BRIEF REPORT

CHAINS: A QUICKBASIC 4.5 PROGRAM FOR STUDYING VARIABLES AFFECTING HUMAN LEARNING

Noah Sontz Dermer and Marshall Lev Dermer

UNIVERSITY OF WISCONSIN--MADISON AND
UNIVERSITY OF WISCONSIN--MILWAUKEE

The procedure known as "the repeated acquisition of behavioral chains" has revealed how learning is affected by variables such as the punishment of errors (Boren & Devine, 1968), drugs (Higgins, Rush, Hughes, Bickel, Lynn, & Capeless, 1992; Thompson & Moerschbaecher, 1979), and age (Perone & Baron, 1982). In each session, a participant learns a sequence of responses ("the chain") that produces reinforcement. The sequences differ between sessions, but with extended practice the participant's error rate stabilizes and provides a baseline for studying variables affecting learning. CHAINS, a QuickBASIC 4.5 (QB4.5) program, modeled after procedures used by Perone and Baron (1982), allows researchers with some knowledge of BASIC to easily implement the repeated acquisition procedure with humans.

CHAINS first instructs the participant that depressing the correct sequence of numeric keys on the number pad produces a reinforcer. Depressing a correct key displays the corresponding numeral on the screen and sounds a high frequency tone. Depressing an incorrect key or responding late momentarily deactivates the keyboard ("time-out" from the opportunity to earn reinforcement) and sounds a low frequency tone. When the participant completes the correct sequence, depressing the "ENTER" key produces a whistling sound that signals a reinforcer has been earned. Subsequently, the screen is cleared and the participant can re-enter the sequence.

Over sessions, participants become proficient at entering sequences, despite the sequence changing between sessions, and their error rates stabilize. At this point interventions such as drugs, distraction, or music may be introduced and withdrawn to determine, for each individual participant (Dermer & Hoch,1999), whether such variables affect the error rate.[1]

Besides studying the acquisition of new sequences, it also may be desirable to study performance with an established sequence (Higgins, Rush, Hughes, Bickel, Lynn, & Capeless, 1992; Perone & Baron, 1982; Thompson & Moerschbaecher, 1979). For example, Perone and Baron (1982) divided each session into 5-min components. Each session began with an acquisition component that alternated with a performance component until there were five presentations of each. The sequences programmed for acquisition components varied across sessions, whereas the sequence programmed for the performance components remained constant across sessions. CHAINS allows the user to program both types of components. To facilitate differential responding between components, CHAINS presents a colored block on the left side of the computer screen; covarying the color of the bar with the current component makes the sequence of components a multiple schedule of reinforcement (Ferster & Skinner, 1957).

HARDWARE

CHAINS requires an SVGA monitor and a parallel printer with a small buffer. CHAINS was developed on an IBM-compatible, 386DX40, with 16 MB of memory, running under DOS 5.0. CHAINS has additionally run, either in the QB4.5 programming environment or as a stand-alone executable file, on newer IBM-compatible machines under DOS or the Windows equivalent.

THE PROGRAM

Users must modify and compile the source code for their purposes. Thus, familiarity with

Special thanks are due Alan Baron, Mark Galizio, Susan Lima, and Michael Perone for their suggestions. Correspondence should be sent to Marshall Lev Dermer, Department of Psychology, University of Wisconsin-Milwaukee, Milwaukee, WI 53201. Electronic mail may be sent to: dermer@uwm.edu.

[1] CHAINS might also be used by neuropsychologists and therapists to measure changes in a patient's ability to learn numeric sequences.

the BASIC or QuickBASIC programming languages is very helpful.

As distributed, CHAINSXX.BAS, TIME_MOD.BAS (a set of timing routines, Perone, 1991), CHAINSXX.MAK (a file that directs the programming environment to read the previous two files), CHAINSXX.EXE (a demonstration program) and ten files with the extension PIC (the images for the integers zero through nine) should be copied to a directory "C:\CHAINS."

There are comment statements throughout CHAINSXX.BAS to help users. Most changes will be made in four subroutines and require only changing the program's parameters. Changes in Subroutine *Sequence*, however, require adding or deleting a few lines of code as detailed below.

Subroutine *SetUpProgram* calls many of the major subroutines the program requires and establishes parameter values. The subroutine first calls a routine that presents the instructions to the participant and then specifies values for: the directory in which the program and image files are stored, component duration, pacing duration (see discussion of "pacing," Perone & Baron, 1982, p. 446), duration of time-out from reinforcement when the pacing duration is exceeded, the duration of time-out for an incorrect response, and the length of the numeric sequence.

Subroutine *AcquisitionSequence* sets the color that signals that the acquisition component is in effect, and specifies the numeric values for the acquisition sequence during this session. The values are selected (without replacement) from the numerals 0 to 9 that have been randomly ordered by Subroutine *Permutator.* A particular acquisition sequence is used for all of a session's acquisition components. Because, however, an acquisition sequence is randomly selected before a session begins, a particular sequence is highly unlikely to be reused during subsequent sessions. For example, there are 7! or 5004 7-digit sequences.

Subroutine *PerformanceSequence* sets the color that signals that the performance component is in effect, and permits the user to specify the numeric values for the performance sequence. This performance sequence is used for all of a session's performance components and is reused during subsequent sessions.

Subroutine *Sequence* specifies the kind, number, and order of the components that will be presented in a session. In the subroutine, "PER" denotes a performance component, "ACQ" denotes an acquisition component, and "END" denotes a session's ending. A session that only presents an acquisition component would be programmed:

```
component$(1) = "ACQ"
component$(2) = "END"
```

A four-component session that alternates between acquisition and performance components would be programmed:

```
component$(1) = "ACQ"
component$(2) = "PER"
component$(3) = "ACQ"
component$(4) = "PER"
component$(5) = "END"
```

There is a limit of 100 components per session.

OUTPUT

For each session the program first prints: the date, the time the session began, the component duration, pacing duration, time-out duration for exceeding pacing duration, and time-out duration for an incorrect response. Additionally, for each component the program prints: component type (acquisition or performance), the numeric sequence, the number and rate of numerals correctly entered, the number and rate of numerals incorrectly entered, the proportion of numerals entered that were incorrect (relative errors), the number and rate of sequences correctly entered, the number and rate of sequences incorrectly entered, the number and rate of time-outs for exceeding the pacing duration, the actual duration of the component (this includes the time specified for entering numerals plus, for example, the time for accessing reinforcers, and various time-outs), and the obtained component duration. The latter duration should closely approximate the component duration value specified by the experimenter.

DEMONSTRATION DATA

Although the repeated-acquisition-of-chains procedure has provided useful data, particularly in the area of behavioral pharmacology (Higgins & Hughes, 1998), CHAINS had not been used to collect data. So, the second author (MLD) self-experimented with CHAINS to determine if it could produce promising data. (Worth noting is the growing and productive literature on self-experimentation and that CHAINS can facilitate such research; see Roberts & Neuringer, 1998.)

Because the effects of circadian rhythms on alertness are well known (e.g., Dermer & Berscheid, 1972), MLD (a 53-yr old male) used

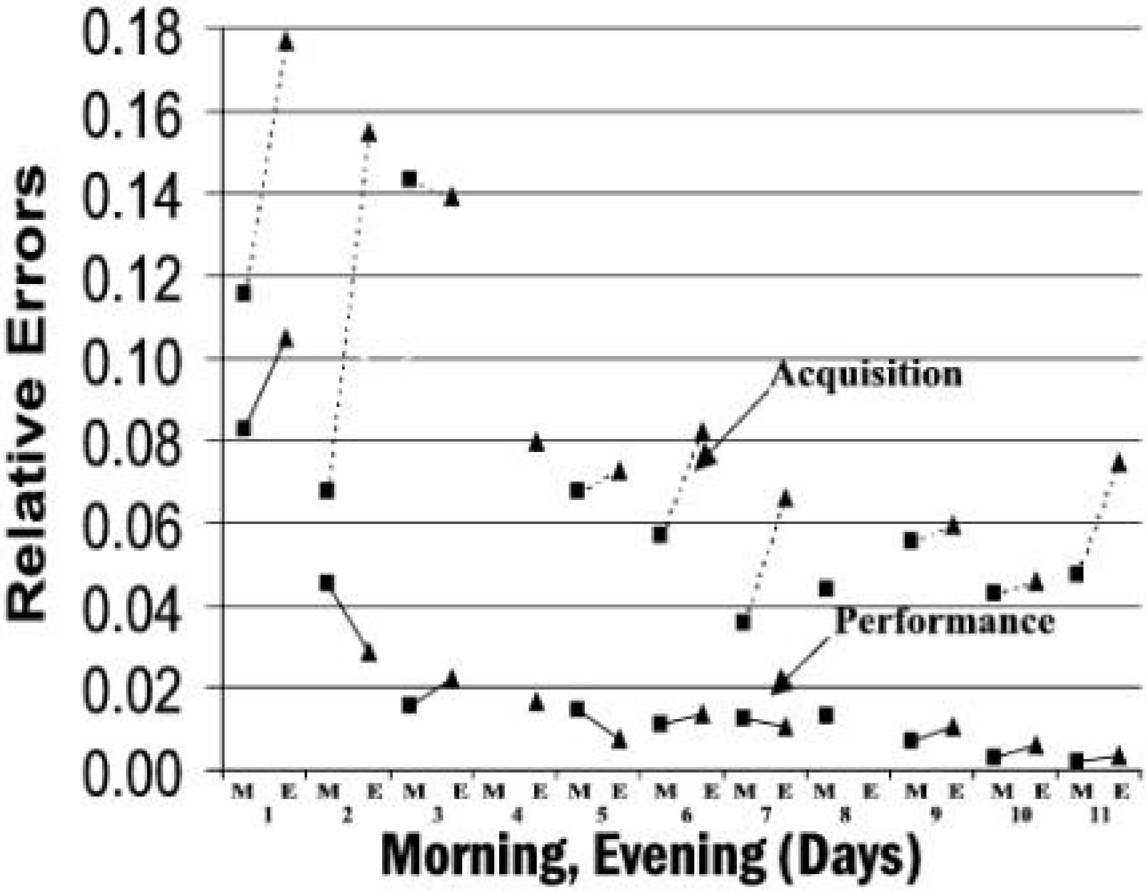

Figure 1

the program twice a day for 11 days: once around 11 a.m., and again around 10:30 p.m, just before retiring.

In this application, a clock in the computer's lower left corner showed the time taken for responding in a component. Component duration was set to 90 s (Actual component duration, which includes the time to deliver consequences, was often twice as long, particularly for the performance component.), pacing duration was set to 60 s (This limit was never exceeded.), duration of time-out for an incorrect response was set to 0 s, and the numeric sequences consisted of seven digits. The one performance sequence, randomly-generated, was 8492536 and was used throughout the experiment. The acquisition sequences, of course, were constant within each session but varied between sessions. Each session included four components presented in this order: performance, acquisition, performance, acquisition.[2]

Figure 1 presents relative errors (the number of incorrect numeric responses divided by the total number of numeric responses)[3] in the acquisition component (dashed lines) and performance component (solid lines) for each morning session (squares) and evening session (triangles). On days 4 and 8 data were collected only in the evening and morning, respectively.

More errors occurred in the acquisition component than in the performance component, but errors decreased over the course of the 11-day

[2] Perone and Baron's (1982) sessions always began with an acquisition component.

[3] Other dependent variables are of interest. Fluency, a high rate of correct responding with a low rate of incorrect responding, may be particularly important in mediating retention and creative performances (Binder, 1996; Johnson & Layng, 1992).

period in both components. Although a stability criterion was not used to terminate the series, the data were becoming stable, particularly during the performance component, during the last three days. Interestingly, for these three days, relative errors increase from the morning to the evening sessions with a larger increase in the acquisition component than in the performance component. It should be noted that the data from days 5-7 also suggest that the acquisition component is most sensitive to the time at which the sessions were scheduled. Unfortunately, because MLD's daily activities were not controlled, it is uncertain whether the inferior performance during the evening is due to time of day or to variations in MLD's activities.

Also worth noting is the large drop in relative errors for the acquisition component between the evenings of days 3 and 4. During the evening session of the third day, relative errors were about .14 but the following evening were only .08. To understand this reduction, recall the sequence of components within a session: performance, acquisition, performance, acquisition. For the first three days, the requirements of the second performance component produced incorrect responses during the initial portion of the final acquisition component (i.e., retroactive inhibition). During the last acquisition component MLD often first "searched" the number pad for the correct numerals even though he had repeatedly entered this sequence earlier during the first acquisition component. On the evening of the fourth day, however, something different happened. MLD had become so fluent (Binder, 1996; Johnson & Layng, 1992) at entering the numerals for the performance component that he no longer verbalized them as he did so. On this evening, he instead began to verbalize the numerals from that session's first acquisition component as he entered the numerals for the second performance component. The onset of the second acquisition component required only that he depress the keys that corresponded to his verbalizations during the second performance component. So, his errors during the final acquisition component dramatically decreased. The process by which this occurred would probably have been unknown had the researcher and participant been different individuals.

SUMMARY

CHAINS, a QuickBASIC 4.5 program, permits users with some knowledge of BASIC to study variables affecting learning and performance. During a session, a participant acquires a sequence of numeric responses ("the chain") that produces reinforcement. From session-to-session the sequence changes, but with extended practice a participant's error rate stabilizes and provides a baseline for studying variables affecting acquisition. CHAINS can also present a numeric sequence that remains constant from session to session for studying variables affecting performance. Both acquisition and performance may be assessed during the same session. Besides its usefulness in basic research, CHAINS may be useful in clinical practice to assess variables potentially affecting learning and remembering numeric sequences.

AVAILABILITY

CHAINS is available as a ZIP file at the BehaviorAnalysis archive at the following URL: ftp://ftp.csd.uwm.edu/pub/Psychology/BehaviorAnalysis/software/.

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