Fig. 2); the S is self-paced. However, the inputs to the ring-counter may be programmed in other ways to suit other experimental requirements. For example, the use of a timer to perform this function would provide an externally paced condition.

Although the present system limits the maximum length of each sequence to eight members, shorter sequences are programmed by means of a binary-counter which counts correct responses. The selectable output of the counter then recycles the ring-counter and advances the projector at the point desired. The control circuit also performs these functions when the S presses an incorrect key—errors terminate a trial and advance the projector. These characteristics of the control circuit are not shown in Fig. 2.

The circuit may be adapted readily for use in experiments requiring lengthy sequences of responses, as in studies of probability learning. If the "0" position of the rotary slide tray is used, 81 slides yielding 648 individual response-key selections can be preprogrammed since each slide permits eight selections from the eight keys. This adaptation described by Siegel (1964) also provides a direct method for continuously recycling the slide tray.

Before applying this system to programming other experiments, consideration might be given to the following characteristics. The interval between slides, the change cycle of the projector, is approximately 1.5 sec. The space required by the photodecoder and the projector is 48 x 15 in.

The photodecoder (\$495) and the logic modules for the ring-counter and gating (\$300) are commercially available.³ The operating voltage of these units is 12 V dc. The additional cost of a slide projector (Kodak Carousel, Model 550, \$110) should be added to that of the photodecoder and logic to obtain the total cost of the system described here. The expense involved with an alternative system using a paper tape reader and punch varies widely. A hand punch available in most dime stores is sufficient for preparing slides, and the punching can be done quickly. Tolerances are sufficiently large that high accuracy in locating programming holes is not an important consideration. Slides also offer great ease of manipulation. The order of slides can be quickly changed as can small segments of the total set. The programming of test trials or probe trials, for example, is readily accomplished by the temporary replacement of a single slide.

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NOTES

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An apparatus for use in 2 by 2 game research¹

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This article describes a solid state apparatus for use in 2 by 2 game research. There are two individual player's boards and a control panel for E. Following E's signal, each player chooses one of two responses. Their choices are immediately registered on E's panel, but appear on each individual game board only after both have responded. Provisions are made for E to transmit false feedback.

Recently there has been an increasing number of studies utilizing two-person, interdependent games.² One of the most popular of these is the 2 by 2 game in which each of two players chooses one of two response alternatives. On the basis of their mutual choices, they each receive a payoff.

Conventionally, these games are represented in the form of a 2 by 2 matrix. The first player controls the rows (X and Y) while the second player controls the columns (A and B). Each chooses one of his response alternatives; usually, it is important that neither player be aware of the other's choice until he has made his own response. When both players have responded, the payoffs are disbursed. The payoffs to each are represented in the four cells of the 2 by 2 matrix, "XA," "XB," "YA," and "YB." The designations "XA," "XB," "YA," and "YB" refer to the intersection of columns and rows.

The present article describes an electric apparatus suitable for such two-person, two-choice games. It is preferable to manual versions on several counts. First, it speeds up the conduct of the game. Second, because there is an "override" circuit by which the E can take the role of a simulated other S, the transmission of false feedback is simplified. And thirdly, it

eliminates the need for the E to be in verbal or visual contact with the players.

The apparatus consists of three interdependent units, a game board for each of the players and a control panel for the E. The schematic diagram appears in Fig. 1.

The players' game boards each consist of a play signal (green-lensed lamps L_1 and L_2), two silent momentary depress push-button response indicators (S_1 and S_2 for Player I, controlling Rows X and Y, and S_3 and S_4 for Player II, controlling Columns A and B), and four white-lensed payoff lights corresponding to the quadrants of a 2 by 2 matrix (Lights 7, 8, 9, and 10 for Player I; Lights 11, 12, 13, and 14 for Player II).

The E's panel houses the following controls: (1) a toggle switch (S_{11}) which activates the apparatus and illuminates the play signals; (2) four lights to indicate the response choices of the two players, L_4 and L_6 to represent Player I's choices of Row X or Row Y, respectively, and L_3 and L_5 to indicate Player II's choices of Column A or Column B, respectively; and (3) override controls, S_9 and S_{10} , which serve to cut in or out E-controlled feedback to Player I and Player II, respectively, while override controls S_5 , S_6 , S_7 , and S_8 provide the false information that the "other player" chose "A," "B," "X," and "Y," respectively. As there are separate override controls for the two players, it is possible to give the participants combinations of false and true information. Whether or not the override mechanism is in use, the S, of course, receives correct feedback concerning his own responses.

As illustrated in Fig. 1, eight silicon control rectifiers (SCRs) are used in a matrix consisting of 12 signal lamps. (The play signals, L_1 and L_2 , are directly controlled by the master power switch, S_{11} .) Each SCR is triggered into conduction by actuating a momentary contact push-button switch, wired

Fig. 1. Circuit schematic for 2 by 2 game research apparatus showing experimenter control unit and two player stations.

through a voltage-divider resistor to the gate lead of each SCR. Once switched into conduction, the SCR will remain in that state until the circuit is broken by the power switch, S_{11} . With the power momentarily removed, and no gate signal present, the SCRs will remain de-energized until again triggered.

When a player activates a push-button switch (S_1 - S_4), the corresponding SCR (SCR_1 - SCR_4) will be activated, causing current to be applied to a corresponding signal bulb in the E's control unit. When both players have actuated their SCRs, current will flow through the individual player's signal lamps. If, for example, Player I actuates Switch "X," SCR_1 will conduct, causing the E's control unit lamp, L_4 , to light. If Player II then activates switch "B," SCR_4 will conduct, illuminating the E control unit lamp, L_5 . With SCR_1 and SCR_4 actuated, current can flow through Lamps L_8 and L_{12} , signifying "XB" on each player's game unit. The matrix wiring of the circuit permits the actuation of signal lamps

corresponding to any combinations of the "X-Y" and "A-B" push-buttons, that is: "XA," "XB," "YA," and "YB."

In addition to the automatic response indicators, switches S_9 and S_{10} permit the circuit to be set to the override mode. In this mode, the E can simulate either S's response through momentary push-button switches, S_5 - S_8 , and their associated SCR latching circuits. Diodes D_1 through D_8 are necessary to prevent sneak paths from providing false feedback information prior to the actuation of the players' switches. A list of basic parts appears in Table 1.

It is possible also to automate the apparatus for pacing trials. In the "override" mode, false feedback can be similarly automated. The player's choices may be recorded by event recorders, cumulative counters or other means, and it would be fairly simple to assess the time interval from illumination of the play signal to completion of a response.

Table 1
Parts List

R_1 - R_7	1000 (Ohm), $\frac{1}{2}W$
L_1 - L_{14}	G.E. No. 44 Lamp
S_1 - S_8	SPST Momentary Contact Push-Button
S_9 - S_{10}	4PDT Switch
S_{11}	SPST Toggle
D_1 - D_8	1N649
SCR_1 - SCR_8	G.E. Type C106Y2
B_1	Heavy Duty 6V Battery

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NOTES

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2. For a review of these studies see Rapoport & Orwant, 1962; Gallo & McClintock, 1965; and Becker & McClintock, 1966.