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AN ELECTRIC MULTIPLE CHOICE MAZE

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An Electric Multiple Choice Maze

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Abstract

A new multiple choice maze has been developed in the Physics Department of the University of Minnesota. The device, named the electromaze, offers some promise as a research instrument in psychology of learning. The electromaze is an application of switching circuits and requires no overt verbal, mathematical, or figure symbols characteristic of paper-and-pencil mental tests. The apparatus has been used as a reasoning test with graduate students in physics and journalism. There was a significant difference in the variabilities of the two groups on four of the seven problems with respect to time, and three of the problems with respect to the number of trials. There were no significant difference between the means on any and all of the problems for the trials and a significant difference on one of the problems for time. A high correlation between the number of moves and time was found for both groups. The correlations between the Miller Verbal Analogies scores, trials, and time were not significant.

An Electric Multiple Choice Maze*

The Electromaze

The First Model

In the summer of 1949 one of the writers (C.E.S.) was scheduled to give a talk before the Physics Journal Club on the design of switching circuits. A colleague suggested that a working model would make the presentation more meaningful. As a result, a device was built and demonstrated. The circuit, shown schematically in Figure 1, was patterned after an electric combination lock given by Shannon⁽¹⁾ in his original paper on switching circuits. The device was presented to the group as a puzzle, the object being to operate the buzzer by the proper manipulation of push-button switches A,B,C,D. The correct sequence of operations is as follows:

1. Push button C. This operates and locks in relay X.
2. Push button A (after having released button C). This operates and locks in relay Y.
3. Push button C again. This operates and locks in relay Z, and in addition operates the buzzer. If at any time buttons B or D are operated, relay W will lock in, thus releasing all the other relays and operating the bell. If button A is pushed before relay X locks in or after relay Z locks in the same thing will happen. Pushing button E releases all the relays, and thus leaves the device in its original state.

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The authors wish to express their appreciation to Prof. M.A. Tinker for helpful suggestions.

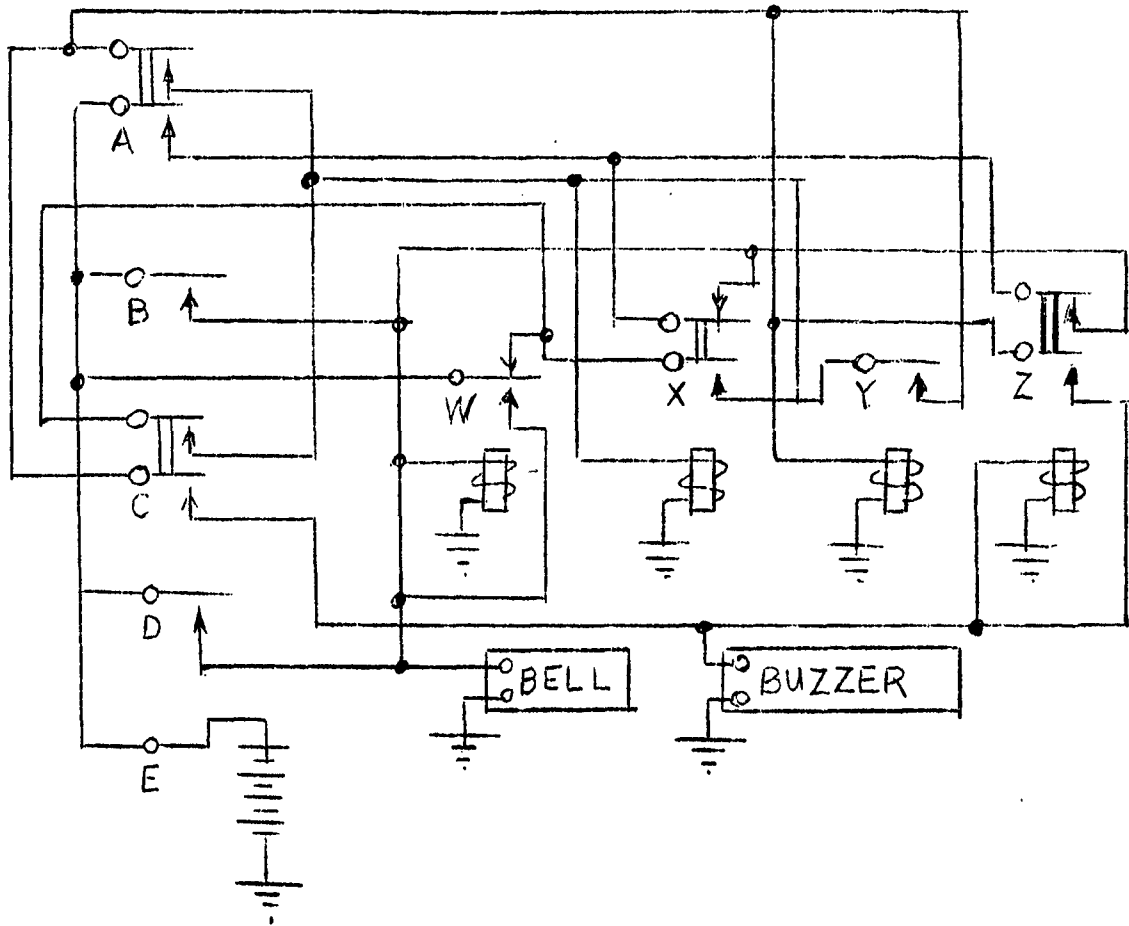


Figure 1. Circuit for a Typical Electromaze Problem

The Second Model

The first model proved to be a useful and popular illustrative device. A more flexible model was built for subsequent talks on switching circuits. The second apparatus had six problems which could be set up by plugging in special cords. A number of graduate students volunteered to try the problems and to keep account of the number of moves and the time for each solution. It became apparent that the device had possibilities as a testing device. A professor of theoretical physics who successfully solved the six problems commented: "This is the type of reasoning I expect my students to be able to do". A mature graduate student said: "This is the best test on the scientific method that I have seen". It was then decided to redesign the apparatus for testing purposes.

The Present Model

The device in its present has been named the electromaze and is shown in Figure 2. The essential components are electromagnetic relays inside the box, gang switches for setting up the problems, a clue plug-in device, a move counter, and a goal plug-in device, push-button switches for locking or releasing the relays.

Six types of problems can be set up on the present model. A problem is solved by operating one or more of the push buttons, singly or simultaneously until the goal is reached. A red light (or a buzzer) is used as a clue. For example, let the problem be to make the bell ring by pressing the second and fourth buttons in sequence. If the second button is pressed there will be no red light; if the third button is operated next, the red light will go on, and will stay on unless the center button is used to

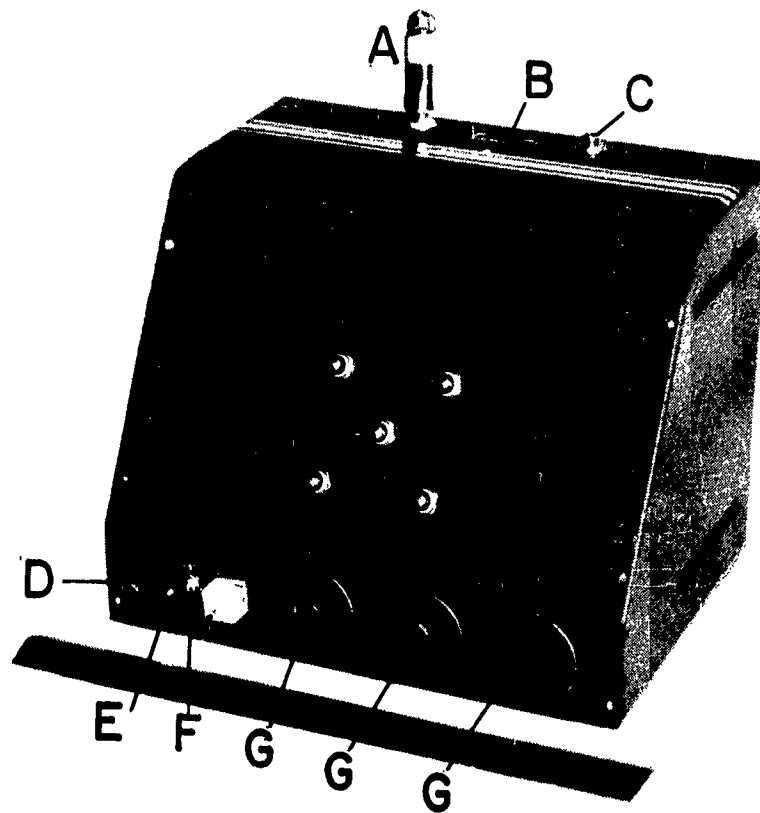


Figure 2. The Electromaze

A - clue device; B - trial counter; C - goal device socket
D - fuse; E - line switch; F - pilot light; G - problem setup switches
1, 2, 3, 4 - push buttons for operating relays; 5 - relay release

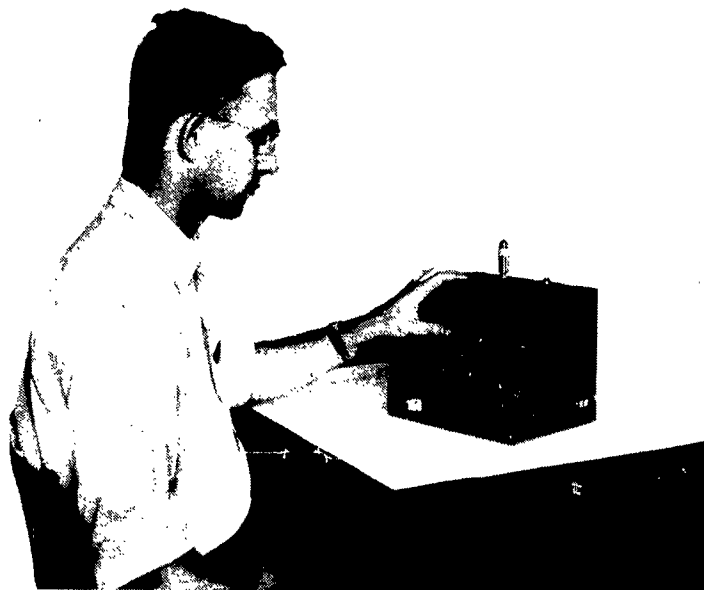


Figure 3. Subject Operating the Electromaze

"erase" the error and the correct move to bring the apparatus to its initial condition. An electromagnetic counter registers the number of times that each of the five push-buttons has been pressed. Reverse clue problems are also possible: the clue light can be made to signify that as long as it stays on, errors have not been made. Each problem type can also be presented with any combination of buttons, thus making possible the randomization of spatial arrangements. In theory there is no limit to the number of push-buttons and hence the complexity of problems that can be incorporated in the electromaze. The difficulty of the task becomes much greater if the subject is not told the meaning of the clue light, or of the eraser button, or both. The clue light and the goal bell can be replaced by light bulbs of any color or by any other electrical device attached to a phone jack.

The Problem

The aptitude measures at the graduate level are usually highly weighted with verbal, mathematical, and other abstract factors. Important as they are these symbolic situations may or may not be related to problems requiring little cognition and overt manipulation of words, formulas, and figures. The electromaze appeared to have possibilities as a performance test of reasoning, requiring a minimum of formal academic training.

During the spring quarter 1952, an experiment was carried out in which the electromaze problems were administered to two groups of graduate students at the University of Minnesota. The

experiment was designed to test three null hypotheses:

1. There are no significant differences between the means of the number of trials required to solve the electromaze problems by two populations of graduate students.
2. There are no significant differences between the means of the electromaze time scores for two populations of graduate students.
3. The correlations between the scores on the electromaze problems and the Miller Verbal Analogies Test are not significant.

Procedure

The Sample Population

The subjects in this study were drawn from two populations of graduate students at the University of Minnesota, Spring quarter 1952. From a total of sixty physics majors, twenty one were randomly selected and given the electromaze test. Fourteen graduate students in journalism - constituting a 100 per cent sample-- also participated in the experiment. Since the Miller Verbal Analogies Test is designed for natives of the U.S.A., foreign born students were eliminated from each of the two samples. The final samples consisted of 19 physicists and 12 journalists.

Administration of the Electromaze Test

The subjects were tested one at a time. No one else was allowed in the room. Rapport was established through a few minutes' conversation about the subject's scholastic background, work experience, childhood interests, etc.

Instructions on the electromaze were read aloud. If a subject did not understand a point, the directions about it were reread. The instructions are reproduced in the Appendix.

Each subject progressed in the same order through the seven problems. The subjects who wanted to give up were encouraged to go on, and all the subjects finished all the problems. The time was measured by means of a mechanical stopclock to the nearest second. The number of moves or trials was read on the counter. Upon satisfactory completion of a problem the subject was requested to repeat the solution; this excluded the random solutions. The electromaze with a subject operating it is shown in Figure 3.

The first problem was not scored as it was used to allow the subject to become familiar with the apparatus. If we number the upper left hand button 1, and the others counterclockwise 2, 3, 4, respectively, the operation sequences for the correct solutions of the problems where as follows: Practice problem; button 1, Problem 1: button 4. Problem 2; button 1, then button 2. Problem 3: buttons 1, 4 and 2 in sequence. Problem 4: buttons 1, 4 and 1 in sequence. Problem 5: buttons 2 and 4 simultaneously. Problem 6: button 4, then 1 and 2 together, then button 3. Problem 7: buttons 1, 4 and 2 in sequence.

On the first four problems the red light always went on when a mistake was made, and stayed off when the subject was on the right path. On number five the red light went on whenever buttons 1 or 3 were pressed, but was off if either 2 or 4 were pressed alone (though this was an error, i.e., did not lead to the solution). In the problem six the correct first button was #4, but the red light remained off if either #1 or #2 were pressed first, lighting up only for button #3. Also either #1 or #2 could be

pressed alone as the second move with no red light indicating that this was an error. In problem seven the red light indicated the correct approach. Due to the enormous number of possible combinations and sequences it was almost out of the question to get a low score by pure guessing, i.e., by totally ignoring the "cues" of the red light.

Results

Number of Trials

The means and standard deviations for the number of moves or trials are shown in the upper half of Table 1. There was a significant difference as shown by the F-ratio test in the variabilities of the two samples on problems 1, 2, 3, and 7. The two groups were homogeneous on problems 4, 5, 6, and the total score. The means were compared by using t-values and the Aspin-Welch y-values(2). It can be seen from the table that the difference between the means were not significant on any of the problems or on the total score.

Time

The means and standard deviations for the time scores of the two groups are shown in the lower half of Table 1. There was a significant difference in the variabilities of the two samples on problems 1, 3, and 5, but not for problems 2, 4, 6, 7, or the total score. The mean time for problem 5 was significantly lower for the journalists than for the physicists. There were no significant differences between the means of the two groups for problems 1, 2, 3, 4, 6, 7, and the total score.

Means, standard deviations, F-ratios, and α -values for the electromaze problems

Physics majors, N=19;

Journalism majors, N=12

	Problems							Total
	1	2	3	4	5	6	7	
Statistics	Number of trials							
M-physics	6.68	15.05	20.68	24.58	296.53	175.26	233.00	771.79
M-journalism	8.50	36.83	39.92	24.08	239.25	256.58	246.50	851.67
-physics	2.67	10.36	11.84	9.84	269.00	127.95	265.60	424.30
-journalism	4.19	46.65	62.51	14.13	298.40	185.70	153.10	530.90
F-ratio	2.55*	20.96**	28.79**	2.13	1.27	2.12	2.91*	1.62
t or v [#]	1.29 [#]	1.53 [#]	1.01 [#]	.11	.54	1.39	.20 [#]	.45
	Time in seconds							
	1	2	3	4	5	6	7	
M-physics	5.84	15.32	20.53	20.21	422.58	337.42	498.00	1319.89
M-journalism	13.5	26.00	39.75	20.50	208.58	443.67	674.50	1426.50
-physics	2.78	18.51	14.64	12.09	427.20	359.80	673.40	936.50
-Journalism	20.83	25.56	68.00	16.54	178.10	341.60	623.80	1002.00
F-ratio	48.33**	1.97	22.29**	1.93	5.57**	1.07	1.13	1.18
t or v [#]	1.21 [#]	1.30	.92 [#]	.06	1.88**	.79	.71	.11

#Aspin and Welch Test, when variances are not homogeneous

**Significant at the one per cent level

*Significant at the five per cent level

Correlation Between the Number of Moves and Time

The product moment correlations between the total number of moves and the total time were computed. The correlation was .76 for the physics students and .75 for the journalism majors, both coefficients being significantly different from zero at the one per cent level.

Correlations Between the Miller and the Electromaze Scores

The product moment correlation between the Miller raw scores and the total number of trials was $-.07$ for the physicists. The correlation between the Miller scores and the total time score was $-.25$. Neither correlation was significantly different from zero. The Miller scores for some of the journalists were not available, therefore the correlations for the journalists students would have been meaningless because of sampling difficulties.

Conclusions

On the basis of the statistical analysis it was reasonable to conclude that there were no significant differences in the abilities of graduate students in physics and journalism as revealed by their respective trial and time scores on the electromaze. The low correlations between the Miller and the electromaze scores can be taken as a strong indication that the electromaze performance depends little on the type of verbal skills and abilities measured by the Miller test.

Discussion

It appears that the physicists and journalists did not come from the same normal population as shown by the significant F-ratios in four of the seven electromaze problems. By the very nature of the subject matter, the physicists are more homogeneous with respect to mathematics and science background, laboratory experience, and interests. On the other hand, of the sixteen comparisons, the means were significantly different on only one. This is indicative of the fact that performance on the electromaze might not be a function of the subject's scholastic background, special skills, experiences and interests.

A number of experiments will have to be carried out with the electromaze to explore its characteristics as a non-specialized performance test. The proposed investigations should answer the questions:

1. To what extent does the average performance on the electromaze depend on the subject's mental ability as measured by a standardized test?
2. Are there any differences in the "verbal" and "technical" majors at the undergraduate level, where the selection is not as rigorous as in the case of the graduate students?
3. To what extent does the electromaze differentiate between various levels of experience in the same field, i.e., electrical apprentices, electricians, electrical foremen, students in electrical engineering and graduate electrical engineers?
4. To what extent does the performance on the electromaze correlate with research ratings by the graduate advisor or job supervisor?

5. Can the populations of graduate students be more sharply differentiated if the tasks are made more difficult?

The electromaze is similar to the Yerkes multiple choice test(3) in that both devices require the subject to formulate hypotheses and to test them. The electromaze, however, has greater flexibility in terms of the possible number of problems and their complexity. It is interesting to note that the experience gained in the construction of the electromaze was helpful to one of us (C.E.S.) in the design of the Multi-component Integrater of Thermal Diffusion Equations. It is hoped that the projected experimentation with the electromaze will reveal its usefulness as a research instrument in psychology.

Summary

A multiple choice performance maze operated by electromagnetic relays has been developed at the University of Minnesota. Preliminary exploration has shown that the device has possibilities as a non-verbal mental test. The electromaze was used to compare graduate students in physics and journalism. It was found that:

1. There were no significant differences in the mean trial and time scores of the two groups;
2. The correlation between the electromaze and the Miller Verbal Analogies scores was low and not significant. Further experimentation is now in progress.

References

1. Shannon, C. E. A symbolic analysis of relay and switching circuits. Transactions of the A.I.E.E., 1938, 57, 713-23.
2. Aspin, A.A. Tables for use in comparisons whose accuracy involves two variances, separately estimated. Biometrika, 1949, 36, 290-293.
3. Thurstone, T.G. & Thurstone L.L. Mechanical aptitude IV. Description of individual tests. The Psychometric Laboratory, University of Chicago, 56, May 1949

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Appendix -- Instructions

In order that all subjects receive the same instructions, I am reading these instructions from a printed sheet. This experiment is one on problem solving. You see here (the experimenter points with his finger) four buttons arranged in a square. They are the solution buttons. If the proper buttons are pressed, this (the experimenter points with his finger) green light will light up. If you press the wrong button or buttons this red light may light up. Normally this indicates that you have made an error and will have to start the problem all over again. This center button (the experimenter points to it) is an "erase" button. When it is pressed the red light goes out and you can start the problem all over again. You will have to solve each problem twice in a row without errors. You can not harm the machine by pressing the buttons in any order or manner. When you have caused the green light to go on call me and I will erase the problem. You must then do it all over again to demonstrate that you know how to solve it. You will not be counted as having solved the problem till you can make the green light go on twice in a row without an error in between. There are seven problems and each gets tougher as you go along. Don't get discouraged as some of them are not at all easy.

You will get two scores on each problem. One is the time it takes you to solve the problem and one is the number of buttons you push in getting the solution. The number of buttons pushed is indicated by this counter (points to it with finger). You will get a short rest period after each problem. Talking and smoking is permitted, but do not ask questions about the experiment if you can help it. Please do not talk about this experiment to your friends as this would make the experimental results valueless.

Instructions for problem 7 after the first 6 are completed:

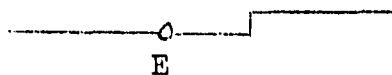
"All I can tell you about this problem is that it is different. Make the green light go on".

If at any time in the experiment the subject should ask about it being O.K. to press two or more buttons simultaneously he will be told:
"You may press two simultaneously if you wish to do so".

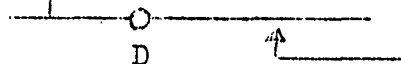
Abstract - Change last sentence to read: "The correlations between the Miller Verbal Analogies scores and either the number of trials or the time were not significant"

Page 2, Figure 1, - Change:

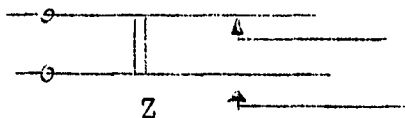
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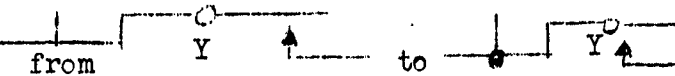
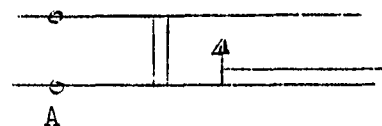
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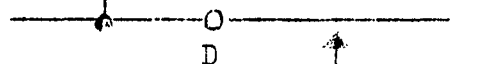
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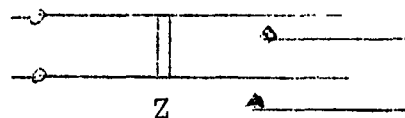
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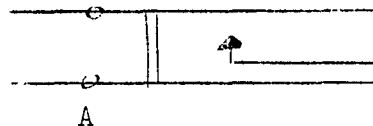
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Page 3 - First line of the second paragraph should read: "The device in its present form has been"

Page 5 - Third line from bottom: Transpose p and s in "psring" to read "spring"

Page 9 - The third and fourth rows of figures in each table should be labeled respectively,
6 - physics and,
6 - journalism.