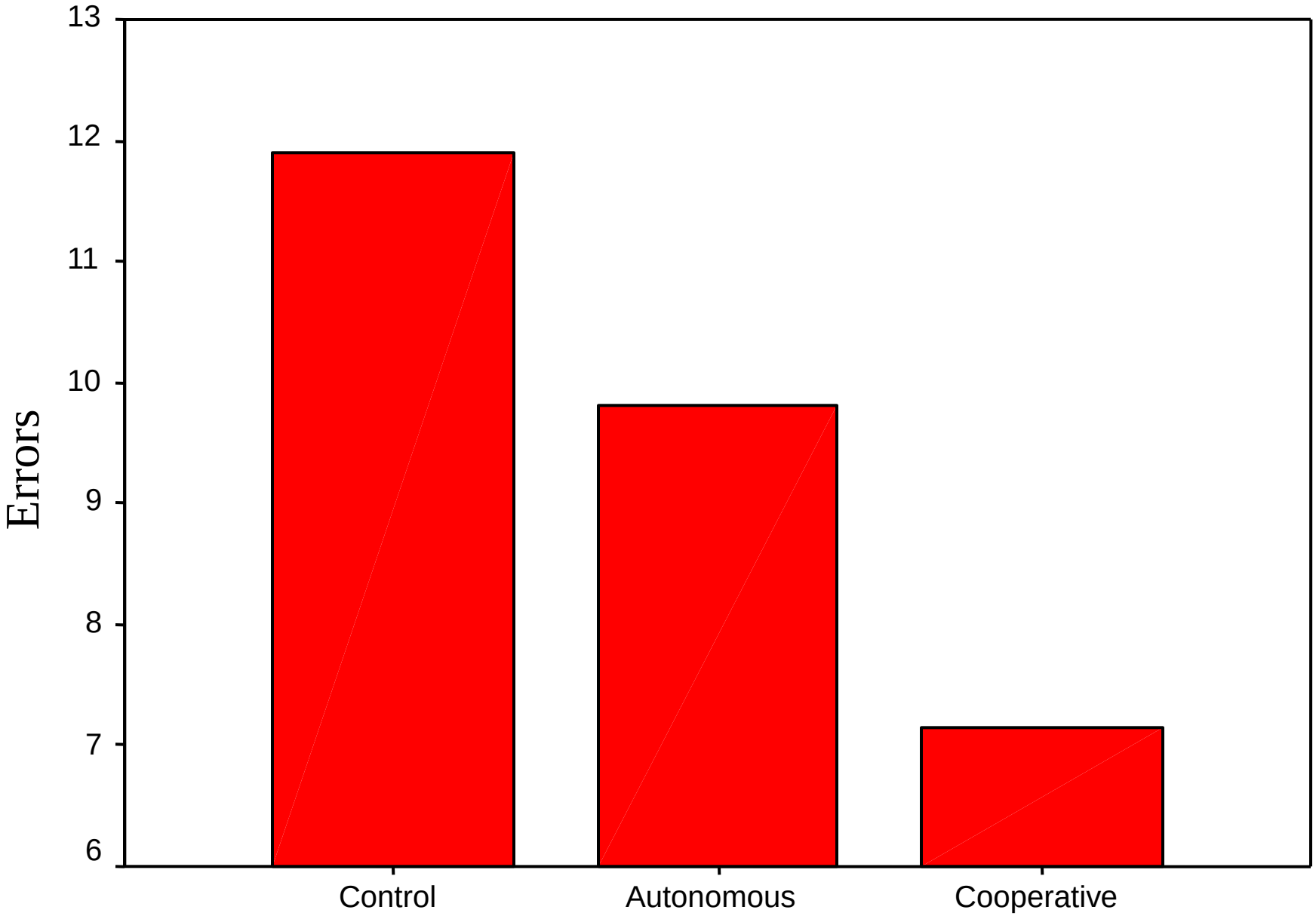
For vehicle selection and rendez-vous: On the more difficult Session 2 Rendezvous:

- Teams using the Cooperative RPA performed best
- Teams using the Autonomous RPA made less appropriate decisions
- Teams using the Route Critic Control performed poorly sometimes failing to rendezvous

For the less difficult Session 3 Rendezvous:

- Performance retains same ordering

Errors in Vehicle Choice session 2



Planning with Different Policies

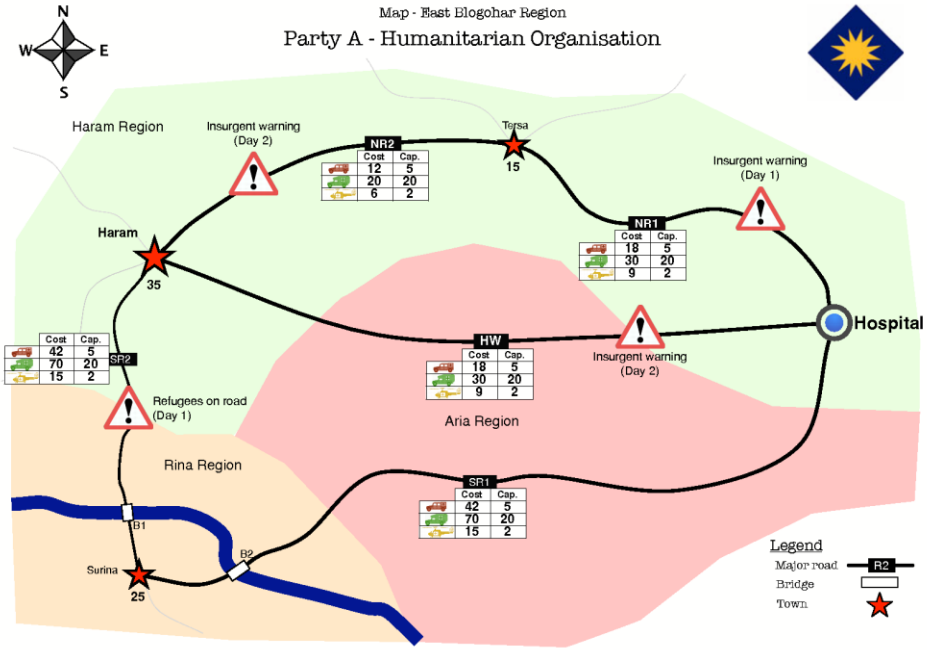
- Assist ad-hoc human teams in a collaborative planning task
- Coalition planning where the different humans belog to different organizations
- Task activities are interdependent
  - Each team member holds a set of policies / norms that constrain the actions they can take
    - Obligations, permissions, prohibitions
  - Team members have to communicate in order to achieve their planning task
    - Policies / norms may determine what information they are obliged, allowed, forbidden to exchange
  - Consequence:
    - No shared policies / norms
    - No overall shared plan, each team member may only know its own (sub-)plan
  - Planning under pressure to observe these norms may pose a substantial cognitive burden

Working Hypothesis

- “If problems are reasonably complex, humans have difficulty reasoning about the norms that govern their actions, when they have to focus on a non-trivial problem (in our case planning)”

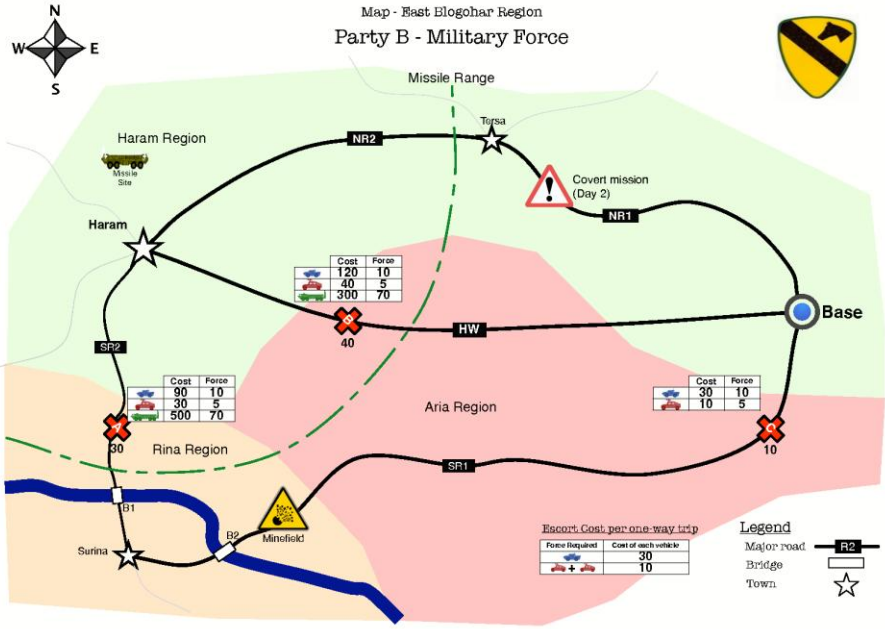
Scenario

Humanitarian Organization



- Evacuate Wounded
- Deploy Field Hospitals
- Maintain neutrality
- Goal: maximize number rescued

Military Organization



- Defeat strongholds to gain control of all areas
- Support / escort NGO
  - Goal: minimize cost

Scenario: Norms/Policies

Humanitarian Organization

- "If:
  - you have intelligence of threats along route R on day D, **AND**
  - you wish to deploy vehicles along route R on day D,
  - **THEN** you are obliged to obtain a commitment of escort from Party B"

Military Organization

- "If:
  - you have granted party A clearance for route R on day D, **OR**
  - you have committed to escort party A along route R on day D,
  - **THEN** you are prohibited from conducting military operations along route R on day D"

Planning Constraints

- Besides Policies / Norms, we also consider operational constraints:
  - Physical constraints capture the physical conditions under which coalition partners may employ particular actions
    - Is a road passable?
    - Transport capacities
  - Routing / planning / scheduling constraints
    - a vehicle cannot be dispatched to more than one city in the same day
  - Resource constraints
    - capture situations of resources being deployed to multiple destinations at the same time
  - Quality-of-Plan constraints
    - Quality is good, if all wounded are treated on the first day of a two-day mission

Experimental Setup

Plan Quality:
- Rescue wounded as early as possible
- Minimize norm violations

Plan Quality:
- Minimize cost of military action and support to humanitarian party
- Minimize norm violations

- Violation of Norms
  - Communication acts may violate norms
  - Planned operations may violate norms

Agent Characteristics

- Agents support the human planners
  - Monitor and intercept communication and planning activities to effectively advise about possible norm violations
- Agent maintains a representation of the normative position of the human planner
- Agent maintains the human planner's planning context
  - Other planners / collaborators
  - Dependencies of plan steps (within own plan, with others' plans)
  - Pending and received requests
  - Given and received commitments
  - Monitors fulfilment of obligations

Agent Monitoring

- Agent monitors the actions of the human planner
  - fulfilment state of obligations and violation state of prohibitions
  - violation of Planning constraints
- Communication actions:
  - Humans use controlled language for interaction
    - assemble messages from pulldown menues (instead of conveying free text)
  - Performative types
    - For requesting and providing commitments for actions or information (intelligence, disclosure of plan steps)
    - For offering and accepting commitments
    - For informing about particular situations
    - For withdrawing commitments
- Planning actions:
  - Plan operators are scenario-specific, agent observes planning actions performed by human planner via the planning environment

Agent Intervention

- Critic:
  - Agent informs the human planer whether an action (planning, communication) would violate a norm and provides suggestions:
    - Example: use more general terms in messages (subsumption) – “ground vehicle” instead of “APC” (disclosure about resources is forbidden)
- Censor:
  - Agent records violations of norms
  - Agent censors outgoing communication – messages are truncated or suppressed, if they convey information that is forbidden from being disclosed

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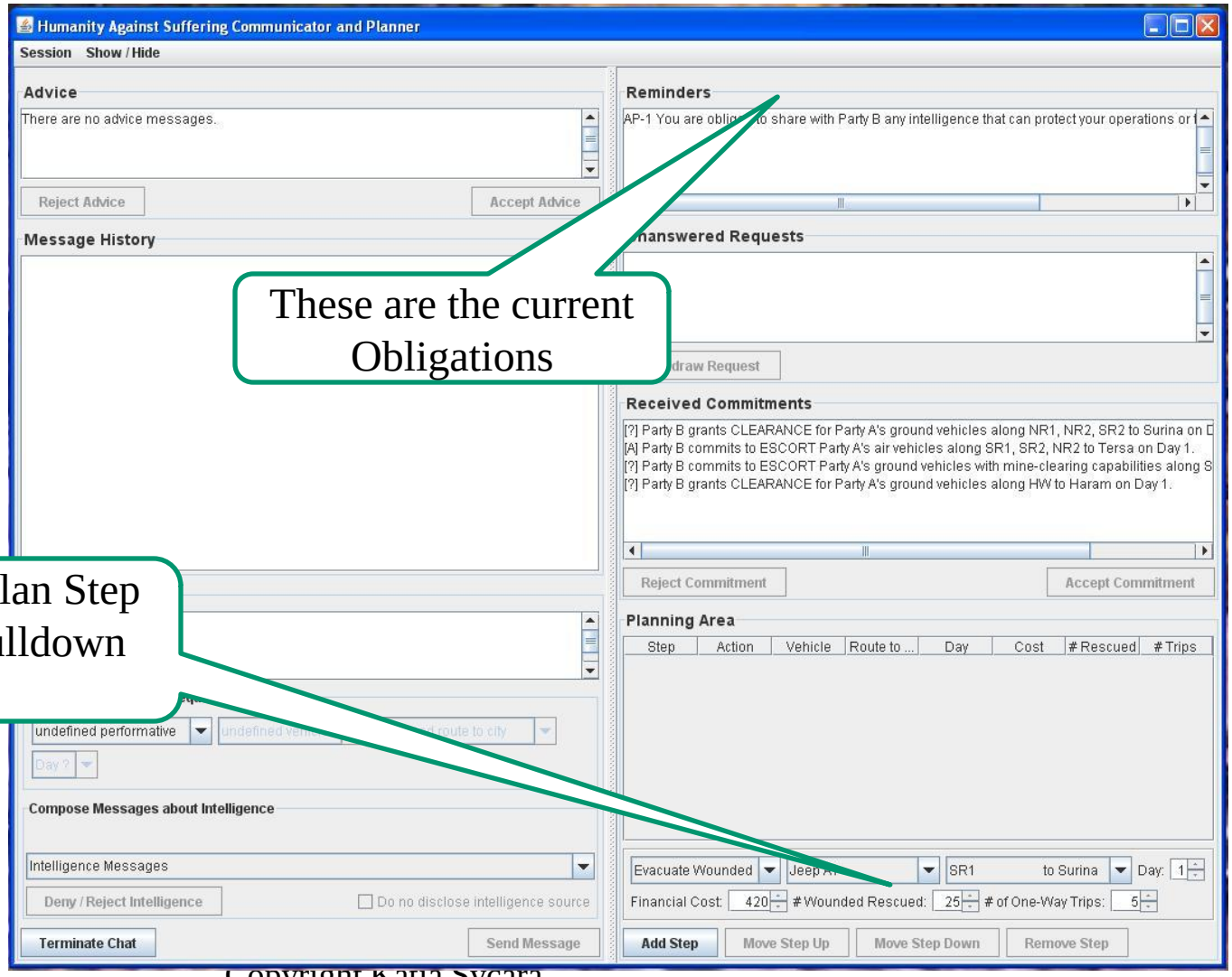
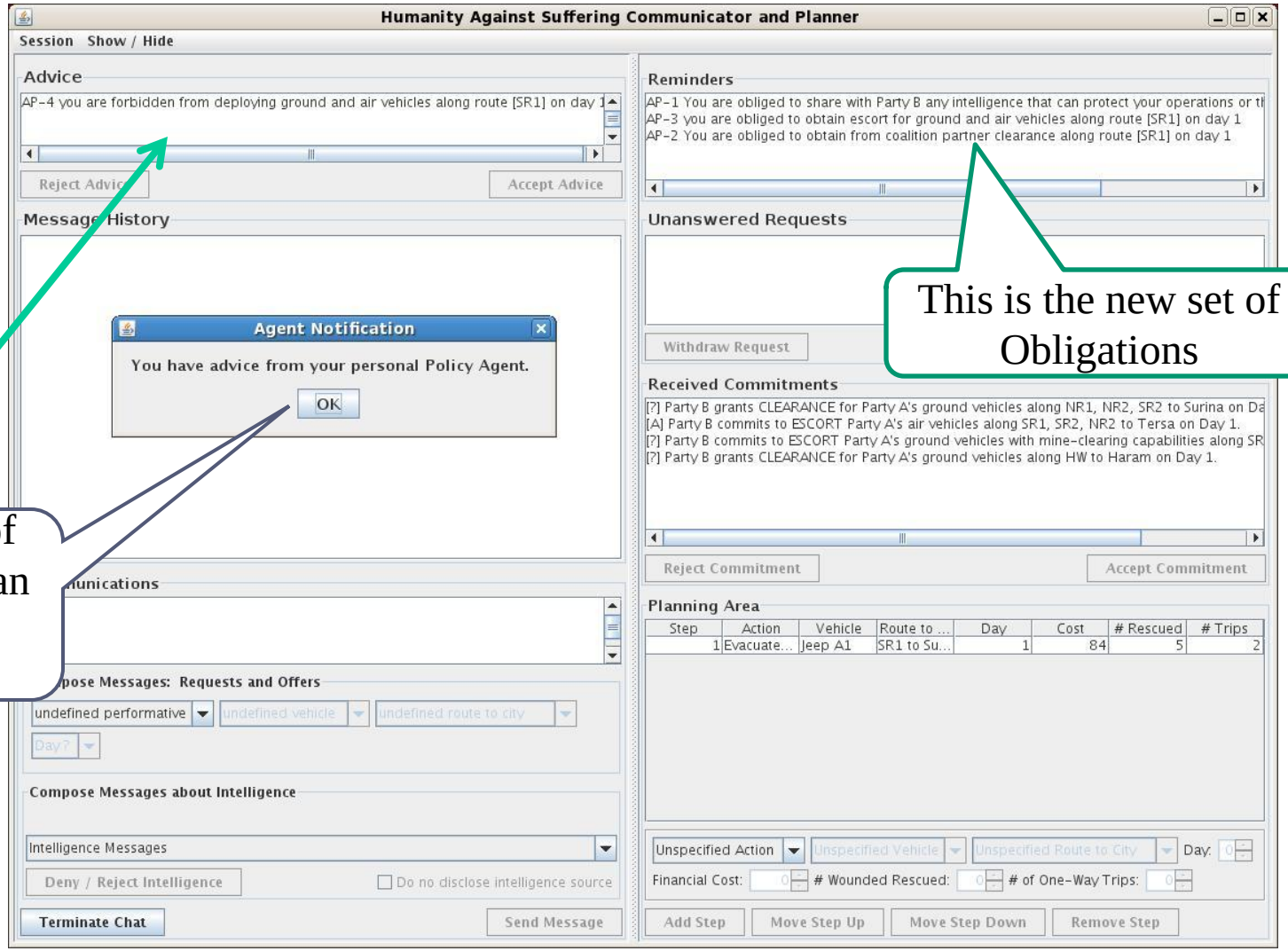
Planning Environment (I)

- Party A is about to enter a plan step ...



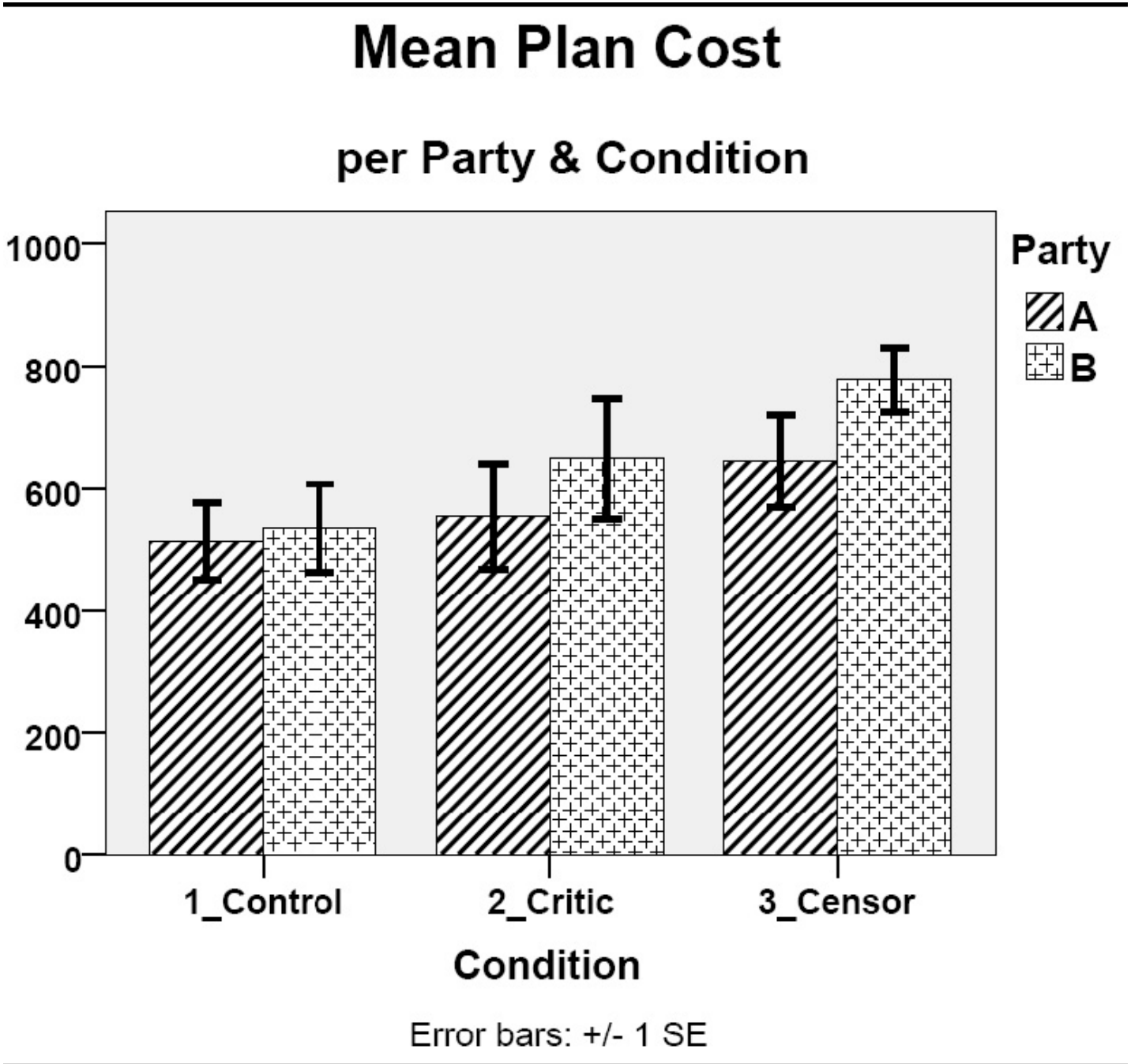
Planning Environment (II)

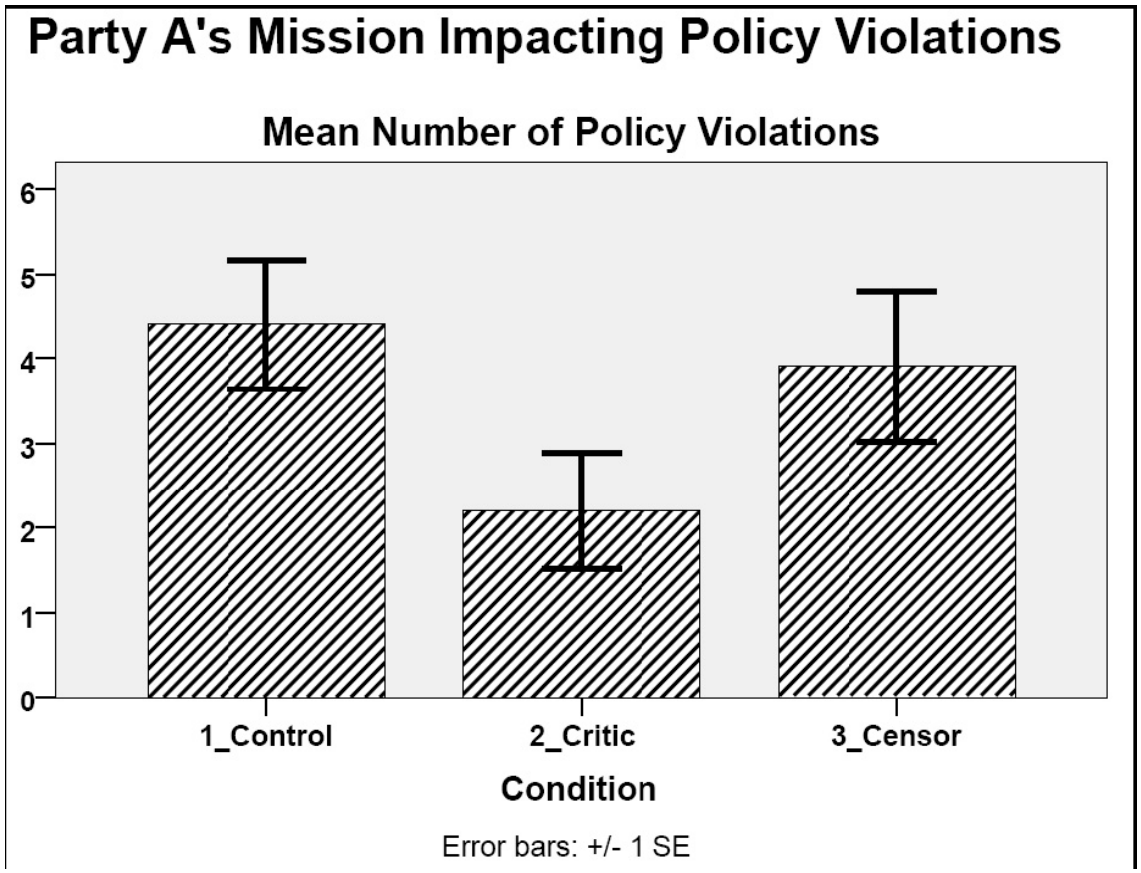
- Agent recognizes Policy Violation and provides feedback
- User has to decide whether to accept



This is the new set of Obligations

Planning Action of the user triggered an advice from the agent


Mean Plan Cost
per Party & Condition
1000
800
600
400
200
0
Party
A
B
1_Control
2_Critic
3_Censor
Condition
Error bars: +/- 1 SE



Results

- Humans make the trade-off between number of norm violations and planning performance – they concentrate on one or the other.
  - Agent assistance seems to reduce the need to make a trade-off decision
- We also observed that users did not rely on the agents to protect them from policy violations

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How Agents might support human teams

- Support domain independent aspects of teamwork in a variety of contexts
- Acting as bridge between stove-piped systems (currently done by humans e.g. Tandem)
- Acting to reduce “the friction of HCI”
  - Cooperative RPA engaged participants in problem solving in the domain rather than in operating the system as the autonomous RPA did
  - Critic agent performed better than censor agent

Challenges in Agent Assistance

- What does an automated assistant need to know to provide reactive and proactive automated distribution of information to the right person at the right time?
  - User task state (where user is in performing the task)
  - User information state (what information the user already has and what he needs)
  - User decision state (what type of decision user must do and how much time is available)
  - User cognitive state (information processing capacity of the user)
- What are effective and computationally efficient strategies for unobtrusive user monitoring? How to recognize when any of user states is changed?
- Decision aids could help address the issue of information overload, and help shared understanding but what is the sweet spot of aiding without taking over?

Open Research Questions

- Mutual Predictability
- Representational mismatches
- Communication
- Trust
- Monitoring
- Interruptability
- Affect
- Mutual adaptation
  - When does a human need help?
  - When does an agent need explication?
- Adjustable autonomy

Cautionary Notes

- Information presentation is a challenging issue: suitable presentation so it does not lead to misinterpretation
- In case of reactive agent assistance there is the potential for users to become “information junkies” asking for more information (since they know they could get it) before they feel they have enough to make a decision

Cautionary Notes

- Speedily sharing the information among all stakeholders both within and across levels of authority and across organizations could induce/exacerbate different interpretations and conclusions rather than produce consensus
- Cultural differences may impede shared understanding

Current Work

- Computational models of cultural factors that affect collaboration and negotiation
- Embody these models into agents that can help humans avoid misinterpretations due to cultural elements

- Consider large scale teams composed of hundreds of humans aided by agents (e.g. large scale disaster relief, network centric military operations)
- We have experimentally observed complex dynamics in such systems
  - How can agents help mitigate harmful effects and promote beneficial ones?
- Exploring a new notion of human cognition, network enabled cognition
  - Role of agent aiding