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DATA COLLECTION VIA A QUASI-EXPERIMENTAL SIMULATION TECHNOLOGY: I. MULTIPLE MEASUREMENT OF PERFORMANCE EXCELLENCE IN COMPLEX AND UNCERTAIN MANAGERIAL TASKS

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A simulation technique is used to determine whether complexity (multidimensionality) of task performance is complex managerial tasks is trainable. The present report is specifically concerned with measurement. Previous simulation based measurement (cf. Streufert, 1983) which had included sixteen measures was extended to thirty-seven primary measures and twelve derived measures. Information is provided on the characteristics and purpose of each of those measures. In addition formulas or related statements that allow calculation of performance scores by other researchers

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and/or in other settings is provided. Further, this report considers the Time-Event Matrix on which measurement is based. Keywords:

Background and Purpose

A contract between the U.S. Army Research Institute for the Behavioral and Social Sciences and Pennsylvania State University, The Milton S. Hershey Medical Center, (S. Streufert, principal investigator) stipulates that the contractor will use a simulation technique to determine whether complexity (multidimensionality) of task performance in complex managerial tasks is trainable. For that purpose, the contractor developed and/or improved a computer based simulation system during the first year of effort. The simulation was to be pretested during the second year of the contract.

Initial development was completed on Apple computers which were, however, too limited in capacity to effectively operate the simulation system. To overcome this problem, IBM AT enhanced computers were ordered. Delivery, as scheduled by IBM, would have resulted in a three months delay in scheduled tasking. Unfortunately, IBM subsequently cancelled all delivery dates because of a faulty component of the AT system and rescheduled delivery for some 8 months later. As a result, final simulation development, design of measurement techniques and simulation pretesting was delayed for periods up to 12 months. With IBM AT systems finally available during the late summer of 1985, efforts to finalize the simulation technology and to develop measurement techniques was initiated. Data collection on those segments of the contracted efforts are now completed. The obtained data and the associated methodology will be considered

in three reports.

The present report is specifically concerned with measurement. Previous simulation based measurement (cf. Streufert, 1983) which had included sixteen measures was extended to thirty-seven primary measures and twelve derived measures. This report provides information on the characteristics and purpose of each of those measures. In addition, it will provide formulas or related statements that allow calculation of performance scores by other researchers and/or in other settings. Further, this report considers the Time-Event Matrix on which measurement is based.

A second, subsequent report will be concerned with measurement reliability. Any procedure which requires test and retest of performance functions must assure the reliable measurement of some phenomenon of interest on two separate occasions. For present purposes, reliability across two measurements from two parallel simulations with diverse scenarios is required. With training interspersed, measurement across simulations must be comparable if changes in performance are to be discovered. Variable error must be kept to as low a value as possible. The second report in this series will focus on the question of inter-simulation reliability of the measures that are considered in this report.

A third report will be based on data analysis that is now in progress and/or in the planning stage. This last report in the series devoted to simulation technology will be concerned

with the interrelationship among the various measures (based on factor analytic techniques) and with measurement validity. Validity analysis will be achieved by calculating correlations among measures that load highly on obtained factor scores with several secondary indicators of performance, e.g. job level (at age), number of promotions, income (at age) and so forth. Reports that follow the present series will be concerned with measured training effects per se.

Discovering Performance Characteristics

A few executives are fabulously successful. Others fail early in their careers. Most do their jobs adequately. What makes the difference?

The majority of executives, especially at senior levels, are highly intelligent. They have gained ample experience. They have been well trained. Yet, if we observe what they understand, what they know and what decisions they make we still cannot distinguish those who are great from those who are mediocre. Many observers of executive performance have watched and recorded what great executives do. Unfortunately, their descriptions of excellence would hold in one organizational setting but may not apply in another.

The difference between excellence and mediocrity is not generally found in what an executive may know, think or decide. The difference is not just determined by the choice of correct and appropriate actions. It is not based on the capacity to follow a preconceived strategy toward some fixed goal. It is

not found in the tendency to amass all relevant information that can be obtained. Even mediocre executives can do all those things - and most can probably do them well.

Excellence in executive performance depends on how an experienced executive thinks, plans and responds to task demands. It is inherent in the creative alternatives that are considered. It is evident in the development of multiple strategies that proceed from step to step, always adaptive, with goals that are general and become more and more defined as they are approached. It is found in conclusions that are checked, reconsidered and reassessed as more information arrives. It is found in the adaptive flexibility that permits different approaches to different people and tasks, that permits the executive to switch from strategic planning to immediate action when emergencies arise and to return to a planning mode when the emergency has been conquered.

How can one measure that executive excellence? It requires a view of an executive's actions over time, in different situations, relevant to diverse task demands. It requires assessing how executives develop, interrelate and apply their ideas. It requires an analysis of the steps which executives take to approach and attain their goals. A simple test, an interview or even a short task cannot provide us with adequate information about executive capacity. Just as a photographic snapshot cannot tell us what a person will do in a few hours, the usual measurement techniques and well intentioned observations tell us

little about executive performance across a variety of task demands.

There have been very few efforts that have analyzed executive performance through a number of potentially interrelated events or through a series of decisions that are part of a strategic effort. If we wish to discover how executives function, such a time oriented analysis is exactly what is needed. Observations that are more or less casual (e.g. those of Peters and Waterman, 1982, Peters and many other recent observers of executive functioning) are indeed valuable, but they rarely generate the necessary depth of understanding. Much more useful are, for example, the careful efforts of Dan Isenberg (1984) who has recorded both the actions and the rational for consecutive executive actions across considerable time periods. The present approach is quite similar to that of Isenberg, but uses a simulation methodology to (1) automate data collection procedures, (2) to obtain multiple independent measures of performance, (3) to maintain control over relevant independent variable manipulation across time and participants and, last not least, (4) to explore lengthy periods of performance during which strategic efforts might develop. The simulation permits this kind of performance measurement in reduced time periods via the compression of time experience. The technique is described in the next section of this report.

Data Collection via a Quasi-Experimental Simulation

The simulation technique which was developed in part for

present research effort is best defined as a "quasi experimental simulation" (Fromkin and Streufert, 1983; Streufert and Swezey, 1985). The methodology allows the introduction of controlled independent variables not only at the beginning of the simulation task but maintains control over independent variables throughout the simulation. The considerable length of time (several hours) during which participants deal with their simulated environment permits the simultaneous and/or successive manipulation of several experimental variables.

Continued control over experimental variables throughout the simulation permits the application of two kinds of performance measurement: (1) repeated collection of data throughout the simulation period to record the effects of conditions that are experimentally modified as the simulation progresses (for example one might measure the effects of different load levels, e.g., Streufert and Driver, 1965; Streufert and Schroder, 1965; Streufert, 1970), and (2) one-time collection of data that are relevant to some specific preprogrammed single event which occurs in the simulation. The former measurement techniques are particularly useful to assess the (structural) "style of thinking" that underlies task performance. The latter can capture structural thought processes only to some extent, but is especially useful to obtain information about the appropriateness, speed and accuracy of responses to specific task demands.

The development of measurement in our quasi-experimental simulation technique is best described as an ongoing process.

Since the computer system which operates the simulation technology records a large variety of actions, plans and response characteristics of participants, newly developed measures can often be derived from data collected at a much earlier date. New measures may or may not be entirely independent of previous measures, (overlap of meaning), others may be entirely independent (orthogonal). The precise interrelationships of the various measures will be evaluated in a factor analytic procedure based on data from approximately 80 simulations. The results will be reported some time later this year (likely in the summer of 1986).

At present, the computerized simulation system records performance characteristics in terms of interrelationship vectors and calculates scores for more than fifty performance measures. Thirty-seven of those measures are more or less complex calculations of performance frequencies. The remaining measures relate these frequencies to the number of actions taken (decisions made) to obtain proportions of performance characteristics as they relate to general activity.

Data collection for the simulation technique is reflected in a graphic procedure that has become known as a "Time-Event Matrix." The rationale for data collection and measurement procedures are best explained via that matrix system. The following section of this paper will focus on the matrix procedure. Subsequently, the measures themselves will be explained in some detail.

The Time-Event Matrix

The task of an individual or a task-oriented group operating in the world outside of the simulation laboratory is rarely limited to deciding on a single event within a limited context. For example, most decision makers in applied settings must respond to an ongoing series of inputs from their environment. The resulting output is usually a sequence of actions determined in part by some plan and in another part by the necessities of dealing with current events. The output may consist of primarily "respondent" actions or it may reflect some degree of "strategy," i.e., decisions which are interrelated with each other and occur in a planned sequence to achieve some kind of goal. Whether or not individual or group actions do reflect pure respondent behavior, whether they reflect some kind of strategy (and the level and/or characteristics of that strategy) may be of considerable importance for the outcome of the task effort. The majority of previous researchers have not focused on measuring or describing such differences. To alleviate that problem, Streufert and associates have developed a time-event matrix to help researchers or observers to identify different kinds of actions and their frequencies, as they occur in naturally complex task settings. Reliability and validity for some of the measures derived from time-event matrices have been established in previous efforts. Additional reliability and validity data will be reported in a subsequent report.

Performance quality, particularly in complex tasks, is

determined by at least two major components of individual or group efforts: (1) appropriate knowledge about what responses are potentially correct or incorrect (where possible) and (2) the ability to develop plans, and to respond at the right time with optimal combination of responses, i.e., the use of strategy. The time-event matrix was designed to measure the latter of the two components. In many cases, the first component, i.e., appropriate content knowledge and understanding of the task situation can be assumed, as long as sufficient training and experience is available. Nonetheless, specific quality performance measures are collected as well, even though they may not be directly captured by the time-event matrix procedure.

Time-event matrices can be used to measure a variety of task performance activities, depending on the interests and orientations of the researcher or observer. This paper cannot cover all of the purposes for which the matrix can or has been employed. For greater ease of communication, let us focus on decision-making matrices as an example for all matrix possibilities. It should be remembered, however, that most other performance areas, aside from decision-making, could have been selected equally well.

The time-event matrix technique was initially developed to measure the interrelationships among actions across time and the effects of information flow which precedes those actions. Details about the construction of time-event matrices will be discussed below. At this point it is merely important to be

aware that these matrices capture all data about incoming information, about decisions and other actions based on that information, about interrelationships among information and decisions as well as interrelationships among decisions (e.g., strategy). The matrices may be used to collect data on measures which reflect how task oriented individuals or groups process information and how that information processing determines or affects observed performance. Measures based on the time-event matrices may be considered "intermediate" assessments of performance quality. They provide a necessary vehicle for estimating and defining important action antecedents of performance (criterion based) quality, particularly in complex tasks. Their predictive validity for success (e.g., managerial excellence) may be accessed in research designs that obtain the predictive validity would hamper each measure (to be reported subsequently).

Tasks and their requirements differ. The same strategy is not necessarily useful in all task settings (aside from differences in knowledge content). As a result, the measures derived from the time-event matrix should be carefully validated against each general performance task. Many tasks will, of course, produce quite similar patterns of "optimal" measurement levels to criterion. As a matter of fact, a number of validations have shown that specific score levels for the measures that will be presented later tend to be quite robust across a number of tasks and a number of performance environments. Where adequate training and/or sufficient experience is likely to result in few

(if any) content errors in performance, predictions of quality task performance made on the basis of matrix measurement is of substantial value. Where training, task familiarity, knowledge and experience with task requirements is minimal, the scores would provide information about the capacity to acquire excellence after training.

The dimensions of a matrix are time and action (here decision) types. Each will be discussed in turn:

(1) Time

Time in the matrix is plotted horizontally. There are no particular restrictions on the gradations to be used (no matter whether time proceeds normally or is - as in some simulations - expanded or condensed), except that events which occur sequentially and independently of each other must appear on different time points. The time dimension moves from the left to the right. The units of the scale used are not of significance, except that decision-making sequences which are to be compared must contain the same scale units (since the formulas should calculate comparable values).

(2) Decision Categories

Decision-making tasks and settings differ. Consequently decisions employed differ as well. For example, executives dealing with the potential purchase of another corporation may be concerned with such action areas as establishing the value of the other company, determining potential duplication of effort, etc. On the other hand, military decision makers may be

concerned with troop movements, air support decisions and so forth. In other words, groupings of decisions (decision categories) must be established separately for each general group of decision-making situations. Selection of predefined decision categories is best accomplished by experts in the field. The selected categories should be inclusive, where possible of approximately equal breadth, and conceptually meaningful and consistent. They should clearly differ from each other in activity, method, meaning, etc. Decision categories should provide the potential for use by decision makers. While some decision makers would likely use one group of decisions, others may focus on a different group, of course with considerable overlap.

While there is no restriction on the number of potential decision categories that might be represented in a time-event matrix, the inclusiveness of decision categories should be selected so that decision makers utilize, on the average, somewhere between ten and fifty different categories of decisions[1] in any time sequence that lasts for several hours. Note, however, that these suggestions are ideal requirements and do not supercede the practical characteristics of any particular task situation. For example, if a decision task requires only one kind of decision, one cannot "manufacture" other decision categories by hook or crook. In effect, the use of the decision

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[1]Since decision makers would rarely employ all available decision categories, the potential for considerably more than 50 categories may be provided.

matrix in such simple situations would have little value. For example, if all actions reflected troop movements, then splitting decisions by the unit moved may not be useful.

(3) Decision Points

Once time is plotted horizontally and decision categories (as selected, for example, by an expert panel) are plotted vertically, each decision made by an individual or a group of decision makers (as desired by the researcher or observer) can be represented by a point placed vertically beneath the time when that decision was made (or announced, or transmitted, again depending on the intent of the researcher or observer) and horizontally next to the decision category represented. All decisions can thus be placed in the matrix.

(4) Information Input

Information input that is received during the simulation (a potential carrier for independent variable manipulations), is considered as it relates to decision output (this limitation was chosen for convenience and is not necessary). Any unit of input which leads to an output is marked (e.g., by a *) under its appropriate (input) time and in front of (on the same decision-type line as) any decision made as a consequence of that input. The input is placed in advance of each output which it produced, i.e., the same input may occur on more than one horizontal (decision-category) line. The distance on the horizontal between the input * and the decision point is marked with a dashed line. It reflects the time elapsed between receipt

of information and relevant response.[2]

(5) Diagonals

As stated above, we are interested in the relationships among decisions as they reflect, for example, the development of plans or strategies. Consequently we wish to know whether a decision made at one time is related (leads) to a decision at a later time. Where a decision in one category is made to make a later decision representing another category possible, the two decisions are connected across time with a diagonal line. An arrow-head points forward toward the later decisions.[3] If two decisions show an isolated relationship to each other, a single arrow is drawn. If, on the other hand, the decision maker(s) decide(s) to engage in decision types A and B at time one to allow for action C in the future, and wants to accomplish C to allow D to occur even later, and if all these decisions are actually made in time, a longer chain of diagonal connections is established:

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[2]See the section on Integration Time Weight (below) for a discussion of time measurement.

[3]Such diagonal connections in the matrix will later be referred to as "integrations."

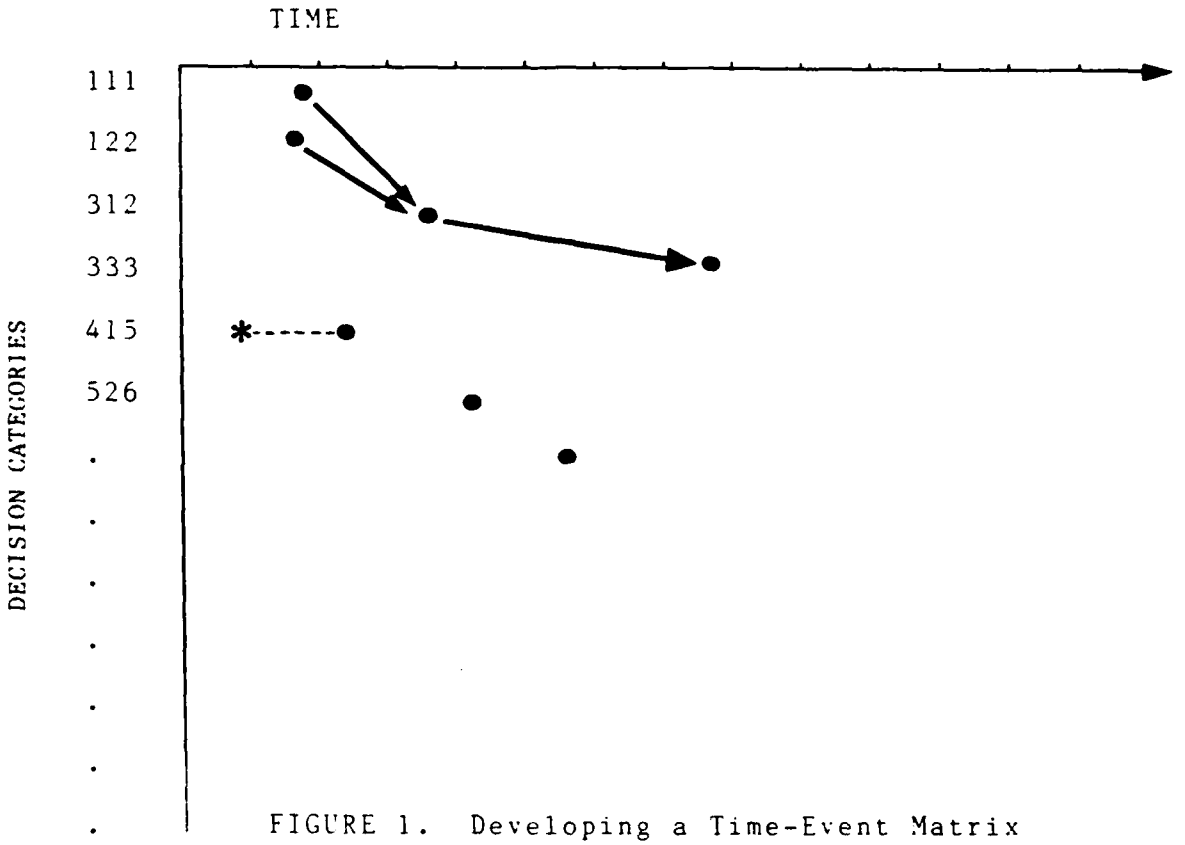

FIGURE 1. Developing a Time-Event Matrix

Number, length and interconnectedness of forward diagonals will be of importance for several of the measures that will be discussed later. Diagonals are sometimes drawn with arrowheads facing backwards. If, for example, a decision maker or a decision-making group engages in action A without considering a future action, but later finds that action A is of use when a later action is decided upon, a backward arrow diagonal between the later action and the previous action may be drawn. As a rule, interconnectedness among backward diagonals does not occur with great frequency.

(6) End Effects

Whether or not a diagonal is drawn depends, of course, on whether a planned later decision is indeed produced as a follow-up to an earlier decision. Where a decision task ends abruptly, the opportunity to carry out planned subsequent decisions may not exist. Ending a simulation could arbitrarily limit the number of diagonals produced by decision makers as reflected in obtained measures (see below). Randomization experimental events may, in some cases, be employed to avoid a constant error. Alternatively, the probabilities of scores that should have been obtained during latter time periods in the simulation may be calculated by comparing earlier and late performance characteristics. This latter method is especially useful if a fixed order of simulated events is needed for purposes of data collection.

(7) Establishing Relationships in the Matrix

It is important to establish clear relationships (a) between inputs and subsequent output decisions, and (b) among decisions which are causally or strategically related (represented by diagonals). Of course, the only perfect representation of these interrelationships exists in the brain of the decision maker(s) at the moment relevant decisions are made. Any measure of those relationships can, consequently, be subject to some error. Clearly, it is important to opt for the least amount of error in any experimental or observational setting. Certainly, the error levels of obtained data would likely be much

smaller in a well designed complex experimental simulation than in research based on observation in an ongoing free environment. For example, in experimental simulations, records of planning can be obtained directly from participants during the planning process. In real-world task environments, less precise techniques such as post-hoc interviews are required.

Ideally, decision maker(s) should be asked immediately (upon making a decision) to indicate (a) any information received upon which the decision is based, and (b) any planned subsequent decisions that they might employ as a follow-up to a current decision. That kind of data can be obtained in complex experimental simulations (the participants may have to be persuaded, however, that indicating previously received information and indicating planned future decisions would be of value to them in terms of long range outcome). In many free simulations (particularly if interrupt control is lacking) or in the observation of real-world decision-making environments these kinds of questions cannot be asked. Collecting those data after completion of their task often introduces serious bias. One might require experts to consider all decisions that were made and to judge whether these decisions represent responses to previous information and/or were part of decision-making sequences that should be represented by diagonal interconnections. Hopefully, interjudge reliability for such a task would be high. Previous experience has shown that judges produce little <u>variable</u> error in making these judgments. As long as the judges have no particular biases for

or against certain decision makers they are evaluating, constant errors across various samples may not be excessive. Nonetheless, the immediate data collection method that can be employed in experimental simulations has considerable advantages over other procedures.

Establishing connections between inputs and decisions on the basis of expert judgments is relatively easy. Respondent decisions are typically directly related to the verbal content of input information or describe the same location or information source contained in the input. When such commonalities are seen, a connection may be assumed to exist. More difficult is the interpretation of connections among decisions. Obviously, where one decision directly refers to a previous decision ("Order the unit which we moved to quadrant X5 to fire on...") a diagonal connection is directly established. However, is this a forward or a backward diagonal? If we were able to ask the decision maker(s) about future decisions, when the original decision to move the unit was made, then we would now know. If we were not able to ask (in free simulations of the type described above or in real-world applied decision-making settings), then we cannot be certain. In these cases forward and backward diagonals cannot be distinguished and arrowheads cannot be drawn.

Whenever no clear relationship is stated by the decision maker(s), aids must be used to determine whether relationships may exist. Such commonalities among decisions as addressee,

location, action etc. can be useful for that purpose. The most reliable indicator of interrelationship is probably location. In a military setting, to give a relatively simple example, moving artillery to quadrant X5, asking it to fire on Y4, moving infantry to Y5 and finally ordering the infantry to attempt to take Y4 would reflect a minimal series of interrelated decisions across time.

It should be noted here that moving troops to Y5 and another troop unit (both infantry) to X5 (at a later time) would not result in a diagonal connection: both actions are included within the same decision category: repetitious action is not necessarily representative of strategic action. If, on the other hand, both units are later asked to attack Y4, separate diagonal connections between each of the two movements and the later attack would be drawn.

Some decision sequences may be difficult to judge in terms of their potential interconnectedness. To the degree to which the judge can develop a picture of the strategy decision makers used (or if the judge can obtain advance information about their plans), the determination of strategic relationships will be considerably easier. In any case, if, after considerable thought, a judge is uncertain whether two decisions are or are not related to each other, it is better to err by omission. Uncertain relationships (interconnections) should not be scored to avoid artificially inflating some of the measures (below) which can show near quadratic effects of erroneously scored

relationships. Of course, the use of direct questioning that is possible in experimental and quasi-experimental simulation techniques would avoid such quandary altogether.

An example of two decision matrices is provided on page 21. The figure shows decision matrices generated by two groups of participants which differed in their decision-making styles (complexity).

MEASURES

A considerable number of measures are presented and explained in this report. Additional measures can be developed if they are useful for any specific task at hand. Calculation of the measures assumes either that a time-event matrix has been drawn (by computer, if obtained from an experimental simulation, or by judges, if obtained from a free simulation or a real-world decision-making environment) or that computer generated vectors for task performance events are available. The various measures were developed to reflect different kinds of task performance. In-and-of-themselves, each measure cannot be considered a reflection of "good" versus "bad" performance with regard to any particular criterion without considering momentary demands (e.g., environmental conditions). Without question, there are situations where complex strategic planning (as, for example, reflected in the QIS and WQIS measures, below) is of considerable value. On the other hand, there are situations where such planning would be superfluous and inappropriate since task demands may require immediate (e.g., respondent, see below)

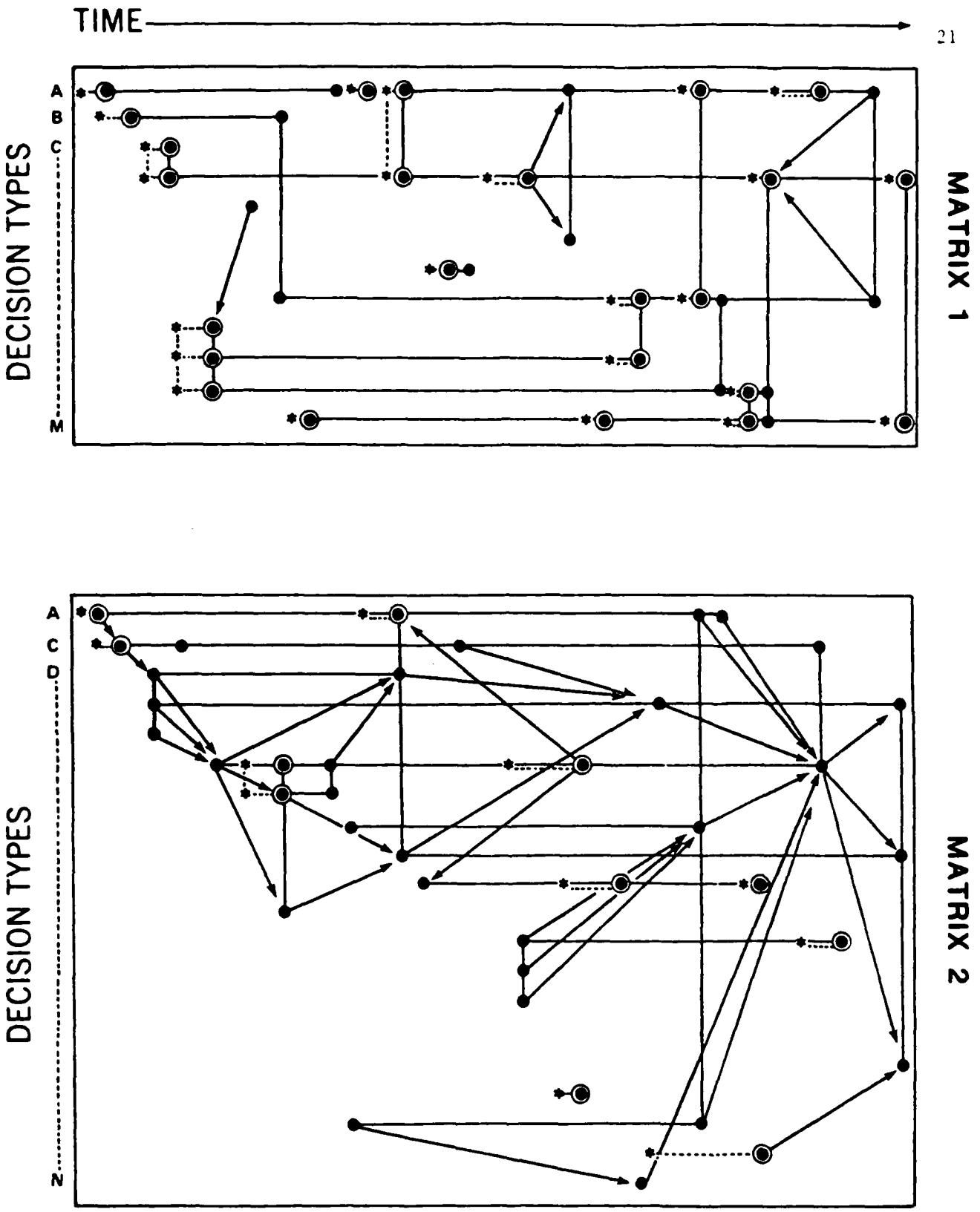

FIGURE 2

EACH POINT REPRESENTS A DECISION
EACH VERTICAL LINE CONNECTS DECISIONS MADE AT THE SAME POINT IN TIME.
EACH HORIZONTAL LINE CONNECTS DECISIONS OF THE SAME TYPE MADE AT DIFFERENT POINTS IN TIME.
EACH DIAGONAL REPRESENTS THE STRATEGIC INTEGRATION OF DIFFERENT DECISIONS AT DIFFERENT POINTS IN TIME. DIAGONALS POINTING FORWARD REFLECT ADVANCE STRATEGIC PLANNING.
EACH CIRCLED DOT REPRESENTS A DECISION RESPONSE TO INFORMATION RECEIVED AT * THE DOTTED DISTANCE FROM * TO ◉ REFLECTS THE INFORMATION TO DECISION INTERVAL.
EACH DECISION TYPE REPRESENTS A SELF SELECTED DIFFERENTIATED DECISION CATEGORY BASED ON AVAILABLE RESOURCES.

actions. Measures for both kinds of these activities (and many relevant others) are included. Each measure and its purpose will be discussed below.[4] Where necessary, calculation examples will be provided.

For convenience of communication, we will again focus on time-event matrices involving decision making. The measures will be presented in the order in which they are printed out by the computer program, i.e., the order in which they were developed. Note, that similar measures may not be located adjacently to each other.

1. Number of Decisions

This measure reflects the amount of decision making activity. It consists of a count of the number of decisions made, i.e., the number of points in the matrix during any period of time that is of interest. The formula for this measure may be written as

$$\sum_{1}^{p} d$$

where 1 through p indicates the time period(s) of interest and d is a decision made within that time.

2. Number of Respondent Decisions

This measure indicates the number of information items that

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[4]Some measures, as the reader will note, are based on factorial combinations of specific values. To reduce artifactual spread in the distribution of higher values (increased artificial distances from regression lines) some measures are calculated via natural logarithm transformations.

were utilized in responses to environmental information. Since any one respondent decision may be responsive to multiple information, the score for this measure may exceed the score for number of decisions.

$$\text{Ln} \sum_{1}^{p} r_i$$

where

r_i is any response to information within a given time period (see below) after receipt of relevant information. A response (respondent decision) in this measure is counted more than once if it responds to two or more items of relevant information that was received previously.

Whether a decision responds to previously received information should ideally (as discussed earlier) be determined by a verbal indicator from the decision maker(s). That is the case in all experimental or quasi experimental simulations. For other research settings, it may have to be determined by competent judges as long as appropriate access to the decision maker(s) for questioning is not available.

Different decision-making situations require diverse time frames for the processing and accessing/communicating of information and development of subsequent decisions. Respondent decisions (as defined here, see some potential modifications below) are most often made quickly after receipt of incoming information. The decision output is usually not extensively

pondered and is rarely considered in terms of existing or emerging plans (strategy). For example, a respondent decision to the intrusion of enemy aircraft into friendly airspace may involve immediate defensive action. Certainly the reasons for that intrusion may be considered subsequently and may be reflected in future activities that may or may not be strategic (reflect planning). Nonetheless the initial action, occurring as immediately as possible, represents (often quite appropriate) one-to-one responding to information. In situations where any meaningful response to information must occur quickly, a time restriction for scoring actions as responsive might be introduced. The time limitation between receipt of information and a response which determines whether a decision follows receipt of that information with sufficient rapidity to qualify as a respondent decision must depend on the constraints of the decision-making situation. In other words, that time frame must be determined individually for each group of decision-making settings (or scenarios) that are of interest. However, that time frame cannot subsequently be changed from one person or group to the next, if meaningful comparisons are to be made.

It should be noted that two variants of the respondent decision-making measure have been used with success. One is "retaliatory decision making" (cf. Measure 8). In this measure, responses to information receipt are not included in the value of "r" if the relevant decision is part of an integrated decision sequence (i.e., is counted in the Number of Integrations

measure). The assessment of retaliatory decision making provides an estimate of non-strategic respondent behavior. A second modification of the respondent decision-making measure eliminates any time constraints for the information-decision sequence. Here all decisions made in response to information (no matter how much delayed) are counted. The resulting score reflects the total amount of respondent activity. Note, however, that these modifications of the respondent decision-making measure are not statistically independent (orthogonal) of each other. Nonetheless they can be quite useful for specific research or observation intents.

3. Number of Decision Categories

This measure is a simple count of the number of decision categories decision makers use during any specific time period. It may be conceived as an approximate estimate of the degree of differentiation in decision making. Any category which is part of the count may have been used once or more than once. The measure reflects whether the decision maker(s) would be likely to select smaller or larger numbers of action types. In addition, further analysis could reveal whether decision maker(s) are likely to select certain specific actions and eliminate others from consideration. The basic measure may be written as

$$\sum_{1}^{p} C$$

where C is the number of categories employed and 1 through p is

the time period of participation in the simulation that is of interest for analysis and interpretation.

4. (and 7). Number of Integrations (Forward, Backward or Total)

The score for Number of Integrations reflects the frequency of the application of single steps of strategy.

$$\sum_{1}^{p} i_f \quad \text{or} \quad \sum_{1}^{p} (i_b) \quad \text{or} \quad \sum_{1}^{p} (i_b + i_f) = \sum_{1}^{p} i$$

where

i_f are forward integrations (relationships, i.e., connections among decision-making points with diagonal arrows pointing forward), (Measure 4),

i_b are backward integrations (relationships, i.e., connections among decision-making points with diagonal arrows pointing backward), (Measure 7),

i are integrations, i.e., relationships where directionality cannot be established, (Measure, 4, modified).

As discussed earlier, some decision-making tasks (particularly real-world decision-making settings where the researcher or observer cannot interfere) may not lend themselves to questioning the decision maker(s) about the intent of decisions. Consequently, it may be impossible to determine whether a connection (relationship) among decisions reflects forward integrations (planning a later decision at the time an earlier decision has been made), or reflects backward integration, (using a previous decision to advantage although the connection

was not considered at the time the earlier decision did occur). However, whenever possible, forward diagonals in the matrix should be counted as forward integrations and backward diagonals should be counted as backward integrations. Translation of diagonals into integration scores is achieved on a one-to-one basis: Counting the number of diagonals of a specific type produces the relevant integration score. Where no distinction between forward and backward diagonals can be made, integrations are counted without concern for the direction of arrowheads.

Example

For simplicity's sake, let us return to the example matrix in Figure 2, page 21. The upper matrix contains two forward diagonals, i.e., a score of 2 for i_f (forward integrations). It contains three backward diagonals, i.e., a score of 3 for i_b (backward integrations). The score for i ($i_f + i_b$) would be 5. Obviously the score for the lower matrix in Figure 2 is considerably higher.

The measures concerned with number of integrations, integration time weight and QIS depend on the diagonals connecting earlier and subsequent decisions, indicating that an earlier decision made a later decision possible (strategic time sequence). Where an entire matrix is analyzed, simple counting or statistical processing of the number of diagonals is sufficient. However, if an experimenter or observer is concerned with a limited time period as part of a larger decision time sequence (e.g., if different experimental conditions are

introduced into an experimental simulation or if artificial or natural probes are utilized in a free simulation), diagonals will often cross the time lines that describe a period of interest. In that case, diagonals are scored for the time period during which they originate. If distinctions between backward and forward integrations (diagonals with backward and forward arrows) can be made, then backward integrations will be credited to the period of the subsequent (of two) decisions. Forward integrations will be credited to the period of the initial (of two interconnected) decisions. If no distinctions between forward and backward diagonals can be made, all diagonals are credited to the time period of the initial decision. If specific experimental manipulations are utilized in experimental or quasi-experimental simulations, the manipulations (if manipulated "within" across time) should, where possible, be randomized in order to replace constant error with variable error. Adjustments to reduce error produced by the end of a measurement period are discussed below.

5. Multiplexity F

The multiplexity F measure is concerned with forward planning only. It considers the QIS value (see below) that would be calculated if only diagonals in the Time-Event Matrix that connect two points ahead in time are considered. As a result, the measure focuses on the degree of strategy that is presently applied and ignores strategic components that have already been completed. It should be noted, that Multiplexity F

is especially sensitive to end effects of data collection or observation. The formula for Multiplexity F is similar to the formula for QIS (with earlier integrations omitted) and may be written as

$$\sum_{1}^{p} W\ (1+n_f)$$

For an explanation of terms, see Measures 6 and 9.

A related measure that is not currently printed by the simulation program but is related to Multiplexity F is called Multiplicity. The Multiplicity measure is also closely akin to the QIS measure (Measure 9). It does, however, not take time between decisions in an integration sequence (See measure 6, below) into account. While Multiplicity is not orthogonal to QIS, it is considered to be supplemental. This measure is potentially more meaningful than QIS in situations where responding (including strategic integrated responding) must occur quite rapidly or where the time delay between an original and a later decision in strategic sequences is more a function of task demand than of planning or task performance. The formula for multiplicity can be derived directly from the QIS formula (Measure 9) by removing the term for Weight (Measure 6):

$$\sum_{1}^{p} (1 + n_p + n_f)$$

For an explanation of terms, see Measure 9.

6. Integration Time Weight

The Time Weight measure calculates the length of time for which plans and/or strategies are developed.

$$Ln \sum_{1}^{p} W$$

Where the measure for number of integrations was merely concerned with the frequency of interconnections (strategic relationships) among decisions, the time weight measure considers the length of time involved in future planning. The measure utilizes the same individual integrations discussed for the integration measure (diagonals) but measures each diagonal on the time dimension (in fixed units chosen by the experimenter or observer, see above) and replaces the value of 1 (for the occurrence of the diagonal) with the value of length of time which the diagonal spans between decisions. Consider, for example, the matrix example in Figure 3, below:

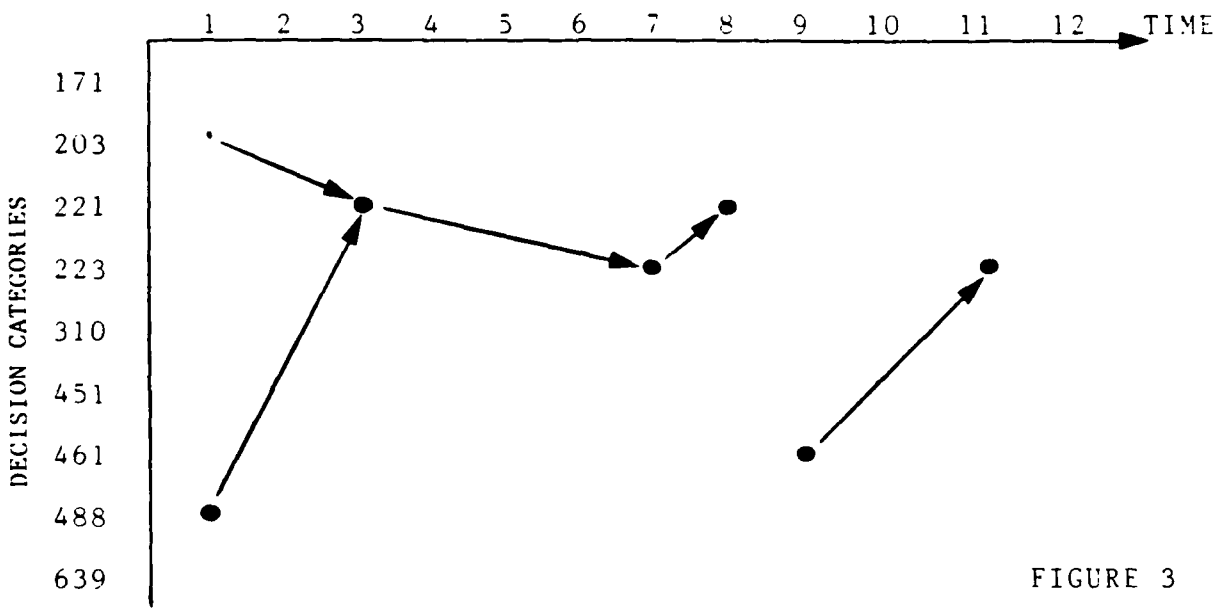

FIGURE 3

The time weight for the forward integrations (diagonal connections) between the initial decisions 203 and 488 which are connected to decision 221 represents two time units each (remember that time units are selected by the experimenter/observer but must be held constant if numerical comparisons among scores for different decision makers are to be made). The connection between decisions 221 and 223 represents four time units. The connection between 223 and 221 represents one time unit, and finally the connection between 461 and 223 represents two time units. The total score for integration time weight in this matrix is then Ln (2 + 2 + 4 + 1 + 2) = the natural log of 11.

7. Backward Integrations

The rationale for scoring backward integrations and a formula for that measure have already been discussed (cf. Measure 4) and need not be repeated at this point.

8. Unintegrated Respondent Decisions (Retaliatory Decisions)

Decisions or other actions which occur in response to information may be part of an ongoing strategy and may reflect an understanding of the interrelationship between events, actions and anticipated outcomes. Alternatively, respondent actions may be retaliatory rather than strategic, i.e., they may be one-to-one responses to incoming information that do not consider the overall impact of information on plans, strategies and so forth. The latter actions are considered in the measurement of unintegrated respondent decision making. Returning to the Time-Event Matrix, all respondent decisions that are not interconnected with other decisions by diagonals would be included in this measure. A formula for this measure may be written as

$$\sum_{1}^{p} r_u$$

where

r_u are all decisions that are made in response to incoming information which are not part of an integrated sequence.

9. QIS (Quality of Integrated Strategies)

This measure provides an indication of the complexity of sequential strategic efforts. Similar data for special applications are represented by the Multiplexity of Integration and the Weighted QIS (WQIS) measures.

$$\text{Ln} \sum_{1}^{p} W(1 + n_p + n_f)$$

Where W represents the length of the time dimensions for any forward integration (or any integration, if distinctions between forward and backward integrations cannot be made). W is the last measure discussed above (integration time weight)

n_p is the number of other forward integrations (or any integration, if distinctions between forward and backward integrations cannot be made) connecting to the decision point representing the initial decision in a diagonal connection between two decisions and

n_f is the number of forward integrations (or any integrations, if distinctions between forward and backward integrations cannot be made) connecting to the decision point representing the subsequent decision in a diagonal connection between two decisions.

The number of integrations n_p and n_f here include only those integrations which are directly connected to either the initial (n_p) or subsequent (n_f) decision points.

The QIS measure assesses the degree to which planning (strategic behavior) follows an overall pattern versus a number of separate unrelated plans. While the score for number of integrations may, for example, be the same in either case, an overall plan connecting all components of a decision-making sequence in a combined strategy would result in a higher QIS score; separate strategic plans would result in lower QIS scores. QIS scores tend to distinguish between excellent and mediocre

decision-making quality where decision makers must operate at advanced decision-making levels. QIS are identical to Integration Time Weight scores where all integrations remain independent of each other, i.e., where an overall strategic plan does not exist.

Example

Let us again return to Figure 3, page 31. A QIS value would be established for each diagonal in the matrix. Let us initially take the diagonal which is connecting 203 and 221. We already concluded that its not yet transformed weight (W) score is 2. There are no diagonals connecting to its beginning point. On the other hand, there are two diagonals connecting directly to its end point. The score would be

$$2(1 + 0 + 2) = 6$$

The same value of 6 would also be obtained for the 488 to 221 diagonal. The 221 to 223 diagonal with a W value of 4 connects to two other diagonals at its beginning point and one other diagonal at its end point. Its score would be

$$4(1 + 2 + 1) = 16$$

In turn the 223 to 221 connection would be

$$1(1 + 1 + 0) = 2$$

Finally, the 461 to 223 diagonal maintains its W value since there are no diagonals connected to either the initial nor the subsequent decisions:

$$2(1 + 0 + 0) = 2$$

For this matrix the total QIS score then would be

Ln (6 + 6 + 16 + 2 + 2) = the natural log of 32

10. Weighted QIS

Weighted Quality of Integrated Strategies (WQIS) is an extension of the QIS measure to obtain scores for the sequential chain of interconnections among integrated decisions over long periods of time (i.e., multiple long-term strategic actions that are coordinated). Where the QIS formula calculated the time weight for an integration (diagonal connection between decision points differing in time) and multiplied that weight value with the number of other diagonals connected directly to the beginning point (initial decision) and the end point (later integrated decisions) of an integration, the WQIS measure considers all integrations (diagonals) which lead in chain sequences to the decision which begins the integration, as well as all integrations (diagonals) which follow the later integrated decision, as long as there is no interruption in diagonal (integration) links. Because of the multiplicative nature of this measure, quite high scores can be obtained whenever additional links are added in any strategic chain of decisions. Where no more than three decision points (differing in time) are connected with diagonals (integrations), the WQIS measure will not differ from the QIS measure. Where four decision points (three sequential diagonals) are involved, the measure will not differ for the middle integration, but will differ for the outer two integration diagonals. With even greater numbers of diagonal connections in chain sequence, the score for WQIS would considerably exceed

the QIS score. The formula for WQIS can be written as

$$\text{Ln} \sum_{1}^{p} W(1 + n_{pp} + n_{ff})$$

where

n_{pp} is the number of forward integrations reflected in the term n_p for the QIS measure plus all other forward integrations connecting to these integrations, and so forth, until all integrations (diagonals in the matrix) which connect to each other and can be traced without interruption to the beginning point of the forward integration of interest have been exhausted.

n_{ff} is the number of forward integrations reflected in the term n_f for the QIS measure plus all other forward integrations connecting to these integrations, and so forth, until all integrations (diagonals in the matrix) which connect to each other and can be traced without interruption to the later decision have been exhausted.

All other terms are the same used in previous formulas.

For the example in Figure 3 on page 31 the WQIS score would be

2(1+0+3) + 2(1+0+3) + 4(1+2+1) + 1(1+3+0) + 2(1+0+0) = the natural log of 38

11. Average Response Speed

The measure reflects the typical time delay between receipt

of information and decision responses to that information.

$$\text{Ln} \quad \frac{\sum_{1}^{p} t_r}{r_p}$$

where

t_r is the elapsed time between information receipt and any subsequent respondent decision, and

r_p is the number of respondent decisions made in the time period between 1 and p.

The response speed measure simply reflects the rapidity with which decision maker(s) respond to incoming information. The time length between each input and the subsequent decision is measured; the sum of those measures is divided by the number of observed responses to information. For this measure it is worthwhile to consider a value for r (number of respondent decisions) which is not constrained by a time limitation between information receipt and subsequent decision.

If no responses to information should occur (a rather unlikely event) the score for Measure 11 must be set to a value that is higher than all other scores in a sample.

12. Serial Connections

The serial connection measure is similar to the Number of Integrations measure but counts interconnections between decisions that are placed into the same decision category. For example, if decision makers decide to move troop unit A and plan

to subsequently move troop unit B, a forward serial connection is established: Both decisions fall into a single decision category: troop movement. They are, by themselves, not likely to reflect an ongoing strategy unless they are also interconnected with other decisions located in different categories (to which they would be connected with diagonals in the matrix). Serial connections without integrations often reflect a stagnating series of moves that frequently fail to take the complexities of a task or environment into account. If associated with strategic moves (as reflected in high scores on such measures as Number of Integrations or QIS), they may be part of a general (e.g., in the military, an encircling) strategy.

Serial connections may be measured (as were number of integrations) in terms of forward, backward or general connections between decisions of a single category:

$$\sum_{1}^{p} i_{sf} \quad \text{or} \quad \sum_{1}^{p} i_{sb} \quad \text{or} \quad \sum_{1}^{p} (i_{sf} + i_{sb}) = \sum_{1}^{p} i_{s}$$

where

i_{sf} are forward serial connections, and i_{sb} are backward serial connections.

13. Planned Integrations

Not all actions, here decisions, which are planned as sequels to current actions will actually be carried out. Time demands, changed situations, forgetfulness, new strategies and more may be the cause of lacking follow-up actions. Where

multiple strategies toward goals were followed, planned actions that are part of strategy may be dropped as unnecessary when some other parallel strategy is about to reach its successful conclusion. In other cases, however, an incomplete connection between a current action and a planned future action may indicate poor implementation of strategy. The Planned Integrations measure reflects the number of times decision makers fail to carry out subsequent future actions that had been previously planned. The formula for planned integrations can be written as

$$\sum_{1}^{p} i_{pf}$$

where

i_{pf} is a planned forward integration which was not carried out in the future.

Planned integrations that did not come to fruition may be compared with the number of integrations which were completed to obtain an estimate of the degree to which decision makers do operationalize their plans. This score would be reflected by the formula

$$\sum_{1}^{p} i_{f} \quad - \quad \sum_{1}^{p} i_{pf}$$

Finally, the planned integration measure may be utilized to estimate the assumed time value for number of integrations where that measure is truncated by the end of a measurement or

observation sequence (e.g., at final participation periods in experimental simulations or at the retirement of an executive or officer prior to final completion of a task). Under these conditions, it may not have been possible to complete all future decisions which were planned when a previous action was initiated. As a result the uncorrected measure for number of integrations would underestimate the strategic planning of the decision maker. This correction may be calculated as:

$$f\left(1 - \frac{\sum_{1}^{pp} i_{pf}}{\sum_{1}^{pp} i_{f}}\right)$$

where 1 through pp is any prior time period (or periods) to which a time period under analysis is to be compared.

The obtained value of this correction is then multiplied with the total number of intended integrations:

$$f\left(\sum_{1}^{p} i_{pf} + \sum_{1}^{p} i_{f}\right)$$

to obtain the estimated value of corrected Number of Integrations. Unless the corrected value is less than the actually obtained score for Number of Integrations, the Number of Integrations score may be replaced by the corrected score. A measure

discussed later in this paper is specifically derived for calculating estimated values on the basis of earlier simulation performance (Measure 36). Similar calculations may be employed to correct other measures which are based on forward or backward integrations.

14. General Unintegrated Decisions

Decisions which are neither part of any integrated strategy nor are made in response to information are defined as General Unintegrated Decisions. In most cases, these decisions are not particularly valuable unless they are part of a tentative probe for preliminary information, e.g., in the form of "I wonder what would happen if...": In a more or less defined task setting with the potential for strategic goal directed actions, an excess of General Unintegrated Decisions tends to reflect poor performance. The formula for this measure may be written as

$$\sum_{1}^{p} u$$

where u is an unintegrated respondent decision.

15. Spread across Decision Categories[5]

This measure, as well as the next measure (Average Spread Across Decision Categories), considers the degree to which decision makers favor certain kinds of actions over other kinds.

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[5]This measure has been slightly modified compared to previous applications.

$$\sum_{1}^{p} 2(d_{Ca} - d_{Cb}) + (d_{Cd} - d_{Ce})$$

where, d is the number of decisions

d_{Ca} is the number of decisions from the category or categories representing the upper ten percent of decision frequency,

d_{Cb} is the number of decisions from the category or categories representing the lowest ten percent of decision frequency,

d_{Cd} is the number of decisions from the category or categories representing the upper fifty percent of decision frequency, and

d_{Ce} is the number of decisions from the category or categories representing the lower fifty percent of decision frequency.

A high value of this measure suggests that the decision maker(s), while not necessarily totally ignoring other potential decision categories, nonetheless concentrate major effort on a limited number of activities. For example, an executive who selects most decisions because they specifically relate to current profit or a military commander who lets the infantry do nearly all of the fighting without support by other units would score high on this measure. A low score, on the other hand, would reflect a more well rounded approach to more or less complex tasks. The measure is not meaningful if only one decision

category is utilized.

Example

Let us assume that decision maker(s) made a total of fifty decisions during a given period of time. These decisions represented the following decision types:

Decision Category	Number of Decisions
111	5
122	10
312	20
333	3
415	8
526	1
527	3
Total	50

The upper and lower ten percent would represent a value of 5 each (10% of fifty) while the upper and lower 50% would represent values of 25 each.

Decision category 312 is included in the upper 10%, providing a value of 20 (the number of decisions in that decision type category) for d_{Ca}.

Decision categories 333, 526 and 527 are included in the lower ten percent providing a value of 7 for d_{Cb}.

Decision categories 122 and 312 are included in the upper 50%, providing a value of 30 for d_{Cd}.

Decision categories 122, 415, 111, 333, 526 and 527 are included in the lower 50% providing a value of 30 for d_{Ce}.

The resulting calculation for spread across decision categories is then: $2(20 - 7) + (30 - 30) = 26$.

16. Average Spread Across Decision Categories

The formula for Spread Across Decision Categories is to some degree affected by the number of categories used (and/or available). To correct for potential errors, particularly when many decision categories are available and utilization differs widely among individuals or groups, an additional measure may be introduced. This measure divides the score for spread across categories by the number of categories utilized. The average spread measure is not assumed (or demonstrated) to be orthogonal from Spread Across Decision Categories. It may be calculated as

$$\frac{\sum_{1}^{p} 2(d_{Ca} - d_{Cb}) + (d_{Cd} - d_{Ce})}{\sum_{1}^{p} C}$$

For the example of decision types and decision frequencies on page 43 the obtained numerical score would be 26 (the value obtained for the Spread Across Decision Categories measure) divided by the Number of Categories measure, here 7 = 3.7143.

17. Number of Decisions in Response

Where Measure 2 was concerned with the number of information items which lead to responses, Measure 17 focuses only on the

number of responses themselves that were, at least in part, generated by information. For example, Measure 2 counts each time that a previous message is listed as one antecedent. For example, if an executive makes three decisions and claims that each of those decisions was based on three previous messages, the resulting score for Measure 2 would have been 9. In contrast, Measure 17 counts only the decisions themselves if they are claimed to be in response to previous information, irrelevant of the number of messages to which those responses were made. In other words, the same person's score on Measure 17 would be 3. Measure 17 may be represented by the formula

$$\sum_{1}^{p} r$$

where r equals the number of decisions that listed previous messages as the basis of decision making. It differs from Measure 2 in the term r which, in that case, was r_i.

18. Most Recent Response Speed

Measure 11 had assessed the mean response speed during any one particular period of interest. The score would be a reflection of both immediate and delayed responding to information. However, some situations do not lend themselves to respondent action until some critical event has occurred. Once that event is observed, an immediate response might only then become optimal. Measure 11 might, in some situations, confound the assessment of the latter response with elapsed time between

earlier, partially relevant information and the arrival of later critical information. That time span is, however, under control of the simulation system and is not affected by any actions of participants. Consequently, it seemed useful to develop a measure that would assess the rapacity of response to the last relevant message received. Measure 18 was designed for that purpose:

$$\frac{\sum_{1}^{p} t_{rr}}{r_p}$$

where

t_{rr} is the time elapsed between receipt of the most recent relevant information and the subsequent respondent decision and

r_p is (as it was in Measure 11) the number of respondent decisions during the time between 1 and p.

If no respondent decisions occur, the score for Measure 18 should be set to a value higher than all other scores obtained from the sample.

19. Total Integrative Activity (TIA)

Total Integrative Activity is a measure of strategic effort. It includes a count of attempted integrations that did not reach fruition and completed integrations. The latter category includes forward integrations that are based on planning

as well as backward integrations that derive from retrospective pragmatic insight. TIA scores are calculated as the simple sum of Measure 4 (Forward Integrations), Measure 7 (Backward Integrations), Measure 12 (Serial Connections) and Measure 13 (Planned Integrations). Persons scoring high on Measure 4 are most likely to score high on this measure. However, many persons scoring high on TIA fail to score high on Measures 4 or Measure 12.

20. Total Forward Integrative Activity (TFIA)

Total Forward Integrative Activity is similar to Measure 19, but considers only planned integrative actions. The measure is calculated as a simple sum of Measures 4 and 13.

21. Integrations Across Categories

Earlier, the method of assigning three digit numbers to decision categories was discussed. The reader will remember that the first digit represents a general characteristic (e.g., economic, military, etc.). Measure 21 was designed to assess the degree to which integrations (strategic actions), as discussed in Measure 4, extend beyond the first digit level of decision categories. For example, if one economic decision was strategically integrated with another economic decision, the score for that integration on Measure 21 would be zero. However, a score of one would be generated if the economic decision was integrated with a military decision, and so forth. In other words, Measure 21 estimates the degree to which strategic (integrative) planning is more generalized or more limited in its

range. The formula for Measure 21 has some similarity to the formula for Measure 4:

$$\sum_{1}^{p} i_{fc}$$

with the term i_f of Measure 4 replaced by the term i_{fc}

i_{fc} is a forward integration (relationship, i.e., connection between decision making points in the time-event matrix with arrowheads pointing forward) if this connection interrelates decisions from categories with a different first numerical digit.

22. Integrations Within Categories

This Measure calculates the frequency of integrative interrelationships that interconnect decision points that are located within the same first digit decision category. While a high score in this category does not suggest a lesser capacity for integrative strategic thought than would be implied by a high score in Measure 21, a disproportionately high score in Measure 22 compared to Measure 21, may represent a lower level of strategic thinking. Where such a lower level is either inappropriate or less effective, considering the task at hand a diminished proportion of scores in Measure 21 over Measure 22 would imply lower levels of performance. Measure 22 can be calculated as

$$\sum_{1}^{p} i_{fw}$$

where

i_{fw} are forward integrations that interconnect decisions located within the same first digit decision category.

Alternately, Measure 22 may be calculated by subtracting Measure 21 from Measure 4.

$$\sum_{1}^{p} i_{f} \quad - \quad \sum_{1}^{p} i_{fc}$$

23. Proportion of Category Integrations

As already suggested, the proportion of Measure 21 divided by Measure 22 may, if tasks are fluid, multifaceted and complex, reflect the overall quality of integrative activity. Measure 23 assesses that quality. It is calculated as

$$\frac{1 + \text{Measure 21}}{1 + \text{Measure 22}}$$

24. Shift 1

This measure assesses the capacity of decision maker(s) to shift their emphasis from an integrative strategic mode to a more respondent mode when task demands require. For the simulations employed by the present research team, an emergency is introduced at the beginning of the fourth playing period in the simulation (approximately after four hours of participation). That emergency is best handled by immediate respondent actions

and without further strategic planning (for the time being). The calculation procedure for the Shift 1 measure would differ, depending on scenario characteristics. In our simulations, no emergencies occur throughout Periods 1, 2, 3 and 6. Periods 4 and 5 present a disaster situation which requires respondent activity. In the case of our simulation design, the formula for Shift 1 would be:

$$\frac{\bar{X}\text{ Measure 4 (for Periods 1,2,3)}}{3} \text{ divided by } \frac{\bar{X}\text{ Measure 4 (Periods 4,5)}}{2}$$

A high score would indicate the presence of strategic integrative activity before the disaster event and a shift to little integrative activity throughout the disaster.

A number of potential problems may emerge for this measure (and some subsequent measures) that must be controlled by the introduction of default values. For example, the complete absence of integrative actions during Periods 4 and 5 would result in a division of 0 + 0 by 2, resulting in zero. The subsequent division of the first part of the formula by zero would not be meaningful. Similarly, some (especially the second) part of this formula may generate a quotient between zero and 1, generating a meaningless increase in the score for this measure. To eliminate these problems, a minimum default value of 1.0 is set for both the first and the second part of the formula.

25. Shift 2

This measure corrects Measure 24 for the actual amount of

activity a person has expended on respondent actions throughout the task. Calculation of the Shift 2 score is based on the proportion of integrative activity and respondent activity as that proportion shifts from time periods where strategic planning should be a priority to time periods where respondent activity should be a priority. For the simulation procedures employed in this research (with planning appropriate in periods 1 through 3 and respondent actions most appropriate in periods 4 and 5) the formula should be

$$\frac{\bar{X}\ \text{Measure 4}}{\bar{X}\ \text{Measure 17}}\ \text{(for periods 1,2,3) divided by}\ \frac{\bar{X}\ \text{Measure 4}}{\bar{X}\ \text{Measure 17}}\ \text{(periods 4,5)}$$

Similarly to other measures which are based on changes in situational demands, the formula for Shift 2 must be modified with changes in the introduction and duration of emergency conditions. Default values must again be introduced if Measure 4 or Measure 17 values are equal to zero resulting in division by zero or division by a fraction.

26. Recovery 1

If stress or emergency situations require a priority shift from strategic to respondent activity, planning and strategy must often re-emerge once immediate problems have been resolved. However, some persons may be overwhelmed by the emergency stress experience and may fail to recover, i.e., may fail to reinstitute strategic and planning activities when appropriate. Those persons would not perform adequately in task settings that contain intermittent stress periods. To assure that assessment

of performance does not miss the potential detrimental impact of stressor experience, two recovery measures were developed. Recovery 1 compares the number of integrations after an emergency has been resolved (period 6 in the present simulations) with the number of integrations which were evident prior to the stressor experience (before the emergency occurred). For the present simulations, the score is calculated as follows:

$$\frac{\text{Measure 4 (Period 6)}}{\bar{X}\ \text{Measure 4 (Periods 1, 2 and 3)}}$$

Where the Mean value of Measure 4 for periods 1 through 3 equals zero, the score for this Measure is equal to the value of Measure 4 in Period 6.

27. Number of Information Search Decisions

This measure simply counts the number of information search activities in which decision makers engage during a time period of interest:

$$\sum_{1}^{p} s$$

Where

s represents a decision with the purpose of obtaining additional information.

28. Number of Integrated Information Search Decisions

This measure is concerned with the purpose of information search. Where information search was initiated for strategic reasons, the search action will typically precede subsequent

related actions, i.e., it will be integrated with those later actions. In the time-event matrix, a forward arrow will appear between the search decision and subsequent related decision(s). The formula may be written as

$$\sum_{1}^{p} i_{fis}$$

Where

i_{fis} are the number of forward integrations that originate in information search decisions.

29. Disaster Response Speed

Measures 29 through 35 focus on the introduction of an emergency that is an intricate part of our own simulation procedure. Where emergencies are not introduced, Measures 29 through 35 are meaningless. The advent of an emergency in our simulations is coded by a message with the number M300. The specified time location of M300 within the simulation allows the calculation of values for emergency responses. The first of these, Disaster Response Speed, measures the elapsed time between the advent of the emergency message M300 and the first respondent decision to that message. The formula may be written as follows:

$$t_{d1} = t_{r1} - t_{M300}$$

Where

t_{d1} is the obtained disaster response speed

t_{r1} is the time of the first respondent decision relevant

to the emergency message, and

t_{M300} is the time of arrival of Message 300 (the emergency message)

If no response to the emergency message M300 is made, the score for Measure 29 must be set to a value that is higher than all other scores in the sample.

30. Average Disaster Response Speed

Most decision makers respond to the emergency message with a number of actions. The present measure calculates the mean time distance between the arrival of the emergency message and the various responses to that message:

$$t_{\bar{X}d} = \bar{X}(t_r - t_{M300})$$

Where

$t_{\bar{X}d}$ is the obtained Mean Disaster Response Speed

t_r is the time of any decision which responds to Message 300, and

t_{M300} is the time of arrival of the emergency message (M300)

If no response to the emergency message M300 is made, the score for Measure 29 must be set to a value that is higher than all other scores in the sample.

31. Integrated Disaster Responses

This measure considers the degree to which the potential of an emergency was included in previous strategic planning. If this measure is to be meaningful, the simulation must be designed so that emergency (or equivalent) problems are viewed as possible

by participants and can be, to some extent, anticipated in their potential characteristics. This is the case for the simulations we have designed. The measurement for integrated disaster response counts the number of forward diagonals that end (terminate) in any decisions that list the disaster message (M300) as a preceding relevant message:

$$\sum {}^{i}_{frM300}$$

Where

${}^{i}_{frM300}$ are all integrations that terminate in respondent decisions based (entirely or in part) on Message 300.

32. Applied Disaster Strategy

While strategic actions in response to emergency situations are not likely and often are not appropriate, some integrated strategies might reasonably originate from responses to an emergency event. The Applied Disaster Strategy measure was designed to assess the number of strategic integrations (forward diagonals in the matrix) that originate from respondent decisions which list Message 300 as a relevant preceding message. The formula may be written as:

$$\overline{\angle} {}^{i}_{friM300}$$

Where

${}^{i}_{friM300}$ are all integrations that originate from respondent decisions that list the disaster message M300 as a preceding message.

33. Number of Disaster Decisions

We are here concerned with the number of respondent actions to the advent of an emergency. The measure simply counts the number of respondent decisions (whether or not they are integrated) that list M300 as a relevant preceding message. The formula may be written as follows:

$$\sum d_{M300}$$

Where

d_{M300} is any decision made in response to Message 300.

34. Disaster Backward Integrations

Actions taken at an earlier time, while not previously planned to deal with potential future emergencies, might nonetheless be useful once an emergency arises. Backward integrations (i.e., pragmatic post-hoc application of strategy) that are applied to actions which respond to emergencies are counted in this measure. The score is obtained with the following formula:

$$\sum i_{bM300}$$

Where

i_{bM300} are all backward integrations connected to respondent decisions that list Message 300 as a preceding message.

35. Disaster TIA

We have already encountered TIA in Measure 19. In this case we are only concerned with Total Integrative Activity as it applies to the emergency situation. Disaster TIA calculates a

TIA value only for those respondent decisions that list M300 as a preceding message. The formula for Disaster TIA is calculated as

$$\sum i_{friM300} + \sum i_{bM300} + \sum i_{pfM300} + \sum i_{sfM300}$$

where the first two terms are applied as previously discussed and

i_{pfM300} are *planned forward integrations* that were not realized and were planned to originate in a respondent decision to Message 300.

i_{sfM300} are serial connections within the same three digit decision category that were realized and originated in respondent decisions to Message 300.

36. Adjusted Number of Forward Integrations

This measure was designed to correct for a potential end effect that might diminish the number of integrations obtained in later periods of any controlled decision making task (e.g., a simulation) or that may be due to the termination of observations in an executive setting. Measure 36 calculates the proportion of realized and planned integration in earlier periods of time and applies that proportion to generate expected values during later time periods. This formula must, of course, be adapted to the length of any simulation or period of observation. For present purposes, the first two periods of participation in our simulations are viewed as a performance baseline. Corrections are applied to all subsequent periods. To obtain the value for

the baseline proportion, the value Y is calculated as

$$Y = \bar{X} \text{ of } \frac{\text{Measure 4}}{\text{Measure 20}} \text{ (for periods 1 and 2)}$$

To obtain a correction coefficient Z, Y is multiplied by Measure 20 for each of the subsequent periods. The value of Measure 36 for each time segment (simulation period) is the larger of either Measure 4 or the calculated value of Z. Measure 36 obtains this score for periods 3-6 of the simulation. As stated earlier, scores for periods 1 and 2 are set to be identical to scores obtained by Measure 4.

Occasionally, the formula may call for decision by zero. Where that is the case the value divided by zero is set to zero.

37. Recovery 2

This measure is similar to Recovery 1 (Measure 26) but employs Measure 36 rather than Measure 4 as the numerator. In other words, it adjusts the obtained score via the adjusted (calculated) number of forward integrations, if they exceed the actual number of integrations in later periods of observation or task performance. For the simulations employed in our research, the formula for Recovery 2 is

$$\frac{\text{Measure 36 (period 6)}}{\bar{X} \text{ Measure 4 (for periods 1, 2 and 3)}}$$

If the numerator in the formula falls below a value of 1.0, the latter will be substituted to avoid an unwarranted increase in the obtained score for the Recovery 2. In other words, if $\bar{X}$ Measure 4 for periods 1, 2 and 3 = 3.0, the value of Measure 37

will be equal to Measure 36.

Additional Measurement

(1) Frequency Proportions

To some extent, performance characteristics of a person or a decision making group may be limited by the overall decision or action output in a task. These limitations could be due either to lack of attention, to a lack of opportunity to respond or to task characteristics that may limit actions. Consequently, the proportion of performance score values as part of total relevant activity may, in some cases, be a preferred measure of performance. For that purpose, the quotient of relevant measures divided by the number of actions taken (e.g., decisions made) could represent an important estimate of actual performance. That quotient is calculated in our computerized measurement system for Measures 2, 4, 5, 7, 8, 19, 20, 21, 22, 27, 28 and 36.

(2) Time Periods and Overall Performance

Performance values on most measures is calculated by the IBM AT based software program for six separate time periods in the simulation. In addition, it is summarized for the entire simulation. All measures are included in the score summary. Measure values that are relevant to only one event in the simulation (e.g., the occurrence of an emergency) are, of course, calculated only once and are provided only as overall values in the final score summary. Scores that are continuously relevant are provided for each period and in the final summary table. An example of such a printout is provided in the Appendix.

(3) Options

Since the underlying simulation software was designed to be flexible, other scenarios may be designed to utilize that program at will. Such scenarios, while they might require modifications of certain measures (as indicated) would also permit the development of additional measures of interest that might be based on data that are automatically collected by the simulation system.

The simulation technique permits the introduction of measures that would assess the correctness and timeliness of the content of decisions and other actions by participants. Those measures would, of course, have to be specifically designed for each particular scenario and would likely require additional programming to permit computer based data collection.

APPENDIX

The following example of a computer printout of Measures from a simulation (taken from the reliability sample) contains information on six playing periods and a final Measure summary. Please note that natural log transformations on the measures are not provided by the computer system and must be performed separately.

```
==================== PERIOD  1   9009DIS   EMCTRL ====================

1-MEASURE= 18   (# OF DECISIONS)
2-MEASURE= 19      105 % (# OF RESPONDENT DEC.)
3-MEASURE= 15   (# OF DEC. CATEGORIES)
4-MEASURE= 12     66 % (# OF FWD INTEGRATIONS)
5-MEASURE= 28     155 % (MULTIPLEXITY F)
6-MEASURE= 451   MINUTES (WEIGHT)
7-MEASURE= 6      33 % (# OF BKD INTEG)
8-MEASURE= 9      50 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 1294   (QIS)
10-MEASURE= 1937   (WEIGHTED QIS)
11-MEASURE= 4.968422   (AVE.RESPONSE SPEED)
12-MEASURE= 2   (SERIAL CONNECTIONS)
13-MEASURE= 25   (PLANNED INTEGRATIONS)
14-MEASURE= 3   (GENERAL UNINTEGRATED DEC.)
17-MEASURE= 15     83 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 3.946667   (MOST RECENT RESPONSE SPEED)
19-MEASURE= 45     250 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 37     205 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TFIA)
21-MEASURE= 10     55 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 2     11 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 3.666667   (PROP.CAT.INTEG.)
27-MEASURE= 14     77 % (# INFO SEARCH DEC.)
28-MEASURE= 8     44 % (# INFO SEARCH DEC.INT.)
36-MEASURE= 12     67 % (ADJUSTED # OF FWD.INTEG.)
```

```
==================  PERIOD  2   9009DIS   EMCTRL ====================

1-MEASURE= 14   (# OF DECISIONS)
2-MEASURE= 14      100 % (# OF RESPONDENT DEC.)
3-MEASURE= 9   (# OF DEC. CATEGORIES)
4-MEASURE= 22     157 % (# OF FWD INTEGRATIONS)
5-MEASURE= 145     1035 % (MULTIPLEXITY F)
6-MEASURE= 184   MINUTES (WEIGHT)
7-MEASURE= 4      28 % (# OF BKD INTEG)
8-MEASURE= 6      42 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 1598   (QIS)
10-MEASURE= 5288   (WEIGHTED QIS)
11-MEASURE= 10.19286   (AVE.RESPONSE SPEED)
12-MEASURE= 7   (SERIAL CONNECTIONS)
13-MEASURE= 26   (PLANNED INTEGRATIONS)
14-MEASURE= 1   (GENERAL UNINTEGRATED DEC.)
17-MEASURE= 13     92 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 8.976923   (MOST RECENT RESPONSE SPEED)
19-MEASURE= 59     421 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 48     342 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TFIA)
21-MEASURE= 19     135 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 3     21 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 5   (PROP.CAT.INTEG.)
27-MEASURE= 1      7 % (# INFO SEARCH DEC.)
28-MEASURE= 0      0 % (# INFO SEARCH DEC.INT.)
36-MEASURE= 22     157 % (ADJUSTED # OF FWD.INTEG.)
```

```
==================== PERIOD 3  9009DIS  EMCTRL ====================

1-MEASURE= 13  (# OF DECISIONS)
2-MEASURE= 22     169 % (# OF RESPONDENT DEC.)
3-MEASURE= 10  (# OF DEC. CATEGORIES)
4-MEASURE= 25    192 % (# OF FWD INTEGRATIONS)
5-MEASURE= 220    1692 % (MULTIPLEXITY F)
6-MEASURE= 303  MINUTES (WEIGHT)
7-MEASURE= 12    92 % (# OF BKD INTEG)
8-MEASURE= 10    76 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 4243  (QIS)
10-MEASURE= 12838  (WEIGHTED QIS)
11-MEASURE= 7.045455  (AVE.RESPONSE SPEED)
12-MEASURE= 3  (SERIAL CONNECTIONS)
13-MEASURE= 28  (PLANNED INTEGRATIONS)
14-MEASURE= 2  (GENERAL UNINTEGRATED DEC.)
17-MEASURE= 13    100 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 4.400001  (MOST RECENT RESPONSE SPEED)
19-MEASURE= 68    523 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 53    407 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TFIA)
21-MEASURE= 17    130 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 8    61 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 2  (PROF.CAT.INTEG.)
27-MEASURE= 2    15 % (# INFO SEARCH DEC.)
28-MEASURE= 0    0 % (# INFO SEARCH DEC.INT.)
36-MEASURE= 25    192 % (ADJUSTED # OF FWD.INTEG.)
```

```
==================  PERIOD  4   9009DIS   EMCTRL ====================

1-MEASURE= 23   (# OF DECISIONS)
2-MEASURE= 43      186 % (# OF RESPONDENT DEC.)
3-MEASURE= 18   (# OF DEC. CATEGORIES)
4-MEASURE= 25     108 % (# OF FWD INTEGRATIONS)
5-MEASURE= 129     560 % (MULTIPLEXITY F)
6-MEASURE= 79  MINUTES (WEIGHT)
7-MEASURE= 42     182 % (# OF BKD INTEG)
8-MEASURE= 28     121 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 734   (QIS)
10-MEASURE= 2162   (WEIGHTED QIS)
11-MEASURE= 16.75814   (AVE.RESPONSE SPEED)
12-MEASURE= 1   (SERIAL CONNECTIONS)
13-MEASURE= 19   (PLANNED INTEGRATIONS)
14-MEASURE= 2   (GENERAL UNINTEGRATED DEC.)
17-MEASURE= 23     100 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 7.130434   (MOST RECENT RESPONSE SPEED)
19-MEASURE= 87     378 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 44     191 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TFIA)
21-MEASURE= 17     73 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 8     34 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 2   (PROP.CAT.INTEG.)
27-MEASURE= 0     0 % (# INFO SEARCH DEC.)
28-MEASURE= 0     0 % (# INFO SEARCH DEC.INT.)
36-MEASURE= 25     109 % (ADJUSTED # OF FWD.INTEG.)
```

```
==================== PERIOD 5  9009DIS  EMCTRL ====================

1-MEASURE= 15  (# OF DECISIONS)
2-MEASURE= 7     46 % (# OF RESPONDENT DEC.)
3-MEASURE= 12  (# OF DEC. CATEGORIES)
4-MEASURE= 2     13 % (# OF FWD INTEGRATIONS)
5-MEASURE= 2     13 % (MULTIPLEXITY F)
6-MEASURE= 2  MINUTES (WEIGHT)
7-MEASURE= 4     26 % (# OF BKD INTEG)
8-MEASURE= 6     40 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 2  (QIS)
10-MEASURE= 2  (WEIGHTED QIS)
11-MEASURE= 13.21428  (AVE.RESPONSE SPEED)
12-MEASURE= 4  (SERIAL CONNECTIONS)
13-MEASURE= 2  (PLANNED INTEGRATIONS)
14-MEASURE= 9  (GENERAL UNINTEGRATED DEC.)
17-MEASURE= 7    46 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 13.21428  (MOST RECENT RESPONSE SPEED)
19-MEASURE= 12    80 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 4    26 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TFIA)
21-MEASURE= 2    13 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 0    0 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 3  (PROP.CAT.INTEG.)
27-MEASURE= 4    26 % (# INFO SEARCH DEC.)
28-MEASURE= 0    0 % (# INFO SEARCH DEC.INT.)
36-MEASURE= 2    13 % (ADJUSTED # OF FWD.INTEG.)
```

========== PERIOD 6 9009DIS EMCTRL ==========

1-MEASURE= 16 (# OF DECISIONS)
2-MEASURE= 9 56 % (# OF RESPONDENT DEC.)
3-MEASURE= 12 (# OF DEC. CATEGORIES)
4-MEASURE= 5 31 % (# OF FWD INTEGRATIONS)
5-MEASURE= 9 56 % (MULTIPLEXITY F)
6-MEASURE= 7 MINUTES (WEIGHT)
7-MEASURE= 7 43 % (# OF BKD INTEG)
8-MEASURE= 5 31 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 17 (QIS)
10-MEASURE= 17 (WEIGHTED QIS)
11-MEASURE= 28.76667 (AVE.RESPONSE SPEED)
12-MEASURE= 4 (SERIAL CONNECTIONS)
13-MEASURE= 2 (PLANNED INTEGRATIONS)
14-MEASURE= 5 (GENERAL UNINTEGRATED DEC.)
17-MEASURE= 9 56 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 28.76667 (MOST RECENT RESPONSE SPEED)
19-MEASURE= 18 112 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 7 43 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TRIA)
21-MEASURE= 3 18 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 2 12 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 1.333333 (PROP.CAT.INTEG.)
27-MEASURE= 7 43 % (# INFO SEARCH DEC.)
28-MEASURE= 1 6 % (# INFO SEARCH DEC.INT.)
36-MEASURE= 5 31 % (ADJUSTED # OF FWD.INTEG.)

MEASURE 15- (SPREAD ACROSS DEC.CAT.)

531	6
513	5
614	4
771	4
731	4
431	4
212	3
221	3
121	3
532	3
714	3
772	3
621	3
611	2
635	2
612	2
752	2
722	2
753	2
721	2
313	2
625	1
639	1
651	1
615	1
633	1
616	1
911	1
699	1
622	1
231	1
732	1
641	1
661	1
224	1
411	1
511	1
712	1
751	1
711	1
211	1
763	1
561	1
781	1
774	1
741	1
775	1
311	1
671	1
461	1
617	1
691	1
692	1
623	1
251	1
762	1

```
==================== OVERALL MEASURES   9009DIS   EMCTRL ====================

1-MEASURE= 99   (# OF DECISIONS)
2-MEASURE= 114      110 % (# OF RESPONDENT DEC.)
3-MEASURE= 13   (# OF DEC. CATEGORIES)
4-MEASURE= 91     95 % (# OF FWD INTEGRATIONS)
5-MEASURE= 533     585 % (MULTIPLEXITY F)
6-MEASURE= 1026  MINUTES (WEIGHT)
7-MEASURE= 75     67 % (# OF BKD INTEG)
8-MEASURE= 64     60 % (# OF UNINTEG.RES.DEC.)
9-MEASURE= 7888   (QIS)
10-MEASURE= 22244   (WEIGHTED QIS)
11-MEASURE= 13.49097   (AVE.RESPONSE SPEED)
12-MEASURE= 21   (SERIAL CONNECTIONS)
13-MEASURE= 102   (PLANNED INTEGRATIONS)
14-MEASURE= 22   (GENERAL UNINTEGRATED DEC.)
15-MEASURE= 1   (SPREAD ACROSS DEC.CAT.)
16-MEASURE= 1.785714E-02   (AVERAGE SPREAD)
17-MEASURE= 80     80 % (# OF DECISIONS IN RESPONSE)
18-MEASURE= 11.20583   (MOST RECENT RESPONSE SPEED)
19-MEASURE= 289     294 % (TOTAL INTEGRATIVE ACTIVITY=TIA)
20-MEASURE= 193     202 % (TOTAL FORWARD INTEGRATIVE ACTIVITY=TFIA)
21-MEASURE= 68     71 % (INTEGRATIONS ACROSS CATEGORIES)
22-MEASURE= 23     23 % (INTEGRATIONS WITHIN CATEGORIES)
23-MEASURE= 2.833333   (PROP.CAT.INTEG.)
24-MEASURE= 1.45679   (EMERGENCY SHIFT 1)
25-MEASURE= 2.144425   (EMERGENCY SHIFT 2)
26-MEASURE= .2542373   (RECOVERY 1)
27-MEASURE= 28     28 % (# INFO SEARCH DEC.)
28-MEASURE= 9     8 % (# INFO SEARCH DEC.INT.)
29-MEASURE= 2.599999   (DISASTER RESP.SPEED)
30-MEASURE= 11.48461   (AVERAGE DISASTER RESPONSE SPEED)
31-MEASURE= 31   (INTEGRATED DISASTER RESPONSE)
32-MEASURE= 15   (APPLIED DISASTER RESPONSE)
33-MEASURE= 13   (# OF DISASTER DECISIONS)
34-MEASURE= 8   (DISASTER BACKWARD INTEGRATIONS)
35-MEASURE= 26   (DISASTER TIA)
36-MEASURE= 91     95 % (ADJUSTED # OF FWD.INTEG.)
37-MEASURE= .2542373   (RECOVERY 2)
```

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