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TEAM PERFORMANCE IN DYNAMIC DECISION MAKING: THE IMPORTANCE OF HEURISTICS (U)

DOROTHY J. McBRIDE, Lt Col

U.S. AIR FORCE INSTITUTE OF TECHNOLOGY

CLIFFORD E. BROWN

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HUMAN SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

NOTICES

TECHNICAL REVIEW AND APPROVAL

AAMRL-TR-89-010

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

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

SUMMARY

The purpose of this report is to present research findings relating to the possible advantages of various graphic information presentations and the use of deicision heuristics as aids to command and control teams. The study described in this report utilized a complex dynamic task requiring extensive interaction among members of three-person teams. Team performance was examined as a function of four presentation schemes with or without the provision of suggested performance strategies (heuristics). Results indicated that, although presentation scheme did not affect performance, decision heuristics significantly improved team performance, particularly: (a) when more time was available to utilize the heuristics, and (b) when teams were deciding whether or not to utilize resources for uncertain targets.

PREFACE

This report was accomplished by the Crew Station Integration Branch, Human Engineering Division, of the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL). It was performed under Work Unit 7184-27-03, "Multi-Operator Performance with Electronic Media." The Work Unit was managed by Ms. Denise Wilson. The Air Force Institute of Technology (AFIT), School of Systems and Logistics, provided human resources to conduct the research. Lt Col McBride is an Assistant Professor of Information Systems at AFIT. The research described in the report was supported by Systems Research Laboratories, Inc. (SRL), Dayton, Ohio, under Contract Number F33615-85-C-0541. Mr. Robert Linhart is the contract monitor.

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BACKGROUND

Huber (1984) predicts that group decision making, which already pervades business, educational, and government organizations, will need to be even more frequent and faster and will need to account for greater complexity in the decision situation. That being the case for decisions under normal circumstances, it is clear that crisis management situations will arouse even more significant demands. Steven Fink, President of Lexicon Communications Corporation, a management consulting firm specializing in crisis management, insists that, "Every crisis demands a crisis management team" (Fink, 1986).

Crisis teams require quick, reliable, and clear information to support their decisions at times when stress and time pressure can lead to information overload and miscommunication (Housel, Sawy, and Donovan, 1986). Information in command and control situations, potentially the most stressful of crisis management situations, "usually concerns the past, present, and future location, identity, and certain other attributes of various objects" to which teams must respond quickly and accurately (Wohl et al., 1984). Performance demands are necessarily high in spite of the dynamic and stressful environment.

Computer-based support of group decision making and the explicit discussion of decision strategies have both been offered as means to improve group performance (Cats-Baril and Huber, 1987). This study examines the impact on group performance of variations in the graphic features of a specific computer-based support system and of the explicit discussion of an experimenter-suggested decision strategy. In particular, this research addresses the problem of facilitating group performance in a dynamic task situation which involves uncertainty, through the use of graphic information presentation and decision heuristics.

Previous research using the Team Resource Allocation Problem (TRAP) as an experimental task has shown that TRAP team performance was better at moderate rather than high levels of time stress, that performance was not strongly affected when the TRAP was presented on one large screen display rather than three individual CRTs (Brown and Leupp, 1985); and that performance was better with a graphic rather than an alphanumeric presentation of the task (Wilson et al., 1987). The intent of the present study was to explore the impact on group performance of variations in the graphic presentation and of introducing heuristics as decision aids.

RELEVANT LITERATURE

Group Decision Making

Group decisions are different from those of individuals. In spite of the potential problems in reaching a consensus and the opportunity for conflict, a group tends to make decisions of higher quality than the average performance of individual members of the group (Miner, 1984; McGrath, 1984). Group decision making, however, also tends to be inefficient and slow. Groups tend to proceed in bursts of activity, frequently jumping from one issue to another while individuals seem able to sustain concentration on a single issue (Fisher, 1980).

Huber suggests that a group's actual decision-making effectiveness equals its potential effectiveness plus gains resulting from group processes minus losses resulting from group processes (Huber, 1982). Groups gain because they have more resources, more sources of information and new ideas, and more perspectives for critical analysis of ideas (Fisher, 1980). They generate more alternatives and are better at analyzing the relative advantages and disadvantages of the various alternatives (Turoff, 1982).

On the other hand, group processes can contribute to losses in decision effectiveness. For example, decision quality can suffer when individual group members dominate the group process beyond the merits of their contributions, when group members miscommunicate, or when there are group pressures to conform (Huber, 1982). The complexity of group communication limits the group's effectiveness, especially when group productivity depends on the coordinated efforts of group members (Hackman and Morris 1983).

Group decision processes vary according to the task. Intellective tasks, such as the TRAP used in this study, have a correct answer. For such tasks, the decision scheme that best fits group performance has been labelled "truth, supported, wins" (McGrath and Kravitz, 1982). In other words, the group accepts a solution as correct if at least two members know it to be correct. A solution presented by only one member, even if it is the correct solution, may not be readily accepted unless the solution can be explained easily and is intuitively compelling once revealed. Groups accept solutions to "eureka" problems, then, on a "truth wins" basis (McGrath and Kravitz, 1982).

Decision Making Under Uncertainty

The environment for decision making in real organizations is uncertain. A state of uncertainty exists when a decision maker has incomplete information on which to base the decision. The dominant theory under which study of decision making under uncertainty has been conducted is the subjective expected utility model (Slovic, Fischhoff, and Lichtenstein, 1977). It has been used as both a normative and a descriptive model of human risky choice behavior (Kahneman and Tversky, 1979). According to the model, "rational" managers weight the utilities of outcomes by their probabilities and choose among alternatives on the basis of the highest expected utility (Muhs and Justis, 1981). Expected utility theory, however, has frequently been criticized as inadequate to describe human behavior. People are, for example, systematically biased in their perception of uncertainty (Grether, 1978).

In addition to being biased in their judgments of uncertainty, humans are often inconsistent in their choices. They frequently do not use obvious optimal strategies for risky choice problems (Little, 1986). To account for human inconsistencies, Kahneman and Tversky have proposed prospect theory as an alternative to expected utility theory. According to prospect theory, people go through two phases in choosing among prospects: an editing phase and then an evaluation phase (Kahneman and Tversky, 1979). In the editing phase, people simplify the statement of the prospects through such operations as coding (formulating the prospect in terms of gains and losses from the current position), rounding off probabilities and outcomes, and discarding extremely unlikely outcomes. In the evaluation phase, the value of each outcome is weighted, not by the probabilities of the outcomes, but by a decision weight that tends to overweight very low probabilities and to underweight all other probabilities.

The combined effects of the editing and evaluation phases account for many of the inconsistencies humans exhibit in risky choices. For example, prospect theory provides an explanation for why humans tend to select certain gains over merely probable gains with comparable or even higher expected value and to select probable losses over certain losses (Kahneman and Tversky, 1979).

Some early research concerning risky choice behavior in groups suggested that groups tended to take greater risks than the group members would as individuals, a finding labelled the "risky shift" (Fisher, 1980). Subsequent studies, however, failed to support the generalizability of the risky shift. Instead, it seems that groups may shift ("choice shift" or "group shift"), but not always in the risky direction. Factors such as the significance of the choice outcomes apparently influence the direction and magnitude of the shift (Muhs and Justis, 1981).

The difficulties of making decisions under dynamic, uncertain conditions call for aids for the decision maker. Among the alternative decision aids are computer-based graphics and decision heuristics, which will be addressed in the following two subsections.

Graphic Representation

Since a graphic representation has been established as superior to a tabular representation for presenting information in a dynamic group decision task (TRAP) (Wilson et al., 1987), comparisons among alternative graphic representations are appropriate. Graphic representations of information can vary along a variety of dimensions. For example, Ives (1982) identified five basic visual input channels available to the human information processing system: color, relative position, brightness, movement, and shape. Appropriate use of these channels has been shown to aid in target identification, a fundamental aspect of the TRAP.

Treisman and Gelade's Feature Integration Theory suggests that for tasks such as visual search and target identification and localization, visual cues that are conjunctions of features (e.g., color and shape) require focused attention and seem to be processed serially. Cues having only a single feature (e.g., color alone) may be processed in parallel (i.e., more quickly). Further, when multiple conjunctively coded objects are presented under time constraints or when attention may be diverted, an individual may incorrectly combine features of unattended objects and falsely report the presence of specified objects (illusory conjunctions). Thus, especially under conditions when attention may be diverted or overloaded, subjects perform visual search tasks more quickly and accurately when the objects vary on a single dimension rather than as conjunctions of features (Treisman and Gelade, 1980; Treisman, 1982). Because other researchers had found qualitative changes in performance on visual tasks with extended practice, Treisman and Gelade examined the effects of practice on searching for conjunctively coded objects. They found no indication of movement from serial to parallel processing over 13 blocks of practice (Treisman and Gelade, 1980).

Considering only single-featured visual codes, both alphanumerics and color have been evaluated as excellent for use in locating objects, although alphanumerics are superior for precise identification of the object (Davis and Swezey, 1983). Christ (1975) reviewed 42 studies published between 1952 and 1973 on the effects of color on visual search and identification performance. In ten studies on the accuracy of identifying objects in a unidimensional display, letters were superior to color, and the advantage for letters increased with increases in the density of the display and with decreases in exposure time. On the other hand, in four studies on the time required to locate objects, color was superior to letters, although the difference was less than that found between color and other visual codes (size, brightness, geometric shapes, etc.).

In a more recent set of experiments, Christ and Corso (1983) determined that there are "no clear and consistent advantages for any one visual code set over the others" (p. 83). Where they found differences in the relative effectiveness of the codes, these differences depended on the other display conditions (e.g., density of the display), the task, and the dependent measure used. Differences did exist under those conditions most closely related to the conditions established for this study. For locating a specified object among 12 randomly located objects in a display, location times were shorter for colored dots than for letters. Christ has also demonstrated that extended practice with a visual task tends to attenuate any differences in performance based on use of different single-featured codes (letters, digits, familiar geometric shapes, and colored dots) (Christ, 1975; Christ and Corso, 1983).

Heuristics for Decision Making

Given that the strategies that decision makers adopt are sometimes biased, some effort has been given to examining the impact of attempts to reduce the biases. Procedures for reducing human bias are collectively known as debiasing methods (Fishchoff, 1982). The nature of a particular debiasing method depends on the perceived source of the bias: if the bias results from a faulty task, fix the task; if the bias results from a biased but perfectible decision maker, provide training/feedback (Fischoff, 1982). Assuming a perfectible decision maker in a probabilistic task, training could take the form of providing prescriptive decision rules, or heuristics, with the intent of determining their impact on decision performance.

Cats-Baril and Huber (1987) examined the impact of providing decision-aid heuristics on the performance of an ill-structured career planning task. The task required participants to identify career objectives, generate alternative strategies for achieving the objectives, and prioritize the alternatives. Some participants were provided with a purpose-expansion heuristic designed to increase the number of objectives and alternatives considered and to explore the alternatives more thoroughly. Participants with heuristics performed better both on objective measures of the number of issues addressed and on expert evaluations of the quality of the plans produced. The researchers called for additional studies on the impact of different types of heuristics on tasks with different levels of structure (Cats-Baril and Huber, 1987).

Johnson and Payne (1985) have defined risky choice heuristics as rules that systematically simplify the choice among alternatives by disregarding some elements of the problem space (ignoring some alternatives, selectively examining outcomes, ignoring some event information, etc.). Different heuristics are based on different simplifications of the choice. Using computer simulation, they compared six heuristics under a variety of conditions for their accuracy (conformity to a choice using expected value) and mental effort required. Their data suggested that "heuristics, in at least some task environments, can approximate the accuracy of normative rules with substantial savings in effort" (Johnson and Payne, 1985).

Arkes, Dawes, and Christensen (1986) studied conditions under which individuals would choose not to use helpful but imperfect decision heuristics in a probabilistic task. In one experiment, subjects were told (correctly) that using the heuristics provided would result in 70 percent accuracy in their judgments. Those who were warned that deviating from the heuristic would result in degraded performance and who received no monetary incentives for performance did best, matching the 70 percent accuracy level. Those who were encouraged to try to improve on the heuristic or who received monetary incentives for performance deviated from the heuristic and judged less accurately. Those who received no immediate feedback on the accuracy of their judgments also outperformed those who did receive feedback; feedback about an incorrect judgment tended to cause deviation from the heuristic and degraded performance on the following trial. In a second experiment, the heuristic provided resulted in 75 percent accuracy. Those who had expertise in the task context (or who thought they did) tended to use the heuristic less and to perform worse than those without expertise.

Team Resource Allocation Problem (TRAP)

The experimental task used in this study was an adaptation of the TRAP (Brown and Leupp, 1985). The TRAP was designed to simulate both the individual cognitive processes and the small group interaction processes involved in making command and control decisions. It was derived from a task used by Pattipati, Kleinman, and Ephrath (1983) to study dynamic individual decision making.

As adapted for this study, the TRAP is designed for three-person teams who are seated side-by-side and allowed to communicate freely. Each team member has a four-button control box [cursor UP and cursor DOWN to select a particular target, and START and RESET to assign or withdraw a resource (Brown and Leupp, 1985; Wilson et al., 1987)]. Identical TRAP displays are presented simultaneously to each team member via computer graphics work stations. Figure 1 portrays a TRAP display at a discrete point in time as it might appear using the alphabetic coding scheme.

As many as 11 targets may be portrayed at a time, each appearing on a separate row in the TRAP display. A team earns points by committing its resources to a target or targets for the required period of time. As briefed to each team during a training session, their objective for the TRAP was

> to accumulate as many points as possible as a team. This means discussing alternatives with the other members of the team in order to make optimum selection of targets. As there will be more targets than the team can possibly process, combinations of targets should be selected which optimize team performance and total point count.

Two types of targets are represented in the version of TRAP used in this study: certain and uncertain targets. The payoff for committing resources to certain targets is known and guaranteed. The payoff for committing resources to uncertain targets is initially unknown and, once known, is not guaranteed. That is, a specified probability exists that no points will be earned for committing resources to uncertain targets.

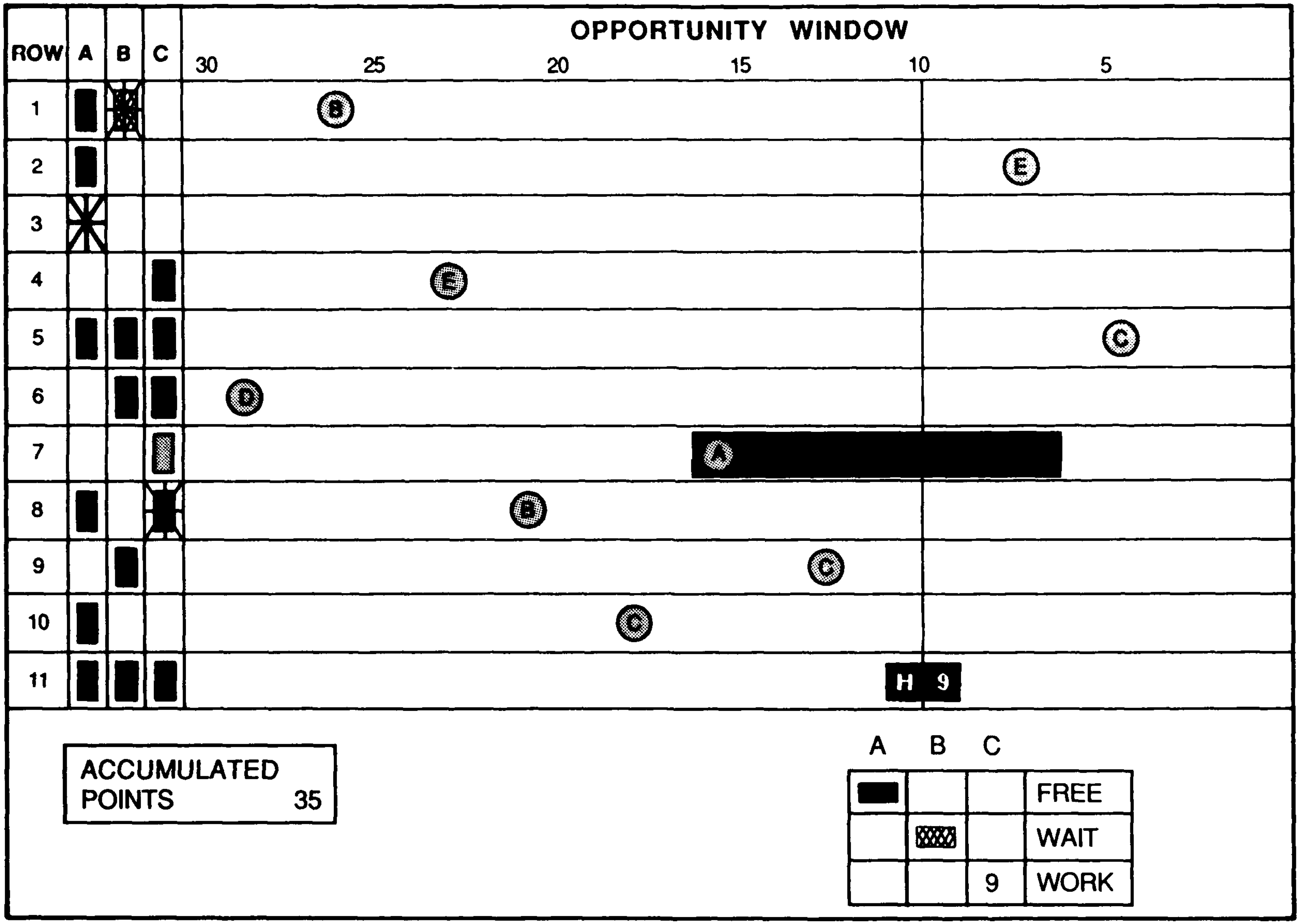


Figure 1. TRAP Display

Table 1 identifies the possible point values for certain targets and the frequency with which each target value appears in a TRAP trial. A TRAP trial presents a total of 44 certain targets, distributed such that each team member has an equal opportunity to participate in targets of a given value (Brown and Leupp, 1985). A small set of targets of randomly selected values is also presented at the beginning and end of each trial; performance on these buffer targets is not analyzed.

TABLE 1. POINT VALUES FOR CERTAIN TARGETS

	Points Per Person	Total Points	Frequency
1-Person Targets	1	1	6
	3	3	12
	5	5	6
2-Person Targets	2	4	6
	4	8	6
3-Person Targets	1	3	2
	3	9	4
	5	15	2

Some targets may be handled by an individual team member; handling other targets may require a specified set of two or all three team members to commit their resources. The black squares in columns A, B, and C in the TRAP display (see Figure 1) indicate which team members must commit resources to a target to earn its points. Each team member controls a separate cursor which can be moved up or down to any row in the member's column on the display. The cursor (an asterisk) is green when the team member is available to commit resources to a target. Once the team member's resources are committed, the cursor turns red. When all required members have committed resources to a target, a horizontal black bar appears in that target's row. The bar graphically indicates how much longer resources must be committed to the target to earn its points. When the required time has elapsed, points for the target are automatically added to the accumulated points table on the display, and the resources are available for assignment to another target.

Four versions of the TRAP were developed to reflect the four graphic presentation formats to be tested. Each version contains the same mix of targets; only the visual representation of the certain-valued targets varies. The original TRAP format was retained as a base for comparison; Table 2 presents the types of targets used in the original TRAP. Using the points available per person in the original format as coding levels, alternative five-level color, alphabetic, and conjunctive (color/alphabetic) coding schemes were developed as shown in Table 3. A 3-person red triangle in the original version, then, appears as a 3-person red target in the color version, as a 3-person A in the alphabetic version, and so forth.

TABLE 2. TRAP TASK POINT VALUES, ORIGINAL PRESENTATION STYLE

1-Person Tasks (A, B, or C)	△ BLUE	△ RED or ○ BLUE	○ RED
Point Value	1	3	5
2-Person Tasks (AB, AC, or BC)	△ BLUE or ○ BLUE		△ RED or ○ RED
Point Value (Per Person)	4 (2)		8 (4)
3-Person Tasks (ABC)	○ BLUE	○ RED or △ BLUE	△ RED
Point Value (Per Person)	3 (1)	9 (3)	15 (5)

TABLE 3. ALTERNATIVE TRAP CODING SCHEMES

	Points Per Person				
	1	2	3	4	5
Color	Blue	Green	Yellow	Orange	Red
Alphabetic	E	D	C	B	A
Conjunctive	Blue C	Blue B	Blue A	Red B	Red A

Mixed randomly among the 44 certain targets in each trial are 20 uncertain targets, represented as rectangles ("black boxes") in all four versions of the TRAP. Participants get additional, though imperfect, information about an uncertain target if all three members move their cursors to the target row and press their start buttons. After a brief delay (one-fifth the time required to complete a target), the number of points possible for completing the target and its probability of payoff appear on the black box. At that point, the team may choose to commit resources to that target or not as with any other target.

The probability of payoff is either 80 percent or 20 percent, shown as H (high) or L (low) on the black box after querying the system. The possible values for high probability targets are 9 and 21 points, and the possible values for low probability targets are 36 and 84 points. Therefore, the expected value of an H21 or an L84 is 16.8 points, and the expected value of an H9 or an L36 is 7.2 points. Each of the four types of uncertain targets is equally likely to occur. Considering the time delay to query the system, an uncertain target is equivalent to a 10-point certain target for a team that chooses to complete every uncertain target it queries. By completing only the H21 and L84 targets it identifies, a team can make uncertain targets equivalent in the long run to 12-point certain targets.

Based on analysis of the performance of teams in earlier studies, interviews with some team members, and information about the structure of the TRAP, a set of heuristics was developed aimed at providing expert guidance for performing the TRAP. Statements of the heuristics were tailored to each of the graphic formats. Stated in terms appropriate to the original version, the heuristics are as follows:

1. In addition to 3-person red triangles, look for a 2-person red target, especially with a 1-person red circle.

2. Next, check as many uncertain targets as you can. Immediately take L84 or H21; ignore L36 and H9.

3. Ignore blue targets except 1-person blue circles and 3-person blue triangles.

4. Keep the team synchronized. All three team members should start a target or targets at the same time.

As in earlier studies, good performance on the TRAP depended on analyzing the available options and choosing those targets that earned the most points for the team. Cooperative thinking and action was essential; for example, skipping a high value 1-person target to participate in a 2-person or 3-person target was sometimes appropriate.

Section 2
METHOD

SUBJECTS

The subjects were 96 paid volunteers, primarily students from the University of Dayton and Wright State University. All had at least 6/12 corrected vision (6/21 vision was adequate to perform the TRAP). All were screened for color vision using Ishihara plates; in those few cases where initial screening suggested color vision limitations, additional screening during the training session assured that all participants could properly distinguish among features on the display. No subjects who had participated in previous TRAP studies were eligible to participate again. Subjects were assigned to teams based on their availability to participate. Eight teams were assigned randomly to each of the four graphic presentation formats. Among each of the 8-team groups, half were randomly selected to receive the heuristics.

EQUIPMENT

The displays were controlled by a Silicon Graphics Model 2400 graphics display processor. Control response buttons on the custom-built response boxes interfaced with the computer via an analog-to-digital converter. The three individual displays were Conrac Model 7211, 33 cm diagonal, full color raster scan CRTs with resolution of 921 horizontal by 739 vertical pixels, and 40 MHz video bandwidth. Character height on the CRTs was .48 cm, subtending an angle of 22.9 minutes of arc at the 46 cm viewing distance.

PROCEDURE

A training session of approximately 2 hours preceded experimental participation. The first stage of the training session replicated training given in earlier TRAP studies (Brown and Leupp, 1985; Wilson et al., 1987). Participants were randomly assigned to seating positions, which were maintained throughout the study. Subjects were seated side by side, and each subject had a CRT and a response box. Participants wore headsets with microphones for recording team communication.

The subjects received thorough instructions, tailored to the presentation format assigned to the team. The instructions described the TRAP and presented the rules determining the point values of targets. Before proceeding with training, subjects were tested on their understanding of the point values. Any incorrect responses were reviewed, and the subjects were retested until they could correctly identify all target values. Next, during a slow speed demonstration of a TRAP trial, further instruction described features of the display, taught subjects how to use their response boxes, and presented rules for working on targets. The first stage of training ended with two practice trials, one under moderate time pressure and one under high time pressure. Subjects were free to ask questions of the experimenter during the instruction and practice and to communicate with one another during this and all subsequent sessions.

The second stage of training introduced the uncertain targets to all teams and the heuristics to half of the teams. During a slow speed demonstration trial, instructions described the appearance of the uncertain targets and provided the rules for querying and committing resources to them. All teams were told about the four possible types of uncertain targets; that each type was equally likely to occur; and that, considering the time delay to query the system, the uncertain targets were about equivalent to 10-point certain targets. They were reminded that the objective remained to maximize team performance. Those teams assigned to the heuristics treatment groups also received instruction on the heuristics appropriate to their presentation format. The instructions included the rationale for each of the heuristics, including an introduction to the concept of expected value. The teams with heuristics were tested to assure that they understood the implications of the heuristics on decisions in various TRAP situations. They were also encouraged to discuss the heuristics along with any other decision strategies they might think to be appropriate. All teams concluded their training sessions with four practice trials.

Each of the two 2-hour experimental sessions consisted of a brief review, a test session made up of eight trials, a short break, and a second test session. The review involved testing (with review and retesting as required) on target values (all teams) and on using the heuristics (teams with heuristics instruction only). Each trial in the test sessions consisted of 64 targets surrounded by a buffer of targets at the beginning and end of the trial; buffer targets were not analyzed. In each test session, there were four fast trials (a new target appeared every 2.73 seconds and remained on the screen for 30 seconds, of which 10 seconds of required resources were needed for completion) and four moderate speed trials (a new target appeared every 5.45 seconds and remained on the screen for 60 seconds, of which 20 seconds of required resources were needed for completion). The sequence of fast and moderate speed trials was randomized in blocks of four trials. The sequence of targets within a trial was randomized for each trial.

Scoring for the uncertain events varies from that for other events. A team that commits resources to an uncertain event expects to receive all or none of the possible points for the event, depending on whether or not the event pays off. Therefore, scores displayed to the team reflect award of all or none of the possible points. Of the five H9 events available in a trial, for example, one is randomly selected in advance to pay no points should the team commit resources to that event.

The researcher, however, is interested in comparing the quality of the decision making rather than degrees of luck among the teams. Scores could be distorted, for example, if a team randomly received a large number of points for committing resources to a few low probability events or if a team failed to gain any points despite committing resources to a number of high probability events. Therefore, separate scores are computed for research purposes which add the expected value (the probability of payoff times the possible point value) of each completed uncertain event to the accumulated points for the certain events. Teams should elect to commit resources to uncertain events only when the events' expected values exceed the values of other events on the display. Therefore, scores based on expected values more accurately represent decision making quality.

Section 3
RESULTS

This section presents the team performance findings, proceeding from an analysis of an overall measure of performance to a more detailed look at factors that contributed to overall performance.

A computer model that uses "correct" logic in performing the TRAP has been developed as a basis for comparison with performance by human teams. The computer model compares values of all alternatives and commits resources to the highest value event or combination of events available at a point in time. It repeats its assessment and resource commitment cycle each time its resources are freed throughout a trial. For research purposes, overall team scores are stated as ratios of the points earned by the team to the points amassed by the model. Team scores reflecting proportions of each event type completed are also compared to model results. Relating team scores to "best possible" scores helps to alleviate any bias associated with variations in the difficulty of the experimental trials, because difficulty may vary due to the randomized sequencing of events. For example, if many targets of high value occur together, neither actual teams nor the model can possibly complete all of them. Therefore, team score relative to the score of the model provides a more accurate measure of the quality of team performance.

The ratio of the raw team score to the score obtained by applying the computer model to the same sequence of targets, an overall measure of performance, was analyzed as a function of presentation style (original, color, alphabetic, conjunctive), heuristics (with, without), time stress (high, moderate), and session (1, 2, 3, 4). Next, a component of the score, the proportion of a team's points earned on certain targets, was analyzed as a function of the same factors. Finally, performance was examined in terms of the proportions of various types of certain and uncertain targets completed.

TEAM SCORE

The team score, expressed as a proportion of the computer model score, was influenced by heuristics, time pressure, session, and the interaction between heuristics and time pressure. Teams with heuristics had higher scores (75.4 percent of model score) than teams without heuristics (70.4 percent of model score), $p = .0011$. Teams also had higher scores under moderate time pressure (79.0 percent of model) than under high time pressure (66.9 percent of model), $p = .0001$. Scores improved from session 1 (70.2 percent of model) to session 2 (72.3 percent of model) and again to session 3 (74.3 percent of model) and then stabilized in session 4 (74.8 percent of model), $p = .0001$. Finally, heuristics had a greater positive influence under moderate time pressure than under high time pressure, p = .00[illegible]. Under moderate time pressure, teams with heuristics averaged 82.3 percent of the model's score while teams without heuristics averaged 75.7 percent, a difference of 6.6 percent. Under high time pressure, teams with heuristics averaged 68.6 percent of the model's score while teams without heuristics averaged 65.1 percent, a difference of 3.5 percent. Contrary to expectations, there were no significant differences in score associated with the style of graphic presentation, $p = .5669$.

COMPONENT SCORE

The portion of the team score achieved by completing certain-valued targets was influenced by heuristics, session, the interaction between heuristics and time pressure, the interaction between heuristics and session, and the three-way interaction among presentation style, heuristics, and session. For the sake of comparison, the model consistently obtained 45 to 46 percent of its points from certain targets. Teams with heuristics got a lower proportion of their points from certain targets (42.0 percent) than did teams without heuristics (59.3 percent), $p = .0071$. The proportion of points from certain targets was lower in session 4 (47.4 percent) than in either session 1 (52.1 percent) or session 2 (53.9 percent), $p = .0081$, with session 3 in between (49.3 percent).

Differences in time pressure had a greater impact on teams without heuristics than on teams with heuristics, p = .0237. Teams with heuristics averaged 41.6 percent of their points from certain targets under high time pressure and 42.5 percent under moderate time pressure. Teams without heuristics averaged 61.5 percent from certain targets under high time pressure and 57.1 percent from certain targets under moderate time pressure. The interaction between heuristics and session indicates that the difference in proportions of scores from certain targets between teams with heuristics and those without was greater in sessions 1 and 2 than in sessions 3 and 4, p = .0026 (Figure 2 and Table 4). Using the averages in Table 4, the differences in the percentage of points from certain targets are as follows: session 1, 22.7 percent; session 2, 22.8 percent; session 3, 13.2 percent; session 4, 10.5 percent. The three-way interaction among presentation style, heuristics, and session shows that the convergence in scores from certain targets between teams with heuristics and those without heuristics occurred at different rates for teams using different presentation styles, p = .0186. The interaction is illustrated in Figure 3 and detailed in Table 5. The differences in Table 5 show the following patterns:

- Teams using the alphabetic style with or without heuristics never differed greatly in proportion of points from certain targets across the four sessions.

- The proportion of points from certain targets for teams using the conjunctive style with and without heuristics converged at a smooth rate across the four sessions.

- The proportion of points from certain targets for teams using the original style with and without heuristics converged most quickly from session 2 to session 3.

- The proportion of points from certain targets for teams using the color style with and without heuristics diverged in session 2, then started to converge in sessions 3 and 4 without ever closing the gap as much as teams using other styles had.

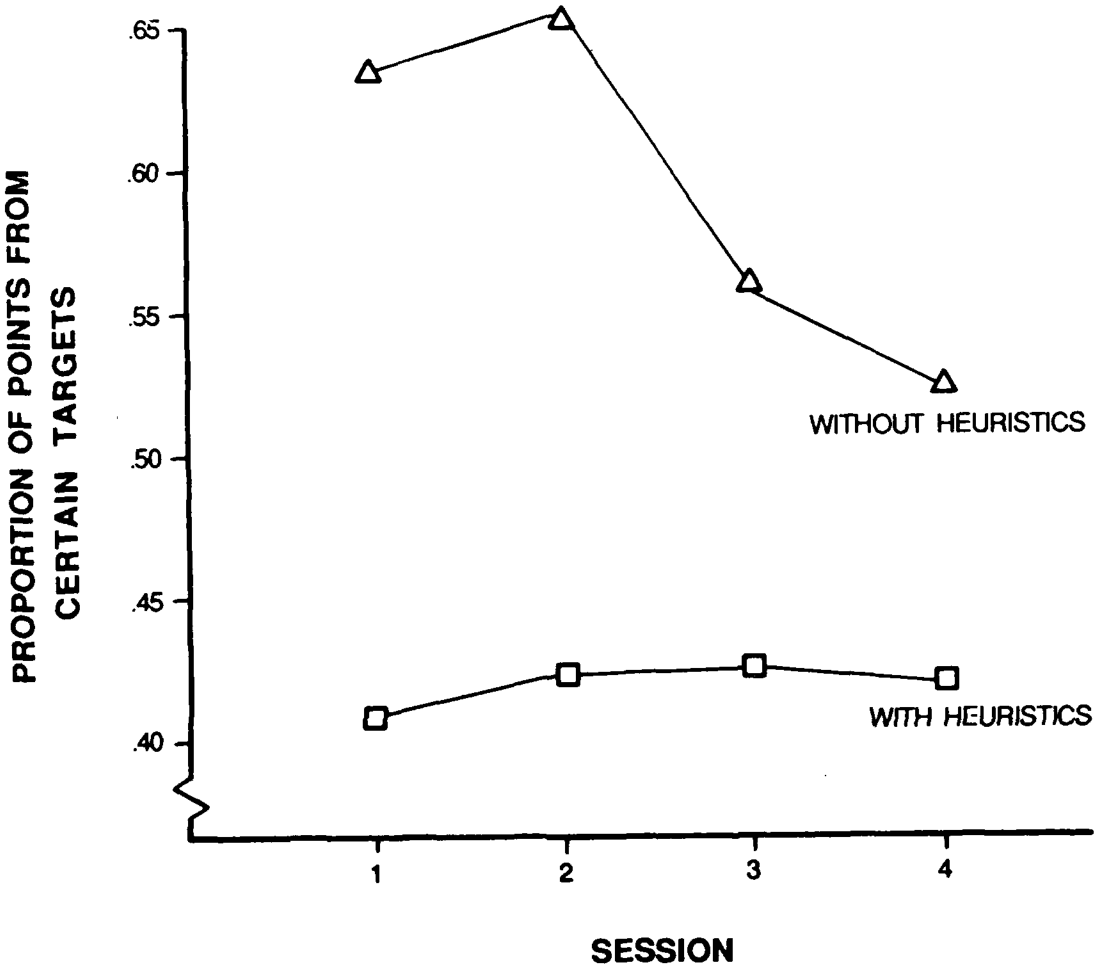


Figure 2. Proportion of Points from Certain Targets as a Function of Heuristics and Session

TABLE 4. PROPORTION OF POINTS FROM CERTAIN TARGETS AS A FUNCTION OF HEURISTICS AND SESSION

	Session 1	Session 2	Session 3	Session 4
With	40.8 Percent	42.5 Percent	42.7 Percent	42.2 Percent
Without	63.5 Percent	65.3 Percent	55.9 Percent	52.7 Percent

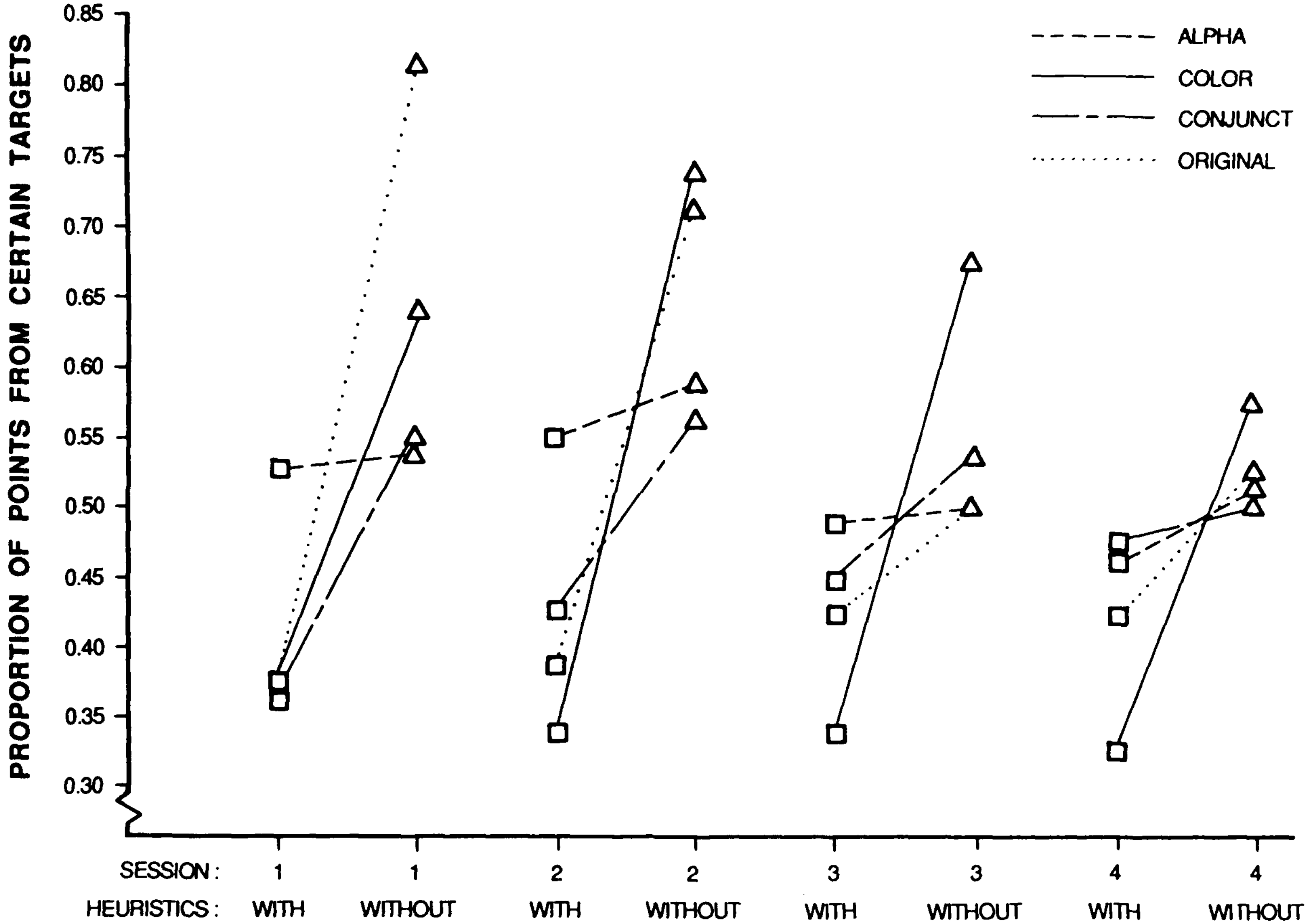


Figure 3. Proportion of Points from Certain Targets as a Function of Presentation Style, Heuristics, and Session

TABLE 5. DIFFERENCES IN PROPORTION OF POINTS FROM CERTAIN TARGETS BETWEEN TEAMS WITH AND WITHOUT HEURISTICS AS A FUNCTION OF STYLE AND SESSION

	Session 1	Session 2	Session 3	Session 4
Color	26.0 Percent	40.3 Percent	33.4 Percent	24.4 Percent
Alphabetic	1.7 Percent	4.5 Percent	0.6 Percent	5.5 Percent
Conjunctive	19.7 Percent	14.0 Percent	8.0 Percent	2.6 Percent
Original	43.2 Percent	32.4 Percent	10.5 Percent	9.7 Percent

PROPORTIONS OF KEY CERTAIN TARGETS COMPLETED

Of the eight types of certain targets included in the TRAP, five were specifically addressed by the heuristics. Teams with heuristics were encouraged to work on two types: 3-person-5-points-per-person targets and 2-person-4-points-per-person targets (especially in combination with high-value 1-person targets). They were also encouraged to ignore three types: 1-person-1-point-per-person, 2-person-2-points-per-person, and 3-person-1-point-per-person targets. Most teams, with or without heuristics, completed no 3-person-1-point-1-per-person targets, so these targets could not be analyzed using ANOVA procedures. Of the 17 such targets completed, 12 were completed by one team using the original presentation style without heuristics. The remaining 5 targets were spread over 4 other teams: 3 targets by 2 other teams using the original style without heuristics, 1 target by a team using the original style with heuristics, and 1 target by a team using the conjunctive style with heuristics. Proportions completed of the other four types of certain targets were analyzed as functions of presentation style, heuristics, time stress, and session.

3-Person-5-Points-Per-Person

The computer model completed 99.95 percent of the 15-point targets. No significant differences were found in the proportion of these highest-valued certain targets completed based on any of the factors analyzed. Teams completed nearly all of these targets under any conditions.

2-Person-4-Points-Per-Person

The computer model completed 58.9 percent of the 8-point targets. Time pressure, the interaction between heuristics and time pressure, and the interaction between heuristics and session influenced the proportion completed by the teams. Teams completed more 8-point targets under moderate time pressure (41.9 percent) than under high pressure (34.3 percent), $p = .0001$. Under high time pressure, teams with heuristics completed fewer 8-point targets (30.0 percent) than did teams without heuristics (38.6 percent), but, under moderate time pressure, teams with or without heuristics completed about the same number (with, 41.3 percent; without, 42.6 percent), $p = .0402$. The interaction between heuristics and session indicates that the difference in proportion of 8-point targets completed between teams with heuristics and those without was greater in sessions 1 and 2 than in sessions 3 and 4, $p = .0056$. Using the averages in Table 6, the differences are as follows: session 1, 12.8 percent; session 2, 9.2 percent; session 3, 1.6 percent; and session 4, -3.9 percent.

TABLE 6. PROPORTION OF 8-POINT TARGETS COMPLETED AS A FUNCTION OF HEURISTICS AND SESSION

	Session 1	Session 2	Session 3	Session 4
With	31.1 Percent	37.3 Percent	36.0 Percent	38.2 Percent
Without	43.9 Percent	46.5 Percent	37.6 Percent	34.3 Percent

1-Person-1-Point-Per-Person

The computer model completed 7.3 percent of the 1-point targets. Presentation style, heuristics, and time pressure influenced the proportion completed by the teams. Teams using the original presentation style completed more 1-point targets (15.8 percent) than did teams using any other style (color, 6.6 percent; alphabetic, 5.4 percent; conjunctive, 4.8 percent), $p = .0209$. Teams with heuristics completed fewer 1-point targets (4.4 percent) than did teams without heuristics (11.9 percent), $p = .0080$. Finally, teams completed more 1-point targets under moderate time pressure (9.0 percent) than under high time pressure (7.3 percent), $p = .0158$.

2-Person-2-Points-Per-Person

The computer model completed 4.2 percent of the 4-point targets. Heuristics and time pressure influenced the proportion completed by the teams. Teams with heuristics completed fewer 4-point targets (1.6 percent) than did teams without heuristics (6.3 percent), $p = .0142$. Teams completed more 4-point targets under moderate time pressure (4.6 percent) than under high time pressure (3.4 percent), $p = .0115$.

PROPORTIONS OF UNCERTAIN TARGETS COMPLETED

Proportions of uncertain targets completed were analyzed in two stages. First, the proportion of all uncertain targets about which teams sought additional information was analyzed as a function of heuristics, type of target (H21, H9, L84, L36), time pressure, and session. Second, the proportion of uncertain targets completed subsequent to seeking additional information was analyzed as a function of the same factors. Because uncertain targets were presented as black rectangles in all presentation styles, and because there were no significant effects associated with style on querying or completing uncertain targets, style was not included in the reported analyses of uncertain targets.

Queries of Uncertain Targets

The computer model sought additional information about 65.7 percent of the uncertain targets. The proportion of uncertain targets queried by the teams was influenced by heuristics, time pressure, session, and the interaction between heuristics and session. Teams with heuristics queried more uncertain targets (57.9 percent) than did teams without heuristics (35.8 percent), $p = .0002$. Teams queried more uncertain targets under moderate time pressure (51.0 percent) than under high time pressure (42.6 percent), $p = .0001$. Teams queried more uncertain targets in session 4 (50.2 percent) than in sessions 1 (44.9 percent) or 2 (44.7 percent), $p = .0036$, with session 3 in between (47.5 percent). The interaction between heuristics and session indicates that, although teams with heuristics queried about the same number of uncertain targets in each session, teams without heuristics queried more uncertain targets in sessions 3 and 4 than in sessions 1 and 2 (Figure 4 and Table 7), $p = .0451$.

Uncertain Targets Completed

The proportion of uncertain targets completed was expressed as a ratio of targets of a particular type completed to targets of that type queried. Five teams failed to query at least one uncertain target of each type at each level of time pressure in each session and, therefore, had at least one ratio of 0/0. After eliminating the five teams, a preliminary analysis, using a general linear model to account for unequal cell sizes, indicated that there was no effect due to session or to any interactions involving session ($p > .05$). Therefore, data were averaged across session. Every team queried at least one of each type of uncertain target during the experiment (no teams had to be eliminated), so an ANOVA model including only time, type of target, and heuristics as independent variables could be analyzed. Using the new ANOVA model, ratios of uncertain targets completed were influenced by heuristics, type of target, and the interaction between heuristics and type of target.

Overall, the computer model completed 52.3 percent of the uncertain targets it queried. Teams with heuristics completed a smaller proportion of the uncertain targets they queried (46.8 percent) than did teams without heuristics (63.3 percent), $p = .0005$. Of the various types of uncertain targets it queried, the computer model completed 99.97 percent of the H21 targets, 100 percent of the L84 targets, 5.0 percent of the H9 targets, and 4.3 percent of the L36 targets. Teams completed a larger proportion of the H21 and L84 targets they identified (94.8 percent and 81.8 percent, respectively) than they did of the H9 and L36 targets they identified (15.2 percent and 18.4, percent, respectively), $p = .0001$. The interaction between heuristics and type of target indicates that teams with and without heuristics completed the same proportion of H21 targets they identified; however, teams with heuristics completed a large proportion of the L84 targets they identified and a smaller proportion of the H9 and L36 targets they identified than did teams without heuristics (Table 8), $p = .0001$.

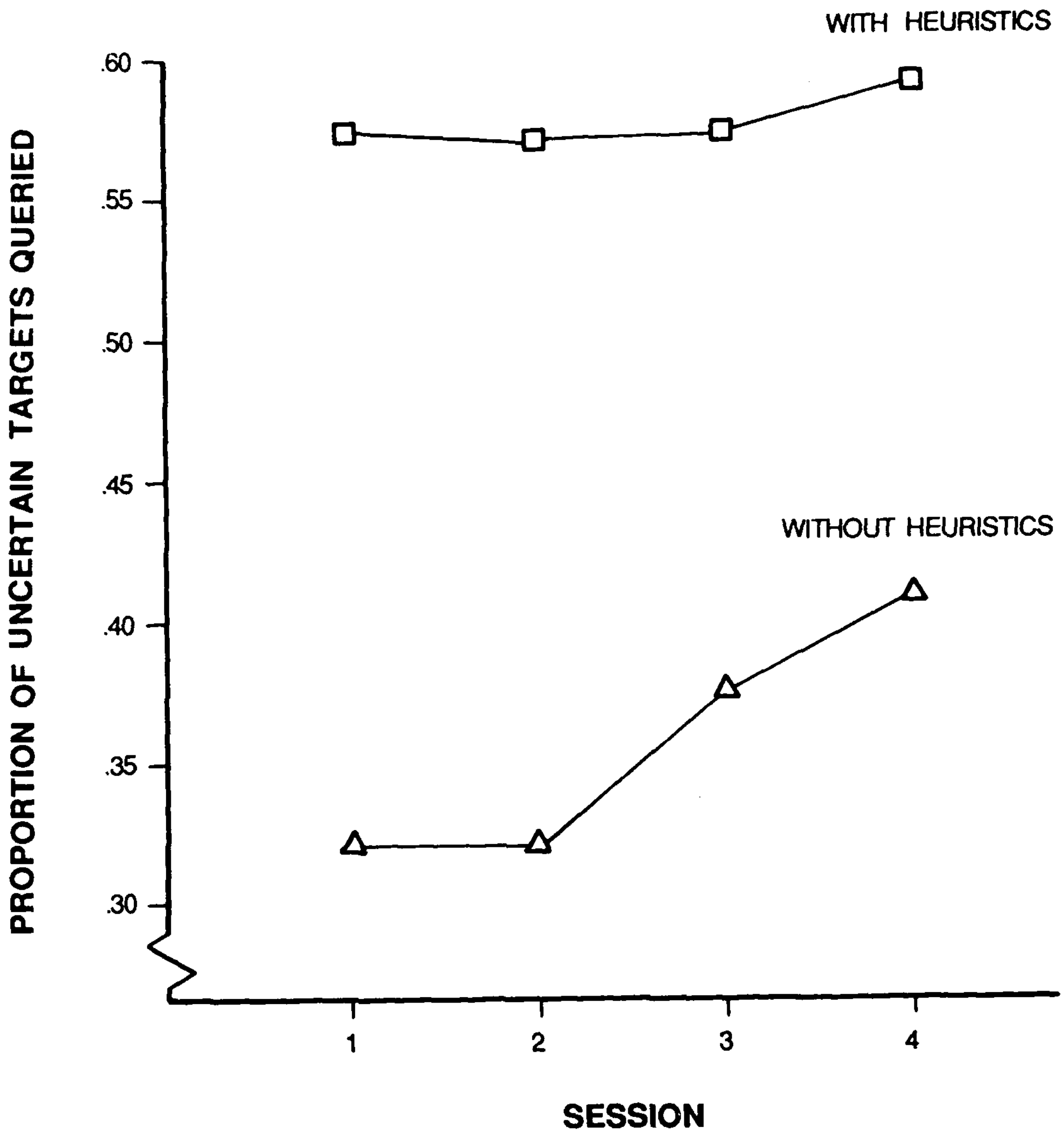


Figure 4. Proportion of Uncertain Targets Queried as a Function of Heuristics and Session

TABLE 7. PROPORTION OF UNCERTAIN TARGETS QUERIED AS A FUNCTION OF HEURISTICS AND SESSION

	Session 1	Session 2	Session 3	Session 4
With	57.7 Percent	57.3 Percent	57.4 Percent	59.1 Percent
Without	32.1 Percent	32.1 Percent	37.6 Percent	41.3 Percent

TABLE 8. PROPORTION OF QUERIED UNCERTAIN TARGETS COMPLETED AS A FUNCTION OF HEURISTICS AND TYPE OF TARGET

	H21	H9	L84	L36
With	93.8 Percent	0.3 Percent	92.6 Percent	0.4 Percent
Without	95.8 Percent	50.1 Percent	71.1 Percent	36.3 Percent

Section 4
DISCUSSION

The purpose of this study was to explore the impact of various graphic presentations and experimenter provided decision heuristics on team decision making in the context of a dynamic situation assessment/resource allocation task which incorporates both certain and uncertain situations.

EFFECTS OF HEURISTICS

The most important findings of the study involve the positive effects of encouraging the discussion and use of experimenter-provided heuristics. Overall, teams with heuristics had higher scores than teams without heuristics. The advantage of using the heuristics was greater on moderate trials than on fast trials, possibly because teams needed time to reflect on and deliberately apply the heuristics. Results relating to each of the four heuristics provided suggest that they varied in usefulness.

Teams were first encouraged to look for high value certain targets and combinations of targets. Teams with and without heuristics completed about the same number of 15-point targets, and teams with heuristics actually completed fewer 8-point targets than did teams without heuristics. Subjective evidence from reviewing videotapes of the experimental sessions suggests, however, that teams with heuristics may have been more appropriately selective in completing 8-point targets. Taken by themselves, 8-point targets are only of moderate value; the computer model completes them almost exclusively in combination with other targets for the third team member, maximizing the <u>total</u> points earned by the team. Combinations of targets are more difficult to identify than are single targets, though; and teams with heuristics tended to complete more combinations of 8-point targets with 3- or 5-point targets than did teams without heuristics. It should also be noted that teams with heuristics completed as many 8-point targets as did teams without heuristics on slower trials when more time was available to look for combinations, and they completed as many as did teams without heuristics in sessions 3 and 4 when teams without heuristics started turning more to uncertain targets.

The clearest effect of heuristics was associated with the instruction to use expected value in handling uncertain targets. As Kahneman and Tversky (1979) suggested, teams operating without experimenter-provided heuristics tended to select certain gains over merely probable gains with comparable or even higher expected value. For example, teams without heuristics got more of their points from certain targets than did teams with heuristics. Teams without heuristics also queried fewer uncertain targets and were less selective in completing them than teams with heuristics. Strategies among the teams without heuristics for completing uncertain targets included variations on completing all the targets they queried, completing the high probability targets, completing the high expected value targets, completing only the H21 targets, and not even querying uncertain targets. By contrast, teams with heuristics consistently queried and completed uncertain targets at rates appropriate to a strategy based on expected value.

The heuristics also suggested ignoring low-value targets and staying synchronized. Teams with heuristics did complete fewer of the low-value targets. Although the finding was statistically significant, the small number of targets involved and their low values meant that the difference had little impact on differences in the overall scores. Team synchronization was not statistically analyzed, but reviews of the videotapes suggest that teams with heuristics lost synchronization less frequently and for shorter durations than those without heuristics. Teams with heuristics concentrated more on 3-person targets (15-point and uncertain targets), which helped to keep the team synchronized.

OTHER FINDINGS

Presentation style did not significantly influence performance on the TRAP. One explanation might be that targets remained on the screen long enough for teams to deliberately identify target values. Good performance did not rely on instant identification of targets for which attention theory would be more applicable. Only one clear finding relating to presentation style emerged: teams using the original style completed more 1-point targets than teams using any other style. The original style had the most complicated coding scheme, and teams using it apparently forgot the values of some targets while performing the task.

The three-way interaction among presentation style, heuristics, and session in the analysis of points gained from certain targets suggests that presentation style may have affected the rate at which teams with and without heuristics moved toward a common strategy toward uncertain targets. There is no theoretically based explanation for this pattern of effects. An alternative explanation involves the number of teams participating and the variety of strategies adopted by teams without heuristics. Of the teams without heuristics, only four teams used each of the presentation styles. Among the 16 teams without heuristics, at least four distinct strategies (with multiple variations and rates of adoption) toward uncertain targets emerged. It is possible that coincidental alignments of similar strategies among teams using common presentation styles could account for the reported interactions.

Evidence of learning effects and time pressure effects emerged as expected. The effects of session on several variables suggest that learning continued beyond the training session. Specifically, teams seemed to become more efficient at responding to targets in session 2 and to make significant shifts in strategy, especially toward completing uncertain targets, by session 3. As in previous TRAP studies, time pressure had a significant impact on performance. Teams completed more of each type of target and scored more points on moderate trials than on fast trials.

The TRAP and its potential adaptations provide a rich environment in which to examine the dynamics of team decision making. Additional research could explore the effects of varying the team structure through assigning different team member roles (functions), constructing teams based on levels of expertise, applying constraints on communication patterns, and so on.

Appendix A

CONSENT FORM

I, ______________________________, having full capacity to consent, do hereby volunteer to participate in a research study entitled, "Team Resource Allocation Problem," under the direction of Ms. Denise L. Wilson, Dr. Clifford Brown, and Major D. J. McBride. The decision to participate in this research is completely voluntary on my part. No one has coerced or intimidated me into participating in this program. I am participating because I want to. ________________________________ has adequately answered any and all questions I have about this study, my participation, and procedures involved. I understand that will be available to answer any questions concerning procedures throughout this study. I understand that if significant new findings develop during the course of this research which may relate to my decision to continue participation, I will be informed. I further understand that I may withdraw this consent at any time and discontinue further participation in this study without prejudice to my entitlements. I also understand that the medical monitor of this study may terminate my participation in this study if he or she feels this to be in my best interest.

I understand that participation in this study may be photographed, filmed or videotaped. I consent to the use of these media and understand that any records of my participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 USC 552a, and its implementing regulations.

I understand that my entitlement to medical care or compensation in the event of injury is governed by federal laws and regulations, and if I desire further information I may contact ________________________________.

I FULLY UNDERSTAND THAT I AM MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

A.M.
P.M.

____
Signature Date Time

I have briefed the volunteer and answered questions concerning the research project.

____
Signature Date

ADDENDUM TO THE CONSENT FORM

Experiment: Team Resource Allocation Problem

You are invited to participate in an experiment designed to study how people in teams work with one another to complete a number of tasks. The situation you will be exposed to has theoretical similarity to those encountered in command, control, and communications (C^3) systems of the U.S. Air Force. A better understanding of the processes by which team members complete tasks will assist in improving these C^3 systems. Your exposure to the equipment is limited to your watching the CRT screen at a distance of about two feet for approximately two hours per day for three days. This does not involve any known risks.

In the experiment, you will be observing a computer generated display of a representation of a work environment. By pressing pushbuttons on a response box, you will work on tasks individually and with your team members. Because there will be more tasks available to you than you can complete, the particular tasks you and your team members choose, and when you choose them, will be of primary interest. You will receive further detailed instructions at the beginning of the experiment.

The responses you make, and the times at which you make them will be recorded for later analysis. Audio and video recordings will also be made for subsequent study. Your name will be recorded along with the dates and times at which the experiment is performed. Your confidentiality as a participant in this project will be protected. Your identity will only be revealed in accordance with the Privacy Act, 5 USC 552, and its implementing regulations. A numeric code will be used to identify the data in any publication.

Any monetary benefits will be in accordance with SRL/Air Force agreements.

You are free to refuse to participate or to withdraw your participation in the experiment at any time. Doing so will not prejudice your relation with the laboratory in any respect.

Any questions you may have should be directed to Ms. Denise Wilson (57572) or Major D. J. McBride (57570).

You willingness to participate in this experiment is greatly appreciated. Your signature indicates that you have decided to participate, having read the information provided above.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP.

Signature ____________________ Date

Appendix B
SAMPLE TRAP INSTRUCTIONS

ALPHABETIC CODING

Before you take seats, please take a card which will determine whether you will be team member A, B, or C for the study. (Subjects draw cards and are seated at appropriate seats.) Each team member has his/her own display and control box at the workstation. You will communicate with your teammates through the headphones proved at the workstation. The microphones on the headsets are called lip mikes because they are intended to be kept nearly touching your lips. To hold the background noise to a minimum and to hear your voices clearly, please remember to keep the mike in this position. (Demonstrate)

GENERAL INSTRUCTIONS

This experiment is concerned with how team members work with one another to accomplish tasks. You and your teammates will work together to decide how best to allocate team resources (your work time) for the good of the team in a task which involves the processing of various targets. You will work on some targets yourself, and on other targets with one or both of your teammates. The major portion of the display will have 11 rows. Targets, represented as circles labelled A, B, C, D, and E will appear randomly in each of these 11 rows. You will earn points for the team by working on these targets before their time runs out and they leave the screen. Working on a target simply means selecting a target by using the buttons on your control box to move a cursor, pressing the start button, and waiting a few seconds for the target to be processed. Because more targets than you can possibly work on will appear on the screen, the particular targets you choose, and their point values to the team, will be quite important. Therefore, it is necessary for you to learn how the point values of targets are determined. Please listen carefully.

ALPHABETIC CODING

The point value of each target depends on two things: the number of required workers and the letter that appears on the target. Overall, the point value of a target is proportional to the number of required workers. The average value of all the targets is 3 points per person. Targets requiring one, two, or three workers are, therefore, worth an average value of 3, 6, or 9 points, respectively, for the team. Whether a particular target is worth this average value of 3 points per person, or somewhat more or less, depends on the letter that appears on the target.

Since the letter A suggests importance or urgency, you will see that targets coded toward the begining of the alphabet are worth more points on the average than targets coded later in the alphabet. With this notion of alphabetic order in mind, let's examine the specific point values assigned to the different targets. (Give subjects the point values table.)

The point values assigned to the different targets are shown in the table.

- A targets are worth 5 points per person.
- B targets are worth 4 points per person.
- C targets are worth 3 points per person.
- D targets are worth 2 points per person.
- E targets are worth 1 point per person.

You should now be able to determine the point value of each target by knowing the number of required workers and the letter that appears on the target.

POINT VALUE TESTING

Because your understanding of the point values is critical to this study, I am going to have you complete a short test to demonstrate your knowledge of the point values of each target. Before taking the test, please examine the summary table of the point values and feel free to ask questions about it. (Pause) Do you have any questions before you take the test?

(Give subjects the test. If any questions are missed, discuss the question with the subject to ensure his understanding and then give him a new test. Repeat this procedure until all subjects have answered all the questions correctly.)

We are ready to continue. (START APPROPRIATE DEMO)

DEMONSTRATION

This is a demonstration of the TRAP task. As you can see, there are 11 rows on which targets appear at random and move across the screen from left to right. The black squares in columns A, B, and C indicate which operators are required to work on each target. The scale at the top represents 30 time units.

Working on a target is very simple. All you do is move your marker, a green asterisk, to a target row and press the start button on your response box. Work automatically begins, and after a short time (10 time units), your team will receive the appropriate number of points for completing the target. These points are automatically added to the accumulated points display (show). When you begin work on a target, a black bar will appear in that target's row. The bar represents the 10 time units required to complete processing of the target. The target will move through the bar as the processing proceeds. When the target moves out of the bar, processing of that target has been completed. In order to complete a target before it leaves the screen, you will have to start it before it reaches the black dashed line (while the target is in the opportunity window).

Work on each target can be done only by a particular team member or combination of team members. As the control box before you indicates, you are either team member A, B, or C. You can work only on those targets which have a black square in your column. If a target has more than one black square in front of it, both or all three corresponding team members will have to work on the target <u>at the same time</u> in order to complete it.

To work on a target, you must move your marker to the corresponding black square. You move the marker by pressing the buttons labeled up and down on your control box. Go ahead and move your marker around. Notice that if you press the up button when you are on the top row, your marker moves to the bottom row. Similarly, if you press the down button when you are on the bottom row, the marker moves to the top row.

Once you have the marker on the row corresponding to the target you wish to work on, all you have to do is press the start button. If you are the only team member required for that target, work automatically begins and the black square will turn yellow. However, if one or more additional team members are required for the target, the black square will turn pink. This means that you are waiting to work. Work will begin only when all the required workers for the target have moved their markers to the target and pressed their start buttons. When this occurs, all the squares will turn yellow indicating that work has begun.

While you are working on a target or waiting for another team member at a target, your marker will turn red. You can move it to any row you choose in preparation for the next target you may wish to start. When you become free, your marker will return to its green color indicating that you are ready to press the start button for another target.

You may wish to stop working on a target before completing it. To do this, you simply press the RESET button on your control box. Your marker will turn green indicating that you are free to start another target. If others were working on the target with you, they will also have to press their RESET buttons to work on a different target. You will receive no points for targets which are not fully completed. If you choose, you may begin to process the target over again, but it will take a full 10 time units to complete it. The RESET button is also used when you no longer wish to wait for other team members at a particular target.

Processing of each target takes 10 time units (TUs). A TU is some arbitrary number of seconds. The current example trial has a TU of 3 seconds. It takes 30 TUs (in this example, 90 seconds) for a target to move completely across the screen. During the actual experiment, the number of seconds for a TU will be less. That is, the targets will move across the screen more quickly and the time spent processing each target will be less.

The table in the lower right hand portion of the display indicates whether each team member is free, waiting, or working. A black square indicates that a particular team member is free, while a blinking pink square indicates that a particular team member is waiting. When a particular team member is working a numeric countdown, in TUs, will indicate how much processing time remains until the team member will be finished with the current target.

The countdown for each target will start at 30 TUs when a target is at the left-most part of the screen, and decrease at a constant rate as the target moves to the right. When a target is at the end of the opportunity window (the black dashed line), the countdown will be at 10 TUs. The target leaves the screen at 0 TU. Since each and every target requires 10 TUs for processing, knowing how many TUs a target will remain on the screen can be useful to you as you decide which targets to work on, and when to work on them. In addition, comparing this information to the countdown of team members who are currently working (show) can provide vital information about whether there will be enough time to process particular targets. For example, if a team member has 6 TUs remaining before completing a particular target, he will not be able to complete both that target and another target that currently has only 15 TUs remaining.

The object of this exercise is to accumulate as many points as possible <u>as a team</u>. This means discussing alternatives with the other members of the team in order to make optimum selection of targets. As there will be more targets than the team can possibly process, combinations of targets should be selected which optimize team performance and total point count.

TRAP Task Point Values

Target	(E)	(D)	(C)	(B)	(A)
Point Value (Per Person)	1	2	3	4	5

Appendix C
INSTRUCTIONS FOR TRAP WITH UNCERTAIN TARGETS

Now that you are familiar with the basic TRAP, we would like to introduce a variation. In order to study how teams perform with incomplete or uncertain information, we have added targets for which the point value is initially unknown. The team may choose to query the system to gain more information about these targets before deciding whether to commit to processing them.

The UNCERTAIN TARGETS, which appear on the screen as black rectangles, all require three persons to process them. There are two features of these targets which may vary:

1. Probability of Payoff: The probability that a team will actually get the points for processing the uncertain target is either 80 percent (high) or 20 percent (low).

2. Point Value: There are two possible point values for each level of probability of payoff.

These two features taken together result in four types of uncertain types as shown as follows:

Probability of Payoff	Point Values	
High (80 Percent)	7 (21)	3 (9)
Low (20 Percent)	28 (84)	12 (36)

Targets with a high probability of payoff, then, have an 80 percent probability of giving points and may be worth either 7 points per person (21 points for the team) or 3 points per person (9 points for the team). Targets with a low probability of payoff have a 20 percent probability of giving points and may be worth either 28 points per person (84 points for the team) or 12 points per person (36 points for the team). Each of the four types of uncertain targets is equally likely to occur.

There is a cost in time (2 TUs) required to get information about the targets. Taking into account the time cost, the uncertain targets are on the average about equivalent to a 10-point three-person target (3.3 points per person).

Initially, the uncertain targets appear on the screen as black rectangles with no information about the probability of payoff or point value. In order to query for information, all three members must move their markers to that row and press their start buttons, just as you would to work on a target. Two TUs after the three team members have pressed their start buttons, information about the target will appear on the black rectangle. The information will include either an H or L, for high or low probability of payoff, respectively, and the total number of points the team may earn for processing the target.

At the time the information is obtained, the team may choose to process that target, which they can initiate by pressing their start buttons a second time (uncertain targets, like the other TRAP targets, require 10 TUs for processing), or they may choose not to process that target, in which case they are free to move their markers to another target or targets. The team may choose, if time allows, to query for information on more than one uncertain target before selecting a target or targets to process.

The rules and procedures for processing the uncertain targets are exactly the same as those for the standard TRAP targets.

As with the basic TRAP, the object of the task is to accumulate as many points as possible as a team. This means discussing alternatives with the other members of the team in order to make optimum selection of targets. The uncertain targets may be viewed simply as additional alternatives. As there will be more targets than the team can possibly process, combinations of targets should be selected which optimize team performance (total point count).

Appendix D

INSTRUCTIONS FOR TRAP WITH HEURISTICS

A heuristic is a "rule of thumb" or a simplified approach to a problem that grows out of experience with similar situations. It may not always lead to the best solution to a given problem, but it generally provides a good solution that can be identified quickly and easily. For example, an appropriate heuristic for the TRAP task might be "Always work 3-person A targets." People who have had experience with TRAP have suggested several heuristics for TRAP, and we encourage you to discuss and to use the heuristics as you start to perform the task.

HEURISTIC #1: In addition to a 3-person A targets, look for a 2-person B target, especially with a 1-person A target.

A 2-person B target worked at the same time as a 1-person A target gets 13 points for the team. Of the "for sure" targets, only a 3-person A target or three 1-person A targets worked at the same time get more points. Even a 1-person C target worked at the same time as a 2-person B target gets more points (11) than many combinations that may be available.

HEURISTIC #2: Next, check as many uncertain targets as you can. Immediately take L84 or H21; ignore L36 and H9.

Heuristic #2 comes from the expected value of the uncertain targets, or the average payoff you'll get for working those targets over time. Taking into account the time delay to identify the targets, the uncertain targets are worth on average about 10 points for the team. (In other words, you should take combinations of "for sure" targets that are worth more than 10 points before you check uncertain targets.) You can compute the expected value of an individual uncertain target by multiplying the probability of payoff by the points available. For example, the expected value of an L84, once you identify it, is $(0.2) \times 84 = 16.8$. Therefore, an L84 will only pay off one out of five times, but the payoff is big when it comes. Your score on one trial may not show the benefit of selecting an L84, but your overall average score will. An H21 also gets an expected value of 16.8, so it is just as valuable as an L84. The expected value of an L36 or an H9, though, is only 7.2, which is so low that there are almost always better options available.

HEURISTIC #3: Ignore D and E targets.

There will almost always be a better combination available than one that involves 1- and 2-point-per-person targets.

HEURISTIC #4: Keep the team synchronized. All three team members should start a target or targets at the same time.

If you can't start working a target very close to the same time as your teammates, you're better off to stay free until they are free again than to start working a 1-person target that comes along after they've started. You'd just end up in an endless round of waiting for someone to be free to start team targets.

Do you have any questions about the heuristics? (Answer questions) You may now have 5 minutes to discuss the heuristics and any other strategies you might choose to adopt. (Give subjects the summary of heuristics.)

HEURISTIC #1: In addition to 3-person A targets, look for a 2-person B target, especially with a 1-person A target.

HEURISTIC #2: Next, check as many uncertain targets as you can. Immediately take L84 or H21; ignore L36 and H9.

HEURISTIC #3: Ignore D and E targets.

HEURISTIC #4: Keep the team synchronized. All three team members should start a target or targets at the same time.

Appendix E

TEAM RESOURCE ALLOCATION PROBLEM

TEST OF POINT VALUE UNDERSTANDING

VERSION 3

Name ______________________________ Team _______ Worker: A B C

Date ________________ Session ____

One-Person Events

1. If A processes (C) the team will accumulate ______ points.

2. If B processes (E) the team will accumulate ______ points.

3. If C processes (A) the team will accumulate ______ points.

Two-Person Events

4. If AB together process (B) the team will accumulate ______ points.

5. If BC together process (D) the team will accumulate ______ points.

Three-Person Events

6. If ABC together process (A) the team will accumulate ______ points.

7. If ABC together process (E) the team will accumulate ______ points.

8. If ABC together process (C) the team will accumulate ______ points.

Appendix F

TEAM RESOURCE ALLOCATION PROBLEM

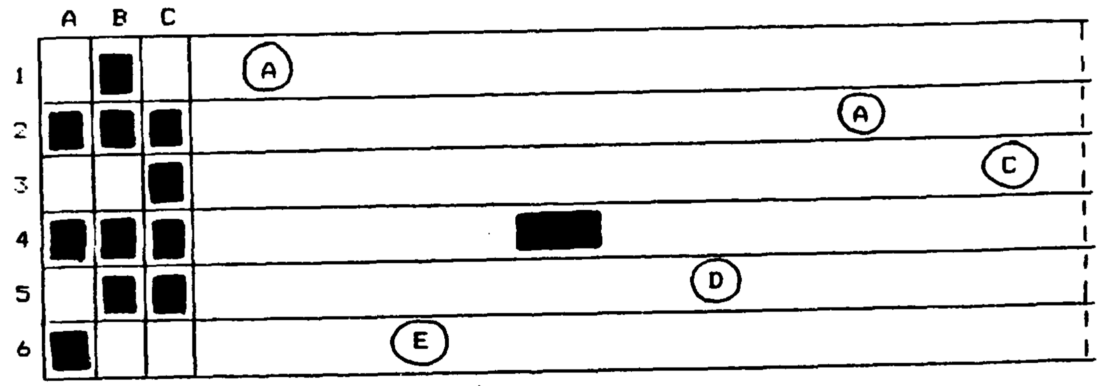
TEST OF HEURISTICS UNDERSTANDING

VERSION 3

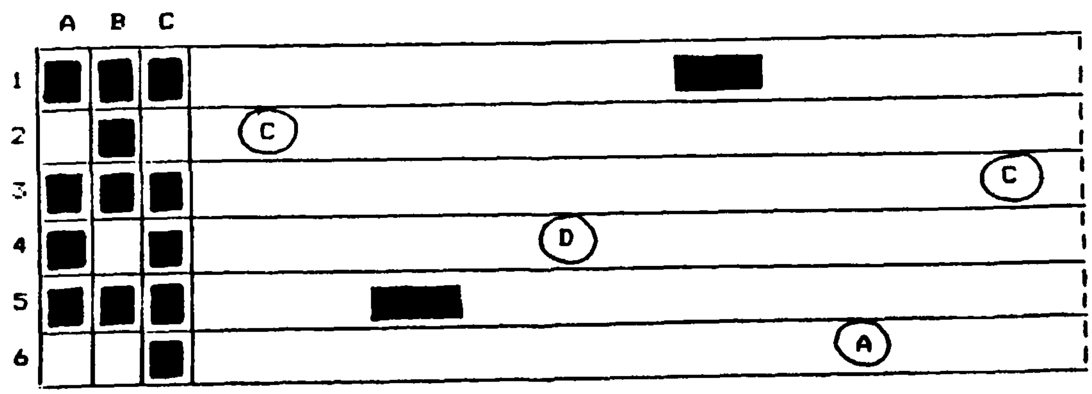
Name ___________________________________ Team ______ Worker: A B C

Date ____________________ Session ____

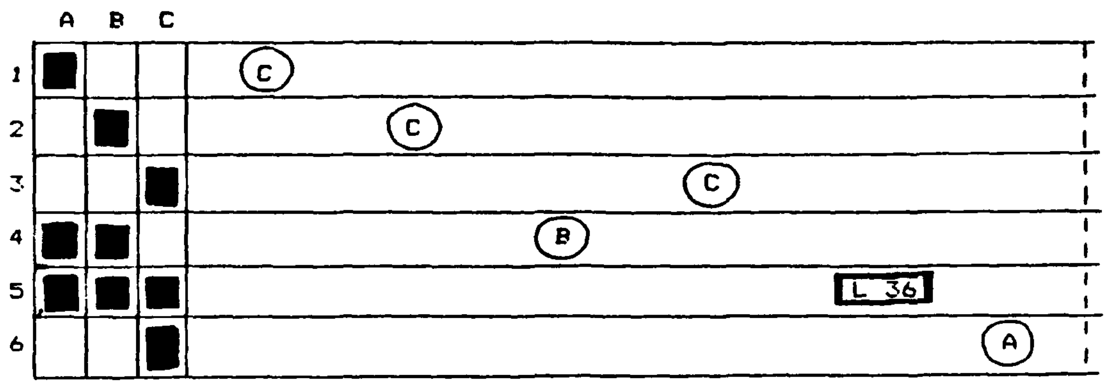
Each of the following diagrams represents a limited version of a situation you could face in the TRAP. Using the heuristics you have learned, examine each diagram, select the action that is most appropriate, and respond to the question following the diagram.



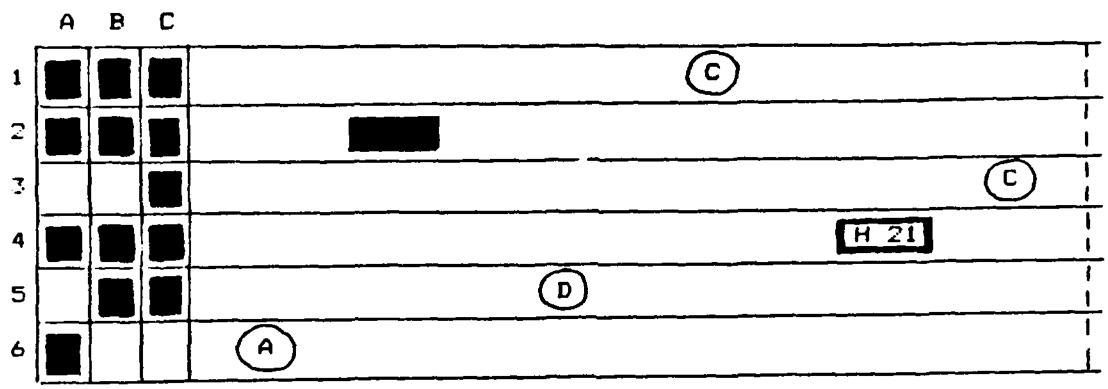
Please indicate which line or combination of lines your team should work on: ______.



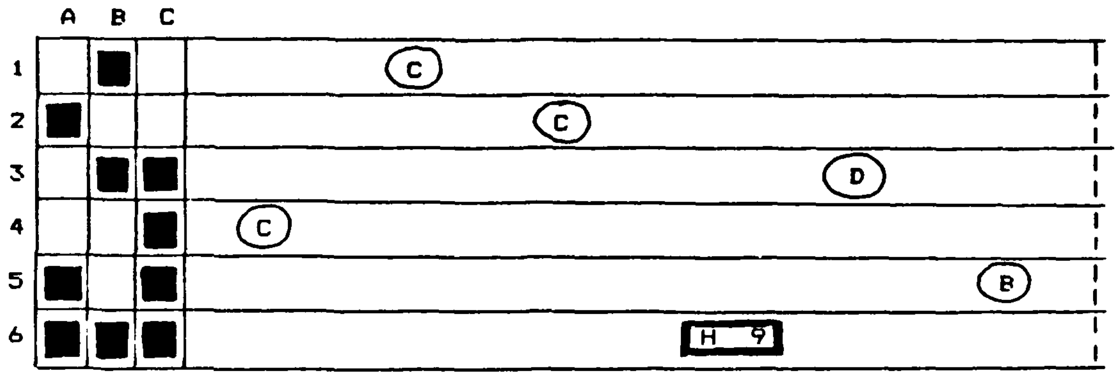
Please indicate which line or combination of lines your team should work on: ______.



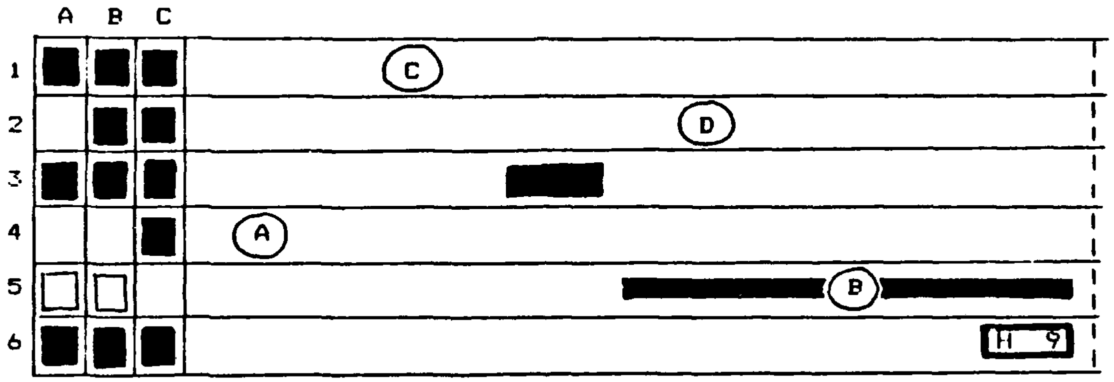
Please indicate which line or combination of lines your team should work on: ______.



Please indicate which line or combination of lines your team should work on: ______.



Please indicate which line or combination of lines your team should work on: ______.



Please indicate the best action for person C (place an X next to the best option):

_____ Get team to reset and start work on line 1.

_____ Suggest line 2 as next target after completing line 5.

_____ Suggest line 3 as next target after completing line 5.

_____ Start work on line 4.

_____ Get team to reset and start work on line 6.

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