Learning and performance of teams with and without redundant members.

Mary Chua. Tiong
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LA THÈSE A ÉTÉ MICROFILMÉE TELLE QUE NOUS L’AVONS RÉCU
LEARNING AND PERFORMANCE OF TEAMS
WITH AND WITHOUT REDUNDANT MEMBERS

by

Mary Chua Tiong

A Thesis
Submitted to the Faculty of Graduate Studies through the Department of Psychology in Partial Fulfillment of the Requirements for the Degree of Master of Arts at the University of Windsor

Windsor, Ontario, Canada
1976
Abstract

Ninety-four unselected University of Windsor students formed 16 teams of two with one redundant member and 20 teams of two without a redundant member. A member was considered redundant if his response was not necessary for the correct team response. The experiment was divided into a learning phase and a performance phase. During the learning phase, both groups of teams were given comparable paired-associates learning tasks consisting of eight pairs of digits. The hypothesis that the group of redundant teams would learn faster was confirmed. In the second phase, both groups of teams continued to be tested on the previously learned stimulus-response pairs, with decreasing time intervals allowed for response, ranging from 5 seconds down to 1½ seconds. It was hypothesized that the decreasing available response time would produce increasing stress, and that the performance of both groups would deteriorate, the overall effect being that of an inverted-U curve. Both of these hypotheses were supported by the data. The hypothesis that the redundant teams would perform better under decreasing available response time in the second phase will eventually deteriorate, was not confirmed. Analysis of variance
on the performance of both groups under decreasing available response time showed no significant interaction between membership redundancy and time factor. Thus, it was concluded that adding a redundant member to a team will allow the teams to learn faster with sufficient response time, but will not facilitate team performance under conditions of decreasing available response time.
ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

ABSTRACT ................................................................. ii
ACKNOWLEDGEMENTS .................................................... iv
TABLE OF CONTENTS ..................................................... v
LIST OF TABLES ............................................................. vi
LIST OF FIGURES .......................................................... vii
LIST OF APPENDICES ..................................................... ix

CHAPTER

I. INTRODUCTION ......................................................... 1

II. METHODOLOGY AND PROCEDURE ................................ 30

III. PRESENTATION AND ANALYSIS OF RESULTS .................. 48

IV. DISCUSSION ........................................................... 61

APPENDICES .............................................................. 68
REFERENCES ............................................................... 80
VITA AUCTORIS ............................................................ 84
LIST OF TABLES

Table 1. Summary of analysis of variance on group learning.......................... 52

Table 2. Means and standard deviations of redundant and nonredundant groups during performance under six levels of response time interval with two trials in each level.................... 56

Table 3. Summary of analysis of variance on correct team responses under six levels of response time interval........ 57

Table 4. Testing the difference between the totals for the redundant group during performance under increasing stress................................. 59

Table 5. Testing the difference between the totals for the nonredundant group during performance under increasing stress................................. 60
LIST OF FIGURES

Figure 1. A graph to show the break-even point of a redundant and nonredundant team....... 15

Figure 2. Relationship between stress, and hence arousal, and performance according to the Inverted-U hypothesis............. 23

Figure 3. The Yerkes-Dodson Law...................... 24

Figure 4. The changes in performance which may be produced by changes in arousal........... 26

Figure 5. A schematic diagram of a subject panel.......32

Figure 6. Timing chart in anticipation learning method for the general learning apparatus.......................... 41

Figure 7. Timing chart during performance phase under 5 seconds response time interval...... 42

Figure 8. Timing chart during performance phase under 4 seconds response time interval..... 43

Figure 9. Timing chart during performance phase under 3 seconds response time interval..... 44

Figure 10. Timing chart during performance phase under 2½ seconds response time interval.... 45
Figure 11. Timing chart during performance phase under 2 seconds response time interval... 46

Figure 12. Timing chart during performance phase under 12 seconds response time interval... 47

Figure 13. Learning curves for redundant and nonredundant teams....................... 50

Figure 14. Histogram of total number of correct team responses for the redundant and nonredundant groups of teams............. 51

Figure 15. Performance curves of both redundant and nonredundant groups under the six levels of response time, using the mean number of correct team responses per two trials as the performance measure... 58
<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Eight stimulus-response paired associates</td>
<td>68</td>
</tr>
<tr>
<td>B</td>
<td>Sequence of stimulus presentation</td>
<td>69</td>
</tr>
<tr>
<td>C</td>
<td>Learning instructions for the redundant group</td>
<td>71</td>
</tr>
<tr>
<td>D</td>
<td>Learning instructions for the nonredundant group</td>
<td>74</td>
</tr>
<tr>
<td>E</td>
<td>Performance instructions for the redundant group</td>
<td>77</td>
</tr>
<tr>
<td>F</td>
<td>Performance instructions for the nonredundant group</td>
<td>79</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

In organizing groups (teams) for performance on a given task, three basic problems must be faced (among others): (1) how to make the group learn the desired performance as fast as possible; (2) how to make its performance reliable under varying conditions, especially those causing stress, and (3) how to balance out the cost of performance against its benefits (i.e. how to make the groups economical). Since the last problem is one of economics it is difficult to handle it in the laboratory. But the first two can be attacked under artificial laboratory conditions before dealing with them in real life. This study dealt with two of these problems. 1. The speed of learning a simple paired-associates task by two-man teams, both of whose members had to perform correctly for the team to be correct (nonredundant or "series" teams), was compared with the speed of learning by three-man teams, only two of whose members had to respond correctly and one (any one) could but did not have to, for the team to be correct (redundant or "parallel" teams). This is the
membership redundancy problem. The stability of the achieved performance level by these two types of teams was tested under increasingly shorter time intervals allowed for responding. This is the problem of team performance under time restrictions.

Membership Redundancy

There is a trend in small group research to utilize learning theory concepts in the study of group or team performance (Glanzer and Glaser, 1961). The use of learning framework or methods assumes that the behavior of teams can be studied in the same manner in which individual behavior had been examined in the past. It is therefore the behavior of the team, rather than the behavior of its members, that is the primary unit of investigation. The team is viewed as a single response unit, or module, having performance characteristics similar to those of the single individuals. Similarly, researchers like Rosenberg (1960), Glaser and Klaus (1966), and Cervin et al., (1971), defined team as a learning

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the terms "group" and "team" are used interchangeably in the literature. A statistical "group" is not equivalent to the psychological group.
unit that reacts to the presence or absence of reinforcement following a response.

Using learning theory to explain the behavior of teams, Rosenberg and Hall (1956, 1959) investigated two-man groups under three different structures. They regarded the composition of information feedback to the individual member as a key aspect of structure. They concerned themselves, therefore, with the relation of structure, defined in terms of information feedback, to performance. Team structure was studied in terms of the effect of one subject's responses on another subject's feedback (reinforcement) and the effect of various feedback arrangements on group (team) and individual behavior (Cervin et al., 1971). The results of the Rosenberg and Hall studies showed that the subjects learn most rapidly and to the highest level of proficiency under direct feedback (feedback contingent upon individual's own performance). With confounded feedback (feedback based on individual's own performance and his partner's responses), the subjects learns, but more slowly and to a lower level of proficiency. With respect to team product, confounded feedback yields team accuracy (average performance) that is at least as good as obtained with direct feedback. "Others" feedback (feedback based on partner's responses) gave clearly inferior individual and team performance.
In 1963, Zajonc, using seven-man teams in his study, compared "direct" with "confounded" feedback and concluded that group performance was better when each member received information about his own performance in addition to feedback on the success of the group as a whole than when only information on the performance of the entire team was presented.

Social psychologists like Glanzer and Glaser (1961), Klaus and Glaser (1960), emphasized the feedback reinforcement contingencies produced as a function of the "group environment." These contingencies are in turn a function of the probability that appropriate responses will be made by group members and the manner in which these individual responses are converted into collective responses. In some cases, team successes can only be attained when both members of the team performed correctly while others would depend only on one of the two members of the group to respond correctly. Glaser and Klaus (1961) and Egerman (1962) investigated the method of improving team performance where two of the members' tasks were in parallel, that is, where one would duplicate the performance requirements of the other member. In any one trial, correct performance by one parallel member made the performance of the other member redundant. Their findings indicated that
reinforcement contingencies set up by the structure of the parallel team could result in performance decrement despite continued practice with reinforcement. This is due to the fact that incorrect responses by one of the parallel members were reinforced whenever the team as a whole performed correctly. Since this occurs intermittently for both the parallel members, both showed a performance decrement with continued performance; consequently, there was a significant reduction in the team's overall performance level.

These researchers treated the team rather than the individual as a learning unit; this enabled the investigators to study the effect of team reinforcement on team proficiency and members responding. The reinforcement is contingent upon team performance at any particular time. These investigators applied the theory of reinforcement on team behavior. This indicates that the learning theory model can be used as a framework for the study of group performance (Berger & Lambert, 1968).

In many civilian and military situations, human monitors are required. Yet, it is a well-known fact that the average human observer is a notoriously poor monitor (Baker, Ware & Sipovich, 1965). Psychologists have begun to make proposals concerning the design of systems which would reduce errors imposed by man as an information processor (Edward et al., 1965). Several investigators have
been studying the extent to which reconnaissance task can be improved by increasing the number of monitors in the system. The rationale behind this is that a team (multi-man system), as contrasted to an individual (single-man system), permits the employment of additional (and possibly more effective) search strategies and detection devices, and the utilization of additional decision making capabilities. One such investigator, Schafer (1949) pointed out that significant increases in detection probability can be realized by the addition of one more observer.

Their findings did not give much evidence however that small group performance will increase as a result of an augmentation of crew members. There is consensus that a unitary task distributed among more than one operator disappointingly shows only a slight gain in performance. That is, if one single operator can handle a task under moderate input load conditions, adding one or more helpers does not increase performance.

On the other hand, Bergum and Lehr (1963) found that two-man teams, where the members worked together and had their responses combined in parallel circuit, out-performed single monitors. Pairs, who merely worked side-by-side and had their performance scored as individuals, detected no more signals than
individually run monitors.

In 1967, Hornseth and Davis compared the performance of individuals and two-man teams in carrying out three target finding tasks. They found that the average team performance was no better than the expected performance of the more capable of the two individual observers. They suggested that team performance would have been improved if the team members were permitted to adopt, or had been assigned, a more suitable organizational structure.

In 1964, Wiener compared the performance of a three-man team with the joint (parallel circuit) output of three men working separately in the same room on a visual monitoring task. Combined performance of the three monitors in isolation was found to be superior to that of the three men working together.

Another study made by horrissette, Hornseth, and Shell (1975), examined monitoring performance of two-man teams working either under a division of labor or under a redundancy organization. In the division of labor organization, the number of displays to be monitored was divided up among the members of the team. In redundancy organization, all displays were monitored by each member. Redundancy here provides a back-up capability (what one team member misses, the other member may detect).
Such characteristics are not present under the division of labor organization. However, an individual team member's workload is less under the division of labor than under the redundancy organization. Consequently, redundancy was considered a more effective team organization for the monitoring tasks used in this study.

The above-mentioned studies indicate that redundancy can be used to improve the reliability of group performance. With increasing automation of many industrial jobs, and the increasing complexity of machinery in systems, the necessity to improve human efficiency is of paramount importance. Failure to respond in a proper manner will become more and more costly. In order to render automation effective by preventing breakdown, and precluding major faults by immediate replacement of components, the system must be endowed with means to cope with all emergencies.

In today's complex organizations, effective performance depend mostly upon the effective coordination of human behavior. Individual failure may cause systems to fail. An example would be the case of the guided missiles, where a relatively low reliability is attributed in part to the inherent weakness of the series circuit system that is used. As a large number of components are included in a system, it is very important that each
component is highly reliable if the system is to be reliable. One solution to increase the reliability of the guided missiles would be the utilization of redundant components (duplicating each component in parallel), with the resulting increase in weight, cost, and volume.

In this study, the team is regarded as a system that consists of interacting components (members) directly responsive to one another (Cervin et al., 1971). When the team is treated as a system, each member of the team must adjust to other members, so that action by one member will affect events in another. System concept is similar to learning-theory approach in the study of group performance, where a team as a learning unit depends upon the feedback reinforcement contingencies produced as a function of the probability of each member responding correctly and the manner in which these members' responses are converted into collective responses. As we have mentioned earlier, the series studies by Glanzer and Glaser (1961), Glaser and Klaus (1960), Egerman (1962), Zajonc (1965), Rosenberg and Hall (1958, 1959), and Cervin et al., (1971), all investigated team performance by studying how each team member affects the others' performance and how it in turn affects the team performance as a whole, under different operating structures designed by each different investigator.
This study therefore may be considered as an extension of the above mentioned studies on group performance in the hope that this research paper may in one way or another bring to light how team learning and team performance can be improved.

In order for a team to function successfully, the team should have high reliability. Reliability of the team is defined as the probability that the team will perform satisfactorily for a required time interval, even under changing conditions. Reliability of a team is of utmost important in this complex and highly automated industrial society. The reliability of a composite system will depend on the reliability of the individual components and how they are combined within the system: similarly, reliability of a team will depend upon its team members and how they are organized as a team. Whatever the case may be, components can be combined either in series or parallel. A series organization has a greater potential for failure, since one subsystem is uniquely dependent on the effectiveness of another, i.e., if any one of the components fails the whole system fails. However, in a parallel system, an additional component is arranged so that if one component fails, the other component that is in parallel to it will continue to perform the required function. This is sometimes referred
to as a "back-up," "stand-by" or a "redundancy arrangement."
Redundancy is therefore one of the techniques to insure high reliability. It acts as a reserve power in case of possible system breakdown.

On the basis of the rationale behind the concept of reliability, this study proposed that team proficiency can be increased by arranging team members in parallel. A redundant team in this study consists of three team members, two of whose members had to perform correctly, and one (any one) could but did not have to, for the team to be correct on a given trial. A nonredundant team is a two-man team, whereby both of its members had to perform correctly on a given trial. It was hypothesized that the redundant group of teams will learn faster than the nonredundant group of teams. During the initial learning period, the probability that a redundant team will be reinforced (correct team response) is greater than the probability of a nonredundant team. If learning depends on the number of reinforcements, then the predictions regarding the speed of learning for both teams should be based on the probability of correct team response.
In mathematical equation, the probability of correct team response for the redundant team in a given trial is:

\[ P(\text{Tr}) = P(A)P(B)P(C^c) + P(B)P(C)P(A^c) + P(C)P(A)P(B^c) + P(A)P(B)P(C) \]

where \( P(\text{Tr}) \) = the probability of correct team response as defined by correct responses of any two team members in a redundant team.

\( P(A), P(B) \) and \( P(C) \) = the probability of correct team member's responses, respectively.

\( P(A^c), P(B^c), P(C^c) \) = the probability of incorrect team member's responses, respectively.

Subscript \( c \) denoted the complement of the event. Such that; \( P(A^c) = 1 - P(A) \), \( P(B^c) = 1 - P(B) \), and \( P(C^c) = 1 - P(C) \).

In any given trial, therefore, the probability of correct team response for the redundant team is equal to the probability of A and B performing correctly, and C performing incorrectly, plus the probability of B and C performing correctly, and A performing incorrectly, plus the probability of A and C performing correctly, and B performing incorrectly, plus the probability of A, B, and C, all performing correctly.
For the nonredundant team, the probability of a correct team response in a given trial is:

\[ P(\text{Tnr}) = P(\ A \cap \ B) = P(A) \ P(B) \]

where \( P(\text{Tnr}) \) = the probability of correct team response as defined by the correct responses of both members in the nonredundant team.

\( P(A) \), and \( P(B) \) = the probability of correct team member's responses, respectively.

\( \cap \) = the interaction of \( A \) and \( B \), when both team members are correct.

The probability of correct team response for the nonredundant team in any given trial is equal to the probability of both \( A \) and \( B \) performing correctly.

The probability values range from 0.00 to 1.00, where a value of 1 stands for the highest proficiency level of a team member and 0, for the lowest proficiency level of a team member.

For example, if team member \( A \) has a performance probability of .50 and team member \( B \) has a probability of .75, then the probability of a correct team response for the nonredundant team is the product of the two, which is 0.375. On the other hand, if the probability of performance of the three members in the redundant team are .50, .75 and .25, respectively, then the probability of correct
team response will be .50. Knowing the proficiency level of each team member therefore, will enable us to calculate for the probability of correct team responses for both teams.

The following graph will show us the predicted performance of the redundant team with a redundant member whose proficiency level ranges from 0.00 to 1.00. For both redundant and nonredundant teams, members A and B have a proficiency level of .50 and .75 respectively, except for the third member, the redundant member, whose performance level varies in order to predict the differences between the two teams, with and without a redundant member. The graph will show us the break even point of the two teams. It will also show us whether adding a redundant member of a very low proficiency level, or a less competent than the other two members, would improve or impede the team performance.
Figure 1. A graph to show the break-even point of a redundant and nonredundant team, when both members A and B have a proficiency level of .50 and .75 respectively for both teams, except for the redundant member whose performance level varies from 0.00 to 1.00.
As shown by the graph, the redundant team is expected to perform better than the nonredundant team, even if the redundant member has a proficiency level of only .05. If however, the redundant member has a proficiency level of 0.00, both redundant and nonredundant teams would be expected to perform equally well.

With the above theoretical predictions in mind, this study therefore attempted to accumulate some empirical results to support the theoretical predictions that redundant team does indeed performs better than the nonredundant team in the real world. If the results of this experiment did support the logical predictions, then only can we say that the theoretical predictions is true about the real life situation.

This study also proposed to find out if membership redundancy will be a facilitating factor in team performance under decreasing available response time. Time limitations has been generally known to cause stress in everyday living as well as in past researches. The operational definition of stress in this study therefore, was the manipulation of time limitation. In order to understand how time restrictions can possibly be one of the factor that causes stress in the human organism, it is necessary to understand the concept of stress.
Stress

Stress has often been cited as the cause of much of man's present ills. It is also one of the most urgent problems of daily living in this fast-paced technological world. People are often faced with the necessity to work under highly stressful conditions. Such is obvious in the case of military combat. The effectiveness of a pilot, gunner or a radar observer must be maintained when he is threatened by physical injury or harrassed by the need to hurry the performance of a complicated task. In instances where group efficiency depends mostly on all participating members to function correctly, a failure of one member will jeopardize the entire team. It is therefore of theoretical and practical importance to understand the effect of psychological stress upon team operations. The problems of stress involve questions of emotions, motivation, and learning. Many theoretical issues in these fields are of basic importance in an analysis of the effects of stress upon performance.

A stressful situation may be regarded as one in which there is a major disruption in the relationship of an individual and his environment. A disruption will
occur when the individual meets a novel situation for which he has no adjustment response readily available, and in which he cannot find such a response until a period of trial and error behavior has taken place. It is only when the individual was confronted with a task so difficult that the individual failed to function correctly, that one may speak of a stressful situation (Schaffer, 1954). Stress therefore appears to arise whenever there is a departure from optimum conditions which the individual is unable to rectify. This implies that man is constituted in such a way that he functions best under conditions where a moderate demand is made upon him: his performance is less than optimal not only when demand is too high, but also when demand is too low. It is therefore necessary to think of both positive and negative departure from optimum as source of stress (Welford, 1973).
There is a growing emphasis upon a general dimension of behavior which is related to the intensity of the individual's functioning and which, on a physiological level, puts meaning into the often employed "concept of organism." On the basis of this concept, Freeman and Hebb suggested an important hypothesis with regard to the relationship between performance level and this intensive dimension which we call the "Arousal Continuum": that is, that there is an inverted-U relationship between the level of arousal and performance level (Stennett, 1957). The inverted-U relationship bears a striking similarity to the Yerkes-Dodson Law (Yerkes-Dodson, 1908), and to the formulation of Arousal Theory (e.g. Hebb, 1955; Kalmo, 1959; Duffy, 1957; and Freeman, 1948) which postulated a general drive state related to performance. In order to understand the relatedness of these theories, each specific theory will be discussed in the following section.

Neurophysiological approach

The Lindsley neurological approach to activation originated in encephalography (EEG). It was discovered that there were patterns characterizing the main levels
of psychological functioning in the progression from
deep sleep to highly alerted states of activity (Jasper,
1941). In deep sleep large low-frequency waves predomi-
nate. In relaxed wakefulness there is a predominance of
waves in the alpha (6-12 c.p.s.) range that changes to
beta frequencies (18-30 c.p.s.) when the subject is
moderately alert. Under highly alerting and exciting
conditions, in addition to the increased frequencies of
beta waves, there is also a change from a regular syn-
chronized appearance of the tracing to an irregular
synchronized appearance, usually of reduced amplitude.
With the discovery of the ascending reticular activating
system, Lindsley found that lesions in the ARAS abolished
"activation" of the EEG and produced a behavioral picture
of lethargy and somnolence (Lindsley, 1957), and that the
desynchronization in the EEG was reproduced by electrical
stimulation of the ARAS.

Hebb (1955), in an attempt to solve the problems
of drives, elaborated on this theory. According to the
activation theory, the continuum extending from deep
sleep at the low activation end to "excited states"
(frequently referred to as the upper end of the activation
continuum) at the high activation end is very largely a
function of cortical bombardment by the ARAS, such that
the greater the bombardment, the higher the activation.
Furthermore, the relationship between activation and behavioral efficiency (level of performance) is described by an inverted-U curve: that is, from low activation up to a point that is optimal for a given function, level of performance rose monotonically with increasing activation level, but beyond this point the relation becomes nonmonotonic: further increase in activation produces a fall in performance level, this fall being directly related to the amount of increase in level of activation.

Behavioral scientists like Duffy (1932) and Freeman (1948) in their attempts to obtain a measure of the intensity dimension of behavior, studied muscular tension and palmar conductance. The findings from these experiments led to the conclusion that there was a lawful relationship between a state of the organism called "arousal," "intensity," "energy mobilizer," or "activation" and level of performance. Their description of an inverted-U curve between the relationship of activation and performance is similar to that of Hebb's, where increases in activation would be associated with an increase in the quality of performance up to a certain point, after which further increases in activation would be associated with increasingly inferior performance. It is possible that if this curve is extended
far enough, a point would be reached at which disruption of all organized activity would occur. The degree of activation of the individual appears to affect the speed, intensity, and coordination of responses, and thus, to affect the quality of performance. In general, optimal degree of activation appears to be moderate, while low activation is associated with lack of alertness, or lack of readiness for response, and with general deterioration of performance. The type of defect in performance associated with this condition would presumably be slowness in responding, the missing of cues, and a relatively small output of work. The arousal theory also implies that the degree of arousal is a function of task difficulty, intensity of stimuli (Duffy, 1951), and time limitation, i.e., other things being equal, arousal is expected to be higher with speed of performance increasing or the increase of task difficulties. The following is an experimental paradigm which Malmo (1958) has proposed:

<table>
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<tr>
<th>Activation Level:</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Performance Level:</td>
<td>Low</td>
<td>Optimal</td>
<td>Low</td>
</tr>
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It is important to note that the measure denoted by "moderate activation level" is only relative, which means, that the level is moderate because it is
higher than the level of low activation condition, and lower than the level of high activation condition. The level of activation which is found to be optimal for one task is not directly comparable with the level of activation which is found to be optimal for a different task.

**The Inverted-U Hypothesis**

The effect of stress on arousal as described by the inverted-U hypothesis simply states that as stress increases and the resulting arousal rises, performance improves until some optimum point is reached but thereafter declines as shown in Figure 2.

![Diagram showing the inverted-U relationship between level of arousal and level of performance](image)

**Figure 2.** Relationship between stress, and hence arousal, and performance according to the Inverted-U hypothesis.
The Yerkes-Dodson Law (1908)

The fundamental law that relates performance to arousal is the Yerkes-Dodson Law, which states that the quality of performance on any task is an inverted-U shaped function of arousal. It means that neither a weak nor a strong stimulus is favorable in the acquisition of a habit. The law further states that the range over which performance improves with increasing arousal varies with task complexity. These relations are schematically illustrated in Figure 3.

---

**Figure 3. The Yerkes-Dodson Law**
In summary, the above theories on arousal have pointed out that variations of arousal have different effect on performance. A description of such a relationship is shown in Figure 4. On the whole, the general state of the system "arousal" ranges from extreme low to extreme high, with both very low and very high level of arousal producing inefficiency, and a moderate degree of arousal producing optimum performance. Another way of putting it is that a man can be too drowsy for efficient work at one end of the scale, or too excited to work efficiently at the other, and the best form of performance would be located in between these two extremes. A state of high arousal is associated with the following effects:

(1) narrowing of attention
(2) increased lability of attention
(3) difficulties in controlling attention by fine discrimination.

On the other extreme of low arousal, the effects are as follows:

(1) a failure to adopt a task set;
(2) a failure in the evaluation of one's performance, resulting in an insufficient adjustment of the investment of capacity to the demands of the task (Broadbent, 1971).
Figure 4. The changes in performance which may be produced by changes in arousal. A rise in arousal may give rise in performance if it corresponds to a movement from $X_1$ to $X_2$; performance will rise from $Y_1$ to $Y_2$. But the same rise in arousal will give a fall in performance if arousal is already at $X_2$; a further rise to $X_3$ will give a drop from $Y_2$ to $Y_3$ (Broadbent, 1971).
In this study an attempt was made to relate arousal to performance. The arousal theory implies that the degree of arousal is a function of the intensity of stimuli and of task difficulties (Duffy, 1951). The level of arousal is therefore expected to increase with an increase in speed or an increase of task complexity.

The second part of this study is concerned with the effects of increasing arousal upon team performance by decreasing the available response time intervals. It was postulated that the overall effect of decreasing available response time on performance of both groups of teams in the second phase will be that of an inverted-U curve (curvilinear). In order to vary the level of arousal of the team members, response time during the performance phase was initially presented at a long interval of 5 seconds, then gradually decreased to a short interval of 1½ seconds. Another hypothesis derived from the arousal theory was that group performance of both redundant and nonredundant groups of teams under decreasing available response time in the second phase will eventually deteriorate. It was assumed that team members will encounter a stress-condition at the 1½ seconds response time interval. Such a short interval may not be sufficient for the team members to respond correctly to a stimulus; thus, inability to meet the demand of a given task will bring about stress, such that
as stress increases the arousal rises. Consequently, the performance will deteriorate. It is also assumed that the optimal range of available response time for the redundant group of teams will be wider than that of the nonredundant group of teams. The redundant teams were expected to perform better over a longer period of time. It was also hypothesized that the overall performance level of redundant teams in the second phase will be better following higher level of learning achieved in the first phase.

The independent variables for the learning phase are: redundancy of a member and trials. The independent variables for the performance phase are: redundancy of a member, and the response time intervals experimentally manipulated in the laboratory.

The dependent variable for both phases is the number of correct responses obtained in a trial.
The specific hypotheses tested were:

1. The redundant teams will learn faster than the nonredundant teams in terms of the increasing number of correct team responses per trial over 18 trials in the first phase.

2. (a) The performance of both groups of teams under decreasing available response time in the second phase will eventually deteriorate.

(b) That the overall effect of decreasing available response time on performance of both groups of teams in the second phase will be that of an inverted-U curve (curvilinear).

3. (a) It is expected that in the second phase the redundant group of teams will perform well over a wider optimal range of available response times than the nonredundant group of teams.

(b) The overall performance level of redundant teams in the second phase will be better following higher level of learning achieved (hypothesis 1) in the first phase.
CHAPTER II

METODOLOGY AND PROCEDURE

Subjects

A group of ninety-four males and females first year students from the Introductory Psychology course at the University of Windsor were assigned to form the Redundant Group and the Nonredundant Group. The subjects were divided into 18 three-man teams (Redundant Group) and 20 two-man teams (Nonredundant Group). For both learning and performance phases, the same number of teams and the same team formation were used; one two-man team was discarded due to a misunderstanding of instructions. It was the experimenter's intention to study 20 teams for each group. However, due to circumstances the experimenter could not control, there were unequal number of cases in this study. The statistical analysis that was carried out therefore follows the techniques for the calculation of unequal sample size.
Apparatus

The automatic General Learning apparatus of the University of Windsor was used (Cervin, 1967). This equipment is a multiple stimulus-response type of learning apparatus with eight interconnected subject panels. A screen functioned to partition one subject from the other. Each subject was confronted with a panel (40 x 50 cm.) which had an inclination of 30 degrees toward the subject. Located at the top middle of the panel was a blue warning light, and in the middle a horizontal row of eight white stimulus lights about one inch apart, with a pair of two-digits numbers immediately below each light. About four inches below the stimulus lights eight response buttons were horizontally aligned to the stimulus light, with a different pair of two-digits numbers on each button. These buttons also served to present the response terms with orange lights. A schematic diagram of a subject panel is given in Figure 5. The presentation of stimulus terms and response terms was done by lighting the corresponding white or orange light respectively. Green lights were vertically aligned on the left side of the panel, and served as feedback for correct responses.
Figure 5. A schematic diagram of a subject panel.
In an adjoining room, the experimenter faced a control panel which allowed the experimenter to program the appropriate lights sequences and timing relations during the experiment. The timing relations for this study are presented in Figures 6 to 12.

Procedure

This study was divided into two phases: the learning phase and the performance phase. The learning phase definition used is that proposed by Tiffin and McCormick (1965) that training is any planned and organized effort specifically designed to help individuals develop increasing capabilities. Training can be carried out within the context of a team where all members received the required amount of team training necessary to perform the team response at a specified level of proficiency. Hunter (1974) found a facilitating effect on the performance when there is pretraining (learning) in both social and technical skills. The learning phase in this study involved the training of individuals in a team setting, learning a paired-associates task.

Each team was run separately for both phases. When all the subjects arrived, they were seated in front of a panel, and each participant was separated from the other by a screen. The experiments started
with the distribution of the instruction sheets to all subjects, to be read silently while the experimenter read them aloud to the subjects. Replies to any questions from subjects during the briefing phase, were related only to specific instructions offered to them. During the experiment, the subjects were left in the experimental room with the experimenter in the control room adjoining it.

**Team organization**

A redundant team is structured in such a way that one of the team members is parallel to another team member at any time interval. For a redundant team to be successful (to produce a correct collective response) in each trial, at least two out of three members had to perform correctly. In this case, the third member become the redundant member whether he (she) performed correctly or not.

In a schematic diagram it would appear as follows:
A nonredundant team consists of only two team members arranged in series. For an operation to be successful (to produce a correct team response), both members had to perform correctly. If either one of the two fails, the team fails. A schematic diagram of a nonredundant team follows:
Learning Phase

Each team from both redundant and nonredundant groups were presented with eight randomly-paired two-digit stimulus and response numbers (see Appendix A). The order of presentation of these eight pairs was randomized, but every pair came up once for every single trial (one full trial consisted of eight presentations). The order of the eight pairs was changed on every trial for five trials in order to minimize serial learning. After five trials, the apparatus recycled automatically to the first trial order (see Appendix B). A total of 18 full trials was given to each team as the arbitrary set criterion measure for the learning task.

The anticipation method of paired-associates learning was employed, wherein the Stimulus Term (ST) was first presented alone while subjects attempted the associated response by pressing a response button, and was followed immediately by the presentation of the correct Response Term (RT), paired with its stimulus term.

During the learning task, team feedback was given in accordance to the team organization. Feedback to team members informed them of the successes or failures of the team as a whole. It was employed to
serve as a guide, a reinforcer, and a motivating factor for team learning. Feedback in the form of green lights was presented to each subject after team response. A redundant team was considered successful in each trial when at least two green lights came on after the members' responses: that is, when at least two team members were able to perform correctly on this trial. This in turn made the third member a redundant member. For a nonredundant team to obtain a team score, both green lights needed to be on after team responses, that is, both team members were required to respond correctly.

The instruction read to each redundant team member was as follows:

Each response numbered button is electrically connected with a different white light. Your task is to learn the correct connections between the stimulus white light and the response button.

1. The blue light will come on first, then the white light in the stimulus row will flash.
2. You are to indicate your response to each white light by firmly depressing one response button.
3. Your task is to find out and learn which white light is connected to which response button.
4. When an orange light comes on after a white light, this indicates to you that the correct response button connection for that particular white light. For example: if white light no. 98 comes on, after you have pressed response button no. 54, and orange light no. 54 comes on, then you know that white light no. 98 is connected to response button no. 54.
5. If two green lights come on after your response, it indicates to you that the group has made the correct response for that particular white light. In order for you to get two green lights, any two among the three of you must respond correctly. If you get three green lights, it is alright. Try to get at least two green lights.
For the nonredundant teams, instructions differed only at passage number (5). It stated that "if two green lights come on after your response, it indicates to you that the group has made the correct response for that particular white light. In order for you to get two green lights both of you must respond correctly." (See Appendix C and Appendix D for more detailed instructions to both groups.)

After instructions was read and understood by all subjects, the learning phase begun with the experimenter recording the appropriate number of green lights in the control room. (See Figure 6 for timing relations for this phase.)

**Performance Phase**

Time limitations for the performance of tasks had served as stressful conditions in many experiments (Lindsley, 1946). In order to find out if such time restrictions would introduce stress in the second phase, the time allotted for subjects to respond were gradually decreased: from 5 seconds to 4 seconds, 3 seconds, 2½ seconds, 2 seconds, and 1½ seconds (See Figures 7 to 12 for timing relations). Effort was made by the experimenter to increase motivation by informing the teams that other teams were also performing...
the same tasks and it was the purpose of this study to find out which team was the best. The subjects were not told that there will be a gradual time limitation for performance of the task. However, they were instructed to respond as quickly as possible.

The same eight pairs of stimulus-response numbers were presented to each subject. The Stimulus Term (white light) was presented first, followed by subjects' responses. The Response Term (RT) was not given as described in the learning phase. In all six levels, two full trials were run (timing charts are presented in Figures 7 to 12). As much as possible, the inter-levels change was manipulated at the control panel without interruptions during the presentation to ensure a continuous flow of presentation throughout the six-levels. The instructions to all redundant team members read as follows:

Now that you have learned the correct association of each stimulus white light and response button, we would like to know how quickly you can respond to each stimulus white light. Other groups are doing the same thing. We want to find out which group will respond faster correctly. Please respond as quickly as you can.

(1) The blue light will come on first.
(2) When the white light comes on, you are to depress the correct response button as quickly as you can.
(3) The orange light will not come on.
(4) If two green lights come on, it means that the group has made a correct response quickly enough on that trial. If they don't, then the group responded too slowly. If three lights come on, it is alright.
Try to get two green lights on as many trials as possible.
(5) Any questions should be asked now. Once we start you cannot interrupt the sequence.
(6) Please do not talk to each other during the experiment.

The instructions for the nonredundant teams differed in instructions number (4). It stated that "if two green lights come on, it means that the group has made a correct response quickly enough on that trial. If they don't, then the group responded too slowly. Try to get two green lights on as many trials as possible." For a more complete instructions to both groups, see Appendix E and Appendix F.

Speed instructions were given before the performance phase with the assumption that it would serve to equate roughly the motivational levels of the team members.
Figure 6. Timing chart in anticipation learning method for the General Learning Apparatus.
Blue Light $\overset{\frac{1}{2} \text{ sec.}}{\longrightarrow}$

White Light (ST) $\overset{5 \text{ sec.}}{\longrightarrow}$

Response Time $\overset{5 \text{ sec.}}{\longrightarrow}$

Green Light (FR) $\overset{7 \text{ sec.}}{\longrightarrow}$

Total Time $\overset{7\frac{1}{2} \text{ sec.}}{-}$

Figure 7. Timing chart during performance under 5 seconds response time interval.
Figure 8. Timing chart during performance under 4 seconds response time interval.
Figure 9. Timing chart during performance under 3 seconds response time interval.
Figure 10. Timing chart during performance under 2½ seconds response time interval.
Blue light  $\frac{1}{2}$ sec.
White Light (ST)  1.2 sec.
Response Time  2 sec.
Green light (KR)  4 sec.
Total Time  4.5 sec.

Figure 11. Timing chart during performance under 2 seconds response time interval.
Blue Light \[\frac{1}{2}\text{ sec.}\]

White Light (ST) \[1\frac{1}{2}\text{ sec.}\]

Response Time \[1\frac{1}{2}\text{ sec.}\]

Green Light (KR) \[3\frac{1}{2}\text{ sec.}\]

Total Time \[4\text{ sec.}\]

Figure 12. Timing chart during performance under \(1\frac{1}{2}\) seconds response time interval.
CHAPTER III
PRESENTATION AND ANALYSIS OF RESULTS

Team Learning:

The dependent variable was the number of correct team responses for the total of 16 full trials during the learning phase. Figure 13 shows faster learning for the redundant group of teams over 18 trials. Neither sample were able to achieve 100% learning in 16 trials. The learning curve for the redundant group of teams indicates an upward trend at the end which may indicate further improvements if the experiment had been further extended. On the other hand, the learning curve for the nonredundant group of teams present a slight stagnation of improvement at the last few trials. It took the nonredundant group of teams eight practice trials to reach what the redundant group of teams had achieved on the third trial, with a continuous lagging behind up to the last trial.

Data analysis was done by using the computer package programs BMDF7D and BMDF1V. The average score of correct team response for the redundant group of teams is 74.44 as contrasted with 40.05 for the nonredundant
group of teams. The sharp difference between the two groups is also revealed from the histogram presented in Figure 14.

To test the significant difference between the two means, the analysis of variance for unequal sample size was applied, and the F value obtained was 134.25, which support the overall indication of a significant difference between the two groups of teams (Table 1).

In conclusion, Hypothesis 1, that the redundant group of teams will learn faster than the nonredundant group of teams, was supported.
Figure 13. Learning curves for redundant and nonredundant teams.
<table>
<thead>
<tr>
<th>Total number of correct team responses over 18 trials</th>
<th>105</th>
<th>98</th>
<th>91</th>
<th>84</th>
<th>77</th>
<th>70</th>
<th>63</th>
<th>56</th>
<th>49</th>
<th>42</th>
<th>35</th>
<th>28</th>
<th>21</th>
<th>14</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midpoints</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Group means are denoted by *M's*.

**Figure 14.** Histogram of total number of correct team responses for the redundant and nonredundant groups of teams over 18 trials.
Table 1

Summary of Analysis of Variance on Group Learning

Scores are Correct Team Responses per Trial

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQUARES</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN GROUPS</td>
<td>11207.16</td>
<td>1</td>
<td>11207.16</td>
<td>134.25*</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>3005.39</td>
<td>36</td>
<td>85.48</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>14212.54</td>
<td>37</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .01
A 2 X 6 factorial design with repeated measures on the time factor was used to analyze the performance of both groups under decreasing available response time. Table 3 presents a summary of the analysis of variance of the data. There appears to be no interaction between membership redundancy and time factor as shown by the $F$ value of 1.21. Decreasing available response time therefore, does not affect the performance of the two groups of teams differently. There is, however, a within team effect.

Table 2 presents the average team responses and the standard deviation made by the redundant teams and nonredundant teams over the six levels of response time interval. Figure 15 is a graphical presentation of the mean number of correct team responses for both groups of teams over the six levels of response time interval. Hypothesis 30, that the overall performance level of redundant teams in the second phase will be better following higher level of learning achieved (hypothesis 1) in the first phase, is supported by the differences in means for the redundant and nonredundant teams.
Hypothesis 3a which states that in the second phase the redundant group of teams will perform well over a wider optimal range of available response times than the nonredundant group of teams, is not supported by the data. A review of the graph in Figure 15 will show that both groups of teams reached their optimal level of performance at the 4-second response time interval and the redundant group of teams did not perform any better at any other response time intervals, that the optimal range of available response time was not wider for the redundant teams.

Since both groups of teams started from different levels of learning, covariance analysis was done to equate the means of the two groups. It shows no significant effect between the two samples. Redundant teams apart from initial advantage, which persisted through the test phases, did not perform better under decreasing available response time.

Orthogonal trend tests on the performance of the redundant teams revealed a significant linear \( (F=57.28; \ df=1, 102; \ p < .01) \) and non-linear \( (F=50.99; \ df=1, 102; \ p < .01) \) trends, indicating that the number of correct team responses decreased as the response time available was decreased.
Orthogonal trend tests on the performance of the nonredundant teams revealed significant linear ($F=26.45; \text{df}=1, 114; \ p < .01$) and non-linear ($F=11.42; \text{df}=1, 114; \ p < .01$) components indicating a deterioration of team performance as the response time decreases.

Hypothesis 2b, that the overall effect of decreasing available response time on performance of both groups of teams in the second phase will be that of an inverted-U curve has been upheld (Figure 15).

To test the significance differences between the six response time interval, the Newman-Keuls test was used. The results obtained is shown in Table 4 and Table 5 for the performance of the redundant group of teams and the nonredundant group of teams respectively. For both groups, the results show significant difference between the last response time interval (1½ seconds) and all other five intervals. It is therefore safe to state that the performance for both groups of teams deteriorated with increasingly shorter response time, which supports hypothesis 2a, that the performance of both groups of teams under decreasing available response time in the second phase will eventually deteriorate.
Table 2
Means and Standard Deviations of Redundant and Non-Redundant Groups During Performance Under Six-Level of Response Time Interval with Two Trials in Each Level.

<table>
<thead>
<tr>
<th>Response Time in seconds</th>
<th>Redundant Mean</th>
<th>Redundant SD</th>
<th>Nonredundant Mean</th>
<th>Nonredundant SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>12.06</td>
<td>1.73</td>
<td>7.65</td>
<td>2.62</td>
</tr>
<tr>
<td>4</td>
<td>13.50</td>
<td>1.42</td>
<td>8.50</td>
<td>3.03</td>
</tr>
<tr>
<td>3</td>
<td>12.89</td>
<td>1.94</td>
<td>8.05</td>
<td>2.61</td>
</tr>
<tr>
<td>2½</td>
<td>12.33</td>
<td>2.30</td>
<td>7.10</td>
<td>3.13</td>
</tr>
<tr>
<td>2</td>
<td>12.27</td>
<td>2.80</td>
<td>7.05</td>
<td>3.49</td>
</tr>
<tr>
<td>1½</td>
<td>7.06</td>
<td>1.63</td>
<td>3.45</td>
<td>1.76</td>
</tr>
</tbody>
</table>
Table 3
Summary of Analysis of Variance on Correct Teams Responses under six-level of response time.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQUARES</th>
<th>df</th>
<th>MEAN SQUARES</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN TEAMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (redundancy)</td>
<td>1247.72</td>
<td>1</td>
<td>1247.72</td>
<td>60.27*</td>
</tr>
<tr>
<td>error</td>
<td>745.29</td>
<td>36</td>
<td>20.70</td>
<td></td>
</tr>
<tr>
<td>WITHIN TEAMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (response time)</td>
<td>809.39</td>
<td>5</td>
<td>161.86</td>
<td>49.00*</td>
</tr>
<tr>
<td>AB (redundancy/ response time interaction)</td>
<td>20.02</td>
<td>5</td>
<td>4.00</td>
<td>1.21</td>
</tr>
<tr>
<td>B X SS within group (error)</td>
<td>594.70</td>
<td>180</td>
<td>3.30</td>
<td></td>
</tr>
</tbody>
</table>

* p < .01
Figure 15.- Performance curves of both redundant and nonredundant groups under the six-levels of response time, using the mean number of correct team responses per two trials as the performance measures.
Table 4

Testing the Difference between the Totals for the Redundant Group during Performance under Decreasing Response Time

<table>
<thead>
<tr>
<th>RT</th>
<th>1sec.</th>
<th>5sec.</th>
<th>2sec.</th>
<th>2.5sec.</th>
<th>5sec.</th>
<th>4sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f</td>
<td>a</td>
<td>e</td>
<td>d</td>
<td>c</td>
<td>b</td>
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<tr>
<td>Tj</td>
<td>127</td>
<td>217</td>
<td>221</td>
<td>222</td>
<td>232</td>
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<td></td>
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<td>b</td>
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<td></td>
<td>-</td>
<td>90*</td>
<td>94*</td>
<td>95*</td>
<td>105*</td>
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<tr>
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<td>e</td>
<td>-</td>
<td>1</td>
<td>11</td>
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<tr>
<td></td>
<td>r</td>
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<tr>
<td></td>
<td>41.40</td>
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<td></td>
<td>35.70</td>
<td>31.45</td>
<td></td>
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</tr>
</tbody>
</table>

* significant at .01 level.
Table 5

Testing the Difference between the Totals for the Non-redundant Group during Performance under Decreasing Response Time Available.

<table>
<thead>
<tr>
<th>RT</th>
<th>1½ sec.</th>
<th>2 sec.</th>
<th>2½ sec.</th>
<th>5 sec.</th>
<th>3 sec.</th>
<th>4 sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tj</td>
<td>f</td>
<td>e</td>
<td>d</td>
<td>a</td>
<td>c</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>142</td>
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<td>f</td>
<td></td>
<td></td>
<td>72*</td>
<td>73*</td>
<td>88*</td>
<td>92*</td>
</tr>
<tr>
<td>e</td>
<td></td>
<td></td>
<td>1</td>
<td>16</td>
<td>20</td>
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<td>d</td>
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<td>19</td>
<td>26</td>
</tr>
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<td>a</td>
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</tr>
<tr>
<td>c</td>
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<td>9</td>
</tr>
<tr>
<td>b</td>
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</table>

* significant at .01 level.

\[ r_{99}^{.99} \text{ Serror} \]
CHAPTER IV
DISCUSSION

This study dealt with the problem in organizing groups for best performance, or more specifically, to find out how teams learn a paired-associates task and how they perform under conditions of time limitations. It was proposed that team learning and team performance would be facilitated by the addition of a redundant member to the team. A redundant member is defined as one whose performance is not required for the team to be correct. The rationale that by adding a redundant member in parallel to other team members was extrapolated from the system theory on reliability of system components. Reliability here is a measure of dependability of performance of a system or individuals in carrying out an intended function. If a system includes two or more components the reliability of the whole system will depend upon the reliability of the individual components and how they are combined within the system. One way of improving reliability is adding components in parallel.
This redundancy arrangement increases the probability of successful operation of a system, wherein one component is back-up to another (McCormick, 1976).

During the learning phase, a total of 18 practice trials were given to both redundant and non-redundant teams on a given paired-associates learning task. The results support the first hypothesis that the redundant group of teams learned faster in terms of the total number of correct team responses. However, both groups failed to learn all the eight paired-associates within the duration of 18 learning trials. The average pairs learned for the redundant teams was 4.12 and 2.14 for the nonredundant teams. Note that the redundant group of teams learned twice as much as the nonredundant group of teams. It is not surprising that mean team proficiencies for both groups of teams were very low, with 9.40% representing the redundant group and 5.47% for the nonredundant group. This may be attributed to the 'confounded feedback' effect; both groups of teams are experiencing during learning, wherein incorrect responses by one team member had the probability of being reinforced in any trial as a consequence of team mate's correct performance. Inappropriate feedback such as this will be an
insufficient condition to achieve group proficiency. Despite the fact that the correct response terms (information feedback) were given after each response, green lights (reinforcing feedback) inappropriately given may be detrimental to learning: they may cause slow learning for the individual, consequently to the overall team learning. The discrepancy of feedback to team members regarding previous actions may hamper the rate of learning. Nevertheless, the 'confounded feedback' can be observed in a real life situation where feedback was given in terms of collective actions and individual feedback of performance was seldom given.

The fact that the theoretical predictions of better performance of the redundant teams than the non-redundant teams coincide with the empirical findings in this study, makes it possible for us to conclude that the redundant teams does indeed performed better than the nonredundant groups of teams under learning conditions.

The second phase of this study involved the performance of both groups of teams under decreasing available response time. Limitation of response time has been known to cause stress in our daily life. This study concerned stress to the extend that the operational definition was the manipulation of time limitation. Since there was no independent measures for stress, post-
experimental interviews with the subjects were carried out. Manipulation of stress, based on the operational definition was adequate. To the extent that stress was caused by time restrictions, it was the reason for the deterioration of group performance of both groups of teams under decreasing available response time in the second phase.

Time pressure has been the most recent disrupting characteristics of modern automated systems. Be it in industrial or military systems, 'meeting the date-line' is a constant pressure on man. Time factor, such as in the ability to complete a certain task within a prescribed time limit was the element studied here. The response time allotted for the team was gradually decreased from 5 seconds to $1\frac{1}{2}$ seconds, requiring each member to respond correctly within the specified time interval. It was assumed that as the response time available was shortened, stress will occur at the last interval since it may be too short for information processing. There are two kinds of limitation on human performance as identified by Posner and Keele (1970): these are limitations of time and space. Here we are more interested in the time factor. First, the amount of time required for information to be transformed into more persistent and abstract representations of events in memory takes time, and second, the
retrieval of information from memory also requires time. The minimum time that elapse from presentation of a signal is about one-sixth of a second for humans. Any complication, such as an increase in the number of possible signals and responses, poor relationship between signals and their corresponding responses increases retrieval time for information regarding appropriate response. Finally, movements also take time. A movement that is controlled by the individual, such as reaching for or grasping an object, takes a minimum of one-tenth of a second. Considering the amount of time necessary for storing, retrieval of information and movement, the 1.5 seconds response time available may be too limited for the team members to respond efficiently, consequently stress, may occur as the individual was unable to cope with the demands of the situations. As has been discussed in the previous chapter, the performance for both groups of teams deteriorated at the last response time interval. The addition of a redundant member does not appear to improve team performance under decreasing available response time in the second phase. The hypothesis that states that group performance for both groups of teams under decreasing available response time will deteriorate, was supported. Decreasing the response time available increases the arousal level of the individual, consequently,
the performance was affected. The hypothesis that states the overall effect of decreasing available response time on performance of both groups of teams in the second phase will be that of an inverted-U curve, was also supported by the data. The inverted-U relationship observed in the performance phase supported the Yerkes-Dodson Law (1908) and the Arousal theory (e.g. Hebb, 1955; Malmo, 1959; Duffy, 1957; and Freeman, 1948) which states that as arousal increases, performance increase to an optimum point where further increase on the arousal level would be associated with a decrement of performance. In the second phase, the attempt to increase the arousal level of the subjects was by increasingly shortening the response time available. While performance was found to be declining as the response time decreased, it would be worth finding out how performance will be affected when the response time is increased. Longer response time available may possibly be related with a low arousal level, which has always been associated with inactivity, boredom, and lack of response. Poor performances are mostly due to omission, not commission. Under these circumstances, perhaps a redundant member will prove to be facilitating.

This study has shown that by adding a redundant
member to a team, the team will learn faster and perform better. However, adding a redundant member means an increase in cost and complexity of the team. In military or industrial situations, when speed and errorless performance are critical, the disadvantages will be overlooked. Nuclear power plant, for example, where failure of the system could be serious consequences, require failure-free operation, which can be achieved by redundancy of their component systems. Aside from military and industrial applications, the concept of redundancy has also been applied in our daily living, for example, vice-presidents, co-pilots, under-studies, and assistants who will take over in case of a member's incapacitation, or in emergencies. Redundancy can insure the continuity of team operation. Whether membership redundancy will improve the quality of team performance under stress, however, remains an open question.
APPENDIX A

Eight Stimulus-Response Paired Associates
(as shown on subject panel)

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>98</th>
<th>35</th>
<th>76</th>
<th>24</th>
<th>82</th>
<th>69</th>
<th>41</th>
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<tr>
<td>Response</td>
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<td>49</td>
<td>91</td>
<td>63</td>
<td>27</td>
<td>75</td>
<td>34</td>
<td>89</td>
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</tbody>
</table>

Pairs

- 98 - 27
- 35 - 63
- 76 - 89
- 24 - 49
- 82 - 34
- 69 - 91
- 41 - 75
- 17 - 54
APPENDIX B

Sequence of Stimulus Presentation

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<thead>
<tr>
<th>First Trial Order</th>
<th>Third Trial Order</th>
<th>Fifth Trial Order</th>
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<tr>
<td>17</td>
<td>69</td>
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<td>69</td>
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</table>

<table>
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<tr>
<th>Second Trial Order</th>
<th>Fourth Trial Order</th>
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APPENDIX C

Learning Instructions
for the
Redundant Group
The experiment will work like this:
Each response numbered button is electrically connected with a different white light. Your task is to learn the correct connections between the stimulus white light and the response button.

1. The blue light will come on first, then the white light in the stimulus row will flash.

2. You are to indicate your response to each white light by firmly depressing one response button.

3. Your task is to find out and learn which white light is connected to which response button.

4. When an orange light comes on after a white light, this indicates to you the correct response button connection for that particular white light. For example: if white light no. 98 comes on, after you have pressed response button no. 54, and orange light no. 54 comes on, then you know that white light no. 98 is connected to response button no. 54.

5. If two green lights come on after your response, it indicates to you that the group has made the correct response for that particular white light. In order for you to get two green lights, any two among the three of you must respond correctly. If you get three green lights, it is alright. Try to get at least two green lights.
6. Any question should be asked for once we start there shall be no interruptions allowed.

7. Please do not talk to each other during the experiment.
APPENDIX D

Learning Instructions

for the

Nonredundant Group
The experiment will work like this:

Each response numbered button is electrically connected with a different white light. Your task is to learn the correct connections between the stimulus white light and the response button.

1. The blue light will come on first, then the white light in the stimulus row will flash.

2. You are to indicate your response to each white light by firmly depressing one response button.

3. Your task is to find out and learn which white light is connected to which response button.

4. When an orange light comes after a white light, this indicates to you the correct response button connection for that particular white light. For example: if white light no. 96 comes on, after you have pressed button no. 54, and orange light no. 54 comes on, then you know that white light no. 96 is connected to response button no. 54.

5. If two green lights come on after your response, it indicates to you that the group has made the correct response for that particular white light. In order for you to get two green lights both of you must respond correctly.
6. Any questions should be asked now for once we start there shall be no interruptions allowed.
7. Please do not talk to each other during the experiment.
APPENDIX E

Performance Instructions
for the
Redundant Group
Now that you have learned the correct association of each stimulus white light and response button, we would like to know how quickly you can respond to each stimulus light. Other groups are doing the same thing. We want to find out which group will respond faster correctly. Please respond as quickly as you can.

The experiment will work like this:

1. The blue light will come on first.

2. When the white light comes on, you are to depress the correct button as quickly as you can.

3. The orange light will not come on.

4. If two green lights come on, it means that the group has made a correct response quickly enough on that trial. If they don't, then the group responded too slowly. If three lights come on, it is alright. Try to get two green lights on as many trials as possible.

5. Any questions should be asked now. Once we start you cannot interrupt the sequence.

6. Please do not talk to each other during the experiment.
APPENDIX F

Performance Instructions for the Nonredundant Group
Now that you have learned the correct association of each stimulus white light and response button, we would like to know how quickly you can respond to each stimulus light. Other groups are doing the same thing. We want to find out which group will respond faster correctly. Please respond as quickly as you can.

The experiment will work like this:

1. The blue light will come first.
2. When the white light comes on, you are to depress the correct button as quickly as you can.
3. The orange light will not come on.
4. If two green lights come on, it means that the group has made a correct response quickly enough on that trial. If they don't, then the group responded too slowly. Try to get two green lights on as many trials as possible.
5. Any questions should be asked now. Once we start you cannot interrupt the sequence.
6. Please do not talk to each other during the experiment.
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