
COMPUTERS IN TEACHING

Using CHAINS, a QuickBASIC 4.5 Program, to Teach Single-Subject Experimentation With Humans

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Students enrolled in a single-subject design course studied the repeated acquisition of response sequences by using CHAINS, a QuickBASIC 4.5 program, which runs in DOS or Windows®. For about 2 months, students examined the learning of such sequences as a function of various treatments. Each week students graphed their data, discussed their research, modified their experiments, and then wrote American Psychological Association-style manuscripts. Students positively evaluated CHAINS and the instructional process. Suggestions for future instruction include distributing students' manuscripts the following semester so new students can replicate earlier work and using the alternating treatments design, which quickly permits comparing treatments.

Although psychological practitioners most often help individuals, psychological researchers most often aggregate data across individuals. Such aggregation, however, may obscure how treatments affect an individual. Single-subject experimentation is important because it can reveal whether and how treatments affect an individual's performance (Dermer & Hoch, 1999). Indeed, researchers in behavior analysis have conducted single-subject experiments that have contributed to a number of highly general technologies for working with nonhumans (e.g., Pryor, 1997) and humans (e.g., Lovaas, 1993).

Despite the utility of single-subject experimentation and recent growing interest in such research with humans (Dermer & Hoch, 1999; Morgan & Morgan, 2001), there is a dearth of instructional software. Silva (1999) introduced software for the Macintosh® operating system that allows students to study shaping. The software tracks how a student moves a cursor on a computer screen and shapes movements as a function of various parameters until the cursor "hits" a target (Silva, 1999; Silva, Yuille, & Peters, 2000).

For the DOS and Windows® operating systems, Dermer and Dermer (2000) introduced software that allows researchers to study the effects of various treatments on human learning and performance. The software, CHAINS, implements the repeated acquisition of chains procedure. The participant's basic task is to depress a sequence of numeric keys (the chain). Depressing a correct key places the corresponding numeral on the screen and sounds a high-frequency tone. Depressing an incorrect key only sounds a low-frequency tone. Each session can include multiple presentations of two components: an acquisition component and a performance component. For both components, depressing a sequence of

numeric keys produces a reinforcer, a whistling sound. The sequence during the acquisition components is constant within sessions but varies across sessions. The sequence during the performance components is constant within and across sessions.

For research purposes, Dermer and Dermer (2000) provided QuickBASIC 4.5 source code, instructions for modifying the software, and a compiled demonstration program. For instructional purposes, I compiled four versions of CHAINS. Each version presents 90-sec performance and acquisition components. Each component is signaled by a colored bar that appears on the screen's left side. For all components the sequence length is constant (e.g., seven keys). For each component CHAINS calculates the proportion of errors (the total number of incorrect responses divided by the total number of responses) and rates per minute of correct and incorrect responding (see Dermer & Dermer, 2000).

By examining these measures as a function of experimental treatments, a researcher can determine whether the experimental treatments affected entering "new" sequences (acquisition data) and entering a "well-learned," highly practiced sequence (performance data). Additionally, a researcher may compare data from these two components because performance data may reflect various uncontrolled variables such as the participant's motivation and alertness whereas acquisition data reflect these uncontrolled variables plus learning.

Researchers may use a number of experimental designs. In the ABAB design, a researcher continues a treatment for many sessions until responding achieves a "steady state," that is, from session to session responding assumes a characteristic level and tends to neither increase nor decrease across sessions (see Baron & Perone, 1998; Perone, 1991). Once responding achieves a steady state, the researcher withdraws the treatment and later reintroduces it after responding has stabilized during a comparison treatment (Barlow & Hersen, 1984, chap. 5). The researcher assesses treatment effects by comparing responding during steady states. In contrast, a researcher using an alternating treatment design can circumvent such a lengthy, steady-state analysis. In the alternating treatment design, the researcher changes treatments from session to session or within sessions (Barlow & Hersen, 1984, chap. 7). The researcher assesses treatment effects by comparing levels of responding given a background of response instability. Next, I describe how my students used these two

designs to examine the effects of various treatments on responding during the performance and acquisition components of CHAINS.

Method

Participants and Setting

Nine students who had completed a laboratory course in research methods in psychology participated as part of their work for a course on single-subject design. The course met once weekly for 2.25 hr. I used Barlow and Hersen (1984) as the primary text. All students conducted and documented a single-subject experiment of their own design. Eight students chose to use CHAINS.

Materials

Software. Four versions of CHAINS (see Dermer & Dermer, 2000) presented four, 90-sec components: performance, acquisition, performance, acquisition. The performance component used a constant numeric sequence from session to session; the acquisition component used numeric sequences that varied across sessions but were constant within a session. Each version of CHAINS presented 7-, 8-, 9-, or 10-digit sequences (e.g., CHAIN147.EXE presents 7-digit sequences). The four versions are in ChainsForClass.EXE, available at <ftp://ftp.csd.uwm.edu/pub/Psychology/BehaviorAnalysis/software/educational/chains-dermer/>. The downloaded, self-extracting file creates the directory C:\CHAINS and loads supporting files. Before activating a program, a 3.5-in. disk should be inserted into the A drive where CHAINS creates data files (cf. Dermer & Dermer, 2000).

Evaluation. Students evaluated instruction using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The evaluative statements were: (a) "CHAINS was easy to install on a computer," (b) "CHAINS was easy to use," (c) "Using CHAINS enhanced my understanding of the process of conducting a single-subject experiment," (d) "For many weeks, students presented and discussed data collected using CHAINS. These presentations and discussions enhanced my understanding of the process of single-subject research: designing, implementing, and evaluating a single-subject experiment," and (e) "I recommend using CHAINS in future single-subject design classes."

Procedure

Students first read and discussed an article that discussed various misconceptions about single-subject experimentation (Dermer & Hoch, 1999) and an article about using CHAINS (Dermer & Dermer, 2000). Next each student designed, conducted, and documented a single-subject experiment in which the student or another student participated. Students collected data at least 5 days per week. In their subsequent American Psychological Association-style reports, students emphasized operations rather than theory. Finally,

students submitted the disk that contained the data files that CHAINS generated and copies of these files they may have printed.

For about 2 months, students conducted experiments, graphed data, and converted graphs to overhead transparencies for class presentations. Each presentation initially required about 12 min, but as the semester progressed 5 min usually sufficed. At the semester's end, five students anonymously responded to the evaluation. Two more students responded to mailed evaluations after course grades were assigned.

Results and Discussion

Most students first used some version of the ABAB design but because of limited time their data did not satisfy conventional stability criteria (see, e.g., Baron & Perone, 1998, pp. 49–57). One student, using an ABA design, did collect rather clear data. Her experiment assessed the effects of the program's auditory feedback, which signals many events including correct and incorrect responding.¹ She aggregated data across the two presentations of the performance and acquisition components to calculate the overall proportion of erroneous responses for each component. Figure 1 shows these proportions as a function of the component in effect and the presence or absence of auditory feedback. For the first nine sessions, the student used the program's auditory feedback. For the next nine sessions she discontinued auditory feedback. This change correlated with an increase in the proportion of erroneous responses for the performance and acquisition components. The increase was somewhat greater for the acquisition component than for the performance component. Additionally, discontinuing feedback correlated with an increase in between-session variability, particularly for the acquisition component. For the last four sessions the student reinstated auditory feedback. This change correlated with an immediate reduction in the proportion of erroneous responses. The reduction was greater for the acquisition component than for the performance component. Reinstating feedback also reduced between-session variability. The entire pattern of changes suggests that discontinuing auditory feedback had two effects: It increased the proportion of erroneous responses and increased between-session variability, particularly for the acquisition component.

In behavior analysis it is customary to further examine data to determine whether other levels of analysis reveal systematic relations. CHAINS calculates a variety of measures to facilitate such an examination. Accordingly, on a component-by-component basis, the student graphed the rates per min of correct responding and separately graphed the rates per min of incorrect responding. These two graphs clarified how these more fundamental measures contributed to the overall proportion of erroneous responses in Figure 1.

Most experiments, however, have not been so definitive. Over several semesters, the treatments that have not affected

¹Janet Adornato collected these data during Spring 2001 and deserves special thanks.

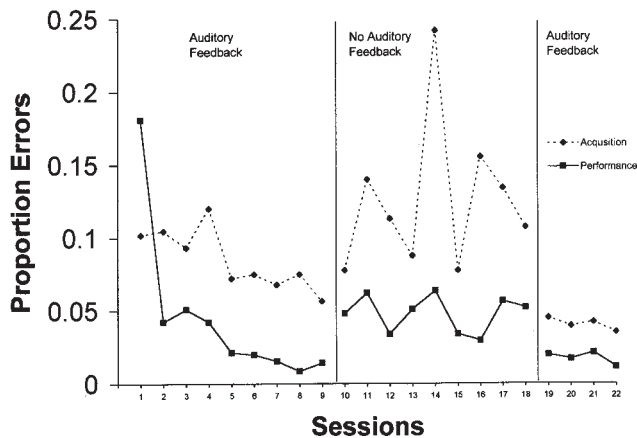


Figure 1. For 22 afternoon sessions, the proportion of errors made as a function of the component in effect and auditory feedback.

responding include a fatty-acid food supplement that purportedly aids memory and playing or listening to relaxing guitar music or exercising before sessions. Whether a treatment affects responding depends on program parameters. A critical parameter is sequence length. Most students used short sequences but longer sequences may be more sensitive. Students should be encouraged to explore these parameters. Such tinkering enhances discerning cause and effect relations at the level of the single participant.

As the semester progressed most students switched from ABAB designs to alternating treatments designs. Review of Figure 1 indicates that an alternating treatments design is embedded within the ABA design. For every session, CHAINS twice presented the performance and acquisition components. As previously noted, during the performance component one sequence is used across sessions whereas during the acquisition component a sequence is unique to a session. Figure 1 indicates that the acquisition component nearly always produced more errors than did the performance component. Moreover, this effect was evident in 9 days despite responding varying from session to session. Although the effect may be limited to the components being presented in a fixed order, the result indicates the utility of the alternating treatments design for quickly comparing treatments given response instability from session to session.

On the evaluation, students reported CHAINS as easy to use and the related instructional activities valuable. All but one student strongly agreed with the four statements assessing easy installation, easy use, enhanced understanding of the process of single-subject experimentation, and recommending future use of CHAINS. All students strongly agreed with the statements that the weekly presentations of data and discussions were useful. Some students also provided comments, for example:

Chains was an invaluable learning tool. I cannot imagine how a textbook or journal article could have been a substitute for the experience of running sessions, graphing data, and deciding what treatment to implement. Also the program, being more or less foolproof, only enhanced the value of CHAINS as an educational tool.

These positive evaluations may have been due to the small class size but during the semester students often mentioned enjoying the freedom of selecting treatments to investigate as well as designing and modifying their research as they collected data. This “tinkering” with the experiment or “investigative play” (Hayes, Barlow, & Nelson-Gray, 1999, pp. 134–136) was absent from the highly structured exercises students completed for their course in research methods in psychology.

There are several ways to further improve instruction. Providing students with reports of experiments conducted during previous semesters would help them document their experiments and encourage them to replicate or refine previous work. Replication and refinement are vital activities that deserve classroom support (for a discussion of the critical role of replication in Pavlov’s laboratory, see Babkin, 1949, pp. 70–72, 112; Campbell, 1969, p. 367). Instruction may be further improved by encouraging students to use alternating treatments designs when comparing fast-acting treatments of short duration. Also, although students in my course usually scheduled only one or two sessions per day, multiple sessions may be completed in a short time if students schedule breaks between sessions.

Although CHAINS is a simple program, its use as an instructional tool may evoke apprehension among instructors new to single-subject research. These instructors may, therefore, want to review introductory texts on single-subject research (e.g., Bailey & Burch, 2002; Barlow & Hersen, 1984) and advanced discussions (Baron & Perone, 1998; Perone, 1991) and perhaps review the literature on repeated acquisition procedures (e.g., Cohn, MacPhail, & Paule, 1996; Cohn & Paule, 1995).

Instructors, however, can best allay their apprehension by conducting single-subject research with CHAINS. For example, I conducted an 11-day experiment in which I collected data at different times during my sleep–wakefulness cycle (about 3.5 hr after arising vs. just before retiring; Dermer & Dermer, 2000). Alternatively, instructors could easily replicate the experiment that manipulated auditory feedback, particularly if they used an alternating treatment design that either alternated or randomized the presence versus absence of auditory feedback for blocks of two sessions. By using CHAINS and analyzing their data, instructors would gain expertise and confidence that they could share with their students. Also, for their research methods courses, these instructors would best know how to design and introduce their new “hands-on” unit on single-subject research.

References

- Babkin, B. P. (1949). *Pavlov, a biography*. Chicago: University of Chicago Press.
- Bailey, J. S., & Burch, M. R. (2002). *Research methods in applied behavior analysis*. Thousand Oaks, CA: Sage.
- Barlow, D. H., & Hersen, M. (1984). *Single case experimental designs: Strategies for studying behavior change* (2nd ed.). New York: Pergamon.
- Baron, A., & Perone, M. (1998). Experimental design and analysis in the laboratory study of human operant behavior. In K. A. Lattal & M. Perone (Eds.), *Handbook of research methods in human operant behavior* (pp. 45–91). New York: Plenum.

- Campbell, D. T. (1969). Prospective: Artifact and control. In R. Rosenthal & R. L. Rosnow (Eds.), *Artifact in behavioral research* (pp. 351–382). New York: Academic.
- Cohn, J., MacPhail, R. C., & Paule, M. G. (1996). Repeated acquisition and the assessment of centrally acting compounds. *Cognitive Brain Research*, 3, 183–191.
- Cohn, J., & Paule, M. G. (1995). Repeated acquisition of response sequences: The analysis of behavior in transition. *Neuroscience and Biobehavioral Reviews*, 19, 397–406.
- Dermer, M. L., & Hoch, T. A. (1999). Improving descriptions of single-subject experiments in research texts written for undergraduates. *The Psychological Record*, 49, 49–66.
- Dermer, N. S., & Dermer, M. L. (2000). CHAINS: A QuickBASIC 4.5 program for studying variables affecting human learning. *Experimental Analysis of Human Behavior Bulletin*, 18, 23–27. Retrieved April 1, 2001, from <http://www.eahb.org/DermerDermer/DermerDermer.pdf>
- Hayes, S. C., Barlow, D. H., & Nelson-Gray, R. O. (1999). *The scientist practitioner: Research and accountability in the age of managed care* (2nd ed.). Boston: Allyn & Bacon.
- Lovaas, O. I. (1993). The development of a treatment-research project for developmentally disabled and autistic children. *Journal of Applied Behavior Analysis*, 26, 617–630.
- Morgan, D. L., & Morgan, R. K. (2001). Single-participant research design: Bringing science to managed care. *American Psychologist*, 56, 119–127.
- Perone, M. (1991). Experimental design in the analysis of free-operant behavior. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior: Techniques in the behavioral and neural sciences* (Parts 1 & 2, pp. 135–171). New York: Elsevier.
- Pryor, K. (1997, May). *History of clicker training I*. Paper presented at the meeting of the Association for Behavior Analysis, Chicago. Retrieved October 6, 2003 from <http://www.clickertraining.com/karen/articles/>
- Silva, F. J. (1999). Beyond the “hot-and-cold” game: A demonstration of computer-controlled shaping. *Behavior Research Methods, Instruments, & Computers*, 31, 63–73.
- Silva, F. J., Yuille, R., & Peters, L. K. (2000). A method for illustrating the continuity of behavior during schedules of reinforcement. *Teaching of Psychology*, 27, 145–148.

Notes

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