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THESIS

THE EFFECTS OF TEAM LEADER FEEDBACK
ON SITUATION ASSESSMENT IN DISTRIBUTED
ANTI-AIR WARFARE TEAMS

by

Mark J.Gough

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Principal Advisor: Michael G. Sovereign

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Part of the Navy's attempt to address this issue is the Tactical Decision Making Under Stress (TADMUS) program. Under TADMUS, the Situation Assessment In Naval Teams (SAINT) experiment was run at NPS in December, 1991. This thesis describes the SAINT experiment and uses data collected during the experiment to study the effects of team leader feedback on situation assessment in distributed air defense teams. The emphasis of study is on performance, (error rate and pattern), subjective workload, and communication rates.

Findings include: feedback of the leader's current assessment lowers explicit coordination; feedback does not affect subjective workload; feedback increases error rates, and may affect error patterns. Evidence of feedback causing confirmatory bias was also found, but more research in this area is recommended.

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THE EFFECTS OF TEAM LEADER FEEDBACK ON SITUATION ASSESSMENT IN DISTRIBUTED ANT-AIR WARFARE TEAMS

by

Mark J. Gough
Lieutenant, United States Navy
B.A., University of Minnesota, 1984

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March 1992

Author: ______________________
Mark J. Gough

Approved by: ______________________
Michael G. Sovereign, Principal Advisor

____
William G. Kemple, Associate Advisor

____
Carl R. Jones, Chairman
Command, Control, and Communications Academic Group

ABSTRACT

Situation assessment is the first step in the Command and Control process. In naval tactical teams, it has become more critical even as it has become more difficult.

Part of the Navy's attempt to address this issue is the Tactical Decision Making Under Stress (TADMUS) program. Under TADMUS, the Situation Assessment In Naval Teams (SAINT) experiment was run at NPS in December, 1991. This thesis describes the SAINT experiment and uses data collected during the experiment to study the effects of team leader feedback on situation assessment in distributed air defense teams. The emphasis of study is on performance, (error rate and pattern), subjective workload, and communication rates.

Findings include: feedback of the leader's current assessment lowers explicit coordination; feedback does not affect subjective workload; feedback increases error rates, and may affect error patterns. Evidence of feedback causing confirmatory bias was also found, but more research in this area is recommended.

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I. INTRODUCTION

A. BACKGROUND

In the past five years, the U.S. Navy has seen a profound shift in the threat it must meet. The probability of a full-scale conventional or nuclear global war with a monolithic, centrally controlled superpower has vanished along with the Soviet Union and the Warsaw Pact. Unfortunately, the luxuries of a single, longtime foe, (e.g., detailed planning, well known tactics, a developed warning system, even a certain predictability of threat), have also vanished. Containment of communism has been replaced with maintenance of global stability.

Today's Navy is faced with the challenge of a growing number of nations which possess sophisticated weaponry, including weapons of mass destruction. Increasing emphasis is placed on regional conflict scenarios. Such conflicts are typically not blue water engagements with inherent warnings and space to maneuver. They are typically near land. A different set of threats to the surface operator are presented in this near land operating area (NLOA): anti-ship missiles launched from shore or from highly maneuverable patrol craft; shallow water mines; shore-based enemy aircraft and a 360 degree threat sector. The results are less room for maneuver and far shorter reaction times to a wider spectrum of threats.

In response, the Navy is developing a "stability strategy" which focuses on two regional contingencies: preventing conflict where it can; and engaging in combat only when it must [Ref. 1:p. 3]. The success of both are dependent on correctly assessing the current tactical situation. Effective command, control, communications (C3) begins with effective situation assessment. Unfortunately, "The uncertainty of the period makes warning signs even more ambiguous, reaction times even shorter, the identity and motives of potential adversaries more vague and the timing and scenario of unfolding events more difficult to discern." [Ref. 1:p. 2] In short, situation assessment in naval teams has become more critical even as it has become more difficult.

In the area of anti-air warfare (AAW), the problem is especially acute. Detect-to-engage sequences have been reduced to minutes; in some cases even to seconds. Yet Combat Information Center (CIC) AAW teams are still trained to fight the traditional, blue water engagement with the bulk of the fighting taking place in an outer air battle (OAB) 100 to 250 nautical miles from the main force. This is done under the assumption that doctrine designed for a blue water engagement in a full scale, declared war is also good for a near-land CALOW (Crisis and Limited Objective Warfare) operation. This is a dangerous assumption and one that is under critical re-evaluation.

Part of this re-evaluation effort is the Navy's Tactical Decision Making Under Stress (TADMUS) program. The purpose of TADMUS is to provide a better understanding of individual and team behavior in distributed naval decision making environments under high stress conditions in order to support the development of new training procedures and non-intrusive decision aides [Ref. 2]. Under the TADMUS initiative, ALPHATECH INC. has developed an experiment to study situation assessment in naval teams (SAINT) [Ref. 3:p. 15].

The first SAINT experiment was run at the Naval Postgraduate School in December, 1991. This thesis will describe the SAINT experiment and will use data collected during the experiment to study the effects of team leader feedback on situation assessment in distributed air defense teams.

B. OBJECTIVE

The objective of this thesis is to identify actions or behaviors that contribute to performance under conditions of high stress. The emphasis was placed on leader feedback to subordinate decision makers concerning his opinion of the hostility of a given contact. This seemed the most likely area in which changes in current Navy training structures could be effected.

1. Research Questions

The first three research questions do not relate directly to the thesis. However, if the data from the experiment is to be used, these questions must be answered affirmatively. If the independent "stressor" variables have no effect on subjective workload, they can not be termed "stressors", and no statements can be made concerning their relationships to dependent variables in the context of stress. The research questions are as follows:

- Does stress due to time pressure increase subjective workload?
- Does stress due to uncertainty, (garbled information), increase subjective workload?
- Does stress due to high target ambiguity increase subjective workload?
- Does leader feedback lower communication rates?

- Does leader feedback lower subjective workload?
- Does leader feedback lower a team's overall error rate?
- Does leader feedback affect the error pattern, (number of false alarms versus misses)?

2. Predictions

Based on a survey of the literature, an attempt was made to predict answers to the research questions. This was not possible in all instances.

With respect to time pressure, it was expected that subjective workload would increase as time pressure increased. In an experimental study on hierarchical team coordination, Wang and Serfaty showed that this was the expected pattern [Ref. 4:p.15].

It was expected that increasing levels of uncertainty, (induced by garbled information), would increase the subjective workload by forcing decision makers (DMs) to probe more often to get the required information [Ref. 5]. The stress associated with receiving no reward, (information), after performing the correct task, (probe), was also expected to add to the subjective workload.

The stress associated with high target ambiguity, (difficulty in discrimination between hostile and neutral), was also expected to increase subjective workload. Entin and Serfaty report that as ambiguity increases, so does subjective workload. Their results were similar under both high and low time pressure. [Ref. 6:p. 46]

Does leader feedback lower communication rates? It is known that as time pressure increases, teams adapt to the increasing subjective workload by reducing rates of explicit coordination [Ref. 5:p. 16]. It has also been hypothesized that the ability of teams to coordinate implicitly is the result of shared mental models of both the task at hand and the capabilities of team members [Ref. 7:p. 1]. Furthermore, expert commanders "...communicate their intent and understanding of the situation frequently in order to maintain a common mental model of the situation, an essential feature to facilitate implicit coordination in the team." [Ref. 8:p.8] It was therefore expected that feedback of the leader's current assessment of the contact would lower communication rates by facilitating implicit coordination.

If, as expected, feedback lowers explicit coordination, it should also lower subjective workload. This may not hold true in the instance of low time pressure, but as time pressure increases and the need for implicit coordination rises with it, feedback should be seen as a factor that helps maintain workload at an acceptable level. At the very least, workload should be less under high time pressure with feedback than under high time pressure without feedback. This should also hold true for the other stressors, such as high uncertainty and high ambiguity.

With respect to the last two research questions, there appears to be little empirical research that has studied the merits of feedback, (as narrowly defined in the SAINT experimental paradigm), on team performance. However, studies have shown that the assessment of a situation is captive to the most recent information received by the decision maker, since all hypotheses under consideration do not have the same prior probability of occurring [Ref. 9:p. 34]. This recency effect is compounded by the fact that people have cognitive limitations that only allow them to maintain a few hypotheses about a current situation at any given time [Ref. 9:pp. 34-35]. This is further complicated in that people do not seek or apply information objectively in an effort to confirm or refute the few hypotheses they do maintain. Rather, they frequently exhibit "confirmatory biases". New information is sought and incoming information is filtered to confirm rather than test a current assessment of the situation [Ref. 9:p. 44]. This can have tragic results.

In the case of the USS Vincennes downing Iran Air Flight 655, the crew appeared to exhibit a classic case of such confirmatory bias.

> TIC (Tactical Information Coordinator) and IDS (Identification Supervisor) became convinced track 4131 was an Iranian F-14 after receiving the IDS report of a momentary Mode-II. After this report of the Mode-II, TIC appears to have distorted data flow in an unconscious attempt to make available evidence fit a preconceived scenario. [Ref. 10:p. 45]

Also,

> In the final minute and forty seconds, the AAW (Anti-Air Warfare officer) tells his captain, as a fact, that the aircraft has veered from the flight path into an attack profile, and is rapidly descending at increasing speed directly towards USS Vincennes. Even though the tone of these reports must have seemed increasingly hysterical . . . the AAW made no attempt to confirm the reports on his own. Quick reference to the CRO (character read-out) on the console directly in front of him would have immediately shown increasing not decreasing altitude. . . . (He) relied on the judgement of one or two second class petty officers, buttressed by his own preconceived perception. [Ref. 11:p. 5]

The crew expected an air attack and all incoming information was construed as confirming an earlier call by IDS of track 4131 as "Iranian F-14". Despite repeated indications of an ascending contact squawking constant Mode-III, the AAW team persisted in its assessment of a descending contact squawking Mode-II. This biased interpretation of the available data was the only one transmitted to the captain, who sought and considered only this interpreted assessment. He did not seek any raw measurements of his own. [Ref. 10:pp. 1-45]

The last two research questions may give some insights into whether feedback of the leader's current assessment of the situation, (i.e., hostile/neutral), intensifies or mitigates the phenomena of recency and confirmatory bias.

II. EXPERIMENTAL DESIGN

A. OVERVIEW

The SAINT experimental paradigm is a modification of the Distributed Dynamic Decisionmaking (DDD-II) paradigm developed by Kleinman, Serfaty and Luh in 1984 and updated by Kleinman and Serfaty in 1989. For the SAINT experiment run in December of 1991, the task was a CIC-type distributed situation assessment problem faced by a four-person hierarchical command team [Ref. 3:p. 16]. The primary goal of the experimental paradigm was for the team to collect, evaluate and fuse data concerning an inbound contact in order to infer correctly its hostility or neutrality in a timely fashion. The simulated environment was an analogue of the anti-air warfare (AAW) team of the Combat Information Center on a cruiser. The four-person team assessing the contact was an analogue of the tactical action officer (TAO) and three of his support staff.

Each of the three subordinate team members performs a different task. ALPHATECH INC.'s original paradigm for SAINT, as set forth in their technical proposal of May, 1991, called for a team structure that provided for partial functional overlap among the decision makers. Each subordinate decision maker was to have the ability to probe for measurements on two of the three contact attributes, (size, altitude rate and radar emission type), with primary responsibility in one and secondary responsibility in the other [Ref. 3:p. 16]. This was to allow for the gathering of data relating to how stress affects team coordination and burden sharing. However, the eventual team structure actually used in the December, 1991, experiment did not provide the overlap [Ref. 12]. Each subordinate had access to only one of the contact's three attributes. No horizontal coordination was required or possible in completing subordinate tasks. Each subordinate team member obtained noisy measurements on one of the attributes by using a mouse to position a cursor over the target icon. When the mouse was clicked, a window was displayed and, after ten seconds, a measurement of the attribute was displayed. Occasionally, no information was provided. A tick mark (-) taking its place. The frequency of this information loss was manipulated as an independent variable and named "uncertainty". After a team member had collected enough readings to determine an attribute's value, this value was passed verbally to the TAO, and manually entered in the subordinate's computer log along with the subjective confidence in the current value assigned to the attribute.

The job of the TAO was to fuse the attribute information provided by the subordinates and make a determination as to the contact's hostility. He not only received verbal reports from the three subordinates, but was also able, with his mouse, to open a window, (see Figure 1), that displayed each of the three subordinates' most recent attribute values and confidence levels as entered in their personal logs. (Note. There was a ten second "communications delay" between the time a subordinate made an entry and the TAO's version was updated.)

However, the TAO did not have direct access to sensors. He had to verbally task one or more of the subordinates to provide additional attribute estimates or raw data as required. The TAO was to make a hostility determination based on current information. The dissemination of this opinion every 45 seconds was manipulated as an independent variable called "feedback".

The TAO had to make a final determination of the inbound track's hostility before it entered the protected zone of the carrier. This final determination, or the contact entering the protected zone ended the trial and all four team members received feedback as to the correctness of their call. This feedback was not manipulated.

B. SETUP

1. Physical

The physical setup of the experiment consisted of four physically separate bays, each containing a single game station. The purpose in separating the stations was to ensure that all communications would be either via voice net, or via the software, and hence recorded. The experiment was hosted on the DDD-II simulator using software developed at the University of Connecticut and SUN workstations connected by a local ETHERNET. Each game station consisted of a graphics display, a keyboard, a mouse and an intercom headset provided by NTSC Orlando.

2. Test Subjects

The test subjects included nineteen junior to field grade military officers and one civilian. The twenty subjects were drawn from the Joint Command, Control, Communications (JC3) curriculum at the Naval Postgraduate School in Monterey, California. The subjects were divided into five teams of four members. Operational

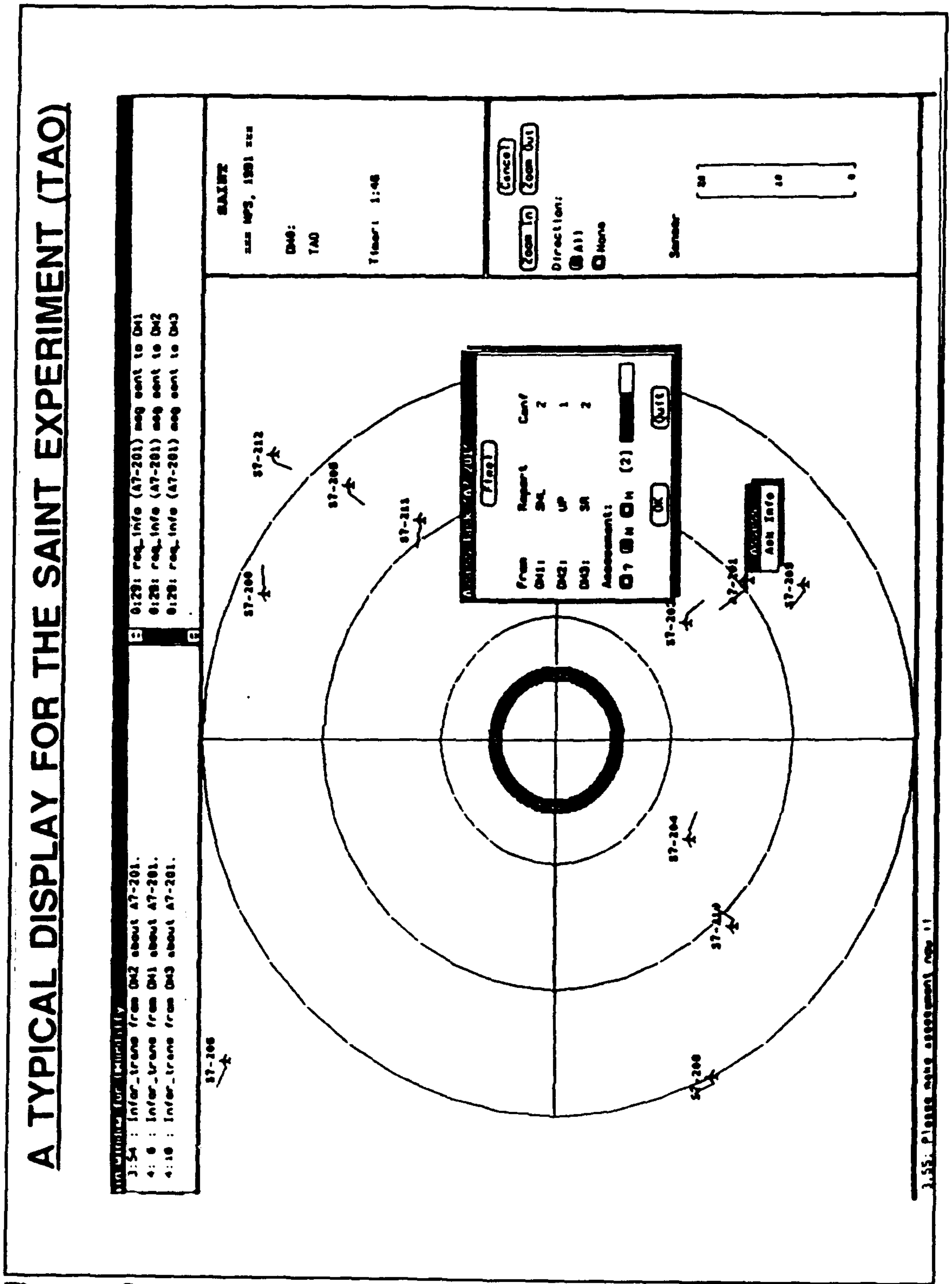

Figure 1: Sample SAINT Display

experience was considered both in selecting the teams and in assigning the TAOs. Team cohesion was maintained throughout the experiment.

3. Special Equipment

Special equipment included a VHS recorder and the intercom headsets with related communications equipment. The audio signal from the communications net was patched directly into the VHS recorder. The TAO's game screen and all verbal communications were recorded in this manner.

C. HYPOTHESES

The purpose of this thesis is to identify actions or behaviors that contribute to the CIC AAW team performance under conditions of high stress induced by time pressure, uncertainty and ambiguity. In narrowing the emphasis, leader feedback was selected as an area with possible implications in effective team training. The following hypotheses are based on the research questions and literature survey discussed in Chapter I:

1. Hypothesis I:

Leader feedback of current hostility assessment lowers explicit coordination.

2. Hypothesis II:

Leader feedback of current hostility assessment lowers subjective workload.

3. Hypothesis III:

Leader feedback of current hostility assessment lowers error rates.

4. Hypothesis IV:

Leader feedback of current hostility assessment changes the error pattern.

D. ASSUMPTIONS

1. General

The major assumption made during this experiment was that the learning curve was completed during the two training sessions, and that the data is therefore free from any effects due to the learning curve. Another assumption was that the subjects were willing and enthusiastic, and that the data is therefore not tainted by halfhearted guessing on the part of the TAO or his staff. This assumption is necessary because subjects were not volunteers.

2. Simplifying Assumptions

In addition to the general assumptions outlined above, there were several simplifying assumptions that divorce the experimental paradigm from reality but are necessary to gain some control over the manipulation of the selected independent variables. These include:

- Strictly an AAW problem;
- No multi-target tracking;
- Semi-artificial roles for subordinates;
- Single intra-team communications net;
- No inter-team (i.e., between platforms) communications;

- Simulates only a small portion of total CIC personnel, activities, noise and confusion.

E. STATISTICAL DESIGN

The experiment was designed to yield balanced data for ANOVA purposes. Four independent variables were part of this design. The first three resulted in 12 different possible combinations (3 time stress * 2 uncertainty * 2 feedback). Each combination was presented twice, for a total of 24 presentations per team. The four levels of ambiguity were manipulated evenly over each group of 12 presentations. The 24 presentations were run on five separate teams, yielding 120 data points for performance measures. The four independent variables are outlined below:

1. Time Induced Stress

Stress due to increasing time compression was manipulated at three levels:

- Low = 6 minute prosecution window;
- Medium = 4 minute prosecution window;
- High = 2 minute prosecution window.

2. Uncertainty

As discussed earlier, this was a measure of how often a probe resulted in no data:

- Low = 10% garbled data (ticks);
- High = 50% garbled data (ticks).

3. Feedback of Hostility Assessment

Under "feedback" conditions, the TAO was required to verbally disseminate his current opinion as to the inbound track's hostility or neutrality every 45 seconds. Under "no feedback" conditions, he was prohibited from ever disseminating his opinion of hostility or neutrality. All instances of improper dissemination were recorded by the observer.

4. Ambiguity

Ambiguity was manipulated as the fourth independent variable. This was a measure of how clearly hostile or clearly neutral the target profile was, (see Figure 2). One half the profiles were ambiguous based on the general definition of "hostile" given to participants. This is further broken down as follows: one fourth clearly neutral; one fourth ambiguous neutral; one fourth ambiguous hostile; and one fourth clearly hostile.

F. MEASURES

1. General

The experiment included both qualitative and quantitative measures. Qualitative measures included: pre-experiment questionnaires to measure team preparation and coordination; pre-presentation predictions of hostility recorded for all subjects; subjective workload assessments after each presentation; subjective performance evaluation questionnaires after each block of six presentations; and a post experiment questionnaire.

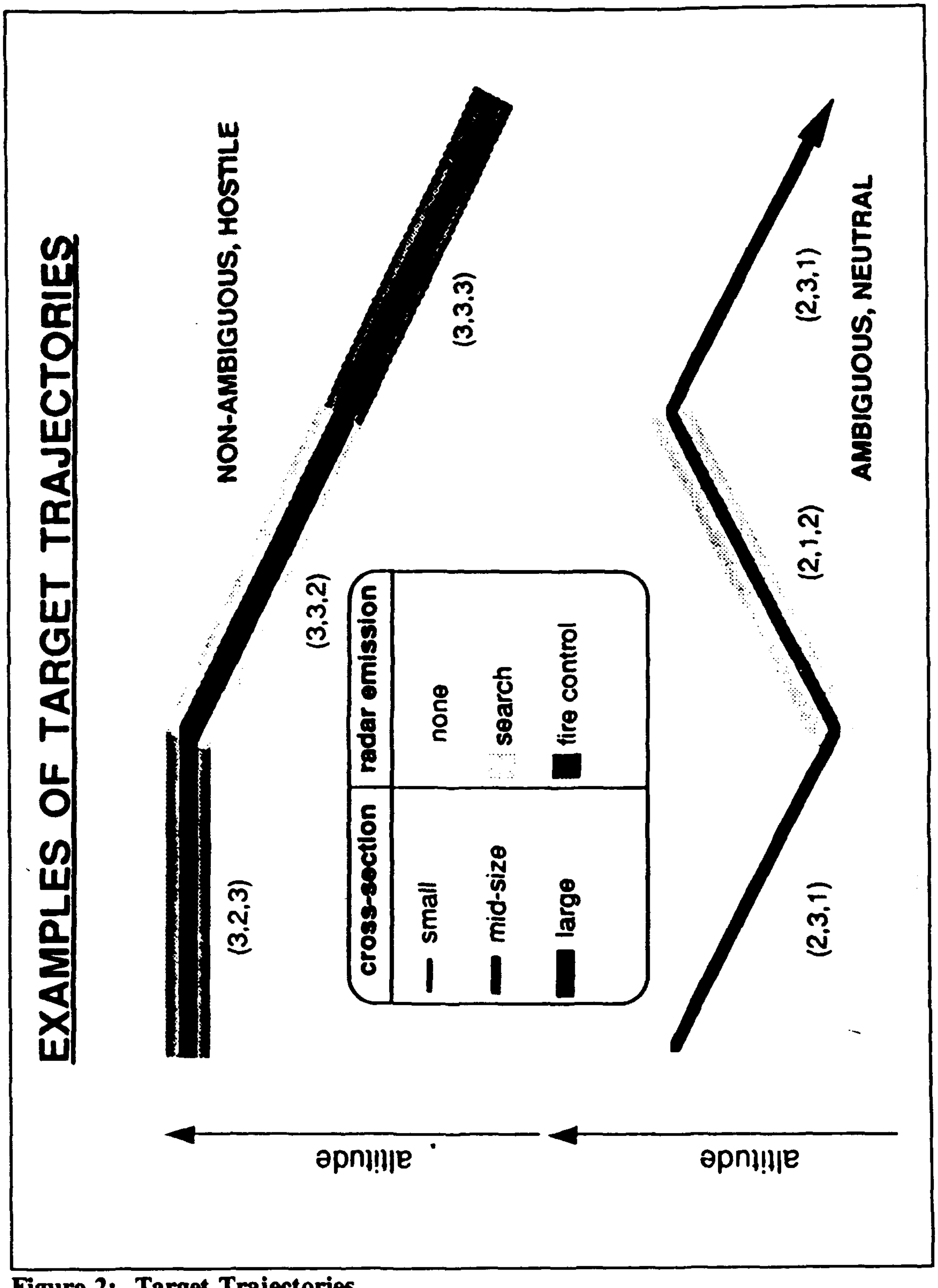

Figure 2: Target Trajectories

Quantitative measures were recorded automatically by the DDD-II simulator. These electronically recorded measures number over forty and range from the TAO's final decision to the number of times each subordinate probed the contact for attribute information. The SWAT data was also recorded by the simulator, (see next section), both for the four individual decision makers and the team. Quantitative measures of verbal communication rates and types were recorded manually by observers with tally sheets.

2. Workload Assessment

In order to assess workload for the purpose of testing the viability of the stressors, each participant completed the Subjective Workload Assessment Technique or SWAT [Ref. 13:pp. 403-406]. SWAT consists of two phases. Phase one should be carried out prior to the data collection part of the experiment. Each participant performs a card sort to develop a unique workload scale. Each card contains a different combination of the three workload dimensions: timeload; mental effort load; and psychological stress load [Ref. 13]. Each dimension has three levels: low; moderate; and high. Crossing dimensions with levels yields 27 possible combinations which are rank ordered by the participant according to the workload described. It should be noted here that this phase was completed after data collection for SAINT, December, 1991.

The second phase occurred during data collection. At the end of each presentation, subjects rated the workload they had just experienced based on the same dimensions and levels described above, (eg. 321 would represent high time load, moderate mental effort, and low psychological stress). Software, developed by G. M.

Reid, ALPHATECH INC, then converts these numbers to a percent workload score based on the unique workload scale developed for that participant in phase one. Zero percent represents very low workload; 100 percent represents very high workload, (unique to the individual).

At the writing of this thesis, converted SWAT data was not available. Means from phase 1 had to be utilized. These means are typically highly correlated with the converted SWAT percentages. [Ref. 14]

3. Subjective Hostility Assessment

In order to determine the subjective definition of hostility for each TAO, so that team performance measures could be adjusted accordingly, TAOs sorted a set of hostility cards similar to the SWAT card sort. There were 27 cards reflecting the three target attributes, (size, altitude rate, and radar emission), and the three levels within each attribute, (small, medium, large; climbing, level, descending; no emission, search radar, fire control radar). In this manner, each TAO's 24 final decisions can be compared to his own definition of hostility, as well as the "ground truth" definition of the paradigm.

The design of the December, 1991 SAINT experiment is sound. The assumptions made were reasonable, and the statistical design should provide balanced data. A more detailed description of the actual data is provided in the next chapter.

III. DATA DESCRIPTION

A. TYPES

As well as being both quantitative and qualitative, the data was collected both manually and electronically. Manually collected data included questionnaires, card sorts, and observation form "tally sheets", as well as the audio/video tape of each presentation. Electronically collected data included the quantitative measures collected by the computer.

B. PROBLEMS

1. Electronically Collected Data

There were no problems with the electronically collected data. Complete data for all 24 presentations on all five teams were collected. In addition, complete SWAT survey data was collected for all 120 runs.

2. Manually Collected Data

There were some actual as well as some potential problems in the manual collection of data. The video/audio tape was not started at the beginning of all runs. This affected three of 120 runs. However, partial runs were recorded in all three cases.

Potential problems lay in the fact that the observation forms for communications analysis can be interpreted differently by each observer, (see Appendices A and B). The categories are too broad, and much data may have been lost or skewed because an observer could not force a comment to fit one of them, either letting it go or placing it where it "best fit". Some effort was made to prevent the inherent variance from one observer to another. In the instance of TAO communications, the same observer, (the author), recorded all 24 presentations for all five teams. This was not possible, from a practical standpoint, in the case of subordinate communications. A total of seven different observers, rotating between teams, recorded subordinate communications. Additionally, some categories are simply not needed based on the experimental paradigm. For example, information transfers of raw data would never be made by the TAO, except to call the original target of interest. Indeed, this should be a category of its own. Careful modifications to the data collection forms could reduce the confusion for observers as well as reduce the amount of potentially lost or skewed data.

C. DATA CODING SCHEME

1. Manually Collected Data

a. Observation Forms

Appendix C contains the coding scheme for data collected manually with observation forms. Two types of observation forms were used: one for the TAO, (Appendix A), and one for subordinates, (Appendix B). These forms illustrate the areas of interest in data collection. The data collection method simply required the observers to keep a tally of all instances of communication made by the test participants. The forms contain separate blocks for each of the varied types of communications of interest to the experimenters. For situations not specifically addressed by the form, a comments section is provided. The problems with this type of data collection were discussed above.

b. Questionnaires

Appendix D contains the data coding scheme for data collected manually using questionnaires. An example of a questionnaire is seen in Appendix E. This particular questionnaire was given to participants after each block of six presentations to solicit opinions and assessments concerning mission accomplishment, team and individual performance and goal achievement.

2. Electronically Collected Data

Appendix F contains the coding scheme used for electronically collected data. Appendix G is an example of this raw data as extracted from the computer after the experiment.

Although both realized and potential problems occurred in data collection, a set of balanced data was produced for purposes of analysis of variance. A description of this analysis is contained in the next chapter.

IV. ANALYSIS

A. METHODOLOGY

After all 120 trials had been run, data was processed by ALPHATECH INC. The dependent variables were first organized into three sets, each with various categories. Set #B1 includes semi-processed data collected on-line by the DDD-II simulator, and was broken into performance, strategy, and workload categories. Set #B2 includes semi-processed data collected by observers It contains communications data on the TAO and subordinate decision makers. Set #B3 includes semi-processed data collected from subjects and contains data from the questionnaires.

The next step by ALPHATECH INC was to formulate a set of aggregated measures with categorization, based on variable sets B1-B3. This set is categorized #A1. The coding scheme for aggregated measures set A1 is contained in Appendix H. The data was then evaluated by subpopulation based on this coding scheme. Means tables were generated for each subpopulation, (dependent variable by independent variable, eg. AP1 by feedback, AP1 by uncertainty, etc.). Analysis of variance (ANOVA) was performed for all dependent variables.

ANOVA generates a "p" value. This value is the probability of making an error in claiming that a given dependent variable is affected differently by different levels of an independent variable. The standard acceptable value is $p <= 0.05$. Another way to view a value of $p<0.05$ would be to say, "I can be 95% certain that the change in dependent variable X was caused by independent variable Y and not by chance."

B. RESULTS

This thesis will only provide results from the data analysis that are pertinent to the research questions stated in Chapter I.

1. Workload Assessment

It was expected that uncertainty, time-stress and ambiguity would all increase subjective workload. This is the case, (see Figures 3-5), however, only uncertainty had a statistically significant effect, ($p<0.045$). The mean workload for the entire population was only 1.3459, (1=low, 2=moderate, 3=high). Under the most stressful conditions, (high uncertainty, high workload, high ambiguity), workload was reported as 1.7709. This is barely "moderate". Clearly, more stressors need to be introduced to the experimental paradigm.

2. Effects of Feedback

a. On Communication Rates

It was expected that TAO feedback of his opinion as to the hostility/neutrality of the inbound contact of interest would lower communication rates by facilitating implicit coordination through an expanded shared mental model.

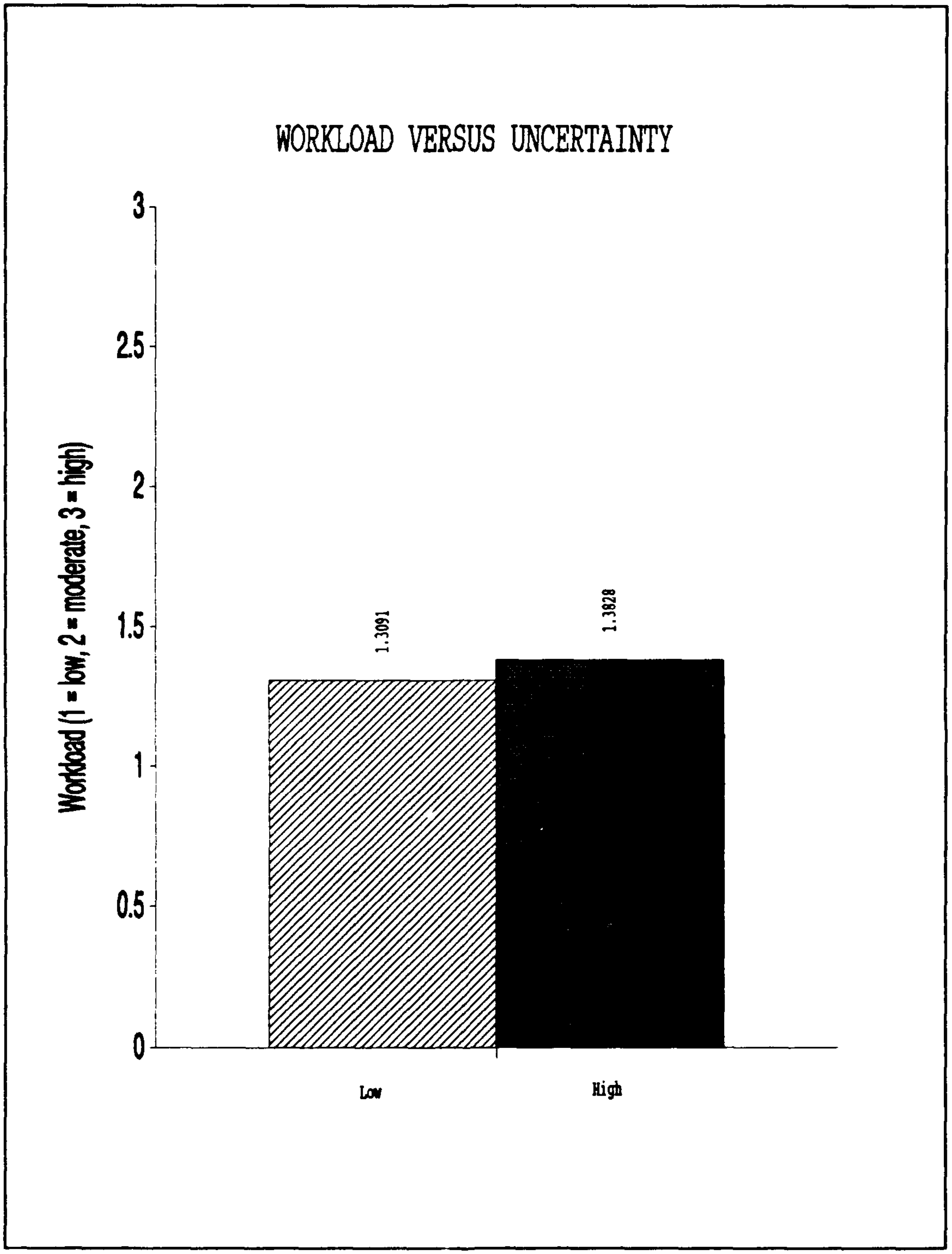

Figure 3: Workload Versus Uncertainty

This does not, at first glance, appear to be the case. Feedback actually increased overall message rate, (messages per minute), from 7.6667 without feedback, to 8.4667 with feedback, ($p < 0.046$). However, this is deceptive. By forcing the leader

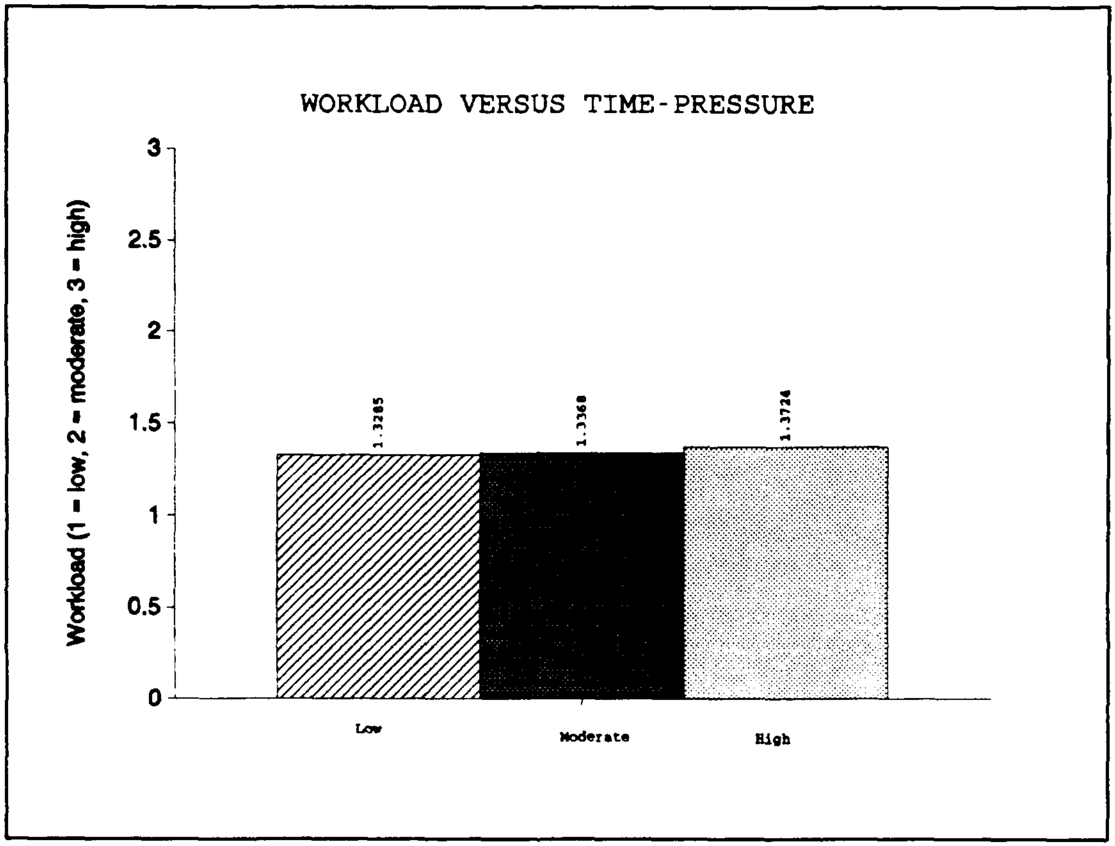

Figure 4: Workload Versus Time-Pressure

to communicate every 45 seconds in the feedback condition, we artificially raise his communication rate to subordinates from 1.4833 to 2.5167, (see Figure 6, $p < 0.002$). If we look at subordinate communications to the TAO, a factor not artificially altered by manipulating the independent variable, we see the mean percentage of communications

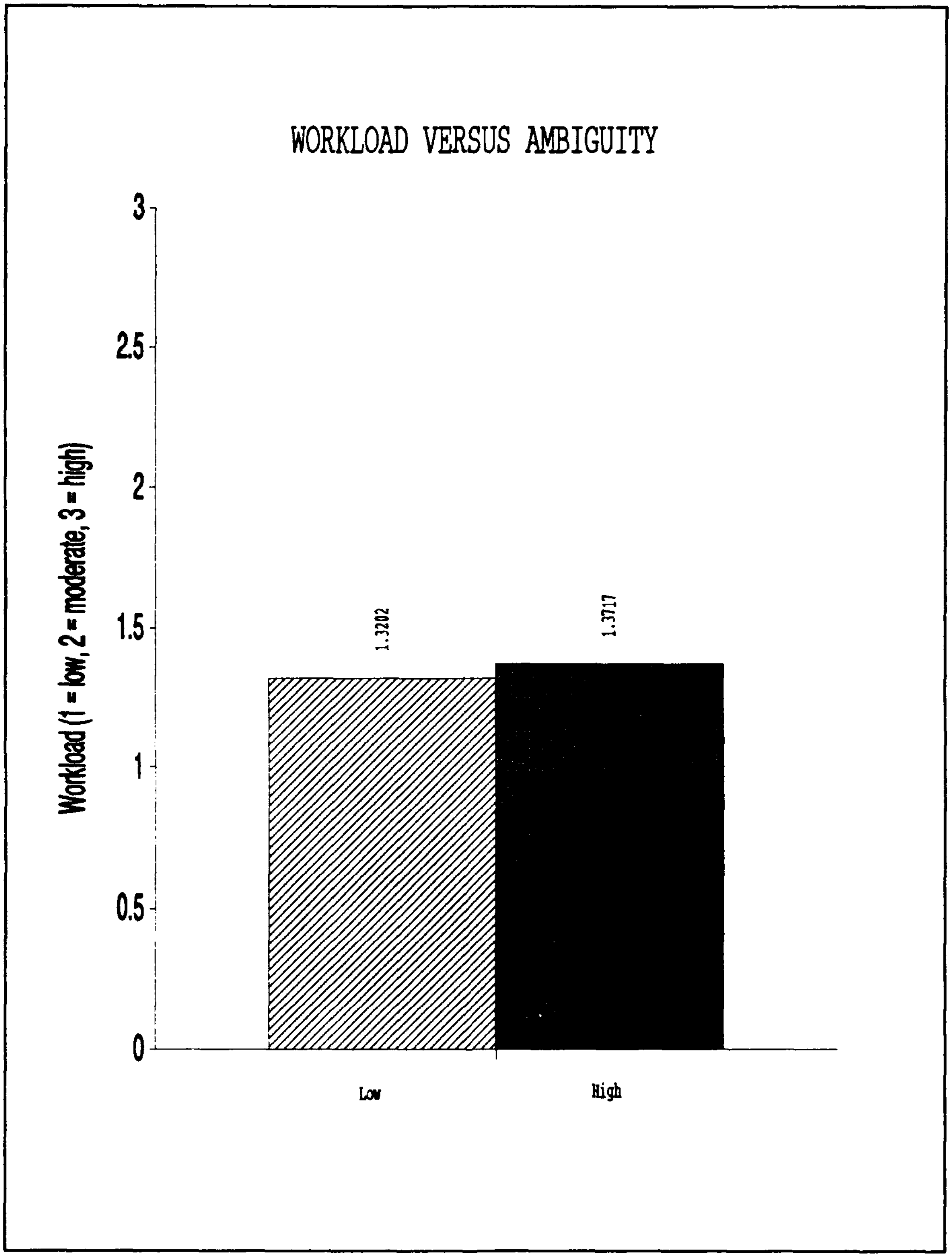

Figure 5: Workload Versus Ambiguity

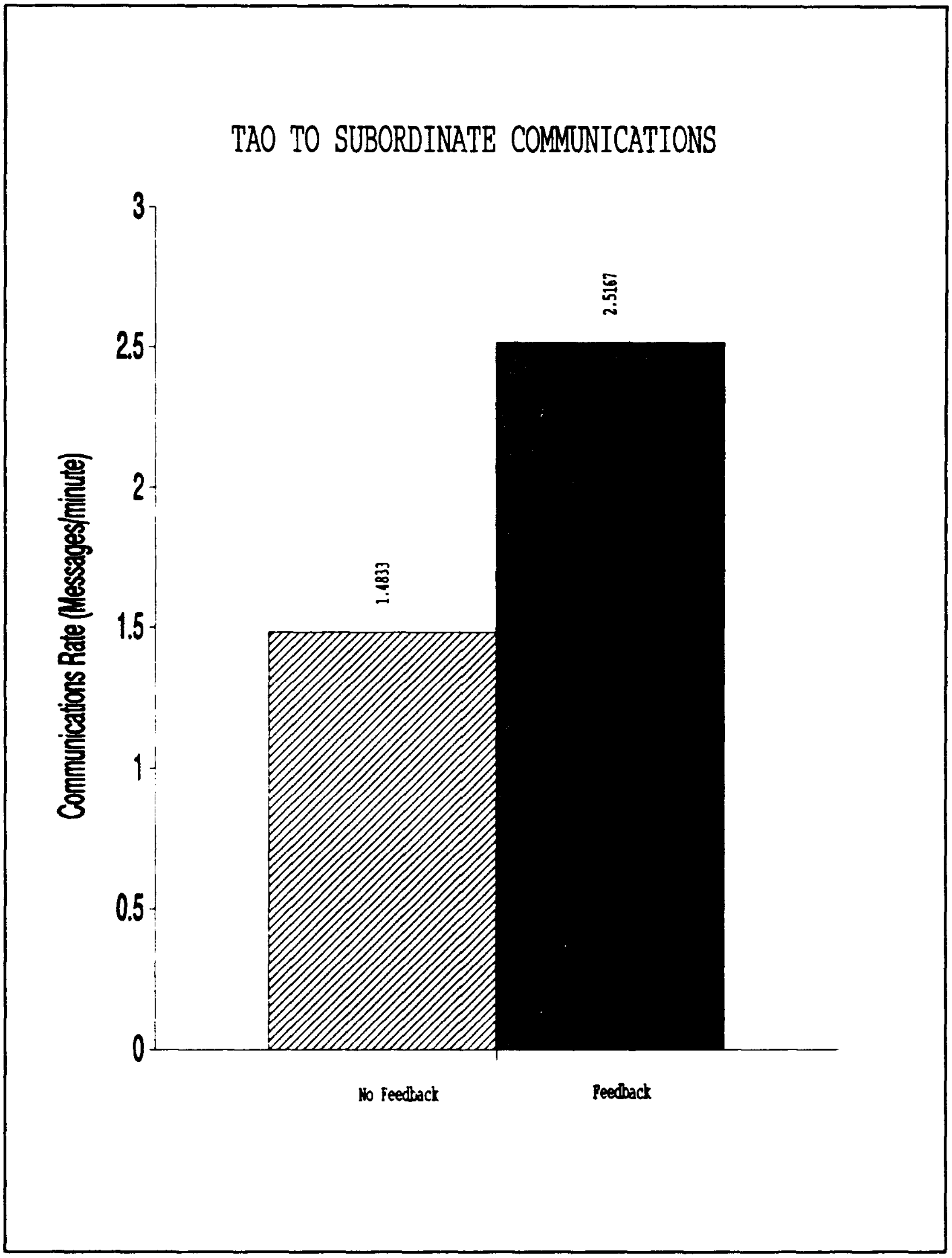

Figure 6: TAO To Subordinate Communications

fall from 77.533 percent to 62.3333 percent under feedback, (see Figure 7, $p<0.005$). Horizontal communications were not affected by feedback, ($p<0.777$), but this is expected in that the experimental paradigm does not require nor encourage communication between subordinates. Feedback does not change this fact. On the whole, feedback would seem to lower explicit coordination.

If we look at the mean number of information requests made by the TAO, we see that they drop from a mean of 2.5167 per presentation with no feedback, to 2.0000 per presentation, with feedback, ($p<0.044$). Another interesting measure is the "anticipation ratio". This is the difference between information transfers to TAO and information requests from TAO, that difference then divided by the information transfers to TAO, expressed as a percent. This anticipation ratio increases from 85.75%, with no feedback, to 87.4333% with feedback, (however, $p<0.325$). Taken together, the drop in information requests and the rise in the anticipation ratio seem to indicate that feedback does play a role in implicit coordination.

b. On Subjective Workload

It was expected that feedback would lower subjective workload. This was not the case. Workload under no feedback conditions was 1.3425 and actually increased very slightly under feedback to 1.3493. These numbers are obviously nearly the same (standard deviation 0.4), and the p value is not significant.

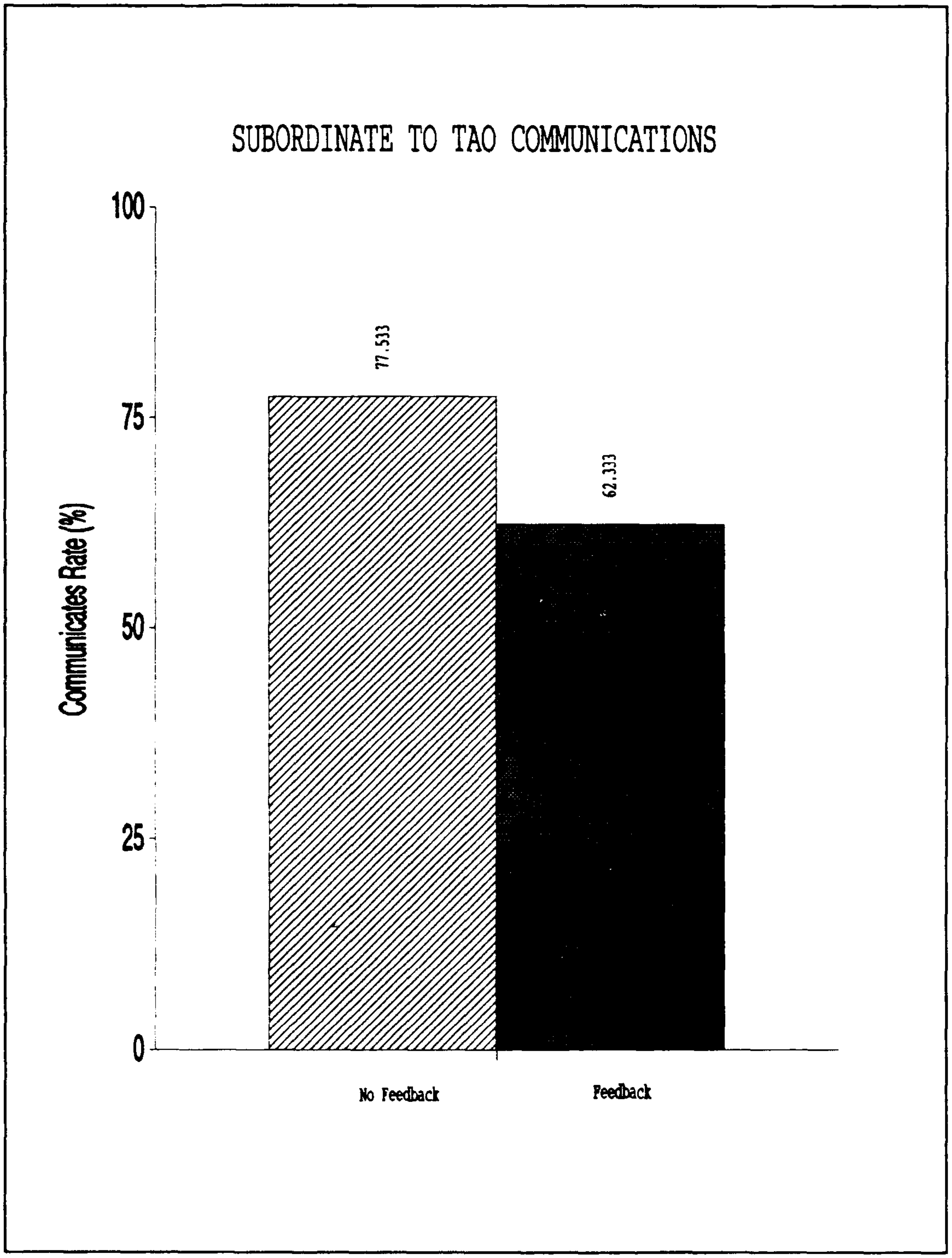

Figure 7: Subordinate To TAO Communications

Feedback also had no effect under the high time pressure condition, which was predicted to be most likely to show effects under feedback.

c. *On Error Rate*

No predictions were made concerning the effects of feedback on error rate. The mean error rate, (according to ground truth in the paradigm), increased from 15.0 percent with no feedback, to 28.33 percent with feedback, ($p<0.078$). When we adjust the data for TAOs' subjective hostility definition, the error rate jumps to 26.67 percent, and is not affected by feedback, ($p<1.0$). Feedback of TAO opinion as to contact hostility has a negative impact on team performance. This is seen graphically in Figure 8.

d. *On Error Pattern*

No predictions were made concerning the effects of feedback on the error pattern, (false alarm rate versus miss rate). As seen earlier, the overall error rate nearly doubles under feedback. Did the error pattern change as well? It would appear not, (see Figure 9). As expected, the false alarm rate and the miss rate are both affected by feedback, ($p<0.099$). Under both conditions, the false alarm rate is larger than the miss rate, and by nearly the same proportion. However, when examined closely, it is seen that

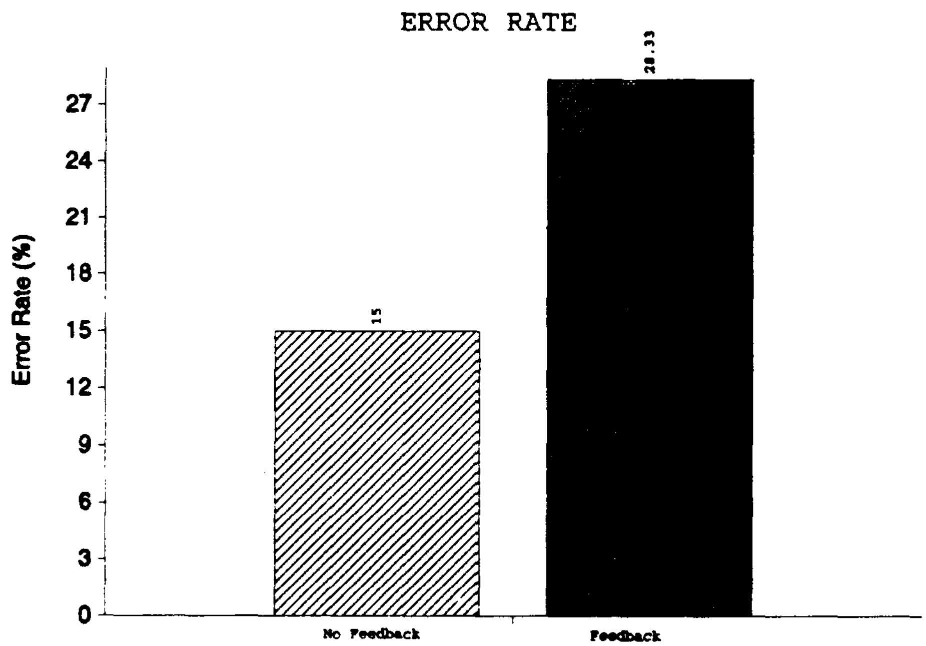

Figure 8: Error Rate

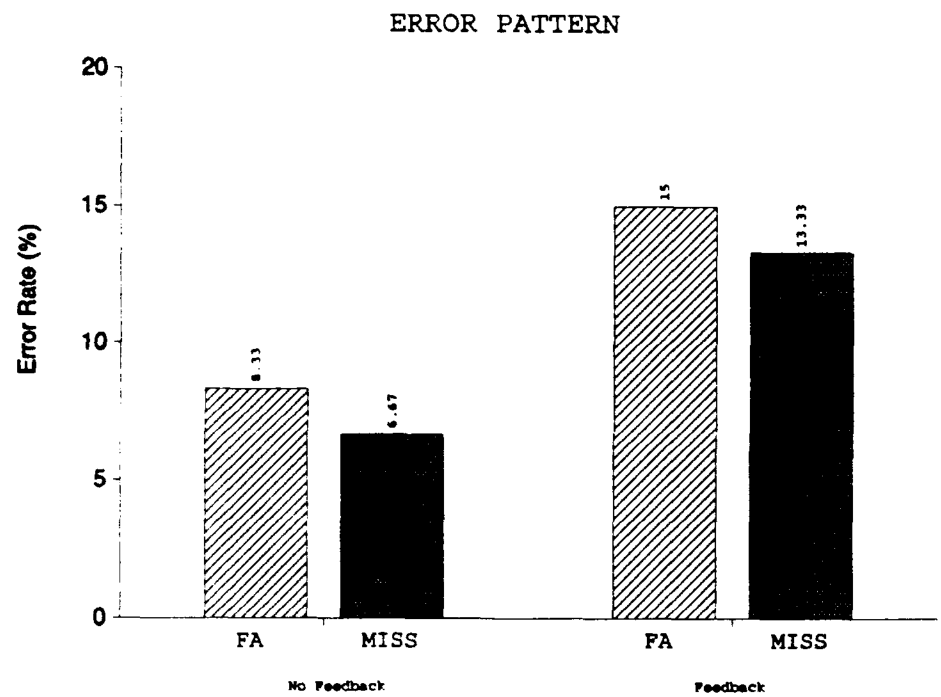

Figure 9: Error Pattern

under the no feedback condition, the miss rate is only 80 percent as large as the false alarm rate. Under the feedback condition, the miss rate rose to 88 percent as large as the false alarm rate. Feedback may have an effect on the error pattern that is too subtle to see readily with the relatively small population of 120 final decisions. Added evidence to this effect may be seen when we look at the TAO initial judgment. Under the no feedback condition, this was 1.4167 (1 = neutral, 2 = hostile). Under feedback, this number drops to 1.3167, ($p<0.109$). Figure 10 shows this in raw percentages. From this figure, it is clear that under no-feedback conditions, TAOs initially report neutrals and hostiles at about the same rate. When TAOs provide feedback, they report neutrals at a 2:1 ratio over hostiles. When compared to the error patterns, we see that as the initial judgement gets closer to neutral, the miss rate increases as a proportion of the false alarm rate. In other words, as feedback drives the <u>initial</u> judgment towards neutral, (from 1.4 to 1.3), TAOs are more likely to call a hostile contact neutral, at <u>final</u> decision, than under the no feedback conditions.

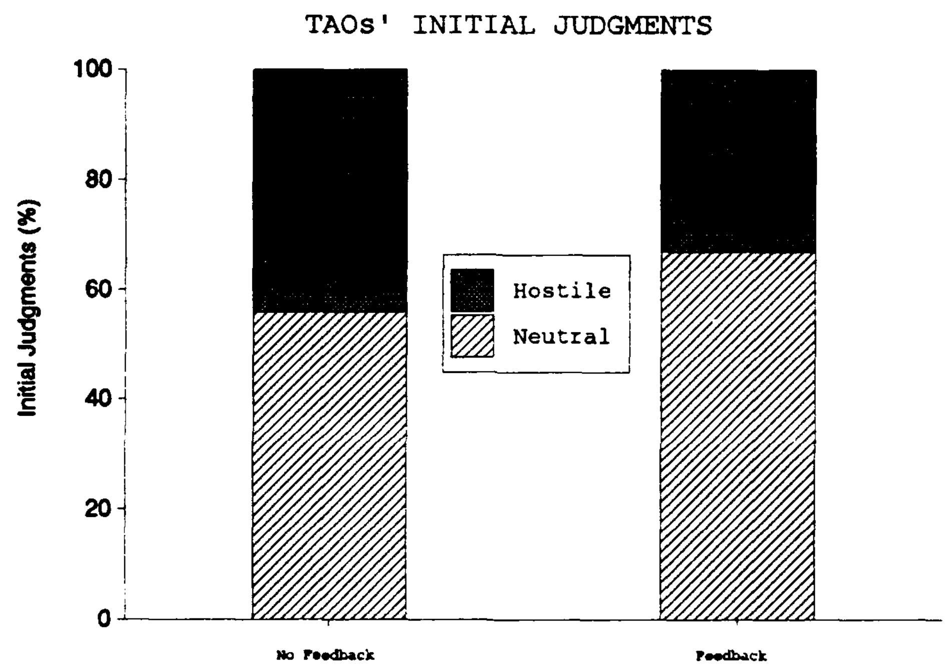

Figure 10: TAO Initial Judgments

e. The Question of Confirmatory Bias

As discussed in Chapter I, feedback may have some influence on confirmatory bias. There is some evidence of this in the two preceding sections. It was stated earlier that feedback increases the error rate. It also lowers the probe rate of the contact by subordinates from .1815 probes per second to .1722 probes per second, ($p < 0.037$). Furthermore, feedback increases slack time, (time remaining at final decision), from 23.25 seconds with no feedback, to 28.7333 seconds with feedback, (however, $p < 0.312$). Confidence on final judgement, (1:low, 2:moderate, 3:high), also increased from 1.6167 with no feedback to 1.6333 with feedback, ($p < 0.034$). When combined, these factors seem to indicate a trend, under feedback, of a willingness to make the wrong decisions more quickly with less information yet with increased confidence. This seems to indicate that feedback of the leader's current situation assessment as to the inbound contact's hostility contributes to confirmatory bias, which in turn reduces overall performance. Further evidence is seen in the fact that confirmatory bias, if it is caused by feedback, would predict the slight change in error pattern caused by the change in initial hostility judgement as discussed in the preceding section.

V. CONCLUSIONS

The purpose of this chapter is to draw conclusions about the four hypotheses of the thesis. They will be made based on the data analysis discussed above. With regard to the first hypothesis, it is concluded that feedback does lower explicit coordination. There is also some evidence, though not statistically significant ($p < .325$), that feedback increases anticipation. It is not clear whether or not the cause of this is an enhanced shared mental model. Further study should be done in this area.

With regard to the second hypothesis, there is little evidence that feedback, in the narrow definition of the experimental paradigm, lowers subjective workload. This should be looked at when the converted SWAT percentages are available, and should be studied again under conditions of truly high stress.

With regard to the third hypothesis, it can not be concluded that leader feedback lowers error rates. Indeed, there is strong evidence to suggest that it increases error rates. The adjustment of the data for subjective hostility definition was inconclusive; all p values jumped to 1.0. This indicates a problem in the method of obtaining this subjective definition that should be addressed prior to the next experiment. It is touched on briefly in the next section.

With regard to the fourth hypothesis, there is some evidence that feedback may have affected the error pattern. However, the evidence is not strong, and further research should be done in this area.

In addition to the four hypothesis, there is evidence that feedback contributes to confirmatory bias, and as a result, lowers performance. On balance there seems to be little to recommend feedback of this nature in situation assessment.

VI. RECOMMENDATIONS

A. FOR FUTURE SAINT EXPERIMENTS

1. Stressors

While the SWAT data indicate that the stressors utilized by the experimental paradigm had the expected effects on subjective workload, it is clear that situation assessment under truly high levels of stress was not observed. The mean subjective workload was only 1.3459, (3=high stress). Under the most stressful conditions, (high time pressure, high uncertainty, high ambiguity), the mean subjective workload was only 1.7709. More realism, and as a result more stress, must be introduced.

The first way to do this would be to add a secondary and even a tertiary task. Keeping an externally located superior informed, (manipulated by superior queries/does not query), is one possibility. Another is making appropriate warnings to the unknown inbound aircraft, (manipulated by a screen prompt). Another way to increase stress would be to increase contact attributes. For example, have another decision maker determine if it is in a designated commercial airway, and have another probe for Identity Friend or Foe (IFF) readings. Adding attributes would not only increase the TAO decision matrix, but it would also increase the stress on the communications circuit by adding more users. A final way to increase the stress on all four players would be to eliminate the "highlight" on the target icon, making more than one of the "clutter" tracks potential targets.

2. Data Collection

As discussed in the section devoted to data, the observation forms should be revised to better reflect the experimental paradigm, and the categories should be more specific. Additionally, all four observers should have headsets so they can hear requests as well as responses. Much data may have been lost because the observers could only hear one side of communications. For example, "Roger." may be classified as no information transfer, a transfer of raw data or a transfer of an opinion on hostility depending on the question or statement which prompted the response.

3. Subjective Hostility

The hostility card sort should be done before data collection, after 12 presentations, and after the last presentation. This is recommended because there is evidence that subjective definitions of hostility changed throughout the experiment. This would have been predicted by Kathryn Blackmond Laskey, who states in a study on assessing preferences in the presence of random response error:

> There are four general approaches.... The first is simply to ignore the problem, treating the decision maker's responses as if they were error free. The second is to average multiple judgments concerning the value or utility of each outcome. If the response errors are interdependent of one another, this averaging strategy will produce more reliable preference assessments. The third approach...is to employ consistency checks by including logically interdependent judgments in the preference assessment task. If inconsistencies arise, the decision maker is asked to resolve them. In the process, decision analysts argue, the decision maker will gain insight into his own preferences, and discover his true preferences. The fourth approach to the problem of respohse error is to fit preference models to the decision maker's responses. [Ref. 15:p. 996]

For the December experiment, it seems Laskey's first approach was used. The card sort should be done in the second recommended manner in order to capture any trends, so that the performance data can be adjusted accordingly. When the sort is done only once, as in the December, 1991 experiment, the adjusted error rates increase instead of decrease, and all associated p values jump to 1.0. This is because we are applying a single subjective definition of hostility to all 24 presentations, when that definition probably changed more than once.

4. For Further Study

As discussed earlier, under the no feedback condition, TAOs initially reported neutrals and hostiles at the same rate. However, under feedback conditions, they reported neutrals at a 2:1 ratio over hostiles. Are TAOs anticipating a subordinate bias towards hostile and unconsciously trying to adjust for this "framing"? Further study is needed to answer this question.

B. For Naval Team Training

The results of this first SAINT experiment would seem to indicate that Navy team trainers should discourage the feedback of the CO/TAO opinion of an inbound contact's hostility or neutrality while the situation is still being assessed. While feedback may help in facilitating implicit coordination by extending the shared mental model, feedback of this specific nature extends the model too far. The goal of the CIC AAW team is to assess an often confusing, uncertain situation. By giving feedback on his current assessment, the leader compounds the negative phenomenon of confirmatory bias, and the error rate increases. Sharing what are essentially predictions of the final decision, biases the team and reduces performance.

There is no room for bias in today's uncertain world where correct and timely situation assessment can mean the prevention of the loss of innocent life, and the avoidance inaction leading to tragedy and disgrace. Indeed, it can mean the difference between war and the avoidance of war, and is therefor a critical aspect of command and control.

APPENDIX A

"SAINT" EXPERIMENT: NPS Nov - Dec 91

OBSERVATION FORM FOR TAO

Team #: 1 2 3 4 5 6 Trial # ______________ Date/Time ______________

Observer ______________

Type		TAO TO: Subordinate 1	Subordinate 2	Subordinate 3	All
Information ~~Requests~~ Transfers	1. Hostile/ Friendly				
	2. Judgment and Confidence				
	3. Raw Data				
Information Requests	1. Hostile/ Friendly				
	2. Judgment and Confidence				
	3. Raw Data				
Others	1. Team Bolstering				
	2. Actions Requests				
Failures		Gave Feedback when shouldn't	Didn't Give Feedback when Should	Time of 1st Hostility Judgment	

Additional Notes on this Trial:

APPENDIX B

"SAINT" EXPERIMENT: NPS Nov - Dec 91

OBSERVATION FORM FOR SUBORDINATES

Team #: 1 2 3 Trial # ______________ Date/Time ______________

4 5 6 Observer ______________

Type		Subordinate to Subordinate	Subordinate to TAO	Subordinate to Team
Information ~~Requests~~ Transfers	1. Hostile/ Friendly			
	2. Judgment and Confidence			
	3. Raw Data			
Information Requests	1. Hostile/ Friendly			
	2. Judgment and Confidence			
	3. Raw Data			
Others	1. Team Bolstering			
	2. Actions Requests			

Additional Notes on this Trial:

APPENDIX C

ALPHATECH, INC.

SAINT EXPERIMENT (TADMUS J3299)

Dependent Variables

Set # B2: semi-processed data collected on-line by observers

I. COMMUNICATION:

I1 Leader (TAO)

INFORMATION COMMUNICATION

C1. Total number of information transfers from leader to subordinates (L/S)
C2. Number of L/S opinion (hostile/neutral judgment & confidence) transfers
C3. Number of L/S processed info. (specialized judgment & confidence) transfers
C4. Number of L/S raw data transfers

C5. Total number of information requests from leader to subordinates (L/S)
C6. Number of L/S opinion (hostile/neutral judgment & confidence) requests
C7. Number of L/S processed info. (specialized judgment & confidence) requests
C8. Number of L/S raw data requests

OTHER COMMUNICATION

C9. Total number of feedback errors
C10. Number of times leader gave feedback when shouldn't have
C11. Number of times leader didn't give feedback when should have

C12. Number of bolstering comments to subordinates
C13. Number of action requests (other than above) by leader to subordinates

TIMELINESS*

C14. Latency of leader's first judgment [secs]

* Although not a communication measure, this latency/delay measure was recorded by the TAO's observer

L2 Subordinates

INFORMATION COMMUNICATION

C15. Total number of information transfers among subordinates (S/S)
C16. Number of S/S opinion (hostile/neutral judgment & confidence) transfers
C17. Number of S/S processed info. (specialized judgment & confidence) transfers
C18. Number of S/S raw data transfers

C19. Total number of information requests among subordinates (S/S)
C20. Number of S/S opinion (hostile/neutral judgment & confidence) requests
C21. Number of S/S processed info. (specialized judgment & confidence) requests
C22. Number of S/S raw data requests

C23. Total number of information transfers from subordinates to leader (S/L)
C24. Number of S/L opinion (hostile/neutral judgment & confidence) transfers
C25. Number of S/L processed info. (specialized judgment & confidence) transfers
C26. Number of S/L raw data transfers

C27. Total number of information requests from subordinates to leader (S/L)
C28. Number of S/L opinion (hostile/neutral judgment & confidence) requests
C29. Number of S/L processed info. (specialized judgment & confidence) requests
C30. Number of S/L raw data requests

OTHER COMMUNICATION

C31. Number of bolstering comments among subordinates
C32. Number of action requests (other than above) among subordinates

APPENDIX D

SAINT EXPERIMENT (TADMUS J3299)

Dependent Variables

Set # B3: semi-processed data collected off-line from subjects

I. SUBJECTIVE RATINGS I: After each experimental block

R1. Subjective rating (1-5) of team's coordination activities (4 blocks over time).

R2. Subjective rating (1-5) of team's radio-net discipline (4 blocks over time).

R3. Subjective estimate (1-5) of the amount of information obtained from other team members to perform job (4 blocks over time).

R4. Subjective estimate (1-5) of the number of measurements (probes) taken per trial (4 blocks over time).

R5. Subjective estimate (1-5) of the number of times communications occurred with other team members (4 blocks over time).

R6.Subjective estimate (1-5) of the amount of time spent communicating with other team members (4 blocks over time).

I. SUBJECTIVE RATINGS II: Post-experiment

TO BE CATEGORIZED

APPENDIX E

"SAINT" EXPERIMENT: NPS Nov - Dec 91
POST SESSION QUESTIONNAIRE

Team #: 1 2 3
4 5 6

Trial # ________________ Date/Time ________________

Please place an X any where on the line that best reflects your response.

1. On average, how difficult were the scenario trials you just completed?

|_______|_______|_______|_______|_______|

Not Difficult At All — Midpoint — Very Difficult

2. How well did you perform your specific task?

|_______|_______|_______|_______|_______|

Not Well At All — Midpoint — Very Well

3. How would you rate your team's coordination activities while performing target identification?

|_______|_______|_______|_______|_______|

Not Well At All — Midpoint — Very Well

4. How well did you exercise radio-net discipline?

|_______|_______|_______|_______|_______|

Not Well At All — Midpoint — Very Well

5. How well did the team exercise radio-net discipline?

|_______|_______|_______|_______|_______|

Not Well At All — Midpoint — Very Well

6. In addition to sensor measurements, how much information did you get from other team members to perform your job?

|_______|_______|_______|_______|_______|

Very Little — Midpoint — A Great Deal

7. On average, how many measurements did you take per trial (for the scenario trials just completed)?

|_______|_______|_______|_______|_______|

0 — 2 — 4 — 6 — 8 — 10 or more

8. O average, how many times did you communicate with another team member (for the scenario trials just completed)?

|_______|_______|_______|_______|_______|

0 — 3 — 6 — 9 — 12 — 15 or more

9. On average, how much time did you spend communicating with other team members (for the scenario trials just completed)?

|_______|_______|_______|_______|_______|

Very Little — Midpoint — A Great Deal

SAINT EXPERIMENT (TADMUS J3299)

Dependent Variables

Set # B1: semi-processed data collected on-line by DDD simulator

I. PERFORMANCE:

ACCURACY

P1. Final decision by Leader (TAO) (1: neutral, 2: hostile)

P2. Final error (1: correct, 0: incorrect, -1: no decision)

P3. Final confidence (1: low, 2: moderate, 3: high)

TIMELINESS

P4. Time remaining at final decision [secs]

II. STRATEGY:

II.1: Leader (TAO)

INFORMATION INPUT/OUTPUT

S1. Number of judgment entries by leader (without final decision)

S2. Number of database queries by leader (to see subordinate's latest judgment)

DECISIONMAKING

S3. Number of judgment changes by leader over time (e.g. 1121 —> 2 changes)

S4. Initial leader's judgment (1: neutral, 2: hostile)

S5. Initial leader's confidence (1: low, 2: moderate, 3: high)

II.3: Subordinates (IDS, TIC, EWS)

INFORMATION SEEKING

S6. Total number of probes by subordinates (information seeking activity)

S7. Information seeking rate: S6 / $(T_{initial} - T_{final})$ [probes/min]

S8. Number of probes by DM1 (IDS)

S9. Number of probes by DM2 (TIC)
S10. Number of probes by DM3 (EWS)

INFORMATION RECORDING

S11. Number of database entries by DM1
S12. Number of database entries by DM2
S13. Number of database entries by DM3
S14. Total number of database entries by subordinates

INFORMATION PROCESSING

S15. Initial judgment by DM1 (1: small, 2: mid-size, 3: large)
S16. Initial judgment by DM2 (1: climbing, 2: leveling-off, 3: descending)
S17. Initial judgment by DM3 (1: no emission, 2: search , 3: fire control)
S18. Initial confidence of DM1 (1; low, 2: moderate, 3: high)
S19. Initial confidence of DM2 (1; low, 2: moderate, 3: high)
S20. Initial confidence of DM3 (1; low, 2: moderate, 3: high)
S21. Final judgment by DM1 (1: small, 2: mid-size, 3: large)
S22. Final judgment by DM2 (1: climbing, 2: leveling-off, 3: descending)
S23. Final judgment by DM3 (1: no emission, 2: search , 3: fire control)
S24. Final confidence of DM1 (1; low, 2: moderate, 3: high)
S25. Final confidence of DM2 (1; low, 2: moderate, 3: high)
S26. Final confidence of DM3 (1; low, 2: moderate, 3: high)

III. WORKLOAD:

INDIVIDUAL RAW SWAT SCORES (T: Time pressure, E: Mental Effort, S: Stress)

W1. DM1's T score (1: low, 2: medium, 3: high)
W2. DM1's E score (1: low, 2: medium, 3: high)
W3. DM1's S score (1: low, 2: medium, 3: high)
W4. DM2's T score (1: low, 2: medium, 3: high)
W5. DM2's E score (1: low, 2: medium, 3: high)
W6. DM2's S score (1: low, 2: medium, 3: high)
W7. DM3's T score (1: low, 2: medium, 3: high)
W8. DM3's E score (1: low, 2: medium, 3: high)

W9. DM3's S score (1: low, 2: medium, 3: high)

W10. Leader's T score (1: low, 2: medium, 3: high)

W11. Leader's E score (1: low, 2: medium, 3: high)

W12. Leader's S score (1: low, 2: medium, 3: high)

TEAM CONSENSUS RAW SWAT SCORES

W13. Team's T score (1: low, 2: medium, 3: high)

W14. Team's E score (1: low, 2: medium, 3: high)

W15. Team's S score (1: low, 2: medium, 3: high)

APPENDIX G

SAINT EXPERIMENT (TADMUS J3299) NPS NOV-DEC 1991

EXPERIMENT DATA SET #1

SUBJECTS
I: Team ID [1,2,3,4,5]

INDEPENDENT VARIABLES
S: Structure [1: no feedback; 2: TAO's feedback]
U: Uncertainty [1: low (10% jamming); 2: high (50% jamming)]
T: Time pressure [1: low (6 min.); 2: moderate (4 min.); 3: high (2 min.)]

SCENARIO ATTRIBUTES
H: Target hostility [1: neutral; 2: hostile]
A: Target ambiguity [1,2,3: low; 4,5,6: high]

INPUT — DEPENDENT VARIABLES

I	S	U	T	H	A	Performance				Strategy/TAO				Strategy/subordinates																					
1	1	1	1	1	5	1	1	2	9	4	0	0	1	2	65	10.51	21	16	28	8	15	27	50	2	1	1	2	2	1	3	1	1	3	1	1
1	1	1	1	2	4	2	1	2	6	9	0	1	1	1	67	10.75	23	16	28	7	13	27	47	3	1	1	3	2	1	3	1	2	3	1	2
1	1	1	2	1	3	1	1	2	133	2	0	0	1	2	22	10.39	6	6	10	5	4	10	19	1	1	1	3	1	3	1	1	1	1	1	1
1	1	1	2	2	1	2	1	3	33	7	0	0	2	1	43	11.37	15	10	18	4	8	16	28	3	1	3	2	1	1	3	1	3	3	1	3
1	1	1	3	1	4	1	1	1	15	2	0	1	2	1	22	10.56	8	5	9	1	5	7	13	1	1	1	3	1	1	1	1	3	1	1	3
1	1	1	3	2	6	2	1	2	22	2	1	1	1	1	18	9.15	6	4	8	2	4	6	12	1	1	3	3	1	2	1	1	3	1	1	3
1	1	2	1	1	2	1	1	2	20	6	0	0	1	1	66	11.00	23	16	27	8	9	25	42	3	1	1	1	1	1	1	1	1	1	1	1
1	1	2	1	2	3	2	1	3	96	4	1	0	2	1	52	10.99	16	13	23	4	7	22	33	3	1	1	3	1	1	3	1	3	3	1	3
1	1	2	2	1	6	1	1	2	17	7	0	2	1	1	44	10.86	13	12	19	4	4	19	27	2	1	2	2	1	1	2	1	1	2	1	1
1	1	2	2	2	5	1	0	2	15	2	2	1	2	2	45	11.02	14	11	20	5	6	19	30	1	1	2	2	1	1	3	1	3	3	1	3
1	1	2	3	1	1	1	1	3	13	3	0	0	1	1	25	11.81	8	6	11	4	2	9	15	1	1	1	1	1	1	1	1	1	1	1	1
1	1	2	3	2	2	2	1	2	9	2	1	0	2	1	25	11.45	9	6	10	1	1	9	11	1	1	3	3	1	1	1	1	3	1	1	3
1	2	1	1	1	5	2	0	2	61	8	0	1	1	1	54	10.16	16	15	23	7	14	23	44	3	1	1	2	1	2	3	1	2	3	1	2
1	2	1	1	2	4	2	1	3	23	9	0	1	1	1	61	10.25	21	15	25	9	14	25	48	2	1	2	1	1	1	3	1	3	3	1	3
1	2	1	2	1	3	1	1	3	209	1	0	0	1	3	7	8.24	2	2	3	0	1	1	2	0	1	3	0	1	1	0	1	3	0	1	3
1	2	1	2	2	1	2	1	1	106	5	0	2	2	1	20	7.79	6	6	8	4	5	9	18	2	1	3	1	1	1	3	1	2	3	1	2
1	2	1	3	1	4	1	1	1	9	3	0	1	2	1	21	9.62	6	6	9	3	4	8	15	3	1	3	1	1	1	2	1	3	2	1	3
1	2	1	3	2	6	2	1	2	20	3	0	1	1	1	20	10.00	7	5	8	1	3	7	11	2	1	1	1	1	1	2	1	3	2	1	3
1	2	2	1	1	2	1	1	2	47	7	0	0	1	1	59	10.63	18	15	26	5	8	25	38	2	1	1	1	1	2	3	1	3	3	1	3
1	2	2	1	2	3	2	1	3	16	9	0	1	1	1	61	10.05	17	15	29	5	10	26	41	3	1	3	1	1	1	3	1	3	3	1	3
1	2	2	2	1	6	1	1	3	43	6	0	0	1	1	32	8.85	8	9	15	5	5	14	24	2	1	1	1	1	1	2	1	1	2	1	1
1	2	2	2	2	5	1	0	2	12	4	1	1	2	1	45	10.89	15	11	19	7	6	18	31	1	1	1	1	1	1	1	1	3	1	1	3
1	2	2	3	1	1	1	1	3	26	2	2	0	1	1	16	8.42	4	5	7	3	1	5	9	1	1	2	1	1	1	1	1	2	1	1	2
1	2	2	3	2	2	2	1	1	14	3	0	1	1	1	21	10.00	7	5	9	1	2	8	11	2	1	1	1	1	1	2	1	2	2	1	2

2	1	1	1	1	2	1	1	2	33	4	0	0	1	2	52	8.99	17	10	25	1	5	2	8	2	1	2	1	1	1	2	1	2	2	1	2
2	1	1	1	2	3	2	1	2	36	9	3	1	1	1	39	6.80	13	11	15	2	5	3	10	3	3	2	2	2	2	3	3	3	3	3	3
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5	2	1	2	1	1	1	1	2	7	12	0	0	1	1	45	10.67	12	18	15	8	16	14	38	1	3	2	1	1	1	1	2	3	1	2	3
5	2	1	2	2	2	2	1	1	7	7	0	1	1	1	37	8.77	11	13	13	4	9	14	27	3	3	3	1	1	1	2	2	3	2	2	3
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5	2	2	1	2	1	2	1	3	36	8	0	1	1	1	55	9.59	15	21	19	6	12	18	36	2	1	2	1	3	1	3	3	3	3	3	3
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SAINT EXPERIMENT (TADMUS I3299)

Dependent Variables

Set # A1: Aggregated measures with categorization
(based on variable sets B1, B2, and B3)

I. PERFORMANCE:

ACCURACY

AP1. TAO's final judgment (1: neutral, 2: hostile)

AP2. Confidence on final judgment (1: low, 2: moderate, 3: high)

AP3. Final composite target hostility judgment [0-100%]

AP4. Error rate (according to ground truth)

AP5. False alarm rate (false positive)

AP6. Miss rate (false negative)

TIMELINESS

AP7. Latency of first hostile/neutral judgment [secs]

AP8. Team explicit information processing time [secs]

AP9. Slack time (time remaining at final decision) [secs]

SUBJECTIVE PERFORMANCE

AP10. Error rate (according to TAO's prior subjective hostility ratings)

AP11. False alarm rate (according to TAO's prior subjective hostility ratings)

AP12. Miss rate (according to TAO's prior subjective hostility ratings)

AP13. Discrepancy factor in composite target hostility judgment (AP3 - HR)

II. STRATEGY:

II.1: Leader (TAO)

INFORMATION INPUT/OUTPUT

AS1. Number of database queries by leader (to see subordinate's latest judgment)

DECISIONMAKING

AS2. Leader's initial judgment (1: neutral, 2: hostile)

AS3. Leader's initial confidence (1: low, 2: moderate, 3: high)

AS4. Leader's initial composite target hostility judgment [0-100%]

AS5. Number of judgment changes by leader over time (e.g. 1121 —> 2 changes)

AS6. Change in leader's confidence over time

II.3: Subordinates (IDS, TIC, EWS)

INFORMATION SEEKING

AS7. Total number of probes by subordinates (information seeking activity)

AS8. Information seeking rate: AS7 / AP8 [probes/sec]

AS9. Information seeking unbalance among subordinates (std. dev. / mean)

INFORMATION RECORDING

AS10. Total number of database entries by subordinates

INFORMATION PROCESSING

AS11. Final judgment by DM1 (1: small, 2: mid-size, 3: large)

AS12. Final judgment by DM2 (1: climbing, 2: leveling-off, 3: descending)

AS13. Final judgment by DM3 (1: no emission, 2: search , 3: fire control)

AS14. Final confidence of DM1 (1; low, 2: moderate, 3: high)

AS15. Final confidence of DM2 (1; low, 2: moderate, 3: high)

AS16. Final confidence of DM3 (1; low, 2: moderate, 3: high)

AS17. Final composite hostility judgment by DM1 [0-100%]

AS18. Final composite hostility judgment by DM2 [0-100%]

AS19. Final composite hostility judgment by DM3 [0-100%]

AS20. Final average composite hostility judgment by subordinates [0-100%]

III. COORDINATION:

COMMUNICATION-GLOBAL:

AC1. Total number of messages sent

[redacted] (AC1 / AP8) * 60 [msgs/min]

COMMUNICATION-DIRECTION:

[redacted] messages from leader to subordinates (down)

[redacted]essages from subordinates to leader (up)

[redacted]essages from subordinate to subordinate (horizontal)

[redacted]munication rate (AC3 / AP8) * 60 [msgs/min] –

AC7. Total number of broadcast messages sent by leader

COMMUNICATION-INFORMATION

AC8. Percentage of information transfers

AC9. Percentage of information requests

AC10. Percentage of non-informational communications (team bolstering, etc..)

COMMUNICATION-INFORMATION FLOW

AC11. Total number of information requests by leader

AC12. Total number of information transfers by leader

AC13. Total number of information transfers by subordinates to leader

AC14. Anticipation ratio (= (AC13 - AC11) / AC13) [0-100%]

COMMUNICATION-INFORMATION GRANULARITY AND DIRECTION

AC15. Total number of processed information messages

AC16. Number of processed information messages sent by leader

AC17. Number of processed information messages sent by subordinates

AC18. Total number of raw data messages

AC19. Total number of raw data messages sent by leader

AC20. Total number of raw data messages sent by subordinates

IV. WORKLOAD:

INDIVIDUAL

AW1. Normalized, calibrated SWAT score for DM1 [0 - 100%]

AW2. Normalized, calibrated SWAT score for DM2 [0 - 100%]

AW3. Normalized, calibrated SWAT score for DM3 [0 - 100%]

AW4. Normalized, calibrated SWAT score for leader [0 - 100%]

TEAM

AW5. Normalized, calibrated average SWAT score for subordinates [0 - 100%]

AW6. Normalized, calibrated SWAT score for team (group scale) [0 - 100%]

AW7. Workload unbalance among subordinates (std. dev. / mean)

IV. SUBJECTIVE RATINGS:

IV.1 By leader (TAO)

PERFORMANCE
AR1.

COORDINATION

TEAMWORK

IV.2 By subordinates

PERFORMANCE

COORDINATION

TEAMWORK

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