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ASSESSING MULTI-PERSON AND PERSON-MACHINE DISTRIBUTED DECISION MAKING USING AN EXTENDED PSYCHOLOGICAL DISTANCING MODEL

A. Rodney Wellens, Ph.D.

UNIVERSITY OF MIAMI

FEBRUARY 1990

FINAL REPORT FOR THE PERIOD JULY 1987 THROUGH JULY 1989

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
Armstrong Aerospace Medical Research Laboratory

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A psychological distancing model of telecommunication effects was used in conjunction with an information processing model of decision making to predict the effect of increasing communication "bandwidth" connecting remotely located teams upon group cohesion, information sharing and task performance. The model was expanded to include human-machine interactions and was used to predict increased "psychological closeness" between humans and intelligent machines as the number of communication channels connecting them increased. These ideas were explored within a series of experiments conducted within a simulated C3I environment.

Results showed that increasing communication bandwidth led to increased cohesion between humans, and to a limited extent, between humans and machines. However, increasing communication richness did not always lead to increased situation awareness or task performance. There was an apparent tradeoff between maintaining communication with remote teammates and attending to local task responsibilities. System designers need to consider these tradeoffs when networking people or intelligent machines for collaborative problem solving.

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Preface

This report summarizes research results obtained during the author's University Resident Research Program appointment to the Armstrong Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH, for the period 16 Jul 87 to 15 Jul 89.

The author wishes to thank the Air Force Office of Scientific Research, University Residence Research Program (URRP), for sponsoring this research. Thanks are also extended to the Armstrong Aerospace Medical Research Laboratory (AAMRL), Human Engineering Division, for hosting the project over its two year duration and to the University of Miami, Department of Psychology, for providing an extended leave to pursue the project. Special thanks are given to Mr. Walter C. Summers, Chief, Technology Integration Office, for extending the original invitation to participate in the program and to Mr. Donald L. Monk, Program Manager for the C^3 Operator Performance Engineering (COPE) project and Lt Col William P. Marshak, Chief, Crew Station Integration Branch, for providing space and operating funds at AAMRL. Thanks are also extended to Mr. William McGovern (experimenter), Mr. Greg Bothe (engineering), Dr. Clifford E. Brown (experimental design consulting), Dr. Deniz Ergener (software), Mr. Curtis Mayrand (software), Mr. Jim Ryerson (software) and Mr. Kevin Holloran (subject recruitment) for their substantial contributions to the project. Finally, the author wishes to thank his wife, Lynda Eager, and children, Marci and Mike, for the kind of continued support only a loving family could provide.

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Introduction

There has been a long history of research dealing with groups and group decision-making (Steiner, 1972; McGrath, 1984). However, this research has traditionally studied groups in face-to-face settings and concentrated on how groups reach decisions on relatively well-defined tasks. There has been relatively little work done on groups whose members are geographically dispersed and must depend upon telecommunication media to function effectively (Short, Williams & Christie, 1976; Johansen, Vallee & Spangler, 1979). There has been even less systematic study of how these groups maintain a common "big picture" when their members are concentrating on different aspects of a problem in different locales. Virtually unstudied are groups whose members include one or more intelligent machines that can automatically respond to events without human intervention (Wellens & McNeese, 1987). With the increased use of telecommunication media and sophisticated computer aides in support of advanced military and civilian decision-making systems, it is important to understand what group communication factors may ultimately affect future system performance.

The present research effort studied multi-person and person-machine decision-making within a telecommunications environment designed to facilitate information sharing among group members who were physically isolated from one another. The research was conducted within the context of an established C^3 Operator Performance Engineering (COPE) project at the Human Engineering Division of the Armstrong Aerospace Medical Research Laboratory (AAMRL), Wright-Patterson Air Force Base, Ohio. The objective of COPE was to improve USAF command, control and communication (C^3) systems by developing design guidelines based upon the performance of humans and machines as information processors and decision makers. Members of the COPE research team have provided command post modeling and design services to various government agencies including NASA and NORAD.

Project Objectives

The research proposed for the author's first URRP year in residence included (1) the integration of a new situation assessment task into the family of COPE performance studies used at AAMRL, (2) the development of a multi-media observation system for AAMRL and (3) the creation of a human-intelligent machine study based upon laboratory observations made of human-to-human communication patterns during situation assessment and cooperative problem solving tasks. The research proposed for the second URRP year focused upon person-machine interactions to (4) determine the extent to which the author's "psychological distancing model" of telecommunication effects would extend to human-intelligent machine interaction.

Paradigm Development

Given the multi-objective nature of the proposed research, it was important to develop a research paradigm flexible enough to allow the examination of human-to-human and machine-to-human interaction within the same context. It was also important to develop a theoretical framework broad enough to capture relevant variables in both domains. The following section outlines the conceptual and physical components of the experimental paradigm that was developed.

Theoretical perspective

An eclectic theoretical approach was taken that borrowed from Wohl's (1987) information processing model of decision-making, Wellens (1986) psychological distancing model of telecommunication effects, and Wellens and McNeese's (1987) analysis of human-intelligent machine interactions. Figure 1 outlines the major components of the information-processing model used. A group's "information space" contains historical data as well as current events that impinge upon the group from multiple sources. "Situation space" represents a commonly held "big picture" formulated by the group after examining its information space. "Action space" represents the behavioral options available to the group for affecting environmental

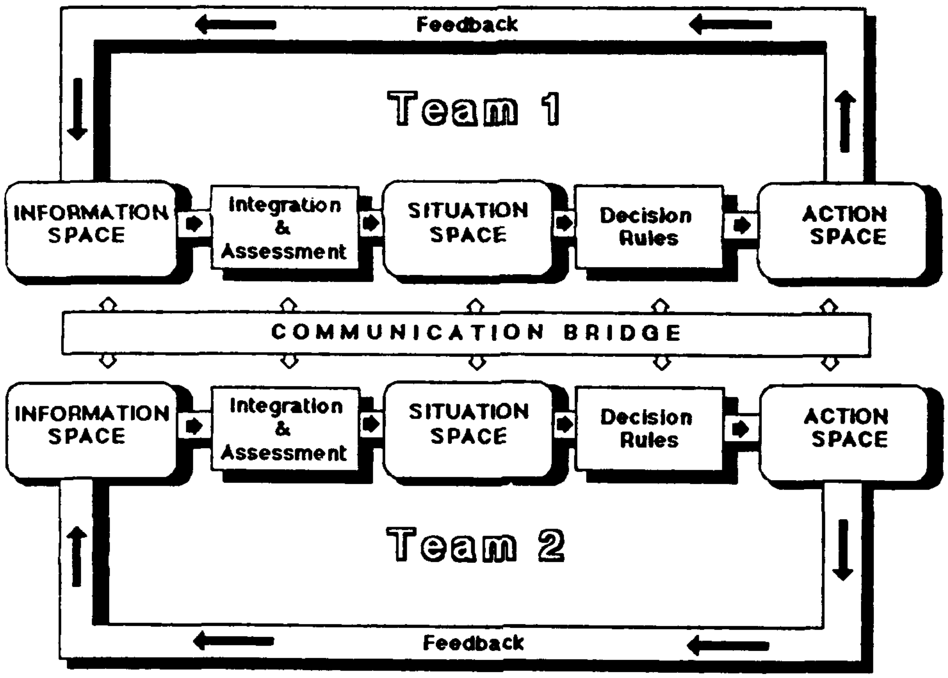

Figure 1. Extension of Wohl's (1987) information processing model of decision-making.

events. Actions taken by the group and the resulting effect on the environment are assessed as "feedback" to the group's information space and further adjustments are made accordingly. When two or more groups attempt to work on a problem in unison, a communication bridge is necessary for them to share raw data, points of view and actions taken.

Figure 2 shows the "psychological distancing" model's conceptual ordering of various telecommunication media used to provide a bridge between decision making groups. As one moves from the informationally rich face-to-face situation to the informationally lean computer messaging situation, the number and type of sensory channels available for information exchange is reduced. The model assumes that as the number and variety of available communication channels is reduced, communication

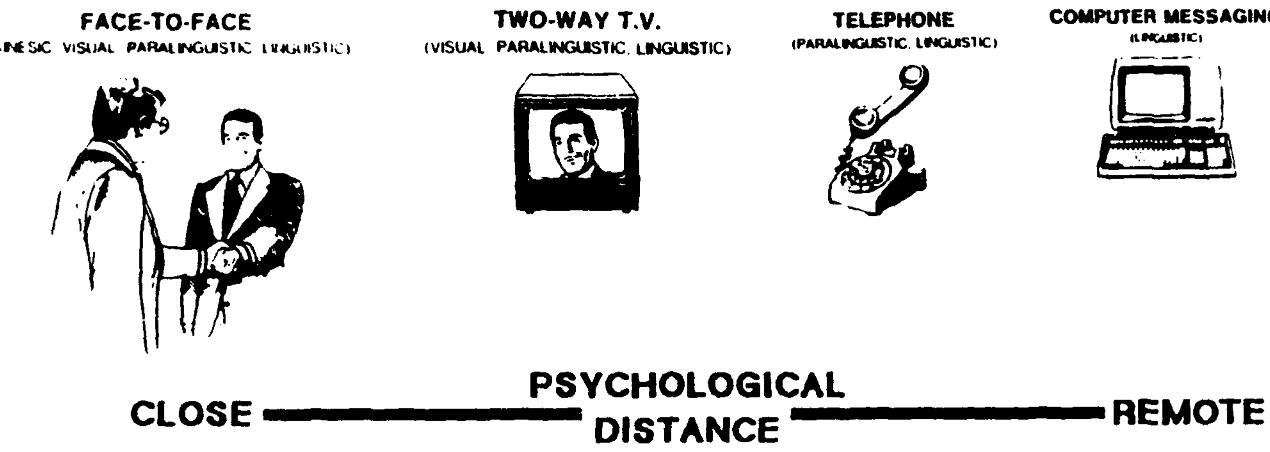

Figure 2. Conceptual ordering of media according to Wellens (1986) psychological distancing model.

style becomes less spontaneous and flexible, feedback becomes slower and interactants feel more psychologically remote. It was assumed in the present study that as team members were made more psychologically remote, their ability to form a common "big picture" would be reduced and overall performance would suffer. This was predicted to hold true whether the remote team was comprised of humans or made up of an expert system designed to emulate human behavior.

Task description

The C^3 Interactive Task for Identifying Emerging Situations (CITIES), was developed by the author under an earlier AFOSR/RIP contract (Wellens, 1987) to examine situation assessment issues in group settings. It allows for the independent control of a team's information space, situation space and action space. CITIES has been described in detail elsewhere (Wellens & Ergener, 1988) and will only be briefly summarized here.

CITIES is a microcomputer-based (Apple IIe and IIc) functional simulation of a emergency dispatch center where information is constantly being received from multiple sources by members of separate semiautonomous teams. Police and fire dispatchers must allocate limited resources to simulated emergency events via touch screens placed in front of computer-generated maps. The police dispatcher responds to events that require police or tow truck resources while the fire dispatcher responds to events requiring fire or rescue resources. Resources correctly assigned to events have the effect of reducing the intensity of the events which would otherwise grow in strength. Team performance is assessed by a numeric index that takes into account the speed and appropriateness with which resources are assigned to events. The pacing, distribution and interdependence of events to which teams must respond is determined by programmed event scenarios. In order to develop a common "big picture" and coordinate activities, police and fire teams must share information and develop response strategies. The channels of communication made available for exchanging information between teams is determined by the experimenter.

Figure 3 shows a typical CITIES map as seen by a fire dispatcher. The number of available fire/rescue resources are displayed in the middle of the screen along with their symbolic icons. Active fire and rescue events are indicated by flame and person icons displayed in various regions of the city. Allocated resources are displayed below the event icons. Resources may be moved about the map regions via the dispatcher's touch screen. A feedback bar at the top of the screen displays the combined intensity levels of all active events within the fire dispatcher's domain. The map used by the police dispatcher is similar in appearance, however, it displays only police and tow events while the fire dispatcher's map displays only fire and rescue events. Figure 3 also shows the various information screens that may be accessed by dispatchers via their touch screen displays. Detailed information regarding all events, regions and resources can be instantly displayed by touching the appropriate section of their display screen.

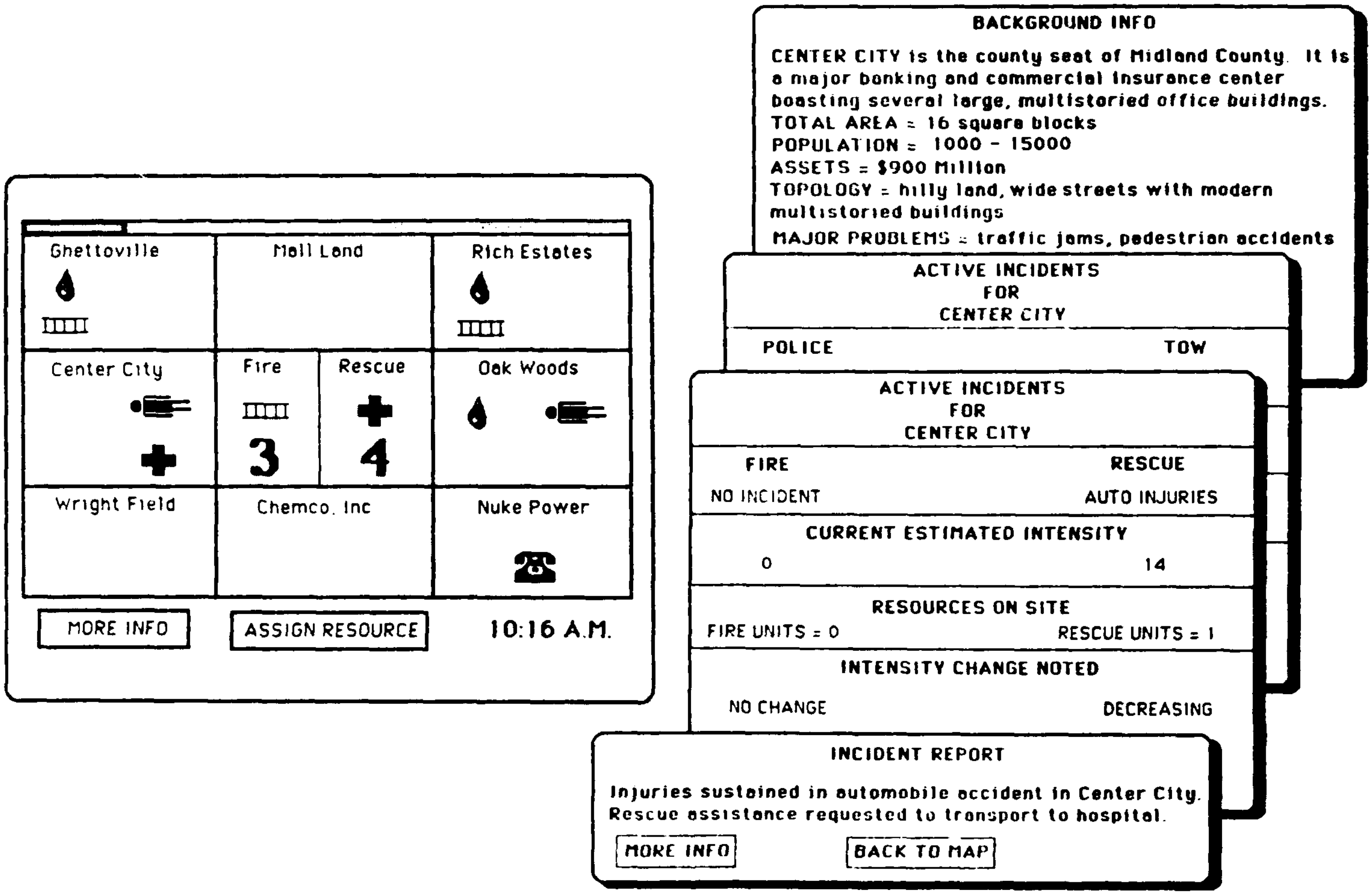

Figure 3. CITIES map and information screens available via dispatcher's touch-screen display.

Two game scenarios were written for CITIES that allowed several opportunities to observe information transfer and coordination of activities between teams. The original scenario used in CITIES (the "Visiting Senator" scenario) gave police teams advanced warning of events that they could share with fire teams to increase situation awareness and improve team performance. This information came in the form of a written itinerary of a visiting senator's planned movements around the city. As the scenario unfolds, disasters follow the senator's route. Fire teams were probed post-experimentally to see if they received and used police information in forming a successful strategy. This scenario took 30 minutes to complete and provided one opportunity to measure task performance. To improve upon this approach, a second scenario was written (the "Three Waves" scenario) that was composed of three successive crises, each balanced with respect to event intensity and pacing. Each crisis began with a police event and reached its zenith with a large fire or rescue event. Fire teams could preassign resources to avoid disaster if the police team issued them appropriate forewarnings. This scenario involved three consecutive twenty-minute episodes and yielded three opportunities to measure task performance within each team per experimental session. This made more efficient use of subject and experimenter time and provided a more powerful method of comparing media differences on collaborative problem solving activities.

Software development. In order to integrate the CITIES task into the family of proposed COPE performance studies dealing with automated systems, additional software development was undertaken. First, a rule-based expert system was written that emulated the ideal CITIES dispatcher. The system was written to automatically respond to all events reported to a particular dispatch center by first choosing the appropriate information screens needed to decide how many resources to allocate to the event. The system would then dispatch the needed resources. The system continuously monitored all events within its jurisdiction and recalled and reassigned resources in order to minimize overall event intensities.

Second, a message generator program was developed that scanned each event being processed by the expert system. The message generator compared each event against a critical list of events that would indicate needed involvement from another dispatcher. If a match was made, then a message was sent to the remote team requesting needed resources (e.g., "I have a fire event in Center City. Please send assistance."). Depending upon which communication mode was selected by the experimenter, the message generator would send messages using computer-generated text or digitized speech accompanied by a dynamic computer-generated graphic of a human head. Figure 4 shows a representative sample of the graphics used to generate one of the animated "talking heads." Both a male and a female version of the talking head were developed using a male and a female model who provided voice samples and posed for six different head positions each. When delivering a message, the digitized head would rotate its face forward, simulate eye contact with the subject, and move its mouth in synchrony with the digitized speech.

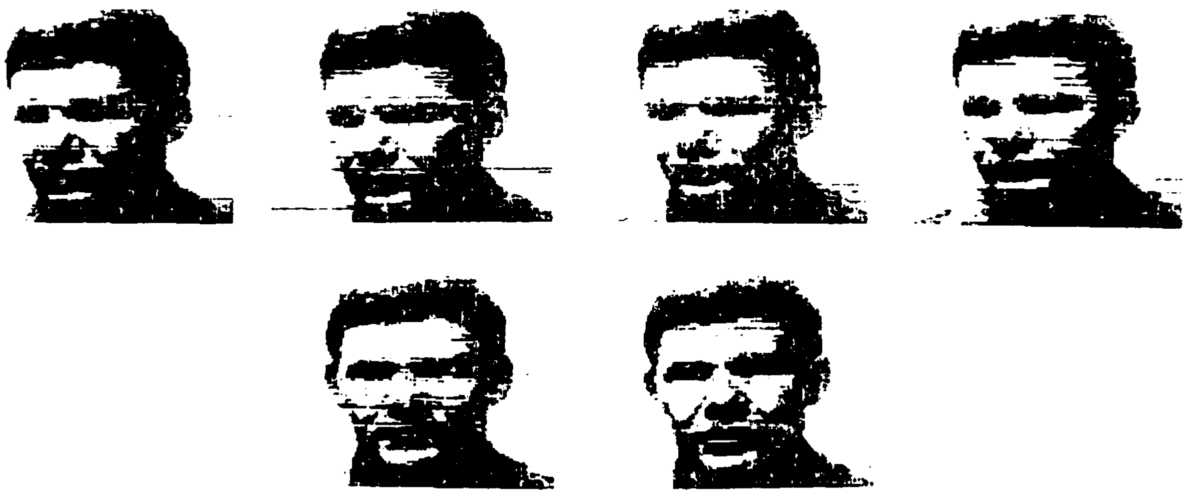

Figure 4. Graphics used to generate one of the computer-animated "talking heads."

Combining the expert system and message generating system represented the operationalization of an "intelligent machine system" within the context of the CITIES task. Having messages delivered by either computer text or by "talking head" represented a manipulation of the communication bandwidth connecting the system to human participants.

Hardware development. In order to create an environment within which to study multi-channeled human-to-human communication, a multi-media observation system was also developed. The system was patterned after one described by Wellens (1979, 1987) and consisted of two isolated work-station rooms electronically linked to one another via a central control room. Figure 5 provides an overview of the room layouts and details of the control room and dispatch workstations. The central control room contained a series of audio and video mixers, video recording equipment, automatic speech detection equipment as well as a series of Apple II microcomputers networked to present stimuli and record responses. A single selection switch allowed the experimenter to choose which of several communication channels (computer messaging, audio intercom, two-way television) would be used to link subjects located in the isolated work-station rooms. All verbal communication between teams was monitored by speech detection circuits that automatically recorded the amount of time each team member talked. A special split screen computer messaging system (Ergener & Wellens, 1985) simultaneously displayed messages typed by each team member and automatically recorded all characters and communication times. A special video recording system (Ergener & Wellens, 1989) recorded each team member's face as well as the computer screen to which he was attending for all experimental sessions. This system also recorded subjects' heart rate during experimental sessions. However, the equipment used to measure this physiological response proved less reliable than anticipated resulting in a data set too small to analyze here.

Figure 5 also shows one of the work-station rooms consisting of a central "two-way" television monitor (Wellens , 1978), headphones with a noise canceling microphone, a keyboard used for sending computer text messages and two additional task display monitors equipped with touch screens. The desktop "two-way" television monitor, detailed within the center portion of the workstation blowup, was designed to display messages from the other workstation site while unobtrusively capturing a full face color view of the subject for video recording. The monitor to the left of the two-way monitor displayed the dispatcher's CITIES map. The monitor to the right of the two-way monitor was added for a followup experiment and displayed the CITIES map being used by the remote team.

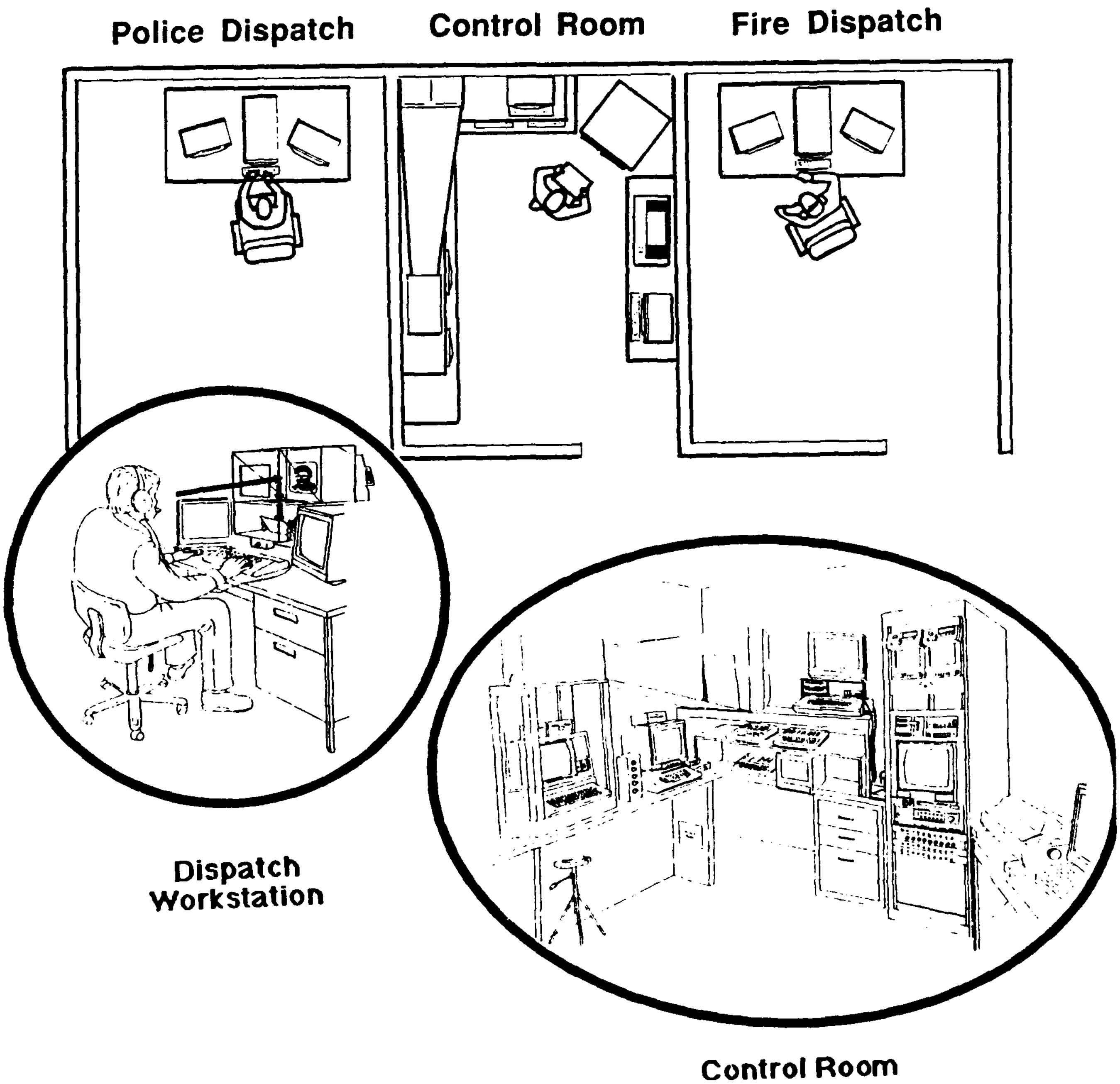

Figure 5. Overview of room layouts with details of dispatcher workstations and control room used in CITIES experiments at AAMRL.

Empirical Observations

Two experiments were conducted using the newly constructed media facility and modified CITIES software. The first experiment focused upon human-to-human telemediated interactions and the second focused upon intelligent-machine to human interactions. Both were concerned with how the channels of communication linking intelligent entities would affect feelings of "teamness" (i.e., psychological closeness), information sharing and task performance.

Experiment 1

The first experiment examined the effects of the telecommunication media used to link hybrid teams comprised of humans and automated machine assistants. One hundred male subjects, recruited from local university campuses, were trained in CITIES procedures. Half of the subjects were randomly assigned to perform the duties of a police dispatcher and half were assigned the duties of a fire dispatcher.

Subjects reported to the laboratory individually and met for the first time over the telecommunications media to which they had been randomly assigned. Four telecommunications conditions were initially compared: computer messaging, audio intercom, two-way television and a no communication control. Ten 2-person/machine teams were assigned to each condition. A fifth, face-to-face condition, was added later as an additional control group. Within the latter condition, subjects sat side-by-side at a single workstation table using separate touch screen displays.

After being exposed to a computerized instructional program designed to teach them CITIES procedures, each dispatcher was given two five-minute practice sessions. One session had them manipulate CITIES resources manually while the other exposed them to the automated dispatch system. When the automated system was turned on it responded to scenario events assigned to the dispatch center by first displaying all the necessary information screens describing the nature and intensity of the event and then assigning the appropriate number of resources. The automated system was developed to allow subjects to concentrate on forming strategies with remote teammates rather than focusing upon the mechanical aspects of the task. Within this initial version of the expert system, no explicit messages were sent from the system to remote teams. The human member of each dispatch team could monitor and override the system at any time using his CITIES map and touch screen. This was encouraged when the human member of the team could anticipate events and preassign resources to appropriate regions.

After the instructional period and two practice sessions, subjects who were assigned to one of the communication conditions were shown how to use the communication equipment. They were then given two minutes to introduce themselves to their human teammate located at the other dispatch center and discuss any strategies they wished to use during the CITIES scenario. Subjects were then exposed to the "Visiting Senator" scenario described earlier.

Immediately following the half-hour experimental session, the communication system was turned off and each subject completed an extensive post-experimental questionnaire that assessed their attitudes toward their remote human teammate, the automated system and the communication system provided. These attitudes were measured using a series of 5-point bipolar adjective scales. The questionnaire also queried subjects to see if they had established any connection between events during the scenario. If they correctly perceived a connection between emergency events and the movement of the senator around the CITIES map, they were considered to be situationally aware.

Following each experimental session, verbatim transcripts were created that listed all communications that occurred between team members. These transcripts were examined for message length (number of words) and the presence of situation awareness information (any mention of the visiting senator's itinerary). Computer records of team performance were also examined to determine the relative effectiveness of each team in relation to the scenario events. Dependent variables were submitted to separate one-way analyses of variance (ANOVAs) to determine the significance levels associated with each effect observed.

Results of Experiment 1 are summarized in Figure 6. The upper left portion of Figure 6 shows the average ratings of "teamness" reported by subjects exposed to each communication condition. As predicted, the perceived "teamness" reported between remote human teammates systematically increased from the no communication control condition through the keyboard (computer messaging), audio and two-way television conditions. A small (nonsignificant) dip in felt teamness occurred in the face-to-face condition. Identical patterns were observed for subjects ratings of trustworthiness and liking for remote teammates.

The upper right portion of Figure 6 shows the average number of words exchanged between remote teammates as derived from session transcripts. This figure shows a systematic increase in the number of words exchanged between remote teammates as communication bandwidth increased from the keyboard through two-way television conditions. An unexpected drop in verbal activity occurred in the face-to-face condition. This was attributed to subjects being able to directly observe what the teammate was doing during the CITIES scenario, thus decreasing the need to verbally communicate.

The lower right portion of Figure 6 shows the percent of police and fire teams in each communication condition correctly reporting a connection between the senator's movements and emergency events (expressed as percent "situationally aware"). It was expected that all police teams would be situationally aware, since all had the information needed to perceive the connection was directly in front of them. Fire teams, who were dependent upon police teams to pass the critical itinerary information to them, were expected to increase in situation awareness as communication bandwidth increased. Figure 6 shows an unexpected decrease in

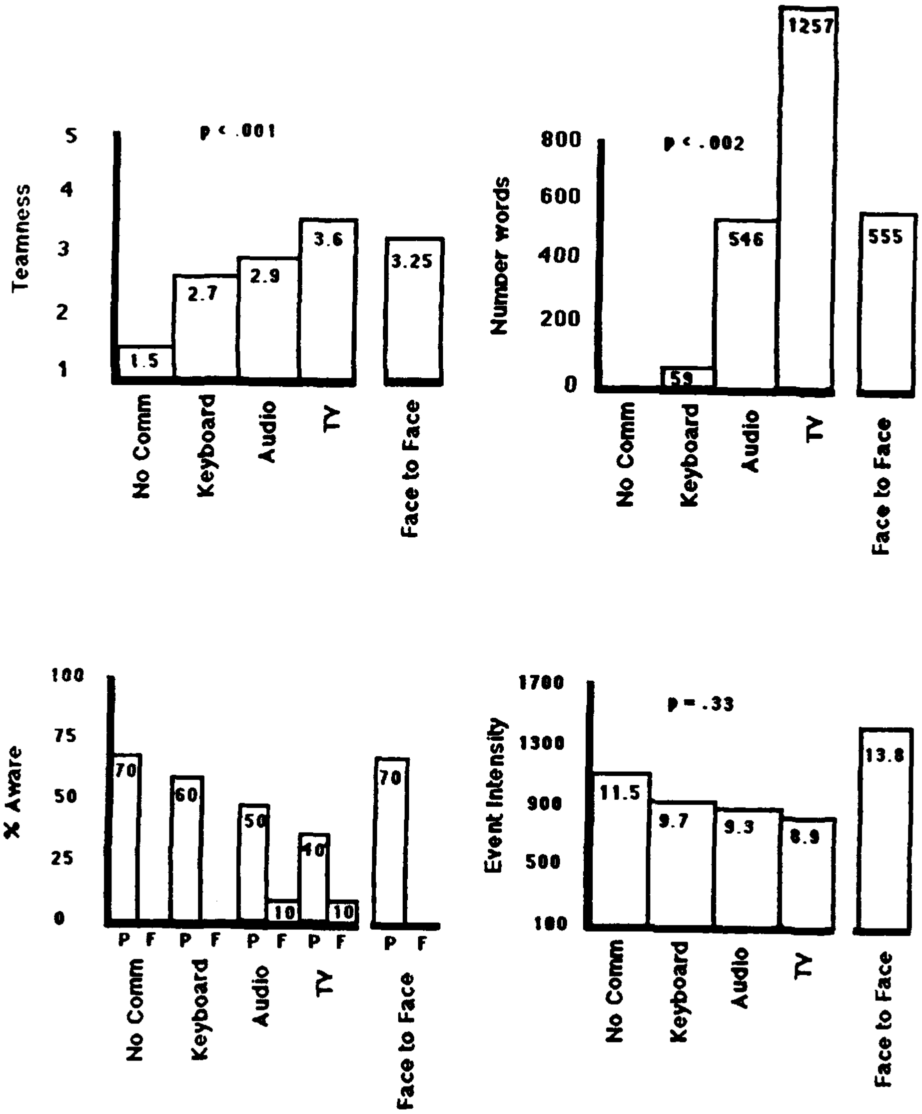

Figure 6. Summary of results from Experiment 1.

situation awareness on the part of police teams as communication bandwidth increased from no communication through two-way television. Fire teams showed only a small increase in situation awareness in the audio and two-way television conditions. The face-to-face condition showed a remarkable similarity to the no-communication control condition. Examination of communication transcripts revealed that the percent of police teams passing critical information to remote teammates increased from the keyboard (50%) to audio (90%) and two-way television (100%) conditions. This decreased slightly in the face-to-face (80%) condition. It would appear that the amount of time taken to transmit critical information to fire teams in the various media conditions detracted from the police teams' ability to use the information themselves in formulating a connection between events.

The lower right portion of Figure 6 shows average team performance scores by communication condition. The total accumulated event intensities summed across the entire CITIES scenario is inversely proportional to the efficiency with which teams applied resources to events. Thus, the higher the intensity rating the poorer the performance. As can be seen, there was a modest trend toward improvement in overall performance as communication increased from the no communication control through the two-way television condition with an unexpected reversal in the face to face condition. However, none of the observed differences in performance scores reached statistical significance.

Figure 7 shows the average reported satisfaction ratings of subjects toward the communication systems used. Subjects were significantly more satisfied with audio, two-way television and face-to-face conditions than with the no communication and keyboard messaging conditions. The deciding factor in these satisfaction ratings appeared to be the presence or absence of an audio channel linking remote teams.

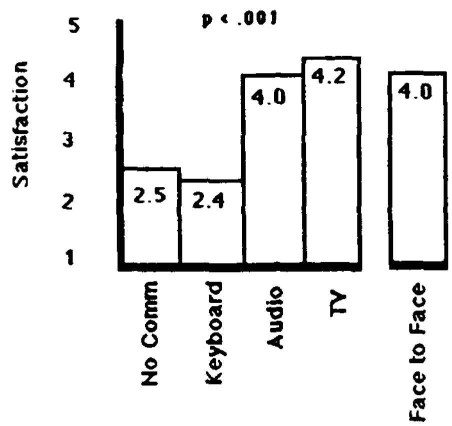

Figure 7. Average satisfaction ratings of subjects toward telecommunication media used in Experiment 1.

The results of Experiment 1 showed good support for the psychological distancing model regarding increases in team feeling and information sharing as media bandwidth increased from no communication, to computer messaging, audio and two-way television. The face-to-face condition was qualitatively different from the other conditions in that team members could directly observe each other's actions and relied less on verbal communication. This led to an unanticipated decrease in the exchange of explicit situation assessment information in the face-to-face condition. Also unanticipated was the apparent tradeoff between the forwarding of critical information on the part of police teams and the ability of these teams to form connections between this information and ongoing events. Examination of the awareness information in Figure 6 suggests that modest gains in situation awareness on the part of remote (fire) teams was generally bought at the expense of decreased awareness on the part of originating (police) teams. The result was no significant increase in performance as a function of communication bandwidth condition.

Experiment 2

The second experiment examined the effects of the telecommunication media used to link humans with a remote intelligent machine system. This experiment employed the expanded expert system described earlier that utilized a message generating system to communicate with remote teams regarding needed resources. The expert system simulated the ideal remote police dispatcher in that it could communicate situation assessment information with 100% reliability without detracting from its own performance. This was accomplished by using parallel processors to work on resource assignments and message generation simultaneously. The expert system handled all police/tow events while the subjects handled all fire/rescue events. The second experiment also utilized the newly developed "Three Waves" scenario, thus reducing the number of subjects needed.

Thirty-six male subjects were recruited from local university campuses. Subjects reported individually to the laboratory on two separate occasions separated by a one week interval. The first appointment consisted of a training session involving the computerized instructional program plus one-half hour of practice as a fire dispatcher using the "visiting senator" scenario. At the end of the first session subjects completed a post session questionnaire and several personality measures that were part of a related study that attempted to isolate individual difference variables that affected CITIES performance. The second session consisted of a review of the computerized instructional program plus three five-minute practice sessions that exposed the subjects to the three different communication conditions used by the remote expert system.

All subjects were exposed to each of three communication conditions: computer messaging, talking head, and no communication control. The order in which these three conditions appeared in the Three Waves Scenario was rotated between subjects according to a Latin square design. Half of the subjects depended entirely upon the message generating system for any contact with the remote electronic teammate. The other half could continuously monitor the remote teammate's actions by way of a second television monitor that displayed the remote dispatcher's CITIES map as well as all information screens being used by the expert system in assigning resources. The latter condition was similar to a "face-to-face" condition in that subjects could look "over the shoulder" of the expert system without waiting for it to communicate directly. An additional between-subjects variable consisting of the "sex" of the electronic teammate (i.e., male vs. female digitized head and male vs. female digitized voice) turned out to have little affect on subjects' perceptions and performance and will not be reported here.

Immediately following each "crisis wave" within the Three Waves Scenario, subjects were asked to complete a questionnaire that assessed their attitudes toward the remote expert system and the communication system provided. Subjects were also asked to estimate the percent of time they were able to preassign response to events. Computer records were examined to determine the effect of communication condition upon team performance. Dependent variables were submitted to separate ANOVAs to determine the significance levels associated with each effect observed.

Results for Experiment 2 are summarized in Figure 8. The left portion of Figure 8 shows subjects' average ratings of teamness with regard to the remote electronic partner as a function of communication condition. As predicted, there was a significant increase in felt teamness between the no communication control and the two remaining communication conditions. Unexpectedly, however, there was no difference between the computer text condition and the talking head condition. Identical trends were found for subjects' liking for and trustworthiness of the remote system.

The center portion of Figure 8 shows the degree of subjects' reported ability to preassign resources to regions in advance of events occurring. This is an indirect measure of successful situation assessment. Results showed a significant effect for communication condition, with the no communication control condition resulting in less ability to preassign than the remaining two conditions. The lower right portion

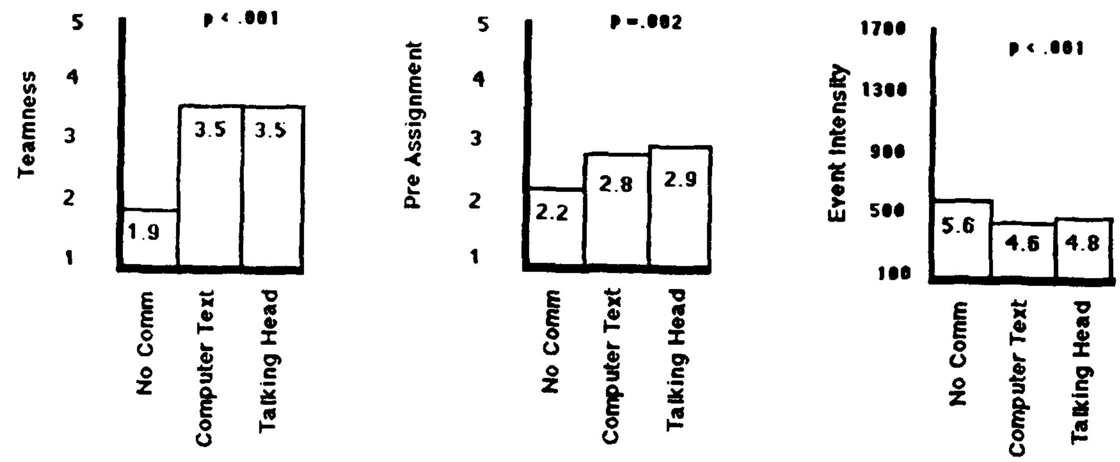

Figure 8. Summary of results from Experiment 2.

of Figure 8 shows team performance as a function of communication condition. Accumulated event intensity was highest (performance poorest) under conditions of no communication as compared to the remaining two communication conditions.

In order to test the effects of "looking over the shoulder" of the expert system, separate ANOVAs were conducted upon the data for subjects assigned to the "messaging only" condition versus the "second CITIES map" monitor condition. Results for the "messaging only" subjects conformed to those already reported for the combined data. Results for the second CITIES map or "over the shoulder" group were also the same as the combined data for subjects' estimates of teamness and reported liking and trustworthiness of the remote system. However, unlike the "messaging only" condition, the "over the shoulder" group showed no significant differences between the two messaging conditions and the no communication condition for preassignment estimates and performance scores. This pattern of means suggested that subjects who had access to the second CITIES map were able to preassign resources and thus improve performance independent of the formal messages sent by the remote system.

Figure 9 shows the average satisfaction ratings of subjects toward the three communication conditions used by the expert system. As can be seen, the no communication control condition produced the least amount of satisfaction, with the computer text and talking head generating the most satisfaction. Subjects were also asked to list the positive and negative features of each communication condition. The most frequently listed attributes are summarized in Figure 10. Subjects found the audio portion of the "talking head" to be useful in that they could continually monitor their CITIES map while listening to incoming messages. Unfortunately, the digitized voice was sometimes difficult to understand and detracted from this condition. On the other hand, computer messaging produced clear, easily read messages, but required the subjects to divert their eyes from the CITIES map in order to read them. Finally, subjects appreciated not being disturbed in the no communication condition, but recognized this meant a corresponding loss of information that could have helped them anticipate events and improve their performance.

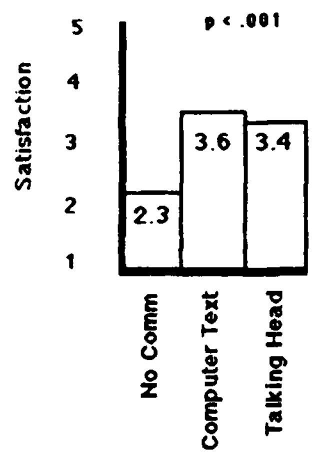

Figure 9. Average satisfaction ratings of subjects toward the expert system communication systems used in Experiment 2.

	Positive	Negative
Talking Head	*Could listen and still look at event map*	*Hard to understand voice*
Computer Text	*Easy to understand*	*Had to look away from map to read*
No Communication	*Not disturbing*	*Couldn't anticipate events*

Figure 10. Most frequently mentioned positive and negative features of communication media used in Experiment 2.

Results of Experiment 2 supported the idea that machine-to-human communication can be used to increase cohesion between humans and intelligent machines and to promote human-machine team performance. Unexpectedly, however, it was found that increasing the bandwidth of communication (computer text vs. talking head) had no apparent additional benefit above that obtained through minimal machine-to-human contact. Analyses of subjects reactions to each communication condition suggested that there were both positive and negative features associated with each communication condition that may have canceled out any net gain expected in the broad bandwidth condition.

Conclusions

The author's psychological distancing model of telecommunication effects was used in conjunction with an information processing model of decision-making to make predictions regarding the effects of various telecommuncation media upon group cohesion, information sharing and task performance. Within Experiment 1 the model correctly predicted an increase in felt "teamness", liking and trustworthiness for remotely located teammates as the communication channels used to connect them widened. The model also correctly predicted a significant increase in information sharing as communication bandwidth increased across telecommunication media. However, the model failed to take into account variables such as increased attentional demands associated with increased communication bandwidth in predicting task outcomes. These additional variables may have contributed to the unexpected decrease in situation awareness in some teams and no overall gain in team task performance observed as communication bandwidth increased.

Within Experiment 2 the distancing model correctly predicted greater feelings of "teamness", liking and trustworthiness for a remote electronic teammate when the remote system included a communication link. However, the model incorrectly predicted an increase in human-machine cohesion as the communication link between machine and human widened. Broadening the communication link connecting an intelligent machine to a human partner appeared less potent than widening the communication link connecting two humans.

From a theoretical perspective, comparing how "communication bandwidth" was manipulated within Experiment 2 with how it was manipulated within Experiment 1 suggests a number of potentially important variables for future study. Thus, within Experiment 1, widening the communication bandwidth between two human teammates meant increasing information flow in two directions. Within Experiment 2, the remote expert system could only transmit information, not receive it. Thus, Experiment 2 dealt with one-way communication while Experiment 1 dealt with two-way communication. In addition, within Experiment 1 the number of messages transmitted between teammates varied as a function of media type. Some media appeared to facilitate message generation while others did not. However, within Experiment 2 the electronic teammate transmitted the same number of 100% reliable messages in both the narrow and broadband communication conditions. Future applications of the distancing model should differentiate between unidirectional and bidirectional communication as well as between increased communication bandwidth opportunities and actual communication channel use.

From an applied perspective, the current series of experiments suggested that "more is not necessarily better" when it comes to building a communication system or computer aide. Adding increased communication capacity beyond that which is minimally needed to accomplish a task may not only fail to increase group performance, but in some cases may even serve to decrease performance. It is clear that communication processes consume time and cognitive resources. It has also become clear that global situation awareness does not occur spontaneously in networked groups; it takes time and effort to accomplish. In designing C^3I systems, a balance needs to be achieved between drawing decision makers together for exchanging critical information and leaving them alone to concentrate on other task goals.

The development of CITIES, together with its supporting computer and communication technologies, has been a useful exercise in C^3I simulation. Having the ability to manipulate variables such as time stress and information uncertainty in addition to communication channel capacity within a controlled laboratory setting provided an attractive adjunct to field studies of command post functioning. The generic nature of the CITIES task together with its scenario-driven presentation format, makes it a good candidate for future studies of both military and civilian decision-making processes.

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List of Project Publications and Reports

The following articles were written while the author was supported on the URRP appointment described in this report:

Ergener, D., & Wellens, A. R. (1989). DataVision: A computer-based system for generating and reading digital information accompanying video images on videotape. *Behavior Research Methods, Instruments and Computers,* 21, 401-407.

Wellens, A. R. & Ergener (1988). The C.I.T.I.E.S. game: A computer-based situation assessment task for studying distributed decision making. *Simulation and Games,* 19, 304-327.

Wellens, A. R. (1989). Effects of telecommunication media upon information sharing and team performance: Some theoretical and empirical observations. *IEEE Aerospace and Electronic Systems Magazine,* 4, 13-19.

Three additional technical memoranda were written in support of the project and are being put in appropriate format for publication:

Bothe, G. & Wellens, A. R. (1989). A simple speech detection circuit for conversational analysis.

Ryerson, J. & Wellens, A. R. (1989). A multi-windowed computer messaging program for the Amiga computer.

Ryerson, J. & Wellens, A. R. (1989). A software-based DataVision decoder for the Amiga computer.

The following oral reports were delivered while the author was supported on the URRP appointment described in this report:

Wellens, A. R. (1988). Social presence in human and intelligent machine interaction. Presented at the Society of Experimental Social Psychology Meeting, Madison Wisconsin, 22 October.

Wellens, A. R. (1989). Effects of telecommunication media upon information sharing and team performance: Some theoretical and empirical observations. Presented at the IEEE National Aerospace and Electronic Conference, Dayton, Ohio, 25-27 May.

Wellens, A. R. (1989). Electronic networking and group interaction: Effects of communication bandwidth upon information sharing and team performance. Presented at the 6th International Conference on Interaction Process and Analysis, Nags Head, N.C., 26 June - 1 July.

The following additional reports have been proposed or scheduled for presentation:

Wellens, A. R. (1990). Group situation awareness and distributed decision-making. To be presented at a symposium on "Naturalistic Decision-Making" during the 1990 Annual Convention of the American Psychological Association, Boston, Mass, 10-14 August.

Wellens, A. R., Brown, C., McGovern, W. & Mayrand, C. (1990). Effects of "electronic propinquity" on perceptions of human-computer teamwork. Poster presentation proposed for the 1990 Annual Convention of the American Psychological Association, Boston, Mass, 10-14 August.

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