KIM and the rabbit: The use of the KIM-1 microprocessor to control classical conditioning of the rabbit's nictitating membrane response

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The KIM-1 microprocessor combined with a plug-board interface provides an inexpensive and highly flexible system for controlling classical conditioning of the rabbit's nictitating membrane response. The system is described in the context of a program for differential conditioning.

It is now well established that the classically conditioned rabbit nictitating membrane response (NMR) is a useful preparation for studying mammalian learning (cf. Gormezano, 1972; Moore, 1972). More recently, a number of investigators have used the preparation as a model system for investigating physiological aspects of conditioning (e.g., Mis, 1977; Moore, in press; Powell, Mankowski, & Buchanan, 1978; Salafia, Romano, Tynan, & Host, 1977; Solomon, 1977; Thompson, 1976).

In this paper, we describe an inexpensive and flexible programming system to control the rabbit NMR conditioning procedure. The KIM-1 microprocessor is used to accomplish this task.

THE KIM-1 MICROPROCESSOR

The KIM-1 is a relatively inexpensive (about \$180) 8-bit microprocessor. It comes equipped with 1,024 bytes of memory and a real-time clock capable of microsecond precision. The microprocessor has 15 input-output bits for controlling or sampling external events. The KIM-1 in "store-bought" form is capable of controlling the classical conditioning paradigm, and it can easily be expanded to accommodate more sophisticated programming tasks. Additional memory is relatively inexpensive, and software packages are now available that give the computer the capacity to accept a variety of programming languages (e.g., BASIC and FOCAL).

The KIM-1 is equipped with a cassette tape-recorder interface that allows the user to store programs on

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ordinary cassette tapes. A 30-min tape can store approximately 14,000 bytes of information in KIM-1 format. This is equivalent to more than a dozen programs, using the full, 1,024 bytes of memory available on the KIM-1 board.

THE PROGRAM

The program for classically conditioning the rabbit's NMR is relatively simple, but it allows a good deal of flexibility. With only minor changes (usually changing the contents of one memory location), the user can alter the CS (or CSs), the presence or absence of the UCS, the intertrial interval (ITI), or the interstimulus interval (ISI).

The sample program described here is for differential conditioning in which the tone CS is always followed by the UCS and the light CS is never followed by the UCS. The ITI is a constant 30 sec, the CS is 500 msec, the CS-UCS interval is 450 msec, and the UCS is 50 msec. The sequence of reinforced and nonreinforced trials

Figure 1. Flowchart for differential conditioning of the rabbit's nictitating membrane response.

Table 1

0200 A9 FF	LDAIM \$00FF	set port A to output mode
0202 8D 01 17	STA \$1701	
0205 A9 00	LDAIM \$0000	set trials counter to 0
0207 85 50	STAZ \$0050	
0209 A9 00	LDAIM \$0000	set cycles counter to 0
020B 85 60	STAZ \$0060	
020D A2 00	LDXIM \$0000	
020F B4 00	LDYZX \$0000	
0211 B5 04	LDAZX \$0004	
0213 8D 07 17	STA \$1707	timing sequence
0216 2C 07 17	BIT \$1707	
0219 10 FB	RPL \$0216	
021B 88	DEY	
021C D0 F3	BNE \$0211	
021E 18	CLC	
021F 8A	TXA	
0220 71 50	ADCIY \$0050	
0222 AA	TAX	execute output command
0223 EA	NOP	
0224 B5 08	LDAZX \$0008	
0226 8D 00 17	STA \$1700	
0229 8A	TXA	
022A 38	SEC	
022B F1 50	SBCIY \$0050	
022D AA	TAX	
022E E8	INX	
022F E0 04	CFXIM \$0004	
0231 90 DC	BCC \$020F	
0233 E6 50	INCZ \$0050	
0235 A5 50	LDAZ \$0050	compare trials register with
0237 C9 0A	CMPIY \$000A	10, branch if less than
0239 90 D2	BCC \$020D	
023B A9 00	LDAIM \$0000	reset trials register to 0
023D 85 50	STAZ \$0050	
023F E6 60	INCZ \$0060	
0241 A5 60	LDAZ \$0060	compare cycles counter with
0243 C9 0A	CMPIY \$000A	10, if less than branch to
0245 90 C8	BCC \$020D	start new cycle
0247 00	BRK	
0000,70		
0001,0A		
0002,09		
0003,01	timing table values	
0004,FF		
0005,62		
0006,31		
0007,31		
0008,01		
0009,25		
000A,2F	output table values	
000B,00		
000C,01		
000D,85		
000E,85		
000F,00		
0300,00		
0301,04		
0302,04		
0303,00	trials sequence table	
0304,04		
0305,00		
0306,00		
0307,04		
0308,00		
0309,04		
0051,03		

cycles in blocks of 10 trials, with each block containing 5 trials of each type.

Figure 1 shows a flowchart for the differential conditioning program, and Table 1 lists the program. The program steps through three timing sequences for each trial: the ITI (followed by CS onset), the CS-UCS interval, and the UCS length (the CS and UCS are coterminous). In addition, 1 sec before the end of the ITI, the microprocessor activates the chart drive on a polygraph that is used for recording the NMR (cf. Gormezano, 1966). The value for each of these times is stored in tables in memory (Table 2). Thus, by changing the contents of one memory location, any of the temporal parameters of the conditioning paradigm can be altered.

At the conclusion of each timing loop (ITI, CS-UCS

interval, UCS length), the computer goes to a table that contains output commands. In the differential conditioning program, these commands vary from trial to trial such that in every block of 10 trials, there are 5 CS+ trials and 5 CS- trials. Thus, at the end of the ITI sequence on CS+ trials, the computer points to a memory location that contains the command to turn on the tone. The program then cycles through the CS-UCS interval timing loop and points to a memory location that contains the command to turn on the UCS. The final timing loop for each trial is the UCS interval, at the conclusion of which, the computer terminates all stimuli and once again begins the ITI loop. The same sequence occurs on CS- trials, except that the CS is a light and there is no UCS output command at the end of the CS-UCS interval (see Table 3).

Table 4 shows the output sequence for differential conditioning. The "execute output command" (see Table 1) sequence of the program makes use of the indirect indexed addressing mode to sequence through the output table. Briefly, at the conclusion of each trial, the computer increments a memory location (0050) that, via the indirect indexed addressing command, points to the next output on the table. When all 10 locations are used, the program cycles back to the beginning of the table. This system provides maximum flexibility. For example, to change to a paradigm that delivers the same stimuli on all trials, the experimenter simply enters the same contents in memory locations 0300 through 0309. Similarly, the user can obtain more than two separate stimulus configurations in any block of 10 (or more) trials by

Table 2
Timing Sequences for ITI, CS-UCS Interval, and UCS Duration

Table 2A - Stimulus Parameters Used

Table 2B - Number of Cycles - Stored in Y Register

Memory Location	Event	of Cycles	Memory Contents (in Hex)
0000	ITI-1 sec (poly-graph on)	112	70
0001	1 sec	10	0A
0002	CS-UCS interval	9	09
0003	UCS length	1	01

Table 2C - Length of Each Cycle

Memory Location	Event	Length of Cycle	Memory Contents (in Hex)
0004	ITI-1 sec (poly-graph on)	.26 sec	FF
0005	1 sec	.10	62
0006	CS-UCS interval	.05	31
0007	UCS length	.05	31

Table 3
Output Commands for CS+ and CS- Trials

CS+			CS-		
Memory Location	Contents (in Hex)	Event	Memory Location	Contents (in Hex)	Event
0008	01	Polygraph on	000C	01	Polygraph on
0009	25	Polygraph + Tone	000D	85	Polygraph + Light
000A	2F	Polygraph + Tone + UCS	000E	85	Polygraph + Light
000B	00	All stimuli off	000F	00	All stimuli off

Output Port A (Memory Location 1700)*

6-V Light CS	28-V Light CS	Tone CS	Vibratory CS	UCS Event Marker	CS Event Marker	UCS	Polygraph on
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Note—The KIM 1 actually has two 8-bit output ports; only one is needed for this particular program. As indicated in the program (Table 1), at the end of the timing sequence, the microprocessor goes to the corresponding memory location in the output table and moves the contents of this location to the output port (memory location 1700). This activates the corresponding 6-V relay(s) on the plugboard, thus delivering the appropriate stimuli.

*A "1" in any location turns on that stimulus.

altering the contents of these 10 memory locations accordingly.

THE INTERFACE

The interface between the KIM-1 and the experimental apparatus consists of a set of 15 mercury-wetted, SPDT, 6-V relays (Midtex Part 166-151 LAZ). The relays are operated by the 15 peripheral output bits of the KIM-1 microprocessor. Since these bits are only capable of supplying about 1 mA at 5 V dc, they cannot drive the relays directly. Each relay is driven by one gate of a Type 7406 TTL hex inverter driver. These gates, in turn, are driven directly by the KIM-1 output bits.

In our laboratory, we use a variety of CSs (e.g., light, tone, vibration, noise, and electrical stimulation of the brain). One KIM output port and corresponding relay is devoted to each. In addition, there are output bits and relays to control the UCS, as well as the event recorder and chart drive on the polygraph. Each relay has a LED to indicate status, allowing the experimenter to continually monitor the stimulus presentations.

We typically run four rabbits simultaneously, and

thus, each relay must be capable of delivering stimuli to all four conditioning boxes. This could be hardwired, but to gain maximum programming flexibility, we bring the switch contacts of the relays out to two 15 by 20 pin plugboards (Vector Electronics PB1520-2). This arrangement allows us to program the stimuli in each conditioning box by means of jumper wires. This flexibility is, of course, somewhat limited, in that the ISI and ITs must be the same in all boxes.

EXPANSION

Roemer, Cegavske, Thompson, and Patterson (1975) have described a computer- (PDP-12) controlled system for acquisition and analysis of both behavioral (NMR) and electrophysiological data during conditioning of the NMR. These capacities could be added to the present system, but, in addition to the transducing devices (i.e., A/D converters), it would be necessary to add additional memory and a display, as well as the capacity to use a simpler programming language (e.g., FOCAL or BASIC). Nevertheless, the KIM-1 lends itself to this type of expansion. It would also be possible to expand the present system to accommodate additional conditioning boxes by simply expanding the plugboard interface.

In summary, the KIM-1 microprocessor used in conjunction with a plugboard type interface provides an inexpensive and highly flexible method for controlling classical conditioning of the rabbit's NMR. The program described in this paper could easily be modified to control other classical conditioning tasks, such as the CER, and with certain additions, the KIM-1 could collect and analyze conditioned response data.

Table 4
Output Sequence for Differential Conditioning

Memory Location	Contents	Trial Type
0300	00	T+
0301	04	L-
0302	04	L-
0303	00	T+
0304	04	L-
0305	00	T+
0306	00	T+
0307	04	L-
0308	00	T+
0309	04	L-

Note—When the computer points to memory location 0300, it adds the contents of this register to 0008 (see Table 1, Steps 0224 and 0225) to get the address of the first output command of the trial (see Table 3). Thus on T+ trials it starts on 0008 and on L- trials it begins on 000C.

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