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Game Interactions with "Humans" and "Machines" and Their Relations to Tactical Behavior and Success

A Technical Report and Research Bulletin

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Abstract

An experiment was performed in which *Ss* engaged in a "Path and Obstacles" game where the *S* had the task of tracing a path on a 5 x 5 plugboard in such a way as to avoid hitting any of the five obstacles that had been placed by the other player. Half the *Ss* were told that the other player was a machine which had been programmed to play the game and the other half were led to believe that they were playing against another human. In addition, half the players were told to compete against the other player while half were told to cooperate. In every instance the setting of the obstacles by the other player was determined by a prearranged plan. In the Human condition the other player was an accomplice who played according to a prearranged plan; the same plans, which determined the placement of every obstacle on every trial, were used in the Machine condition.

Two strategies of obstacle placement were used. One, called the Fixed Path strategy, moved the obstacles in such a way as to never block one certain path. The trial to trial movement of the obstacles was basically random. The other strategy, called the Variable Path strategy, did not move the obstacles randomly from trial to trial, but rather in a highly systematic way. Whereas the Fixed Path strategy encouraged the *S* to use the same path repeatedly, the Variable Path strategy could not be solved by repetition. The latter encouraged the *S* to find a principle which was responsible for the movement of the obstacles.

Striking differences in success were found. The *Ss* performed much better when their competitive opponent was a "machine" than they did when he was a "human." On the other hand, cooperation with "humans" was significantly more successful than cooperation with "machines."

It was concluded that an _S_'s expectations concerning the other player are a critical element in determining whether his performance on the task will be affected by a "human" or "machine" other. It was also tentatively concluded that "human" others induced more irrationality than "machine" others.

GAME INTERACTIONS WITH "HUMANS" AND "MACHINES" AND THEIR RELATIONS TO TACTICAL BEHAVIOR AND SUCCESS[1]

The traditional man-machine system could be described as a symbiotic relationship in which the man provided the brains and the decisions and the machine provided the power. The tractor does not decide where to plow, it merely performs the labor. But recently we find that the machines are beginning to make decisions. Just as the heating thermostat has relieved the house owner of the need to make decisions as to when to turn on the furnace, machines with self-regulating systems are relieving men of decision-making responsibilities in more complex areas with increasing frequency. As the machine is made into a decision maker, the man-machine system is being transformed into a system which integrates the activities of two decision makers.

This situation creates a whole new area of study for the psychologist. The study of the interaction between decision makers has, in the past, been the study of the interaction of people. With the advent of mechanized decision makers, there arises the problem of determining if the principles of behavior that describe and explain the behavior of an individual in a human dyad are appropriate for his behavior in a mixed dyad.

Hemphill and McConville (1962) attacked this problem directly. They investigated whether or not people perform in the same way when

[1]The authors would like to acknowledge Herbert Gerjuoy, John Hemphill and Harold Schiffman for their discerning and rigorous reviews of the manuscript and Ellery Pierson for his assistance in collecting and analyzing the data.

they were interacting with machines as they did when they were interacting with other people. In one condition (Machine), an S was told that his partner was a machine which had been programmed to perform this task; in another condition (Human), an S was told that his partner was a student like himself. In both cases the play of the partner was made by an experimenter who followed the same strict set of rules.

The results of this study suggested that there were no differences in performance of Ss in the Human and Machine conditions. This result was a little surprising in that the task involved the implementation of strategy and it seemed difficult to believe that the same strategies would be used with people and machines. Since there was some indication that there were attitudinal differences between the conditions, it seemed possible that the lack of performance differences might be attributed to specific characteristics of the task that was used. However, recent work by Rosenberg (1963a; 1963b) suggests that certain strategic situations may produce differences while other situations may not. There is no indication at the present time as to what variables might be responsible for these effects.

The present experiment was designed to investigate this problem further. There were two elements in the research strategy which were paramount. First, we wanted to build upon the findings presented by Hemphill and McConville. For that reason it was important that an experiment be designed that was as similar as possible to the experimental situation used by them. Second, while maintaining as much similarity as possible, we wanted to do everything possible to foster differences in performance between Ss in the Machine and Human conditions. The purpose was not to show that the Hemphill and McConville findings were wrong, but rather to determine their generality. It was felt that if differences in performance could not be noticed, even after our best efforts to produce them, that generality could be attached to the previous findings with considerable confidence. If, on the other hand, differences were noted we would be in a fairly good position to identify those factors which accounted for the differences.

The major independent variable in the present study was, of course, the human vs. machine set. In addition, however, it seemed quite possible that any differences which might exist between interactions with "humans" and interactions with "machines" could be seriously affected according to whether the task was Cooperative or Competitive. It is well known that people behave differently in Cooperative settings than they do in Competitive ones (e.g. May & Doob, 1937; Deutsch, 1949), but it is not known if the same kinds of changes may be seen in interactions with machines as is seen in interactions with people. To investigate this issue, Competitive and Cooperative conditions were designed into the experiment.

It seemed possible that the type of strategy used by the other player could have an important effect on the results of the experiment. One type of behavior on the part of the other player might produce one set of results while another type of behavior might produce another set of results. In order to provide a basis for the generality of the results, two sets of strategies were developed for use by the other player, who in the Human condition was an accomplice and in the Machine condition one of the experimenters. These have been named the Fixed and Variable Path strategies and will be described below.

There were, then, three experimental variables: (1) the type of other player ("human" or "machine"), (2) the nature of the task (Cooperative or Competitive), and (3) the nature of the other player's strategy (Fixed or Variable path). These variables will be related to success and to an index of tactical behavior.

Method and Procedures

Subjects

Sixty-four undergraduates from Princeton University who responded to an advertisement in the student newspaper were used as Ss. They were paid for their participation.

Task

A "Path and Obstacles" game was designed for play on the same 5 x 5 electrical plugboards used by Hemphill and McConville. An extensive description of the apparatus is given in their report. The Ss were given the task of tracing an unbroken path from the top row of the plugboard to the bottom row. They were instructed to trace the path in such a way as to avoid occupying the squares simultaneously occupied by the obstacles which were set by the other player.

The game continued for a maximum of 45 trials. On each trial the S was given an unlimited amount of time to decide upon the path he preferred for that trial. Simultaneously, the other player, who was using a separate plugboard and was not visible to the S, placedfive obstacles in his board. When the moves were completed, lights would flash on the S's board showing him the obstacle positions occupied by the other player.

If the obstacles did not intercept the path at any point, the trial was a "success." When the lights went out, after 20 seconds, the next trial began. All Ss were encouraged to spend the 20 seconds that the lights were on keeping records of the moves made by both players on paper provided by the experimenter. All Ss kept records of their opponent's moves although some did not record their own moves.

Four game restrictions were made explicit in the instructions. They were: five and only five obstacles had to be used on each trial; there had to be one obstacle in each row; the obstacles could not be placed in a straight line (eliminating the possibility of placing all the obstacles in the diagonal, which is an unbeatable defense); all changes in path direction had to use right angles, i.e., the path was not permitted to move diagonally across the board. Only the last restriction was directly applicable to the S.

Instructional Sets

Four sets of instructions were used. They are shown in Appendix A. The sets were identical in their description of the apparatus, the rules of the game and the use of record sheets. They differed in their discussion of the other player ("human" or "machine") and of the nature of the task (Competitive or Cooperative).

The Competitive Condition. Half the Ss were told that the object of the game was to beat the other player. These Ss were told that they would be declared the winner if they were able to achieve six consecutive successful trials and that the other player would be the winner if he (it) could keep the game going for 45 trials. Play was stopped when the

S scored six consecutive successes or at the end of 45 trials, whichever occurred first.

Pilot work indicated that there was one by-product of the standardized play of the other player which could be troublesome. It was important, of course, that the S actually believed that the other player was trying to beat him in the Competitive condition or trying to help him in the Cooperative condition. Since the placement of the obstacles was predetermined, there was, obviously, no real attempt to help or hinder the S. Therefore, it was necessary to invent a reason why the other player did not play as well as the S might anticipate. The pilot work had suggested that if the other player played with a gross lack of insight the Ss tended to believe the game was rigged.

As a result it was implied that the other player had, in addition to the restrictions mentioned above, some restrictions upon him which the S did not know about. This permitted the S to interpret any rigidity or stupidity on the part of the other player as the result of these unknown restrictions. Since we did not want the Ss in the Competitive condition to assume that the other player would be severely shackled by these restrictions, this material was presented in a somewhat cursory manner.

The Cooperative Condition. The instructions for the Cooperative condition were almost identical to those used in the Competitive condition. Isolated words and phrases were changed to indicate that the S was in a cooperative situation. The other player, he was told, would do everything he (it) could to help the S successfully reach his goal. The S and his partner either won as a team because they had six consecutive successes or they lost as a team because they were unable to do so by the 45th trial.

There was, however, one important difference in procedure. It was noticed that pilot Ss had some difficulty understanding the role that the other player was to have in the situation. It was not clear to them how their partner was going to go about moving the obstacles out of the way. To help them overcome this difficulty, the Ss in the Cooperative condition were given five practice trials in which they switched jobs with their partner. That is, the S placed the obstacles and his partner traced the path. The purpose of this training was to give the S an idea of what it was like to try to avoid the path of his partner when operating under the game restrictions.

The role of game restrictions was even more crucial in the Cooperative task than in the Competitive task. The S expected his partner to help him but found that the patterns played by his partner were not particularly helpful. The partner, of course, was playing the exact same set of obstacle patterns used in the Competitive condition and was in reality doing nothing to help the S. In order to make the Cooperative set believable, it was more necessary to emphasize that the partner was operating under a severe set of restrictions than it was for the Competitive Ss. It was, in general, considerably more difficult to induce the Cooperative set than the Competitive set. In the practice trials, therefore, the S was required to comply with certain restrictions which made it difficult to place the obstacles in a way which would facilitate success for his partner. After the practice trials the S was told that his partner had a different set of restrictions which hindered his ability to be helpful. They were impressed with the fact that the partner would frequently be prohibited from making advantageous placements of the obstacles. Having already experienced this difficulty themselves, the Ss were able to be more understanding about their partner's apparent lack of cooperation. In general this procedure accomplished its purposes although there seemed to be a certain ineffable ambiguity concerning how one goes about cooperating with a machine.

The Human Condition. Half the Ss played against "human" opponents. The opponents were actually accomplices of the experimenters and played according to a prearranged plan. Four students of the Westminster Choir College in Princeton and one college-age employee of ETS were used as accomplices.

The Ss and accomplices were greeted as strangers in an anteroom next to the laboratory and then were ushered to a room in which two plugboards were placed on a large table with a divider between them. Thus, the S, who was always called "Subject #1," and the accomplice, who was called "Subject #2," were not able to see each other when seated at the table. A one-way vision mirror permitted observation by the experimenters. The two players were then told how to play the game described above.

The Machine Condition. This condition was identical in every way to the Human condition except that (a) the Ss were told that they were playing against a machine that had been programmed to play this game and (b) they played in a room that had only one plugboard. The obstacles were actually moved by an experimenter who was located behind the one-way mirror.

"Strategies" of the Other Player

As indicated above, the accomplice played according to a prearranged plan. Actually there were two such plans, each of which specified the exact location of every obstacle throughout the entire game. The two plans differed according to the type of solution that was necessary to "beat" them. They have been called the Fixed Path and the Variable Path strategies. The locations of the obstacles in both the Fixed and Variable Path strategies for all 45 trials are shown in Appendix B.

Fixed Path. In the Fixed Path strategy there was a single path that was always left open by the accomplice. That is, no obstacles were ever placed in a certain path which had been arbitrarily chosen before the start of the experiment. Since the criterion path required six spaces, the obstacles had to be placed in the remaining 19 spaces. The obstacles were distributed on a random basis among the remaining 19 spaces within the confines of a game restriction which required that there be one and only one obstacle in each row.

Since pilot testing indicated that it was fairly difficult for the S to win, another set of cues was introduced into the accomplice's play: the patterns he used began to repeat themselves. It was found from study of the random patterns that were generated that every other possible path was blocked at least twice during the first 16 trials. In order to make the task easier, therefore, the patterns were repeated every 16 trials.

There were, then, three ways in which the S could achieve six consecutive successes. First, he could realize that the criterion path was open and trace that path for six trials. Second, he could notice from a study of his records that the patterns were repeating themselves and, with this knowledge, manage to avoid the obstacles with any one of the many paths which would be successful on any given trial. Third, he could be "lucky" and, just by chance, manage to avoid the obstacles for six trials. This last method is extremely unlikely.

Variable Path. The second type of strategy played by the accomplice was the Variable Path strategy. Here, the five obstacles were not moved at random from trial to trial, but rather, in a highly systematic and orderly way. In contrast to the Fixed Path strategy where the basic solution was the repetition of a certain response, the Variable Path defense could not be beaten with six repetitive responses. The S had to learn the principle which determined the movement of the obstacles and choose a path accordingly.

The following was used: after an arbitrary starting position, for ten trials all the plugs were moved to the right one space, then down one space, then to the right, then down, etc. Every ten trials the principle of movement alternated between right-down and right-up. The board was considered as continuous. Thus, when a plug was moved off the right edge or off the bottom, it appeared at the left edge (in the same row) or at the top (in the same column). The continuity acted to change the Gestalt of the obstacles on every trial.

Repetition of the patterns also occurred with this strategy. In order to maintain consistency in the movements of the obstacles, it was not possible to introduce repetitive patterns until the 20th trial.

Once again, there were three ways in which the S could win this game. He could learn the principle which moved the obstacles, he could notice the repetition of patterns, or he could be "lucky."

Measures

Success. The data were scored on a trials-to-criterion basis. Accordingly, the score for every individual was the trial number of his last error. From this point on, this score will be referred to as the "last error score." If, for example, an S was successful in the game by virtue of being correct on trials 21-26, he would be given a score of 20. Scores ranging between 0 and 39 indicate successful solutions of the task while scores from 40 to 45 indicate failure on the task. The success data could, therefore, be analyzed as being either continuous or dichotomous (success-failure).

Path Complexity. One of the rules of the game specified that the Ss were allowed to change directions only if they used right angle turns. That is, they were not allowed to make diagonal moves. If the Ss refrained from having part of their path move away from the bottom row (which was always the case), there could be from zero to seven right angles in their path. The number of angles in each path is an index of how complex the path is. It should be pointed out that paths with an odd number of angles inevitably included a "bad" move in that they involved the use of a superfluous plug. This extra plug could only work to their disadvantage. Nonetheless, these mistakes were made fairly often and there were several instances of paths with one, three, five and seven angles.

There is no doubt that the paths with many angles are more complex than those paths with few angles. In this situation, however, they are also more foolish since the chances of hitting one of the five obstacles obviously increases as the S uses more plugs to trace his path. To the degree that it is apparent to the S that the more complex paths necessarily fill more spaces and thereby increase his chances of hitting an obstacle, this measure may be an indication of foolishness or irrationality. In addition, it might be argued that it represented some form of mild incompetency not to notice this relationship. The reader may consider the possibility that this measure of complexity is also a measure of irrationality.

Results

In the analysis of success scores it was not desirable to combine the competitive and cooperative data into a single analysis. The competitive data required non-parametric treatment owing to skewed distributions with truncated variances, while the cooperative data permitted parametric treatment. Rather than discard the added power of analyses of variance by combining the competitive and cooperative data for a single non-parametric analysis, the conditions were analyzed separately.

Success Data for the Competitive Condition

The distributions of the Last Error scores are given in Tables 1a and 1b. Since it was not possible to justify the use of parametric procedures for the data in the Competitive condition, the scores were reclassified as Success (0-39) and Failure (40-45) and analyzed by a chi-square partitioning procedure (Winer, 1962, pp. 631-633). This analysis, which is summarized in Table 2, indicated that the Ss in the Machine condition were far more successful than the Ss in the Human condition ($p < .001$).

The analysis also indicated that there was no difference in the Fixed and Variable paths in terms of their difficulty. This was not, however, a very powerful test of whether one of the strategies was more difficult than the other owing to the very strong effects of the Human vs. Machine set.

Success Data for the Cooperative Condition

After verifying that the variances were homogeneous by a Bartlett test, an analysis of variance of the data for the Ss in the Cooperative condition showed that both main effects were significant at the .05 level. That is, the Fixed path was easier than the Variable path, and the Human Ss did significantly better than the Machine Ss. (See Table 3.) The latter finding is, of course, just the reverse of what was found in the Competitive condition where the Machine Ss did better. It should be noted, though, that the differences were not as dramatic among the Cooperative Ss as they were among the Competitive Ss. Among the former, 12 of the 16 Human Ss were successful and 7 of the 16 Machine Ss were successful, while among the Competitive Ss there were 14 successes against "machines" and only 4 against "humans."

Path Complexity

The means and variances for the average number of angles in each S's paths are given in Table 4. A Bartlett test indicated that the variances of these scores were homogeneous. An analysis of variance, which is summarized in Table 5, showed that the Human Ss used significantly more angles in their paths than the Machine Ss did ($p < .05$).

The data on path complexity are extremely confusing. On every logical basis we should expect to find less complexity in the Cooperative setting than in the Competitive. In the present experiment, however, any tendency for differences has been in the opposite direction. If there had been significant negative correlation between the complexity repetition scores in the Cooperative condition, it would have been possible to construct an argument which stated that the S believed that it was necessary for him to follow the lead of his partner and that the imposed restrictions required a complex solution. But this correlation is +32 ($p < .10$), which clearly does not lend support to this position. Since these data do not seem to conform to logical expectations, it is perhaps best, pending replication and further research, to regard the complexity score as a measure of irrationality. The tentative conclusion would be, then, that human "others" induce more irrationality than machine "others."

Discussion

The meanings of stimuli are profoundly influenced by the characteristics of the source which produces the stimuli. Since the "humans" and "machines" in this study produced the same stimuli, it is apparent that the Ss imposed different characteristics on these sources. In the following discussion we will argue that it is the relevance of these imposed characteristics to the task which will determine whether there will be differences in behavior with "humans" and "machines."

Hemphill and McConville (1962) found no differences between Human and Machine conditions. In two experiments using a completely different type of task Rosenberg had one set of findings which indicated differences (Rosenberg, 1963a) and one set which indicated no differences (Rosenberg, 1963b). The present findings have, seemingly, evened the score. Although it would be difficult to determine when differences could be expected and when they could not be expected from any one of these studies, the four studies in conjunction do suggest a plausible answer.

Let's consider first the studies which did not find differences (Hemphill & McConville; 1962, Rosenberg, 1963a). The tasks used in these studies were quite different. Nonetheless, they had one important feature in common. In both tasks the Ss were asked to approach a spatially defined goal region on a series of trials. This required that the Ss make a series of adjustments, from trial to trial, to reduce their distance from the goal. In the process of learning how to make the adjustments, it made little difference how any particular distance came to be. It did not matter whether the distance occurred through interaction with men or machines. There was no characteristic of men or machines which was the least bit relevant in helping the S decide how to reduce the immediate distance.

An illustration might be helpful with this important point. A housewife sees a faucet running and immediately sets for herself the task of shutting it off. Although it may be relevant for a great number of other reasons for her to know how and by whom the faucet was left running, this information would have no value for her with respect to the specific task of shutting off the water.

Hemphill and McConville were so impressed with the ability of their Ss to do well on the task without really understanding what was happening that they suggested that the Ss didn't need to have any idea of how their partners would react. All they had to do was to learn, by rote if necessary, how to respond to each stimulus condition. The S could operate successfully, they suggested, on an individual rather than a team basis.

In contrast, the present study and one by Rosenberg (1963b) had situations in which characteristics of the other players were quite relevant to the task given to the S. Rosenberg's data suggest that his Ss were influenced by certain intentions of the other player. More specifically, his Ss acted as if "human" partners had goals similar to their own while they acted as if "machine" partners had no goals at all. Since these imposed intentions were highly relevant to the task, they were instrumental in generating differences in behavior.

There is no reason to suppose that there were different intentions imposed upon the other players in the present study. But there is good reason to think that the Ss imposed quite different sets of capabilities on the "human" and "machine" players. Many Ss stated after the experiment that they expected the machine to be inflexible in some way. They felt that they could succeed if they could exploit the inflexibility of the machine.

When, for example, an S who is competing with a "human" sees a pattern of obstacles which he has seen before, he might think that his opponent is simply using a defense which had been previously successful. Why not? If it works, use it again. But an S who is competing against a machine might view a repeated pattern in a very different light. Repetition may indicate inflexibility. The S may then look for the antecedent conditions which were responsible for the machine's use of identical responses and for ways of exploiting any cyclical behavior in the machine.

It was stated earlier that a major purpose in this type of research was to determine if the existing theories and data on the interaction between "humans" were appropriate for describing the interaction of men and machines when both have decision-making responsibilities. A superficial look at the present data might suggest that the answer is negative. But upon consideration of the four experiments which have been discussed, it seems that the previous work is relevant if appropriately qualified.

There are a number of ways in which machines differ from people. There are also a number of ways in which machines are erroneously believed to be different than people. In any given case, these characteristics may or may not be relevant to performing the task. When they are not relevant, man-machine interaction should be expected to be identical to man-man interaction. When, on the other hand, characteristics of the machine are directly relevant to the task itself, as it was in the present experiment, differences in performance should be expected. From this point of view, future research in the interaction of men with decision-making machines should be directed towards the isolation of those machine characteristics which are relevant to the accomplishment of the task.

In his concern with group interaction and leadership, Hemphill (1958) has suggested that consistent patterns of interaction are frequently found in a group. These consistent behaviors are brought about by the development of a structure through which the group members can, with some degree of success, predict the behavior of other members of the group. The initiation of a new "structure-in-interaction," says Hemphill, is the definition of a leadership act.

It seems quite possible that the presumed capabilities and intentions of the other players in the present experiment directly influence the type of structure-in-interaction which is developed and which is responsible for its initiation. In addition, these characteristics may determine whether a structure-in-interaction is necessary at all. The present study suggests that there was, in Hemphill's terms (1958), a differentiation of structure-in-interaction; the interactions with "machines" were different from the interactions with "humans." It is possible that these differences in performance reflect not only differences in structure, but also an initial difference in the need for structure and the ability to initiate it.

As a final note we should point out that the objective reality of the experimental situations were undoubtedly quite different from the expectations of the Ss in the various conditions. Further, the expectations of the Ss in certain conditions were probably closer to the objective state of affairs than were the expectations of Ss in other conditions. It would be inappropriate to conclude, for example, even on the basis of the dramatic differences found in this study, that people are more effective when they compete against machines than when they compete against humans. A more proper conclusion would be that success comes to those whose expectations are consistent with what actually happens. The existence of an inappropriate set can only lead to confusion. The interesting point suggested by this experiment is that such tremendously diverse expectations exist, that they can be easily manipulated, and that these manipulations can have a profound impact on the individual's effectiveness.

Summary

An experiment was performed in which Ss engaged in a "Path and Obstacles" game where the S had the task of tracing a path on a 5 x 5 plugboard in such a way as to avoid hitting any of the five obstacles that had been placed by the other player. Half the Ss were told that the other player was a machine which had been programmed to play the game and the other half were led to believe that they were playing against another human. In addition, half the players were told to compete against the other player while half were told to cooperate. In

every instance the setting of the obstacles by the other player was determined by a prearranged plan. In the Human condition the other player was an accomplice who played according to a prearranged plan; the same plans, which determined the placement of every obstacle on every trial, were used in the Machine condition.

Two strategies of obstacle placement were used. One, called the Fixed Path strategy, moved the obstacles in such a way as to never block one certain path. The trial to trial movement of the obstacles was basically random. The other strategy, called the Variable Path strategy, did not move the obstacles randomly from trial to trial, but rather in a highly systematic way. Whereas the Fixed Path strategy encouraged the S to use the same path repeatedly, the Variable Path strategy could not be solved by repetition. The latter encouraged the S to find a principle which was responsible for the movement of the obstacles.

Striking differences in success were found. The Ss performed much better when their competitive opponent was a "machine" than they did when he was a "human." On the other hand, cooperation with "humans" was significantly more successful than cooperation with "machines."

It was concluded that an S's expectations concerning the other player are a critical element in determining whether his performance on the task will be affected by a "human" or "machine" other. It was also tentatively concluded that "human" others induced more irrationality than "machine" others.

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Table 1a

Last Error Scores in Competitive Condition: 0-39 Represent Success; 40-45 Represent Failure

Condition	Strategy: Fixed		Variable	
Human	14	45	14	45
	17	45	20	45
	44	45	44	45
	44	45	44	45
Machine	9	23	4	29
	14	25	10	33
	15	27	13	45
	19	29	22	45

Table 1b

Means and Variances of Last Error Scores in Cooperative Condition

Condition	Strategy: Fixed	Variable
Human	$\overline{X} = 14.13$	$\overline{X} = 32.75$
	$\sigma^2 = 127.1$	$\sigma^2 = 147.2$
Machine	$\overline{X} = 29.75$	$\overline{X} = 36.50$
	$\sigma^2 = 224.4$	$\sigma^2 = 90.00$

Table 2

Partitioning of Chi-square on Success Scores

in Competitive Condition

Partitioned Variables	df	X^2	p
Other Player (Human vs. Machine)	1	0.00	
Path (Fixed vs. Variable)	1	0.00	
Success (Success vs. Failure)	1	.50	
Other Player x Path	1	0.00	
Other Player x Success	1	12.50	<.001
Path x Success	1	.50	
Triple Interaction	1	.50	
Total	7	14.00	

Table 3

Analyses of Variance of Success Scores

in Cooperative Condition

Sources	df	ms	F
Other Player (Human vs. Machine)	1	750.8	4.46*
Path (Fixed vs. Variable)	1	1,287.7	7.06*
Other Player x Path	1	266.4	1.58
Error	28	168.2	

* = significant at .05 level.

Table 4

Means and Variances of Number of Angles in Each Path

Condition		Human	Machine
Competitive	Fixed	$\bar{X} = 3.13$ $\sigma^2 = 0.475$	$\bar{X} = 2.18$ $\sigma^2 = 0.486$
	Variable	$\bar{X} = 2.62$ $\sigma^2 = 0.206$	$\bar{X} = 2.45$ $\sigma^2 = 0.795$
Cooperative	Fixed	$\bar{X} = 2.92$ $\sigma^2 = 1.520$	$\bar{X} = 2.84$ $\sigma^2 = 0.475$
	Variable	$\bar{X} = 2.84$ $\sigma^2 = 0.499$	$\bar{X} = 2.27$ $\sigma^2 = 0.253$

Table 5

Analyses of Variance of Number of Angles in Path

Source	df	ms	F
Other Player (Human vs. Machine)	1	4.33160	5.312*
Path (Fixed vs. Variable)	1	1.46712	1.799
Task (Competitive vs. Cooperative)	1	.64601	0.792
Other Player x Path	1	.00000	0.000
Other Player x Task	1	.62607	0.768
Path x Task	1	.01076	0.013
Triple Interaction	1	.92400	1.133
Error	56	.81542	

* = significant at .05 level.

APPENDIX A

Instructions for the Subjects

The Competitive Condition

The Human Condition

The purpose of the experiment in which you are about to take part is to study differences in problem-solving strategies. You will be using the red and black board in front of you. Your opponent has an identical board. Placing a plug in your board will cause the corresponding square to light in his board and vice versa. You might like to place a plug in the board to see how it operates--you will notice that his plugs cause lights on your board. Your selection of squares is marked by your plugs on your board and his selection is marked by lights on your board.

You will notice that you have a "Subject Number" printed on the white card before you. Please listen carefully for your instructions as the game is explained. The object of the game for S1 is to peg out an unbroken path from the top row of the board to the bottom row without occupying a square simultaneously occupied by your opponent. S1, you may use as many plugs as you wish, but of course, no fewer than five plugs will do the job. In order to increase the difficulty of the task a little, you will be limited in that you may not plot a path diagonally. You will be allowed to change direction only at right angles to yourself--in other words, to make square corners in your path. (Demonstrate.)

S2, within the limitations imposed upon you, you will compete against S1, i.e., you will be reacting to whatever he does in order to obstruct his path as often as possible. In other words, you will do what you can to minimize his opportunities to reach the goal. Your restrictions are indicated on the card in front of you and they include, as you see, that you will have five plugs only and you may not arrange them in a straight line in any direction, and that you must have one and only one plug in any row.

What each of you does, of course, is determined in part by what the other does, so you will need to observe both sets of moves. To assist you in this, record sheets have been provided on which you should record both your positions and your opponent's positions trial by trial. (Indicate the record sheets.)

The procedure will be as follows: At the starting signal, all the power to the boards will be cut off. S1 will set his plugs to mark his path. Simultaneously, S2 will set his plugs. When all the plugs are set, the observer will turn the lights on. Should either of you wish at any trial to repeat a path or a set of positions you have just used, you will need to signal the observer that this is your intention. Do this by removing the bottom plug and replacing it. When the lights come on they will remain on for 20 seconds during which time you will record on the sheets before you both the path chosen by S1 and the positions occupied by S2 for that trial. When the lights go out, the next trial has begun and you should reset your plugs. While there is no actual time limit on your moves, it is desirable that you should make them as promptly as possible.

Remember to observe carefully what your opponent is doing. Only in this way will you be able to anticipate what will occur on the next trial.

The game will end when it becomes apparent that S1 has solved the problem for every subsequent trial or at the end of 45 trials, whichever occurs first. It will be apparent that S1 has a solution when he can achieve six consecutive successes. Going to 45 trials will, of course, be a victory for S2.

The Machine Condition

The purpose of the experiment in which you are about to take part is to study differences in problem-solving strategies. You will be using the red and black board in front of you. Placing plugs in this board will activate a machine programmed to play the game with you. The machine will light squares in your board. You might like to place a plug in the board to see how it operates--you will notice that your selection of squares is marked by your plugs and that the machine causes other squares to light.

The object of the game is for you to peg out an unbroken path from the top row of the board to the bottom row without occupying a square simultaneously occupied by the machine. You may use as many plugs as you wish, but of course, no fewer than five plugs will do the job. In order to increase the difficulty of the task a little, you will be limited in that you may not plot a path diagonally. You will be allowed to change direction only at right angles to yourself--in other words, to make square corners in your path. (Demonstrate.)

Within a set of limitations imposed upon it, the machine's response will be to obstruct your path by minimizing your opportunities to achieve the goal. However, the machine's program is limited. In particular, it does not permit the activation of all five lights in a straight line in any direction, and it requires that there must be one and only one light in each row. What it does is, in part, determined by what you do, so you will need to observe both what you do and what it does. To assist you in this, record sheets have been provided on which you should record your path and the machine positions trial by trial. (Indicate the record sheets.)

The procedure will be as follows: At the starting signal all connection between your board and the machine will be cut off. You will then set your plugs to mark your path. Simultaneously, the machine will select five positions. When a complete path has been set and the machine positions have been determined, the connection will be made and the lights on your board will come on showing you the machine positions. Should you wish at any time to repeat a path you have just used, you should remove the bottom plug and reinsert it as a signal that this is your intention. When the lights come on they will remain on for 20 seconds during which time you should make your record. When the lights go out, the next trial has begun and you should reset your plugs. While there is no actual time limit on your moves, it is desirable that you should make them as promptly as possible.

Remember to observe carefully what the machine is doing. Only in this way will you be able to anticipate what will occur on the next trial.

The game will end when it becomes apparent that you have solved the problem for every subsequent trial, or at the end of 45 trials, whichever occurs first. It will be apparent that you have mastered the problem when you can achieve six successive solutions. Going to 45 trials will, of course, be a victory for the machine.

The Cooperative Condition

The Human Condition

The purpose of the experiment in which you are about to take part is to study differences in problem-solving strategies. You will be using the red and black board in front of you. Your partner has an identical board. Placing a plug in your board will cause the corresponding square to light in his board and vice versa. You might like to place a plug in the board to see how it operates--you will notice that his plugs cause lights on your board. Your selection of squares is marked by your plugs on your board and his selection is marked by lights on your board.

You will notice that you have a "Subject Number" printed on the white card before you. Please listen carefully for your instructions as the game is explained. The object of the game for S1 is to peg out an unbroken path from the top row of the board to the bottom row without occupying a square simultaneously occupied by your partner. S1, you may use as many plugs as you wish, but of course, no fewer than five plugs will do the job. In order to increase the difficulty of the task a little, you will be limited in that you may not plot a path diagonally. You will be allowed to change direction only at right angles to yourself--in other words, to make square corners in your path. (Demonstrate.)

S2, within the limitations imposed upon you, you will cooperate with S1, i.e., you will be reacting to whatever he does in order to do everything you can to help him make successful paths. In other words, you will do what you can to maximize his opportunities to reach the goal. Your restrictions are indicated on the card in front of you and they include, as you see, that you will have five plugs only and you may not arrange them in a straight line in any direction, and that you must have one and only one plug in any row.

What each of you does, of course, is determined in part by what the other does, so you will need to observe both sets of moves. To assist you in this, record sheets have been provided on which you should record both your positions and your partner's positions trial by trial. (Indicate the record sheets.)

The procedure will be as follows: At the starting signal, all the power to the boards will be cut off. S1 will set his plugs to mark his path. Simultaneously, S2 will set his plugs. When all the plugs are set, the observer will turn the lights on. When the lights come on, they will remain on for 20 seconds during which time you will record on the sheets before you both the path chosen by S1 and the positions occupied by S1 for that trial. When the lights go out, the next trial has begun and you should remove all your plugs and reset them. While there is no actual time limit on your moves, it is desirable that you should make them as promptly as possible.

In order to give you an idea of what your partner's job is like, we are going to let the two of you switch positions for five practice trials. That is, S2 will make the path and S1 will set the obstacles.

I have already mentioned certain limitations which are placed upon each of you. In addition, however, we have some limitations for the person setting the obstacles which his partner is not allowed to know. These limitations will probably make it more difficult for you to have frequent successes since the person setting the obstacles is often forced to do things he would rather not do.

Here are the secret restrictions that we will use for the practice trials:

Trial 1.	One column must be open
Trial 2.	No column must be open
Trial 3.	No column must be open
Trial 4.	Two columns must be open
Trial 5.	Two columns must be open

S1--You may place the five obstacles anywhere you wish as long as you stay within the confines of these restrictions. You should place the obstacles in such a way as to make it as easy as possible for your partner to trace a successful path. (Make sure S1 understands without informing S2.) You must remember, of course, to follow the rules given before (a. 5 plugs, b. no straight lines, c. one plug in each row, d. no diagonal turns).

(After 5 practice trials)

I hope you have some idea of what will be going through your partner's mind while you are playing this game.

Now I am going to give S2 the secret restrictions he is going to use during the game. Let me emphasize for your benefit, S1, that these are different restrictions and of a completely different nature than those you had. I'm sure you would be misled if you attempted to use the restrictions you had as a guide.

Finally, here's the way we score the game. If your team can get six consecutive successful trials in a row, you will have beaten the game. If your team goes 45 trials without getting six successes in a row, you will have failed.

The Machine Condition

The purpose of the experiment in which you are about to take part is to study differences in problem-solving strategies. You will be using the red and black board in front of you. Placing plugs in this board will activate a machine programmed to play the game with you. In this game, the machine is your partner. The machine will light squares in your board. You might like to place a plug in the board to see how it operates--(pause)--you will notice that your selection of squares is marked by your plugs and that the machine causes other squares to light.

The object of the game is for you to peg out an unbroken path from the top row of the board to the bottom row without occupying a square simultaneously occupied by the machine. You may use as many plugs as you wish, but of course, no fewer than five plugs will do the job. In order to increase the difficulty of the task a little, you will be limited in that you may not plot a path diagonally. You will be allowed to change direction only at right angles to yourself--in other words, to make square corners in your path. (Demonstrate.)

Within a set of limitations imposed upon it, the machine's response will be to avoid your path by maximizing your opportunities to achieve the goal. However, the machine's program is limited. In particular, it controls only five lights, it does not permit the activation of all five lights in a straight line in any direction, and it requires that there must be one and only one light in each row. What it does is, in part, determined by what you do, so you will need to observe both what you do and what it does. To assist you in this, record sheets have been provided on which you should record your path and the machine positions trial by trial. (Indicate the record sheets.)

The procedure will be as follows: At the starting signal all connection between your board and the machine will be cut off. You will then set your plugs to mark your path. Simultaneously, the machine will select five positions. When a complete path has been set and the machine positions have been determined, the connection will be made and the lights on your board will come on showing you the machine positions. When the lights come on, they will remain on for 20 seconds during which time you should make your record. When the lights go out, the next trial has begun and you should remove all your plugs and reset them. While there is no actual time limit on your moves, it is desirable that you should make them as promptly as possible.

In order to give you an idea of what the machine's job is like, we are going to let you play its positions for five practice trials. That is, the machine will set the path and you will place the obstacles.

I have already mentioned certain rules in playing the game. In addition, however, there are added limitations imposed upon the member setting the obstacles. In the practice trials, you will be setting the obstacles. Therefore, you will have the added restrictions. During the regular trials the machine will be setting the obstacles and, therefore, have restrictions which will be unknown to you. These limitations will probably make it more difficult to have frequent successes since the member setting the obstacles is often forced to make moves that are not necessarily the best moves available.

Here are the special restrictions that we will use for the practice trials:

Trial 1.	One column must be open
Trial 2.	No column must be open
Trial 3.	No column must be open
Trial 4.	Two columns must be open
Trial 5.	Two columns must be open

You may place the five obstacles anywhere you wish as long as you stay within the confines of these restrictions. You should place the obstacles in such a way as to make it as easy as possible for the machine to trace a successful path. You must remember, of course, to follow the rules given before. (a. 5 plugs, b. no straight lines, c. one plug in each row.)

(After five practice trials.)

I hope you have some idea of the kind of logic that might be in the machine's program.

Now that we are about ready to play the game, let me remind you that the machine has a special set of restrictions built into its program. Let me emphasize for your benefit that these are different restrictions and of a completely different nature than those you had. I'm sure you would be misled if you attempted to use the restrictions you had as a guide.

Finally, here's the way we score the game. If you can get six consecutive successful trials in a row, you will have beaten the game. If you go 45 trials without getting six successes in a row, you will have failed.

APPENDIX B

Schedule for Obstacle Placements in the Fixed and Variable Paths With Example Performance Records of Subjects in Each Condition

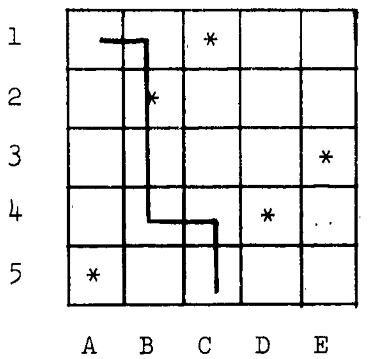
The Fixed Path
(Trials 1 thru 9)

H
M

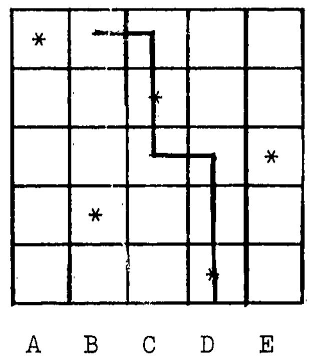
F1

Subject Example Subject #1 Record Sheet

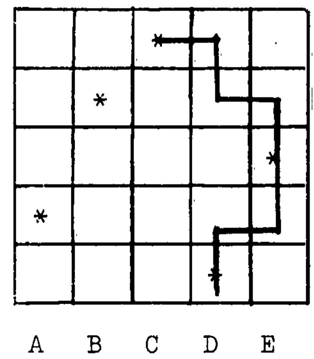
(This subject was successful in the game)



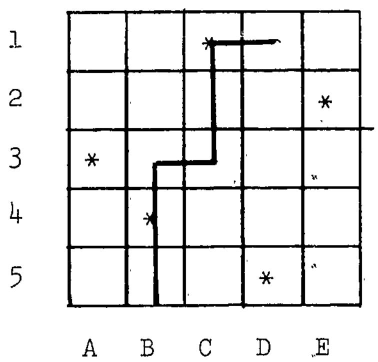
Time in
Secs. 1.__________



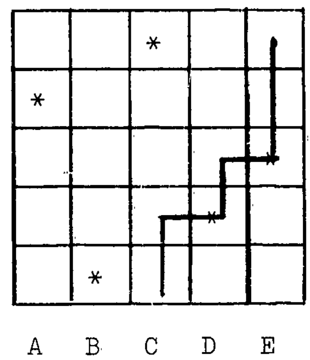
2.__________



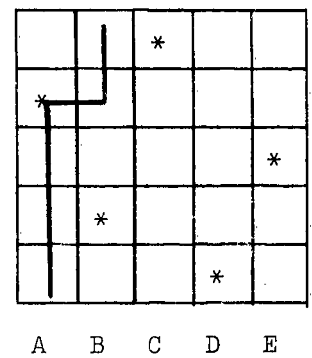
3.__________



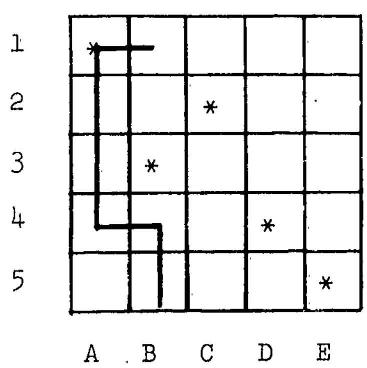
Time in
secs. 4.__________



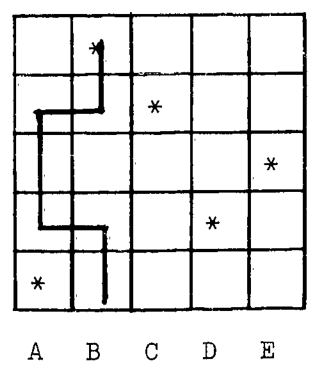
5.__________



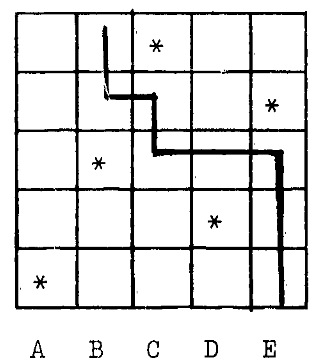
6.__________



Time in
secs. 7.__________



8.__________



9.__________

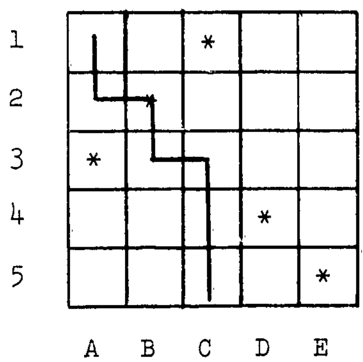
B-2

The Fixed Path

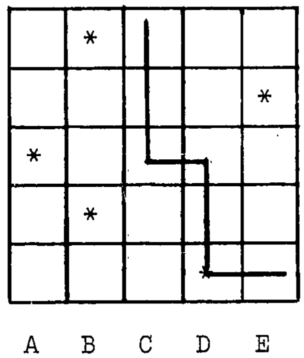
(Trials 10 thru 18)

H M F2

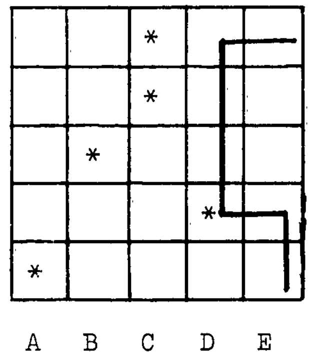
Subject Example Subject #1 Record Sheet



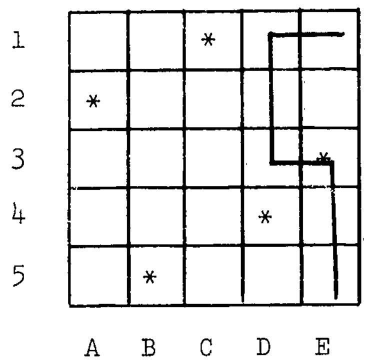
Time in secs. 10. ______________



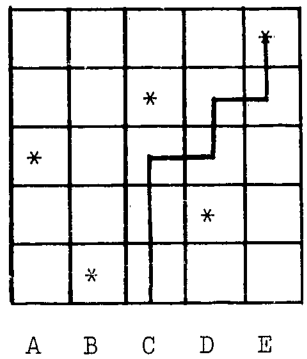
11. ______________



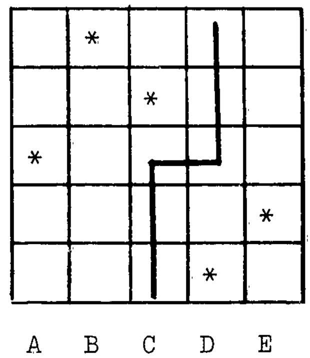
12. ______________



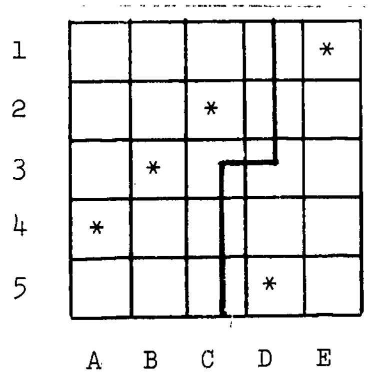
Time in secs. 13. ______________



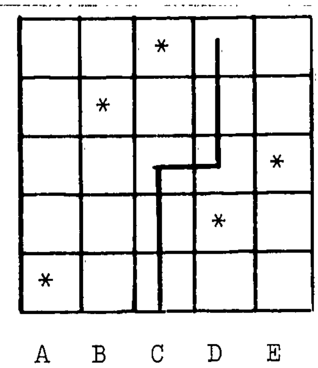
14. ______________



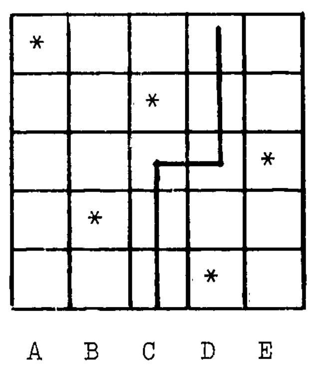
15. ______________



Time in secs. 16. ______________



17. ______________



18. ______________

H
M

F3

The Fixed Path

(Trials 19 thru 27)

Subject Example Subject #1 Record Sheet

	A	B	C	D	E
1			*		
2		*			
3					*
4	*				
5				*	

Time in secs. 19. ____________

	A	B	C	D	E
1			*		
2					*
3	*				
4		*			
5				*	

20. ____________ Game was terminated because subject reached criterion.

	A	B	C	D	E
1			*		
2	*				
3					*
4				*	
5		*			

21. ____________

	A	B	C	D	E
1			*		
2	*				
3					*
4		*			
5				*	

Time in secs. 22. ____________

	A	B	C	D	E
1	*				
2			*		
3		*			
4				*	
5					*

23. ____________

	A	B	C	D	E
1		*			
2			*		
3					*
4				*	
5	*				

24. ____________

	A	B	C	D	E
1			*		
2					*
3		*			
4				*	
5	*				

Time in secs. 25. ____________

	A	B	C	D	E
1			*		
2		*			
3	*				
4				*	
5					*

26. ____________

	A	B	C	D	E
1		*			
2					*
3	*				
4		*			
5				*	

27. ____________

H
M

F4

The Fixed Path
(Trials 28 thru 36)
Record Sheet

Subject Example Subject #1

	A	B	C	D	E
1			*		
2			*		
3		*			
4				*	
5	*				

Time in secs. 28. ____________

	A	B	C	D	E
1			*		
2	*				
3					*
4				*	
5		*			

29. ____________

	A	B	C	D	E
1					*
2			*		
3	*				
4				*	
5		*			

30. ____________

	A	B	C	D	E
1		*			
2			*		
3	*				
4					*
5				*	

Time in secs. 31. ____________

	A	B	C	D	E
1					*
2			*		
3		*			
4	*				
5				*	

32. ____________

	A	B	C	D	E
1			*		
2		*			
3					*
4				*	
5	*				

33. ____________

	A	B	C	D	E
1	*				
2			*		
3					*
4		*			
5				*	

Time in secs. 34. ____________

	A	B	C	D	E
1			*		
2		*			
3					*
4	*				
5				*	

35. ____________

	A	B	C	D	E
1			*		
2					*
3	*				
4		*			
5				*	

36. ____________

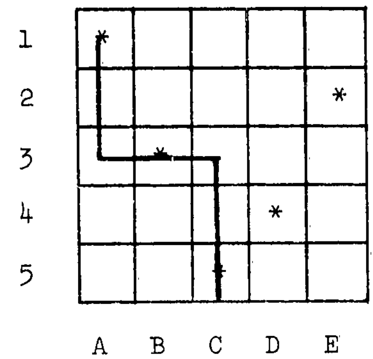
The Variable Path
(Trials 1 thru 9)

H
M

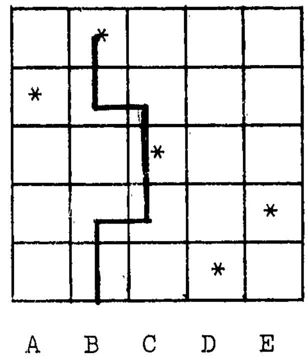
V1

Subject Example Subject #2 Record Sheet

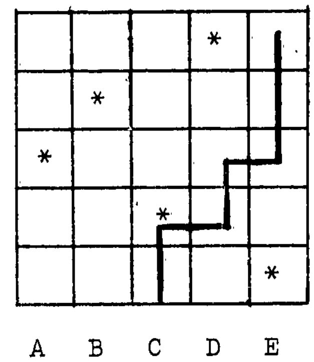
(This subject was unsuccessful in the game)



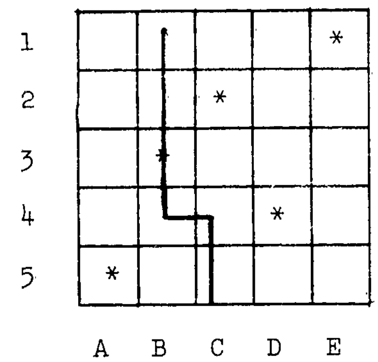
Time in secs. 1.________________



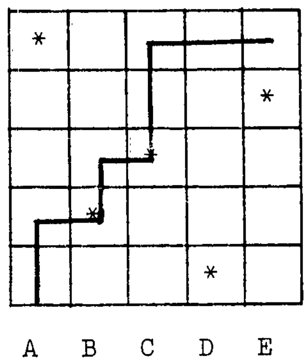
2.________________



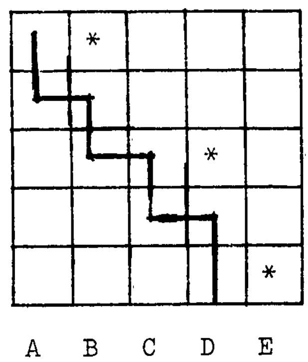
3.________________



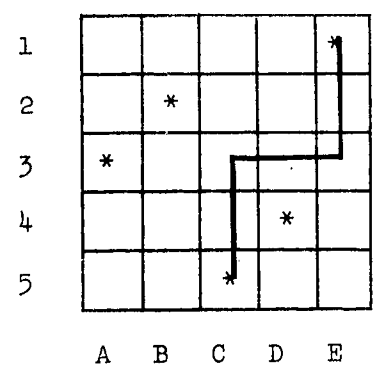
Time in secs. 4.________________



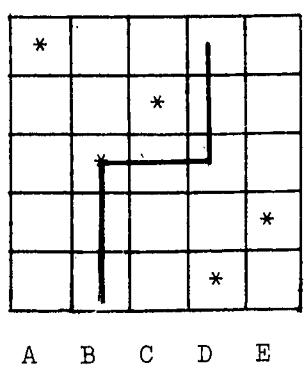
5.________________



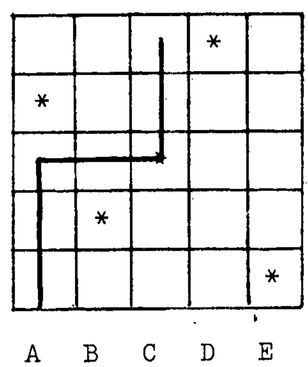
6.________________



Time in secs. 7.________________



8.________________



9.________________

B-7

The Variable Path

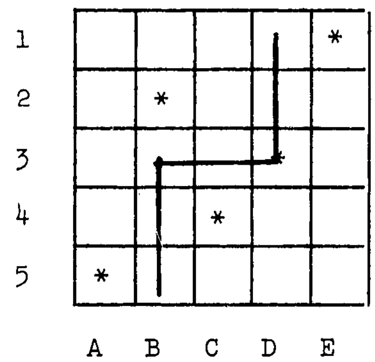
(Trials 10 thru 18)

H
M

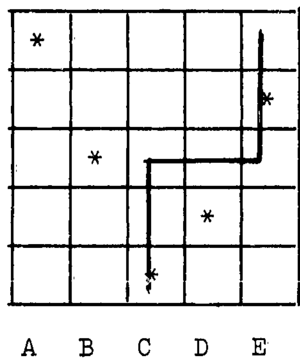
V2

Subject Example Subject #2

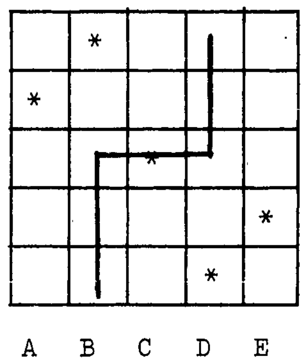
Record Sheet



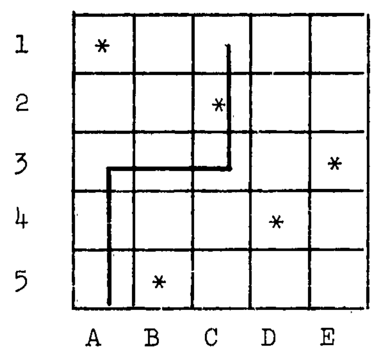
Time in
secs. 10.________



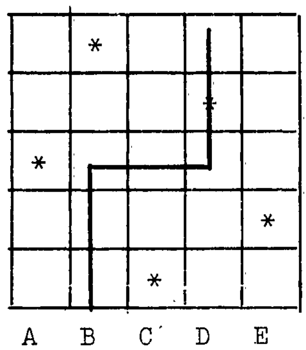
11.________



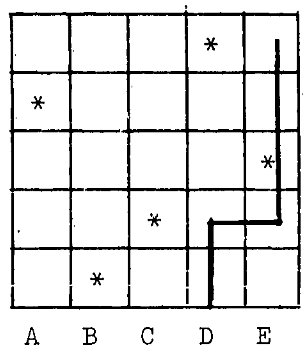
12.________



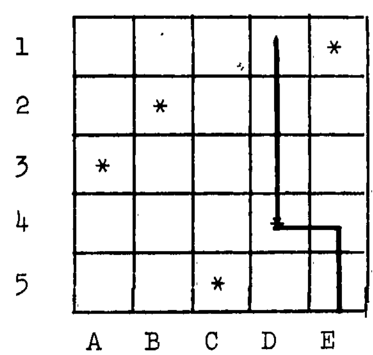
Time in
secs. 13.________



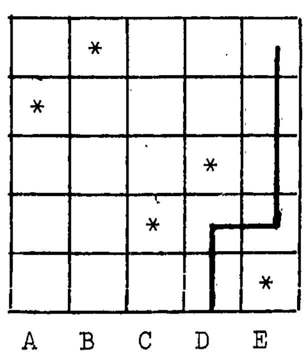
14.________



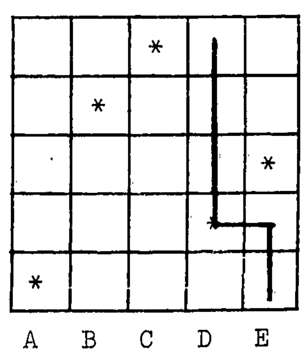
15.________



Time in
secs. 16.________



17.________

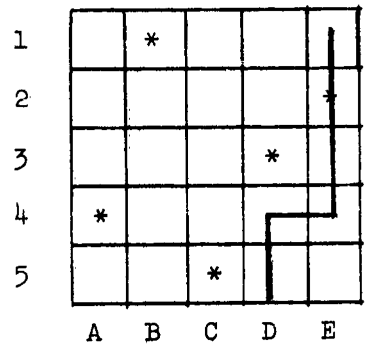


18.________

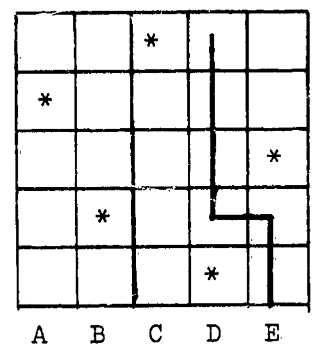
The Variable Path

(Trials 19 thru 27) H M V3

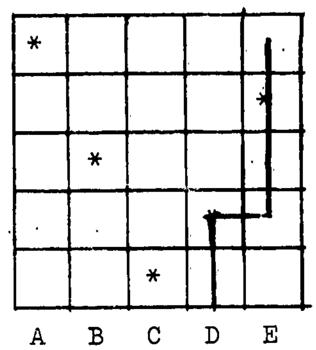
Subject Example Subject #2 Record Sheet



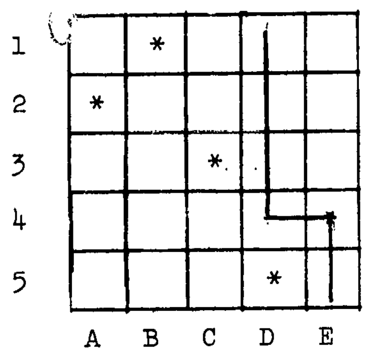
Time in
secs. 19.____________



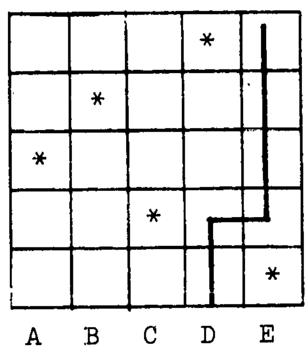
20.____________



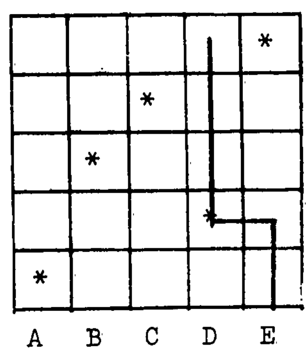
21.____________



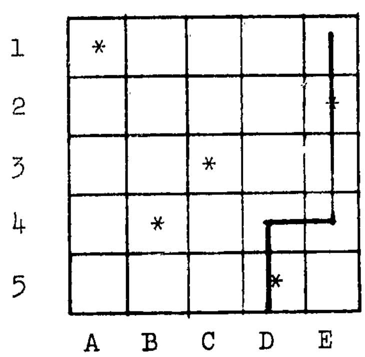
Time in
secs. 22.____________



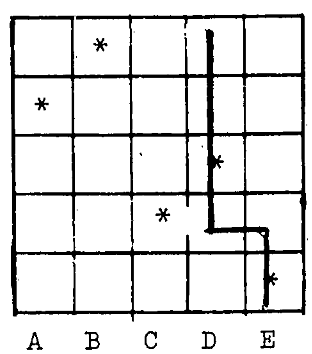
23.____________



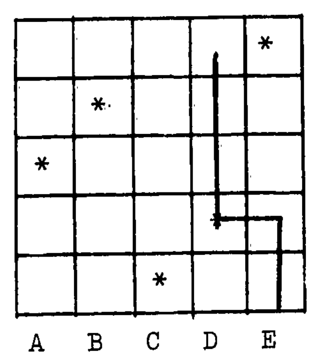
24.____________



Time in
secs. 25.____________



26.____________



27.____________

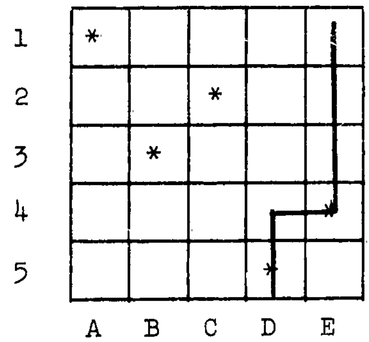
The Variable Path
(Trials 28 thru 36)

H
M

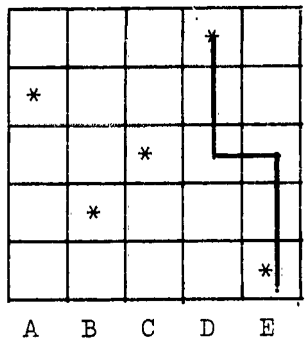
V4

Subject Example Subject #2

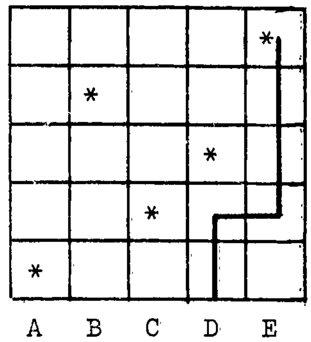
Record Sheet



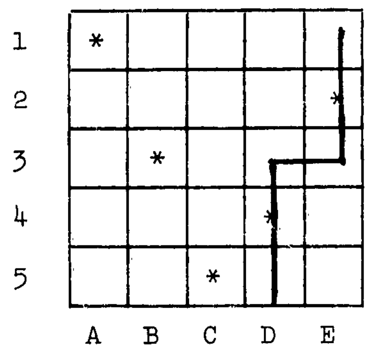
Time in
secs. 28. ________________



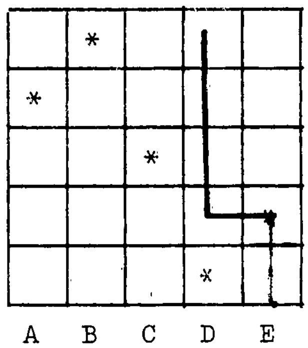
29. ________________



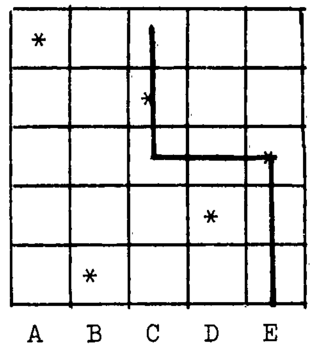
30. ________________



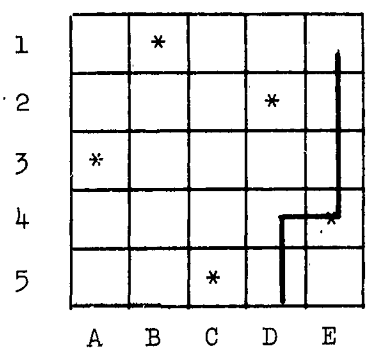
Time in
secs. 31. ________________



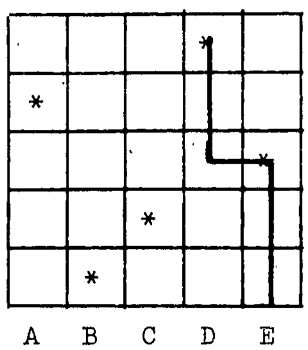
32. ________________



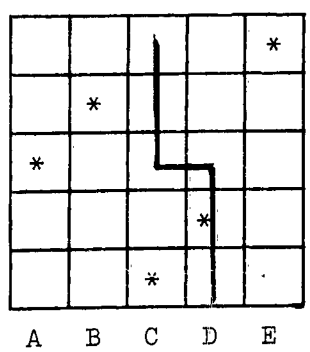
33. ________________



Time in
secs. 34. ________________



35. ________________



36. ________________

B-10

The Variable Path

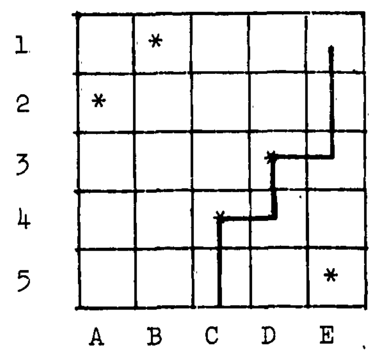
(Trials 37 thru 45)

H
M

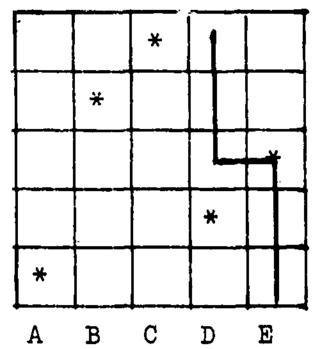
V5

Subject Example Subject #2

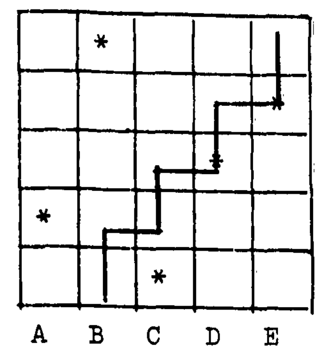
Record Sheet



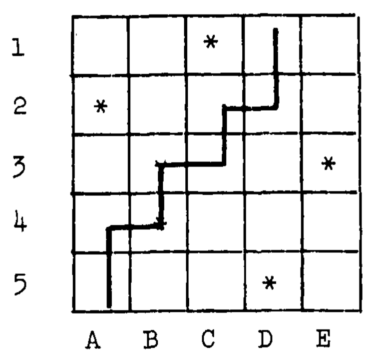
Time in secs. 37. ____________



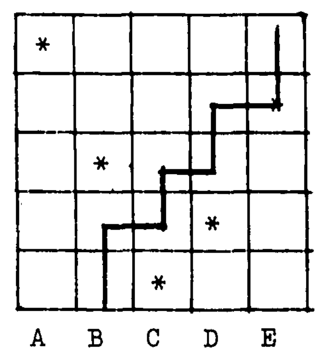
38. ____________



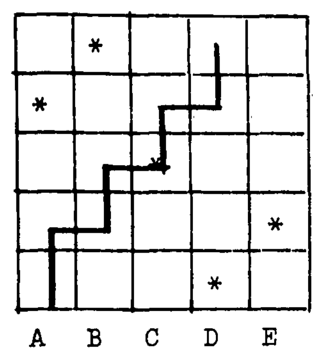
39. ____________



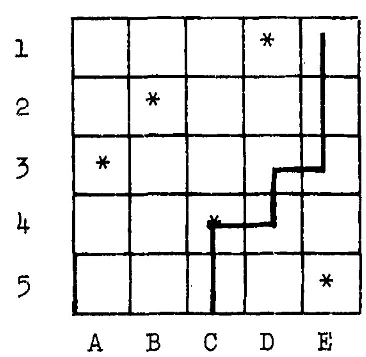
Time in secs. 40. ____________



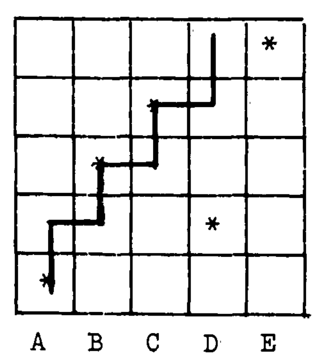
41. ____________



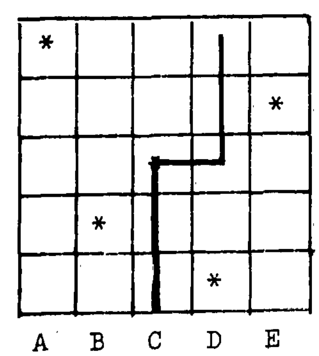
42. ____________



Time in secs. 43. ____________



44. ____________



45. ____________