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THE EFFECT OF TIME PRESSURE AND DISPLAY FORMAT ON CUE UTILIZATION
IN MULTIPLE CUE DECISION MAKING

by

NANCY E. SHAFFER

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
MASTER OF ARTS

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ABSTRACT

The Effect of Time Pressure and Display Format on Cue Utilization in Multiple Cue Decision Making

Nancy E. Shaffer

It has been hypothesized that under time pressure decision makers increase the weight given to the most important information cues at the expense of other available relevant information. Three studies were performed to test this hypothesis. Subjects saw information displayed in graphical and tabular formats. There was no evidence for greater use of the most informative cues, but there was a tendency for more even weighting of cues in the graphical display format high time pressure condition. Subjects appeared to make decisions in this condition using a quick, global information gathering and integrating strategy.
Acknowledgements

This research was supported by the U.S. Army Research Institute, Contract MDA 903-85-C-0347. I would like to thank Drs. David M. Lane, William C. Howell, and Kenneth R. Laughery for their co-operation in serving as members of my committee, especially David Lane for his continued guidance in planning and carrying out the research and preparation of the thesis. I would also like to thank my family and friends for their moral support.
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The Effects of Time Pressure and Display Format on Cue Utilization in Multiple Cue Decision Making

Decision makers often integrate information from one or more sources in order to decide among alternatives (Slovic, 1982). There has been speculation and some empirical evidence that time pressure affects the way decision makers select and integrate information. Specifically, it has been hypothesized (Ben Zur & Breznitz, 1981; Payne, 1982; Wright, 1974) that under high time pressure, decision makers depend too heavily on information that tells them the most about the correct decision at the expense of other relevant information.

High information load within a limited time span may cause the decision maker to become more aroused, and the range of attention may be narrowed so that less information can be considered. This idea comes out of early research on stress by Yerkes and Dodson (1908) and Easterbrook (1959), who hypothesized that arousal focuses attention, affecting performance in a curvilinear fashion. According to Easterbrook, increases in arousal result in a restriction in the range of information cues that are used in performing a task. At low levels of arousal, performance is poor because selectivity is low and subjects pay attention to irrelevant information. As arousal increases, more information is utilized, and performance improves. At very high arousal levels, selectivity is so high that some relevant information is ignored and performance declines. Several arousal agents have been found to induce this effect including heat (Bursill, 1958), found to induce this effect including heat (Bursill, 1958), incentive (Bahrich, Fitts, & Rankin, 1952), amphetamines (Callaway & Thompson, 1953), and noise (Hockey, 1970a, 1970b). In addition, Janis and Mann (1977) identified time pressure as one source contributing to stress in decision making.
It was thought that arousal caused selective attention through a focus of the effective visual field on the center of a display, but there is evidence that supports the idea that arousal focuses attention towards the most important parts of the display (Bacon, 1974; Cornsweet, 1969; Hockey, 1970). Cornsweet found evidence for this using a task in which the most relevant information cues were in the periphery. In the experiment by Hockey, there was one condition in which signals were more likely to appear in the center of a display and one in which central and peripheral signals were equally likely. Increased arousal (as induced by loud noise) improved responsiveness to central relative to peripheral signals only when central signals were more likely. Thus, when the center of the display was not more important (contained more information) than the periphery, arousal did not result in a redistribution of attention.

Ben Zur and Breznitz (1981) have proposed a cognitive filtration mechanism that operates under time pressure, selecting the most relevant dimensions for observation while disregarding others. As time pressure lessens, however, all dimensions can be considered, and use of information is less sensitive to the underlying attentional processes of the filter. It is not clear whether this results from an increase in the salience of the most important dimension or simply because under time pressure subjects do not have time to process more than one or two dimensions. Payne (1982), in his review of research on decision making, concluded that it has not yet been determined whether or not time pressure changes the salience of information.

If time pressure does indeed cause selective use of information, this should be reflected in decision making. Previous research supports the hypothesis that as time pressure increases, subjects' ability to process information becomes overloaded, causing subjects to simplify the decision process in some way in order to reduce cognitive load (Ben Zur & Breznitz, 1981; Hansson, Keating, & Terry 1974; Wright, 1974; Wright &
Weitz, 1977; Zakay & Wooler, 1984). The way the decision process is simplified is not clear, however. One suggestion is that subjects use suboptimal methods of combining information into one decision. The decision maker engaged in a complex decision task sometimes appears to adopt heuristic strategies in order to keep information processing demands within the bounds of limited cognitive capacity (Christensen-Szalanski, 1980; Payne, 1980; Payne, 1982; Zakay & Wooler; 1984). In these studies, time pressure had an effect on decision making by creating a higher information load, demanding that information be processed in smaller amounts of time, and subjects had to limit this information so it was within processing limits.

Stamm (1969, cited in Jacoby, Szybillo, & Berning, 1976) let subjects request information about the various alternatives they had to choose from. He found that under circumstances of high time pressure, people were more likely to request information about only a single alternative. Subjects were more likely to ask about two alternatives when under moderate levels of time pressure. Also, Jacoby, Kohn, & Speller (1973) found that subjects reduced the time they spent acquiring information when the amount of information exceeded a limit by tuning out some of the information so that it was not available for processing.

Wright & Weitz (1977) have investigated the effects of time pressure on the way people use information in decision making by using the immediate time horizon, which is defined as the amount of time before a decision must be made. Wright and Weitz manipulated the immediate time horizon by allowing some subjects 10 seconds to evaluate different birth control products and others 40 seconds. They gave probability information for pregnancy and side effects for the different products, and subjects responded with the probability that they would purchase that product. They found that to lighten the processing load when deliberation time was limited, the subjects in the 10
second condition based their decisions on less of the available information about the products.

Jones, Schipper and Holzworth (1978), however, found no change in the decision makers' strategies as the number of cues increased. They manipulated information load by increasing the number of cues to be used in a binary decision. They also varied the diagnosticity of cues. They found no change in the decision makers' decision strategies as the number of cues increased. In addition, the reliability of the decision policies went down as the number of cues went up.

If decision makers limit information, what information do they choose? There is evidence that they rely on information that tells them about the possible risk of negative consequences that may result from their decision. Decision making under time pressure has been called "a stressful condition adding to apprehension induced by threat of negative consequences..." (Ben Zur & Breznitz, 1981, p. 101).

Wright (1974) found that subjects tend to make more use of cues that give information about the negative consequences of various choices when they are under time pressure than when they were not. In the study, subject's strategies of using each type of information were described by additive compensatory mathematical models (Slovic & Lichtenstein, 1971). Each subject's weighting of the importance of various cues into the final decision were compared to linear decision models in which negative information was emphasized, positive information emphasized, or an unbiased model, where both kinds of information were equally emphasized. Wright found that in low time pressure or no time pressure conditions, subject's information use policies were equally represented by all three models. When the subjects were under high time pressure, two-thirds of the subjects' policies were described by the negative model. In addition, Wright's experiment gave indications that subjects used less information in
making their decisions under high time pressure. The number of information cues with statistically significant ($p < 0.05$) weights was calculated for each subject. This gave an estimate of how many factors had been systematically used by the decision maker to make the final judgement. The maximum number of dimensions that were used was five. Mean number of significant dimensions was 1.50, 2.33, and 2.08 for the high time pressure, low time pressure, and undefined time pressure conditions, respectively.

Ben Zur and Breznitz (1981) had subjects choose between gambles with the same expected values but different variances. They gave subjects information about the amount to win and lose and the probability of winning and losing, and measured subjects’ preferences for this information under three levels of time pressure. There was a slight tendency to prefer negative information more often in choosing gambles when time pressure increased. In addition, preference for using dimensions of information were analyzed. Preference was operationally defined as the number of observations made on each dimension divided by the total number of observations made during a trial. For example, if a subject made 3, 4, 2 and 3 observations on AW, AL, PW, PL, correspondingly, during one trial, the proportions for each dimension were 0.25, 0.33, 0.17 and 0.25 correspondingly. Proportions were used in order to partial out the individual tendency to use many or just a few observations as time pressure became high. The score for each subject was the average of proportions for each dimension over the 12 trials in each time pressure condition. The effect of time pressure on dimension preference were of small magnitude, but indicate that dimensions preferred by subjects in the high time pressure condition were chosen a higher percent of the time than preferred dimensions in the other conditions, and the unpreferred dimensions less than in other conditions. This indicates that under high time pressure subjects restricted the proportion of information they sought to that which they, presumably, thought was more
important.

The time pressure effects found by Wright and Weitz (1977) were also affected by negative evidence. In evaluating the utility of birth control devices under short time horizons, subjects showed a preference for paying attention to information describing the less-than-desirable outcomes. The utility functions observed were consistent with the idea that people dichotomize evaluative factors in a loss-aversive way. Hansson, Keating, and Terry (1974) found that voters told to vote their conscience on different issues voted significantly more conservatively than pre-vote measures of liberal-conservatism would have predicted when they were under time-stress conditions. Conservative shifts were interpreted as a function of overload.

Finally, there is evidence that subjects alter their strategy of combining information. In a study of decision making training, Zakay and Wooler (1984) taught subjects to use information in making decisions according to multi-attribute utility (MAU) model. The decisions made by the subjects were then compared to a criterion score derived the model. Zakay and Wooler found that the strategy the decision makers used diverged from the MAU method in proportion to the amount of time pressure. It is not clear whether subjects under time pressure used older, more practiced methods of combining information, or simplified the information-combining method under time pressure. Christensen-Szlanski (1980) tested the hypotheses of a model of decision strategy selection (Christensen-Szlanski, 1978) about the effects of varying the deadline for a decision on the strategy the decision maker used. They found that for immediate deadlines the strategy that produced the best expected outcome was not always possible to follow within the time constraints. The model predicts that in this case the decision maker will use the strategy that has the highest probability of creating the best outcome possible within the time constraints. Subjects in the immediate deadline condition used a
less costly and less accurate strategy than that associated with the best expected outcome, which was used in a distant-deadline condition.

These studies depict the decision maker under time stress as one who takes various short cuts in order to make a decision in the allotted time. Possible risks become very salient, and optimal information combining strategies cannot be followed. The present question concerns whether time pressure increases the extent to which decision makers rely on the information that is most diagnostic of the possible outcome of their decision at the expense of other information.

Although there are studies that support the idea that arousal narrows attention and restricts the range of cues used in a decision, recent evidence has called into question the generality and robustness of the arousal theory for other stimuli such as noise and chemicals (Forster & Grierson, 1978; Loeb & Jones, 1978; Pearson & Lane, 1984). It is possible that despite the indications found in previous studies (Ben Zur & Breznitz, 1981; Wright, 1974), decision makers under time pressure do not restrict their use of cues to those that are most informative.

Research has shown that the format of displays affects subject's decision making (Anderson, 1977; Bettman & Kakkar, 1977; Kerkar, 1984; Kerkar & Howell, in press; Knox & Hoffman, 1962; Russo, 1977). Specifically, the display format of decision information affects how subjects weigh information cues in their final judgment (Kerkar, 1984). Slovic (1972, in Payne, 1982) found that in situations demanding high amounts of information processing, only information that was explicitly displayed was used in making decisions and only in the form in which it was displayed. Phelps and Shanteau (1978) showed that the number of cues used to make a judgment depended on the degree to which a stimulus display was decomposed by dimensions for the decision maker.

Bettman and Kakkar (1977) have pointed out that the strategies used to acquire
information in a decision-making task are strongly affected by the structure of the information presented. They found that subjects acquire information in a fashion that is consistent with the display format. For example, in a typical supermarket display designed to encourage consumers to process information by comparing alternative brands, more alternative-based processing was observed. Huber (1980) demonstrated that whether information is presented in a numerical or verbal form can affect decisions. Numerical information elicits more direct quantitative comparisons of different attributes and less use of qualitative comparisons of an attribute to some criterion. Subjects in studies of information format often seem unwilling to infer information not directly displayed (Bettman & Kakkar 1977; Russo, 1977). On the other hand, subjects will use information available to them that is not in the display if they are familiar with the kind of information provided (Lynch & Srull, 1982). There have been many studies comparing verbally presented information with graphical and numerical information (Hammond, 1971; Wickens & Scott, 1983). Graphical and tabular formats elicit more accurate decisions, better response times, and more efficient learning than do verbal formats.

Kerkar (1984) and Kerkar and Howell sought to determine the effect of numerical and graphical representation of cues on subjects' weighting of those cues in judgments and decisions. They found that the display format of the cues was important to the weighing of the cues, with subjects processing the same cues differently under the numerical and graphical displays. There was a tendency for the graphical format to produce a more even weighting of cues than the numerical format. This was attributed to a tendency to process graphical displays holistically while alternatively processing numerical graphs serially. Thus, Kerkar and Howell concluded the graphical display would encourage subjects to pay more attention to all the available cues.

The current studies address the effect of time pressure on the weight the decision
makers give to information cues in a binary decision task when the cues are not all equally informative. It was hypothesized that subjects under time pressure would give more weight to cues that are more diagnostic of the correct alternative than those that are less diagnostic. To test for possible interactions with display format, the different cues were presented in graphical and tabular form.

Experiment 1

Subjects. Sixteen subjects were recruited from undergraduate psychology courses at Rice University and received course credit in exchange for their participation. An equal number of subjects was assigned randomly to one of the eight conditions. There were five female subjects and eleven male subjects. Three female subjects were in the equal group and two in the unequal group.

Task. Subjects made binary decisions based on the values of four separate information sources (cues) over several trials. Each subject was asked to play the role of an operator controlling ground-to-air missiles in battle. Subjects were told to protect troops in their area from approaching enemy aircraft by determining from the cues whether or not each approaching plane was an enemy aircraft and shooting down the enemies while giving the friendly planes free passage.

Stimuli. The subjects were presented with a computer display depicting either graphical or tabular information (Appendix A). The four types of information were presented in random order for each subject but the order any particular subject received stayed the same throughout the experiment. The values given to each cue for each plane were randomly generated so that the cues would not be correlated with each other. The four cues were: flight path (the more different the path of the plane from the safety corridor followed by friendly planes, the more likely the plane is to be an enemy); aircraft origin (where the plane is in the sky when it is first detected); enemy activity (the
higher the level of enemy activity already in the area, the greater the probability that the approaching plane is an enemy plane); and aircraft type (a composite rating about available information on the size, shape, and color of the aircraft). The values of the cues for each trial were ratings from one to five for each plane. The ratings corresponded to a display on the screen that gave the diagnostic probabilities for the rating levels of the cue. There were three possible ranges of probabilities (95 80 50 20 5), (75 60 50 40 25), (60 55 50 45 40). The subject was told that these numbers were the probabilities that the plane was an enemy as could be determined by each type of information. Each cue was assigned to one of the ranges. For an equal importance group, each subject was randomly assigned to one of the ranges and each cue followed that probability scheme. For the unequal group, each cue was randomly assigned a range so that not all four cues would have the same range of probabilities. The 75-25 range had double the chance of being assigned to all the cues of any given subject in the equal ratings group and any given cue for a subject in the unequal probabilities group. A rating of one on a cue meant that the information available from that cue for that plane indicated a LOW probability (5, 25, or 40 depending on the range assigned to the cue) that the plane was an enemy, a three meant relative uncertainty either way (50 for each cue), and five meant it was MORE likely to be an enemy (95, 75, or 60). These probabilities did not change for the subject throughout the experiment.

Also on the screen was a button that read "FIRE". The subject was required to press the button using the pointer from the mouse pointing device if he or she decided to fire at the plane, and to do nothing if he or she decided not to hit the plane. The decision was followed either by the words "TARGET HIT" if they decided to fire, or "TARGET ALLOWED" if they decided not to fire.

Design. A 2 x 2 x 2 factorial design was used with display format (tabular vs.
graphical) and time allotment (5 vs. 15 seconds) as within-subjects variables and the cue probabilities (equal vs. unequal) as a between-subjects variable. Display formats and time allotments were presented in blocks such that subjects received a different display for each half of the experiment, and for each display each subject received a block of one time allotment followed by a block of the other time allotment. All order presentations were counterbalanced. Half the subjects received cues that were equally diagnostic as described above, while half the subjects received unequally diagnostic cues, with the particular diagnostic weightings randomized across subjects.

Procedure. The subject was seated before a Macintosh computer. The instructions were given to the subject in written form and the experimenter read these to the subjects in groups of 1 or 2 as the subjects read along. The computer screen displays, the importance probability scheme of the cues, and the different conditions they would make decisions under for their condition was explained. For the different weighting groups, it was explained that the probabilities signified that the four types of information were either equally informative or that some types of information told more than others about the possible identity of the plane. The instructions ended with the reminder, "Remember, during the battle there is never complete certainty that any plane is an enemy. Nevertheless, you must rely as much as possible on the provided information in making your decision."

In the experiment, a computer program gave the subject 200 planes on which to make decisions. Each trial began with the appearance of the display showing the four cues and their graphical or tabular values (Appendix A). The appearance of the display signaled the beginning of the set of trials, and the subjects had 10 practice trials followed by forty experimental trials for each display/time allotment combination. A ten-second time out was given between the presentation of each set of trials. At the end of the
experiment, the subject was provided with feedback about his or her performance in successfully detecting and shooting down enemy aircraft. The computer calculated the probability of each plane being an enemy based on the ratings of the cues and their corresponding probabilities. A random number from 0 to 1 was then generated. If this number was less than the total probability of the plane being an enemy, the plane was designated as an enemy. The designation of the plane (enemy or friendly) and the decision of the subject (fire or not fire) were recorded for each of the non-practice trials and the results displayed to the subject in a 2 x 2 table at the end of the experiment. The subjects were debriefed about the hypothesis and purpose of the experiment before they left.

The responses for the first 10 trials in each condition were not recorded, allowing the subject to become familiar with the task and to allow them to develop a consistent choice strategy. The remaining 160 trials gave 40 observations for each condition.

**Results and Discussion**

One way to determine how information is used is to get an index of the subject's actual information use policy under different conditions, i.e., how decision makers combine information, as opposed to merely examining the performance of correct decision outcomes, or what they choose. In order to capture the subjects' information use policies a paradigm was developed based on the idea of policy capturing. Policy capturing (Slovic & Lichtenstein, 1971) is a method of quantifying the process by which decisions are reached by getting numerical estimates of the importance or weight that a subject attaches to the available predictive items (cues). Policy capturing involves regressing the subject's decisions on the values of the cues they used in making the decision, which results in a regression equation of the form

\[ Y = c + b_1X + b_2X + b_3X + \ldots + b_iX \], where \( c \) is the intercept, each \( b \) represents the raw
(unstandardized) regression weight given to each cue (X) over all the decisions. The regression weight then serves as an index of the relative weight a subject gave to a particular cue. These weights are then used as raw data in evaluating how subjects used information to make decisions in different conditions. For each subject, four regression equations were obtained, one for each display/time allotment condition, by regressing the values of the ratings of four cues of each trial with the decision (0 or 1) for the trial. The raw score regression weights obtained for the four cues under a particular display/time allotment served as an index of the subjects' weighting of those cues for that display. Weights given cues by the subjects ranged from -0.0346 to 0.2637 with a mean of 0.1226.

The effect of display and time allotment on cue utilization was determined by two different methods. The cue-weight difference, defined as the difference between the weights given to the most informative cues and the weights given to the least informative cues for the unequal group was used as a one measure of the hypothesized effects of display format and time pressure when the cues varied in diagnosticity. The other measure was to compute the standard deviation of the regression weights for each condition. The standard deviation is a measure of the spread among the weights of the cues. Therefore, subjects in the equal importance group should have weights with a smaller range (standard deviation) than the unequal importance group, especially under time pressure.

All but one of the subjects correctly understood the different diagnosticity ratings given the cues in their task. The other subject weighed the importance of the cues in a reliably backwards scheme, and so the results for this subject were not included in the analyses.
**Cue-weight differences.** The results of the cue-weight differences for the unequal group are shown in Table 1 broken down by display format and time pressure. As can be seen in the table, there was no support for the hypothesis that subjects give greater weight to high diagnostic cues under high time pressure than under low time pressure. In fact, there was a slight (but nonsignificant) tendency for cue-weight differences to be smaller under high time pressure than under low time pressure, at least in the graphical condition. The means under the graphical display were analyzed with a one-way within subjects ANOVA. The difference between the high and low time pressure conditions approached significance, \( p = 0.0960 \). The results of the two-way within subjects ANOVA are shown in Appendix B.

**Cue-weight standard deviation.** The results for diagnosticity, display and time pressure are shown in Table 2. As predicted, the unequal importance group had significantly greater standard deviations in cue weights than the equal importance group, \( p = 0.0322 \), indicating that when cues to be judged have different diagnosticities, there is a larger difference between the weights given the cues. There is a non-significant tendency for a greater standard deviation in the cues under high time pressure.

The results of this study show no support for the hypothesis that more attention is given to important cues under high time pressure. It is possible that the values of the time allotments were not different enough from each other to create differences that might occur under "high" and "low" time pressure. Indeed, one subject commented that in the 15-second time condition he was able to make his decision in the first 5 seconds and had to spend the remaining 10 seconds waiting for the next trial. Subjects could be giving differential weight to important and unimportant cues regardless of the amount of time they were given. Time allotments were redefined in the second experiment to strengthen the time pressure manipulation. In addition, in the second experiment subjects were
### Table 1

*Cue-weight Differences for Display Format x Time Pressure: Experiment 1*

<table>
<thead>
<tr>
<th>Display Format</th>
<th>Time Pressure</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphical</td>
<td>Low</td>
<td>0.1199</td>
<td>0.0773</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.1129</td>
<td>0.1252</td>
</tr>
</tbody>
</table>
Table 2

**Cue-Weight Standard Deviations for Diagnosticity x Time Pressure x Display Format:**

**Experiment 1**

<table>
<thead>
<tr>
<th>Display Format</th>
<th>Graphical</th>
<th>Tabular</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Pressure</strong></td>
<td><strong>Low</strong></td>
<td><strong>High</strong></td>
</tr>
<tr>
<td><strong>Diagnosticity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal</td>
<td>0.0431</td>
<td>0.0565</td>
</tr>
<tr>
<td>Unequal</td>
<td>0.0621</td>
<td>0.0632</td>
</tr>
</tbody>
</table>
given points for the actions they made, with different pay-off matrices, in order to make the pay-off for the two responses (fire and not fire) explicit.

Experiment 2

Subjects. Thirty-two subjects were recruited from undergraduate psychology courses at Rice University and received course credit in exchange for their participation. An equal number of subjects were assigned randomly to one of two groups, and within the groups, in different counterbalancings.

Task. Subjects made binary decisions based on the values of three separate information sources (cues) over 200 trials in the same ground-to-air battle paradigm.

Stimuli. The subjects were presented with a computer display depicting either graphical or tabular information (Appendix A). The three types of information were presented in the same order, Flight Path, Enemy Activity, and Aircraft Origin, for each subject. The values given to each cue for each plane were randomly generated. The values of the cues for each trial were ratings from one to four for each plane. The ratings corresponded to a separate display chart that gave the diagnostic probabilities for the rating levels of the cue. There were three possible ranges of probabilities (40 30 20 10), (35 27.5 22.5 15), (30 26.7 23.3 20), that were assigned to Flight Path, Enemy Activity, and Aircraft Origin, respectively. These probabilities were explained as the percent of times enemy planes were given a 4, 3, 2 or 1 rating, giving an indicie of cue reliability. The computer screen also displayed a 2 x 2 pay-off matrix that indicated how many points could be gained or lost from the actions made. Subjects were either told they were the first line of defense, in which case they lost more points if they shot friends than if they let enemies pass, hereafter known as the Friend group, or they were told they were the last line of defense, in which case they lost more points if they let enemies pass than if they shot friends, hereafter known as the Enemy group. A rating of
one on a cue meant that the information available from that cue for that plane indicated a low probability (10, 15, or 20 depending on the range assigned to the cue) that the plane was an enemy, and four meant it was more likely to be an enemy (40, 35 or 30). These probabilities did not change for the subject throughout the experiment.

The subjects were required to press the "FIRE" button if he or she decided to fire at the plane, and to do nothing if he or she decided not to hit the plane. The decision was followed either by the words "ENEMY HIT" or "FRIEND HIT" if they decided to fire, or "ENEMY ALLOWED" or "FRIEND ALLOWED" if they decided not to fire.

**Design.** A 2 x 2 x 2 factorial design was used with display format (tabular vs. graphical) and time allotment (3 vs. 9 seconds) as within-subjects variables and the pay-off manipulation (enemy group and friend group) as a between-subjects variable. Display formats and time pressure allotments were presented in blocks such that subjects received a different display for the first half of the experiment, and for each display each subject received a block of one time allotment followed by a block of the other time allotment. All order presentations were counterbalanced.

**Procedure.** A similar procedure was followed for the second experiment as the first. In addition, the pay-off matrix was explained to each pay-off group. Each trial began with the appearance of the display showing the three cues and their graphical or tabular values. The appearance of the display signaled the beginning of the set of trials, and the subjects had ten practice trials followed by forty experimental trials for each display/time allotment combination. At the end of each trial, the subject was provided with feedback about his or her performance both with displayed words and an updated point total. The designation of planes as enemies and friends was randomly decided at the start of each trial. To determine the values of the cues, three random numbers between 0 and 1 were generated, one for each cue. These numbers were compared to
the corresponding cue probabilities shown the subjects and the actual identity of the plane to determine the cue values for that trial. The designation of the plane (enemy or friendly) and the decision of the subject (fire or not fire) were recorded for each of the non-practice trials. The subjects were debriefed about the hypothesis and purpose of the experiment before they left.

Results and Discussion

Cue weightings. The effects of cue number, time pressure and display are summarized in Table 3. Average cue weightings were compared across the three cues for each subject in each condition. As can be seen from the table, the effect of the diagnosticity of the cues on the weights given cues was significant across all conditions ($p < 0.0001$). This indicates that the instructions to subjects about the relative importance of cues were followed.

Again, no evidence was found for the hypothesis that greater weight is given more important cues under high time pressure. The cue weights under the graphical and tabular conditions are depicted in Figures 1a and 1b respectively. As can be seen in Figure 1a, in the graphical condition, there were no differences in weights given cues under low time pressure and high time pressure. In Figure 1b, a slightly greater difference between the most diagnostic cue and the least diagnostic cue in the tabular high time pressure condition can be seen. However, neither the effect of time pressure, display format, cue order nor any interaction was significant. In an analysis of the tabular condition, the cue order x time pressure interaction approached significance, $p = 0.0737$.

The enemy group weighted the three cues lower than the friend group ($p < 0.10$). The reason for this is not clear.

Cue-weight standard deviations. The effects of pay-off, time pressure and display
format are summarized in Table 4. Again, there is no support for the hypothesis that subjects pay more attention to important cues under high time pressure than they do under low time pressure.

**Performance measures.** Hit and false alarm rates were also collected, and are summarized for pay-off, display format and time pressure in Table 5. The hit rate was defined as how many times the subject fired when that was the correct decision to make. The false alarm was defined as how many times the subject fired when they should not have. Pay-off had a significant effect on both hit and false alarm rates ($p < 0.06$ and $p < 0.05$, respectively). This is to be expected, since firing cost the enemy group less points than it did the friend group. Under high time pressure, the hit rate and false alarm rate were lower than under low time pressure ($p < 0.01$ and $p < 0.05$, respectively). A better hit rate was achieved in the tabular condition ($p < 0.05$). Both hit and false alarm rates were lower in the graphical display. A measure of sensitivity as used in signal detection theory, $d'$, was computed for both pay-off groups. Sensitivity in this case was ability to correctly identify enemy versus friendly planes. The $d'$ was 0.92 for the enemy group, and 0.98 for the friend group. The larger the $d'$, the more sensitive the group was. The enemy group was slightly more liberal in choosing to shoot down enemies, as was expected.

Experiment 1 failed to find any evidence for the hypothesized effect under high time pressure. Experiment 2 provided some evidence in the tabular condition. There is still the possibility that the amount of information subjects had to process in these experiments did not overload the subjects enough to create the selectivity effect. A third study was conducted to rule out this possibility.
Table 3

*Cue Weights for Cue Number x Display Format x Time Pressure: Experiment 2*

<table>
<thead>
<tr>
<th>Display Format</th>
<th>Graphical</th>
<th>Tabular</th>
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</thead>
<tbody>
<tr>
<td>Time Pressure</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Cue 1</td>
<td>0.2531</td>
<td>0.2492</td>
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<tr>
<td>Cue 2</td>
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<tr>
<td>Cue 3</td>
<td>0.0784</td>
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</table>
Figures 1a and b. Cue Weights in Experiment 2
Table 4

Cue-Weight Standard Deviations for Pay-off x Display Format x Time Pressure:

Experiment 2

<table>
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<th>Display Format</th>
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<th>Tabular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Pressure</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Pay-off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enemy</td>
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<td>0.0961</td>
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<tr>
<td>Friend</td>
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Table 5

Hit and False Alarm rates for Pay-off x Display Format x Time Pressure: Experiment 2

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Time Pressure</td>
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</table>

Pay-off

<table>
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<th>False Alarm</th>
<th>rate</th>
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<tr>
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<td>Low 0.7119</td>
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<tr>
<td></td>
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<td>High 0.4160</td>
<td>High 0.3430</td>
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<td></td>
<td></td>
<td></td>
<td>Low 0.8299</td>
<td>Low 0.4078</td>
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<td></td>
<td></td>
<td></td>
<td>High 0.7633</td>
<td>High 0.3296</td>
</tr>
</tbody>
</table>
Experiment 3

Subjects. Twenty-four subjects were recruited from undergraduate psychology courses at Rice University and received course credit in exchange for their participation. An equal number of subjects were assigned randomly to each of the different counterbalancings.

Task. The subjects made binary decisions based on the values of ten separate information sources (cues) over several trials. The subjects played the same army simulation.

Stimuli. The subjects were presented with a computer display depicting ten uncorrelated graphical or tabular information cues (Appendix A). The ten cues represent ten radar stations that have each made identification ratings from one to five of the approaching plane. The ratings corresponded to a separate display given to the subject that gives the diagnostic probabilities of the cue. The ratings tell the probability of a plane being an enemy given that a cue has a certain rating. The ten ranges of probabilities are shown in Table 6. These probabilities were explained as the percent of times enemy planes were given a 5, 4, 3, 2 or 1 rating, giving an indicee of cue reliability. Some of the stations will be completely unreliable in the information they provide as a way of providing greater information overload to the subject.

The computer screen also displayed a 2 x 2 matrix that counted the number of enemy and friend planes that were hit and allowed. Also on the screen were two buttons that read "ENEMY" and "FRIEND". The subject pressed the button he or she beleived was the identity of the plane using the mouse. The decision was followed by feedback to the subject on the results of their decision. The subject was instructed to try to make a decision in the time alloted, and if no decision was made, this was recorded as such.

Design. A 2 x 3 within subjects factorial design was used with display format
Table 6

Diagnosticity display for ten cues in Experiment 3

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<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>20</td>
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<td>19</td>
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<td>5</td>
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<td>10</td>
<td>15</td>
<td>15</td>
<td>18</td>
<td>20</td>
</tr>
</tbody>
</table>

RADAR STATIONS
(tabular vs. graphical) and time allotment (3 seconds, 9 seconds, and no time allotment). The no time allotment condition was put in to provide an idea of how long it takes a decision to be made. Display formats and time allotments were presented in blocks such that subjects received a different display for the each half of the experiment, and for each display each subject received a block of each time allotment. All order presentations were counterbalanced.

**Procedure.** A similar procedure was followed for the second experiment as the first. In addition, the point matrix was explained to the subjects. In the experiment, a computer program gave the subject 240 planes on which to make decisions. Each trial began with the appearance of the display showing the ten cues and their graphical or tabular values (Appendix A). The appearance of the display signaled the beginning of the set of trials, and the subjects had ten practice trials followed by thirty experimental trials for each display/time allotment combination. At the end of each trial, the subject was provided with feedback about his or her performance both with displayed words and an updated point total. The designation of each plane's identity and the cue values were determined as in Experiment 2. The designation of the plane (enemy or friendly) and the decision of the subject (fire, not fire, and no decision) were recorded for each of the 180 non-practice trials as 1, 0, and 2, respectively. The subjects were debriefed about the hypothesis and purpose of the experiment before they left.

**Results and Discussion**

For each subject, six raw regression equations were obtained, one for each display/time allotment condition, and the cue weights, cue-weight standard deviations and performance measures were analyzed as in Experiment 2.

**Cue weightings.** The mean cue weighting for each cue number across conditions are listed in Table 7. The effect of weights given cues across all conditions was
significant \( (p < 0.0001) \). This indicates that the instructions to subjects about the relative importance of cues given by the separate cue probabilities display were followed. The cue weightings are shown by display format and time pressure in Figures 2 a and b. In both display conditions, the most important cue was rated lower under high time pressure than it was under low time pressure. This result is more pronounced under the graphical display format. The original hypothesis, that higher weights should be given to the first cues in the high time pressure condition, was not supported.

Under graphical high time pressure, cue weightings tended to have a much shorter decline, and both graphical functions were smoother than the tabular functions. Further, in an analysis of the graphical condition, the Cue order x Time pressure interaction did not approach significance, \( p > 0.7 \). However, a score similar to the cue-weight differences in Experiment 1 was created by subtracting the weight given the fourth cue by the weight given the first cue. These scores were analyzed by time pressure conditions for the graphical display condition. The difference in the first and fourth most important cues was significantly smaller in the graphical high time pressure condition, \( p = 0.0507 \).

**Cue-weight standard deviations.** The results for time pressure and display format are shown in Table 8. It can be seen in this table that standard deviations were greater under high time pressure than under low or no time pressure, and this effect was significant \( (p < 0.005) \). These higher standard deviations obviously did not result from subjects giving more weight to more important cues under time pressure, because there was no evidence for this in the cue weightings. The standard deviation measure in these experiments did not turn out to be a measure of the spread in the weightings between the most important and least important cues, but reflected differences among all the cue weightings. The tabular high time pressure standard deviation was the highest, as was
Table 7

Average cue regression weights across conditions: Experiment 3

<table>
<thead>
<tr>
<th>Cue</th>
<th>Weight</th>
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<tbody>
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<td>3</td>
<td>0.0674</td>
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<td>4</td>
<td>0.0577</td>
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<td>5</td>
<td>0.0346</td>
</tr>
<tr>
<td>6</td>
<td>0.0257</td>
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<tr>
<td>7</td>
<td>0.0226</td>
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<td>8</td>
<td>0.0192</td>
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<tr>
<td>9</td>
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<td>10</td>
<td>0.0083</td>
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</table>
Figures 2 a and b. Cue Weights for Experiment 3
Table 8

*Cue-Weight Standard Deviations for Display Format x Time Pressure Experiment 3*

<table>
<thead>
<tr>
<th>Time Pressure</th>
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<th>Low</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Display</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphical</td>
<td>0.0706</td>
<td>0.0591</td>
<td>0.0647</td>
</tr>
<tr>
<td>Tabular</td>
<td>0.0788</td>
<td>0.0641</td>
<td>0.0611</td>
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</tbody>
</table>
found in Experiment 2, although this was not significant. The graphical display condition produced lower standard deviations, except in the low time pressure condition.

**Performance Measures.** Hit and false alarm rates for display format and time pressure are shown in Table 9. In Experiment 3, the hit rate was highest in the tabular low time pressure condition. It was also high under the graphical high time pressure. The false alarm rate varied as a function of time pressure under the graphical display. In the tabular condition, the false alarm rates for the three time pressure conditions were not different. None of these results were significant.

**General Discussion**

The present series of studies provided a direct test of the hypothesis that decision makers rely on cues with greater diagnosticity under time pressure, a phenomenon that has been noted among the results of past studies of time pressure (Ben Zur & Breznitz, 1981; Wright, 1974). The results of these three experiments do not support this hypothesis. When there was a difference between weights given cues in different conditions, the graphical display high time pressure actually caused a more even weighting of cues.

Overall, there is one strong conclusion and one indication that can be drawn from the present studies. The strong conclusion is that there was no evidence that subjects under high time pressure give more attention to more informative cues. This result calls into question the generality of the theory introduced by Easterbrook (1959) and extended by Hockey (1970) that arousal focuses attention on the most important information in a display. If the time pressure manipulation in the present studies was strong enough to cause arousal, it can be added to other studies (Forster and Grierson, 1978; Loeb and Jones, 1978; Pearson and Lane, 1984) that did not find an effect of arousal on the
Table 9

Hit and False Alarm rates for Display Format x Time Pressure Experiment 3

<table>
<thead>
<tr>
<th>Display Format</th>
<th>Graphical</th>
<th>Tabular</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time Pressure</td>
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</tr>
<tr>
<td>Hit Rate</td>
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<tr>
<td>False Alarm Rate</td>
<td>0.0771</td>
<td>0.1433</td>
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</table>
breadth of attention. Secondly, there is an indication that the graphical display format, especially under high time pressure, produced a more even weighting of cues.

These results draw a picture of subjects under the high time pressure condition as processing graphical displays holistically. In both Experiments 1 and 3 the cue-weight measure showed a bigger difference between the most diagnostic cue and the fourth most diagnostic cue under low rather than high time pressure. This could have happened because a graphical display is generally intuition-inducing and should therefore produce more equal cue weighting than the analysis-inducing tabular display (Kerkar, 1984). Kerkar (1984) has suggested using the general cognitive processing framework from Hammond's Cognitive Continuum theory (Hammond, McClelland, & Mumpower, 1980) to understand how different display formats affect subsequent judgment and decision making. Hammond has suggested that two processing modes are brought to bear in varying degrees on particular cognitive tasks. Cognitive processing of different display formats ranges on a continuum from a step by step, conscious, logical defensible analytical process to an intuitive process that somehow permits a judgment without the use of a conscious, logical, step-by-step approach. Since intuitive processing results in quicker, less reliable judgments than analytical processing, the two modes produce differences in decision performance. Graphical displays generally produce more equal cue weighting than tabular displays because they are processed holistically rather than analytically.

These results have implications for design of displays used in decision making. Decision tasks under time pressure can be aided by using the appropriate display format. If it is desired that subjects under high time pressure use a heuristic strategy of giving attention to the most important pieces of information, tabular presentation of the information should be used. Graphical formats should be used if an "over-all jist" of the
information is desired.

Time pressure also needs to be studied with different task factors. The present studies were binary decisions. Choice decisions over many alternatives may produce different information use results (Payne, 1982; Wright, 1974). In addition, time pressure may interact with display clutter, in which information irrelevant to a particular task in shown along with relevant information. If it appears attending to important information is a good heuristic strategy under time pressure, the effects of highlighting such information so that it is attended to could also be studied.

Decision makers do not always have the luxury of having all the time they need to consider all the relevant information in a decision. Decisions with important consequences are often made under time pressure. It is important in these cases to learn how time pressure affects what information decision makers use, because the information used will determine the quality of the decision they make. Understanding human limitations can help designers, trainers, and others to create systems that work at their full potential of efficiency.
References


Cornsweet, D. J. (1969). Use of cues in the visual periphery under conditions of


### Target Identification Ratings

#### Aircraft Type
- 1

#### Flight Path
- 4

#### Enemy Activity
- 5

#### Aircraft Origin
- 3

#### Target Allowed

![FIRE]
<table>
<thead>
<tr>
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</tr>
</thead>
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</tr>
<tr>
<td>Friend</td>
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</table>

- **FRIEND**
- **ENEMY**
<table>
<thead>
<tr>
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**TARGET IDENTIFICATION RATINGS**

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</tr>
<tr>
<td>Friend</td>
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</tbody>
</table>

Time Left

- O FRIEND
- O ENEMY
## Appendix B

### Analysis of Variance Summary Table

#### Cue-Weight Differences

#### Experiment 1

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F-Ratio</th>
<th>Probability Level</th>
</tr>
</thead>
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<td>0.0155731</td>
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<td></td>
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Analysis of Variance Summary Table

Cue-Weight Standard Deviations

Experiment 1

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### Analysis of Variance Summary Table

#### Cue Weightings

**Experiment 2**

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Analysis of Variance Summary Table

Cue-Weight Standard Deviations

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## Analysis of Variance Summary Table

### Hit and False Alarm Rates

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| **False Alarm Rate** |                    |                |              |         |                  |
| Pay-off             | 1                  | 0.2884201      | 0.2884201    | 5.53    | 0.0254           |
| Subjects            | 30                 | 1.5633255      | 0.0521109    |         |                  |
| Display             | 1                  | 0.0026631      | 0.0026631    | 0.14    | 0.7074           |
| PxD                 | 1                  | 0.0066038      | 0.0066038    | 0.36    | 0.5551           |
| Error               | 30                 | 0.5563090      | 0.0185436    |         |                  |
| Time                | 1                  | 0.0647568      | 0.0647568    | 5.49    | 0.0259           |
| PxT                 | 1                  | 0.0004306      | 0.0004306    | 0.04    | 0.8497           |
| Error               | 30                 | 0.3538141      | 0.0117938    |         |                  |
| DxT                 | 1                  | 0.0005621      | 0.0005621    | 0.04    | 0.8469           |
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| Error               | 30                 | 0.4443891      | 0.0148130    |         |                  |
## Analysis of Variance Summary Table

### Cue Weightings

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Analysis of Variance Summary Table

Cue-Weight Standard Deviations

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Hit and False Alarm Rates

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