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CONTINGENCIES OF SUPERSTITION: SELF-GENERATED RULES AND RESPONDING DURING SECOND-ORDER RESPONSE-INDEPENDENT SCHEDULES

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Experimental conditions explored the development of fallacious rules and assessed the rates and durations of superstitious responding by children under the influence of standard and second-order response-independent reinforcement. During the presentation of computer-generated math problems, subjects in Experiment 1 had access to a computer and keyboard. Group 1 received second-order, random-time (RT) reinforcement by way of a coin toss graphic procedure (mean reinforcement rate of 1/min). This procedure rendered an effect analogous to a "slot-machine" and matching icons produced monetary reinforcement displayed on the computer screen. A second group obtained response-independent reinforcement according to a standard random-time (RT) 30-s schedule (mean reinforcement rate of 2/min). A control group received no scheduled consequences but was exposed to the same demand conditions. After 10 min, students in all groups answered questions regarding "why" they had performed problems. Subsequently, experimental subjects were exposed to the same conditions for 10 min after which reinforcement was terminated; however, a series of problems remained available for solving. Over the course of the experiment, and particularly during extinction, Group 1 subjects performed at higher rates and longer durations. Experiment 2 replicated Experiment 1, but it examined the effects of second-order response-independent reinforcement on fixed-time (FT) schedules. Students who had been exposed to second-order response-independent reinforcement demonstrated higher rates and longer durations of problem solving. Outcomes suggest that, independent of FT or RT schedules, second-order response-independent contingencies appear to generate elaborate fallacious rules and particularly long durations of superstitious responding.

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Solving problems and performing behaviors based on solutions occurs continually throughout our daily activities. Sometimes, our actions can be characterized as logical, sometimes as fallacious. In either case, our success is often gauged by the moment-by-moment consequences of our actions. Human behavior appears to be particularly susceptible to fallacious rules and unnecessary behaviors in contexts that provide response-independent reinforcement. That is, circumstances that engender spurious correlations between behaviors and consequences may lead us to describe particular environmental events as dependent on our actions when, in fact, those consequences may be forthcoming independent of what we do. For example, simple games of chance that generate random winnings, such as slot machines, may lead gamblers to form and believe complex rules regarding the "special things" they must do in order to increase their chances of "hitting the jackpot" (Dixon & Hayes, 1998; Radin, 1997). By the same token, baseball players are notorious for developing superstitious "logic" and rituals while inside the batter's box (Malott, Whaley, & Malott, 1997). Although it is true that hitting jackpots and home runs both entail some very relevant responding, the potential for outcomes to become coincidentally *correlated* with superfluous and irrelevant behaviors dramatically increases the probability of players generating fallacious rules to guide their behavior in future endeavors.

Malott et al. (1997) describe irrelevant responding, initiated and maintained under the influence of adventitious contingencies and irrational rules, as "superstitious." Once a person has learned to respond under the control of a superstitious rule, compliance with that rule may preclude contact with the natural or programmed contingencies (Catania, Matthews, & Shimoff, 1982; Ono, 1994).

Current research in the experimental analysis of human behavior suggests that this phenomenon may be quite pervasive (cf. Lee, 1996), and the expression *superstitious rule* has been introduced to characterize verbal descriptions of response-consequence relations that are not in effect during scheduled contingencies (Heltzer & Vyse, 1994). Superstitious rules may operate as discriminative stimuli or contingency-specifying stimuli (Schlinger & Blakely, 1987) and may continue to function as such as long as the irrelevant behavior is reinforced via adventitious contingencies (Baron, Perone, & Galizio, 1991; Dermer & Rodgers, 1997; Heltzer & Vyse, 1994; Leighland, 1996; Newman, Buffington, & Hemmes, 1995; Rosenfarb, Newland, Brannon, & Howey, 1992; Vyse, 1991).

As a classic illustration, Wagner and Morris (1987) had preschool children perform in a free-operant environment during time-based, response-independent reinforcement conditions. Subjects received marbles (later exchangeable for toys) according to either a fixed-time (FT) 15-s or a FT 30-s schedule. Seven of the 12 children exhibited a clear and "specifiable dominant response" pattern (e.g., touching a clown on the nose) reminiscent of superstitious behaviors. Using a computer-interactive environment, Cerutti (1991) had subjects attempt to avoid time-based, response-independent tones by pressing panels during various mixed random-time (RT) and FT schedules. In this context, subjects' inaccurate guesses (as to the best way to avoid tones) were shaped by computer feedback. Results suggested that the subjects' verbal behavior in the form of guesses and panel pressing were more likely to be controlled by the shaping of guesses when response-independent tones were transmitted during highly indiscriminable random schedules. A replication by Cerutti (1994) forwarded the notion that compliance with shaped guesses was occasioned by indiscriminable random schedules as well as conspicuous monitoring (filming) of the subjects. Following these outcomes, Cerutti concluded that random distribution of events *across time* is a critical component to the self-generation of superstitious rules and behaviors (cf. Ninness & Ninness, 1998).

In a unique analysis of time-based, adventitious contingencies, Hackenberg and Joker (1994) contrasted the effects of schedule and instructional control on humans' choices between FT and progressive-time (PT) schedules. Initially, the instructions accurately described the scheduled contingencies, and under these conditions, subjects' choice patterns provided the greatest amount of monetary reinforcement. Although instructions remained constant, optimal choice patterns gradually shifted across conditions through changes in the PT schedule. Instructional control was maintained for several conditions, but eventually diminished as responding came under schedule control. On the basis of verbal reports gathered at 15-min intervals during the course of the experiment, Hackenberg and Joker suggested that for at least some subjects, responding may be attributable to gradually changing accurate or fallacious self-instructions during the programmed contingencies.

Laboratory experiments with lower organisms have established that superstition is not exclusively a human phenomena (Skinner, 1948; cf. Staddon & Simmelhag, 1971) and continuing animal research demonstrates the intrusive and diversified effects of time-based, response-independent reinforcement, schedules (e.g., Lattal & Abreu-Rodrigues, 1997). Research with lower organisms has also demonstrated that *second-order schedules* may amplify performance and resistance to extinction within a wide range of contingencies. For example, Findly and Brady (1965) were able to induce extended performances in chimpanzees during fixed-ratio (FR) 4,000 by displaying a mediating food-hopper stimulus light after every 400 responses and providing tangible reinforcement after 10 displays. This contingency was described as a FR 10 (FR 400:S) where S referenced the stimulus light delivered after every 400 responses. Thus, in both response-independent reinforcement schedules and second-order schedules, nonverbal organisms tend to perform at unnecessarily high rates and extended durations. We speculated that combining second-order schedules with response-independent reinforcement may yield *analogues* for human superstitious behavior within computer-interactive environments. For example, generating a coin toss graphic after every random-time (RT) 30-s and providing monetary reinforcement only when the coins match according to RR 2 (p = 0.5) may be described as a second-order schedule consisting of RR 2 (RT 30-s:S) where S represents the stimulus provided in the coin toss graphic procedure.

Such an analogue may be congenial with conceptual issues from an earlier study in which we found that students who were given fallacious rules coinciding with FT contingencies demonstrated particularly high rates and long durations of solving math problems (Ninness & Ninness, 1998). The present investigation sought to extend our previous research on verbal control of computer-interactive math performance. First, we were interested in developing a format that provided a computer-interactive verbal analogue to second-order response-independent contingencies during problem solving. Second, in this context, we sought to examine self-generated rules and resistance to extinction during second-order RT schedules and standard RT schedules. Third, we wanted to analyze self-generated rules and resistance to extinction during second-order FT schedules and standard FT schedules.

Experiment 1

Method

Participants, setting, and apparatus. Fifteen 5th-grade students, ranging from 10 to 11 years of age, from a self-contained, regular education classroom participated. The students were randomly assigned to three groups of five subjects. Following informed consent, all experimental sessions were conducted on one of two available Toshiba notebook computers during the school day in two separate partitioned corners of the students' regular classroom. The computers were positioned so as to preclude distractions or interference from other students. The software was written by H. A. Chris Ninness in QBASIC for IBM PC compatible machines.

Experimental design. A between-group design was used. Experimental conditions were designed to investigate the participants' generation of fallacious rules and associated responding during and after the presentation of computer-generated math problems and response-independent reinforcement. During the experiment, students were able to respond to multiplication problems by typing answers on the keyboard. Correct answers/min were calculated by the computer program and were automatically recorded on disk throughout each experimental session.

For students in the two experimental groups, reinforcement was delivered independent of problem solving. Students in experimental Group 1 were provided response-independent reinforcement according to a second-order schedule consisting of RR 2 (RT 30-s:S) where the occurrence of the RT coin toss fluctuated between 15 s and 45 s. The probability of obtaining a match at any given RR 2 (RT 30-s:S) interval was always 0.5 (mean reinforcement rate of 1/min). Students in experimental Group 2 were provided standard RT 30-s reinforcement (mean reinforcement rate of 2/min). Control subjects were exposed to the same demand conditions but did not obtain access to programmed reinforcement while sitting at the computer. For this group, responding to math problems simply provided access to a continuing series of problems.

Following the first 10 min of the experimental sessions, ail subjects in all groups were provided questions regarding why they were performing problems at the computer. These questions were posted on the computer screen and could be answered with pen and paper adjacent to the computer. After posting these questions, the program continued providing response-independent reinforcement to subjects in both experimental groups for an additional 10 min. Subsequently, all forms of reinforcement were terminated, but math problems continued to become available on the screen for an additional 25 min. Pilot studies and previous research (e.g., Belfiore, Lee, Vargas, & Skinner, 1997) suggest that because of apparent demand characteristics some students may perform math problems with minimal prompting or access to external reinforcement. To assess the effects of demand conditions independent of monetary reinforcement, a control group was included in the first experiment.

Reliability checks. Before and after the experiment, one of the researchers performed math problems at the computer as an independent observer tallied the number of correctly completed problems each minute for 15 min. Calculation of agreements were obtained by dividing the number of min-by-min agreements by the number of agreements plus disagreements and multiplying by 100. Reliability coefficients between the observer and computer calculations were at 100% for observations conducted before and after the experiment.

Procedure. During the experimental session, 5 students (3 males and 2 females) in Group 1 were asked to sit in front of a computer. No instructions were given to the students; however, the computer screen presented the subjects with an opportunity to perform a series of multiplication problems by displaying the following message: "CONTINUE?" Below this question were the words, "TYPE "Y" TO CONTINUE. TYPE "N" TO STOP." If "N" were typed, the program terminated; if "Y" were typed, a multiplication problem appeared and could be answered by typing the number key/s. The program did not require the student to press the enter key. As soon as the number keys were typed, the student's response appeared briefly on the screen below the problem. This was followed by the prompt, "CONTINUE?", and the cycle repeated itself according to the same format. In this context, a unit of measured behavior always entailed a combination of two or three key presses (the letter "Y" followed by a single or double digit answer). If students pressed "N" to the prompt "CONTINUE," one more question was posted before the session ended.

Pilot research demonstrated that students who stopped responding for longer than 3 min subsequent to identifying the noncontingent reinforcement did not reinitiate further problems solving. Therefore, if during the course of the experiment, no responding occurred over a 5-min period, the program automatically produced a closing question, and the session ended. However, subjects were not aware of this arrangement until they were debriefed at the completion of the study.

Students in Group 1 were provided RR 2 (RT 30-s:S) reinforcement. At the end of every RT 30-s, the computer screen randomly strobed the words "HEADS" or "TAILS" on each side of the screen for approximately 1 s. (This procedure rendered an effect comparable to a "slot-machine" with only two icons.) At the end of this brief interval of simulated coin flipping, the two sides of the screen either "matched" (two heads or two tails) or did not match. If a student obtained a match, the computer strobed the word "WINNER," and displayed a cumulative number of pennies in multiples of 5 cents. For example, following approximately the first 30 s (plus or minus 15 s), the computer posted the following 1-s message: "WINNER!!!!! YOU NOW HAVE *5* CENTS." The next second-order RT 30-s that produced a match increased the amount to *10* cents, and so on. If, however, the simulated coin toss graphic did not match, the computer posted the following message, "SORRY, NO MATCH THIS TIME." for approximately 1 s. The coin toss procedure reduced reinforcement allocation by a factor of two. That is, the probability of obtaining a match at any given RR 2 (RT 30-s:S) interval was 0.5 (mean reinforcement rate of 1/min).

After 10 min of RR 2 (RT 30-s:S) reinforcement, the computer program presented the student with three questions. The following queries appeared on separate screens that automatically cleared after 3 min: "WHY ARE YOU DOING PROBLEMS?", "WHEN DID THE COMPUTER GIVE YOU MONEY?", and "DOES WORKING PROBLEMS QUICKLY SEEM TO HELP?". Upon responding to these questions, the students could continue problem solving by typing "Y." if "Y" were typed, the program continued providing reinforcement according to the same RR 2 (RT 30-s:S) schedule for another 10 min. Subsequently, extinction procedures were invoked and all "coin flips" resulted in the computer posting the same negative message: "SORRY! NO MATCH THIS TIME," according to the RT 30-s schedule. When the student pressed "N" to the prompt, "CONTINUE?", the program terminated with the presentation of one more question, "WHY DID YOU STOP?". The program instructed the participants to write their responses on the same piece of paper adjacent to the computer. However, if students simply stopped responding without typing "N," reinforcement continued at the same rate.

Students in Group 2 (1 male and 4 females) were provided the same experimental preparations; however, no coin toss graphic was employed. At the end of every RT 30-s, the computer simply posted a cumulative amount of money. For example, after the fourth RT 30-s transpired, the computer posted: "WINNER!!!!! YOU NOW HAVE *20* CENTS." Because the probability of obtaining reinforcement at the end of every RT 30 s was 100% (mean reinforcement rate of 2/min), Group 2 students acquired twice as much money, per unit of time, as students in Group 1.

After 10 min of RT 30-s reinforcement, the computer program presented the student with the same three questions submitted to Group 1 students. As with Group 1, the computer screen instructed students to provide their answers on a piece of blank paper adjacent to the computer. Upon responding to these questions, the students could continue problem solving by typing "Y." If "Y" were typed, the program continued providing reinforcement according to the RT 30-s schedule for an additional 10 min. After this 10-min period, all reinforcement procedures were stopped. Nevertheless, multiplication problems continued to appear on the screen, and pressing keys provided students with a continuing series of problems. When the student pressed "N" to the prompt, "CONTINUE?", the program terminated with the presentation of one more question, "WHY DID YOU STOP?". The program instructed the participants to write their answers to this question on the paper next to the computer.

Control subjects (4 males and 1 female) were exposed to all of the above "demand" conditions, but these students did not have access to computer displayed reinforcement procedures. Because the probabilities of obtaining monetary reinforcement were nonexistent, Group 3 subjects were operating independent of any external reinforcement throughout the duration of the experiment. However, responding to math problems provided access to a continuing series of problems. If control students performed for 10 min, the program afforded only 2 questions: "WHY ARE YOU DOING PROBLEMS" and "DOES WORKING PROBLEMS QUICKLY SEEM TO HELP?" in the same format as those given to the students in the experimental groups. After students responded to those questions, the program continued providing multiplication problems. When students pressed "N," one more question, "WHY DID YOU STOP?" appeared on the screen, and the program ended. If, at any time during the session, no responding occurred over a period of 5 min, the program provided the same question and ended the control subject's session; however, the subject was not aware of this contingency until after the experiment had ended.

Results and discussion. The results may be characterized at group and individual-subject levels of analysis (Fisher, Piazza, Zarcone, O'Conner, & Ninness, 1995). The group data were summarized by obtaining the mean number of correct answers for subjects in each of the three groups during selected conditions. Using randomization tests for nonrandom samples (Edgington, 1995), systematic permutation procedures for family-wise and planned comparisons were performed. Figure 1 illustrates the total number of correct answers for each subject in each group.

Systematic permutation procedures yielded a significant effect for the family-wise comparisons ($p < .05$). Additionally, one-tailed planned comparisons were computed by determining the proportion of permutations that provide a statistic for *P* values. These analyses revealed that the control group performed significantly fewer correct answers than Group 1 ($p < .003$) and Group 2 ($p < .01$). A statistically reliable difference between Group 1 and Group 2 was also found ($p < .04$), with more problem solving performed by Group 1.

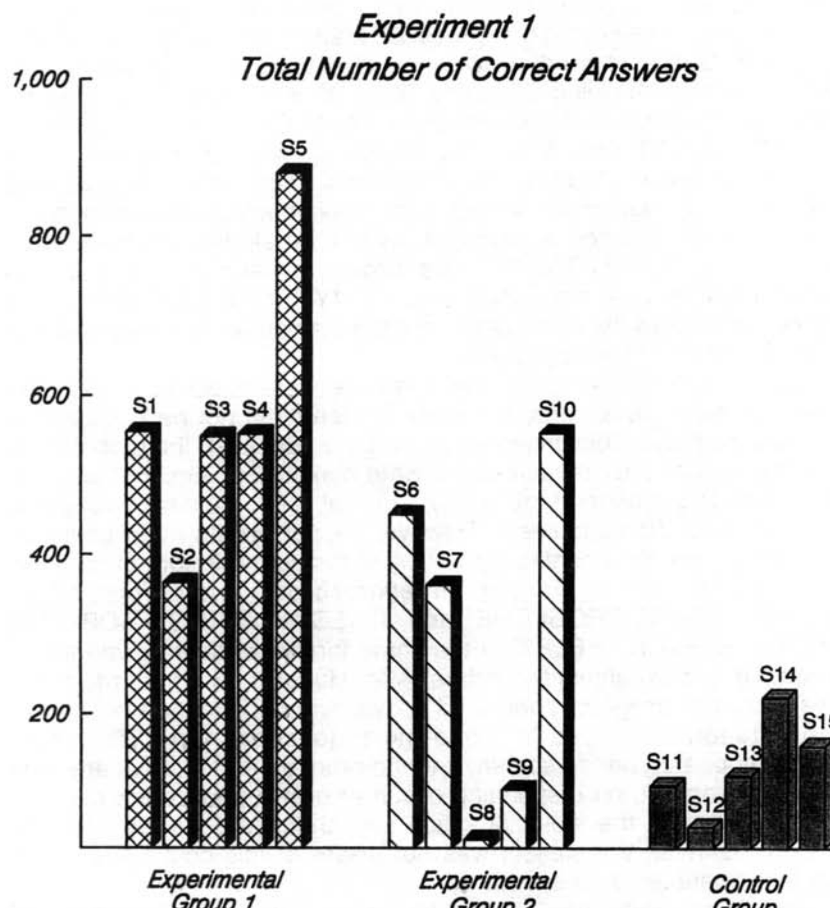

Figure 1. Total number of correct answers for subjects in each group during Experiment 1.

Individual subject data results were assessed in terms of rate and duration of correct answers/min within each student's experimental or control condition. Noteworthy is the fact that all students performed relatively few incorrect answers during any of the experimental conditions. However, Figure 2 reveals that all 5 students in experimental Group 1 performed multiplication problems at a relatively low rate during the first 3 to 5 minutes of RR 2 (RT 30-s:S) reinforcement. During this

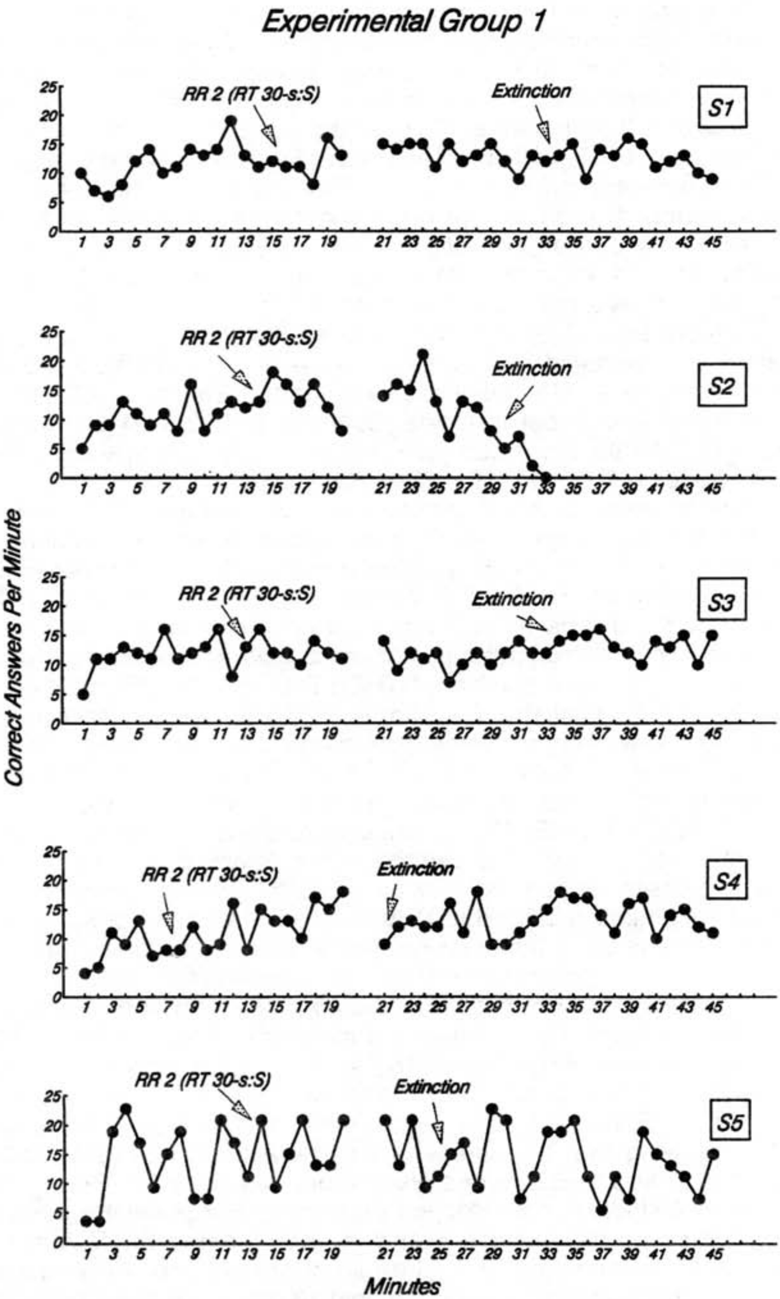

Figure 2. Frequency and duration of correct math problems for 5 subjects in Group 1 receiving second-order RT 30-s reinforcement.

time, intervals in which no responding occurred were likely to be correlated with noncontingent reinforcement. Thus, it is somewhat surprising that none of these subjects slowed their rate or stopped performing problems and simply let the computer provide reinforcement independent of their behavior. Quite to the contrary, the trend lines for each subject show a gradual acceleration of problem solving during the first few minutes of each session. Performance rates were not conspicuously altered by the brief questioning that the computer provided at the end of the 10th min of each subject's session. Most subjects reached an asymptote by the 7th or 8th min, but Subject 4 continued to show a gradual acceleration throughout most of the first 20 min of his session. Subject 5 demonstrated the most minute-to-minute variation. She averaged 19.6 over the course of 20 min of RR 2 (RT 30-s:S) reinforcement. Her response rate ranged from 3 to 24 correct problems/min throughout this time. Subjects 1, 2, 3, and 4 averaged 11.65, 11.55, 11.95, and 10.95 correct answers/min, respectively, during the 20 minutes of RR 2 (RT 30-s:S) reinforcement.

Students' answers to the computer-posted questions at the end of the 10th min of the experiment were revealing of their individual "interpretations" of the ongoing experimental contingencies. When the computer posted the first question, "WHY ARE YOU DOING PROBLEMS?", all subjects in Group 1 provided brief written responses to the effect that the computer paid them to answer problems correctly. In response to the next question, "WHEN DID THE COMPUTER GIVE YOU MONEY?", 4 of the 5 students provided written responses suggesting that working problems gave them a chance to match "heads" and "tails"; however, Subject 3 simply wrote, "when I had two of a kind." In response to the last question, "DOES WORKING PROBLEMS QUICKLY SEEM TO HELP?", all students responded in the affirmative by writing "yes". Subject 5 added the words, "most of the time." These written responses are suggestive of the students' "belief" in some form of ongoing contingent relationship between their continued performance and the acquisition of financial compensation. As such, the student chronicles seem to represent the formation of superstitious rules.

After the first 20 min of the session, the computer program terminated the possibility of obtaining a match on HEADS or TAILS. The coin toss graphic continued according to an RT 30-s schedule, but the acquisition of noncontingent financial reinforcement ended. Nevertheless, Subjects 1, 3, 4, and 5 sustained their rates of correct problems solving over the course of the following 25 min (M = 12.84, 12.36, 13.28, and 19.52 correct answer/min, respectively). During this time, these 4 students only stopped performing multiplication problems when the computer program ended their sessions. Subject 2 discontinued performing at the 33rd min of the session. He averaged 10.23 correct answers/min during the final 13 min in which no matching of HEADS or TAILS occurred.

At the end of the 45-min session, subjects responded to a final

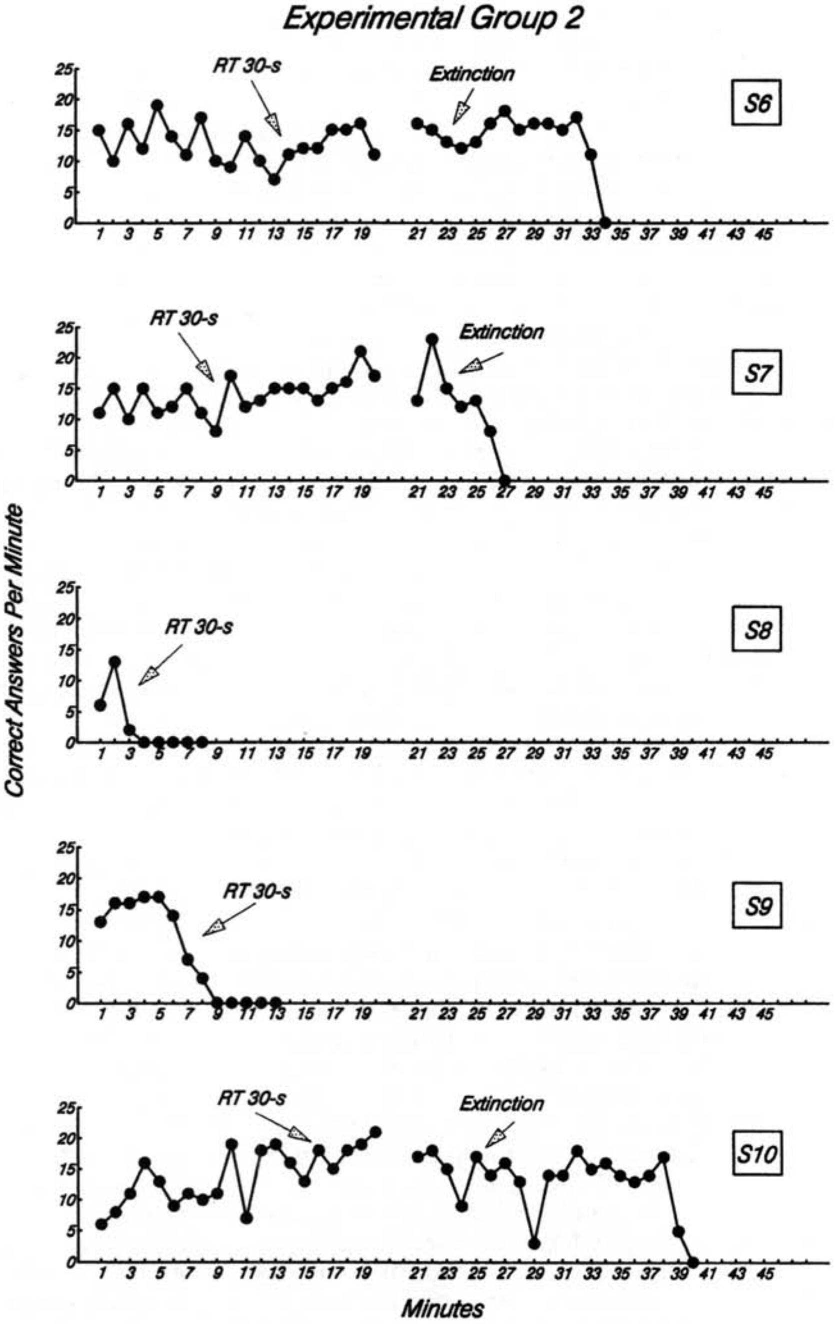

Figure 3. Frequency and duration of correct math problems for 5 subjects in Group 2 receiving RT 30-s reinforcement.

question, "WHY DID YOU STOP?", that appeared on the computer screen when the program ended. Of the 5 subjects, 4 gave answers that clearly indicated that they only stopped because the program terminated; however, Subject 2 who typed "N" to the prompt "CONTINUE" 33 min into the program wrote, "I got tired." None of these written responses seem to suggest a clear recognition on the part of any student that reinforcement possibilities had ended 25 min earlier.

Figure 3 indicates that Group 2 students did not continue to perform math problems over the extended period of time demonstrated by Group 1 students. Subject 6 apparently exited the program by mistake at the beginning of the session. Upon asking for assistance, she was allowed to reinitiate the program. Thereafter, she maintained a comparatively steady rate of correct problems/min. Subjects 6, 7, and 10 provided answers to the computer-posted questions at the end of the 10th min of the experiment suggestive of their individual "interpretations" of the ongoing experimental contingencies. When the computer posted the first question, "WHY ARE YOU DOING PROBLEMS?", Subjects 6, 7, and 10 all drafted answers indicating that they were working problems in order to have a chance at winning more money. In response to the second question, WHEN DID THE COMPUTER GIVE YOU MONEY?", Subjects 6 and 7 provided response indicating that correct answers were necessary in order to gain more money. Subject 10 did not respond to this question. These 3 students produced trend lines similar to those of Group 1 students. That is, they started performing somewhat slowly and gradually developed relatively stable rates during the 20 min of RT 30-s reinforcement (M = 12.8, 13.85, and 13.9 correct answers/min). Written responses, as well as rates and durations of correct problems/min produced by these 3 students, suggest that they each had generated fallacious rules regarding the programmed contingencies.

During this extinction phase, Subjects 6, 7, and 10 maintained responding (M = 13.79, 12, and 13.7) for another 14, 7, and 20 min, respectively. Upon exiting the program, the computer posted the question, "WHY DID YOU STOP?". Subject 6 indicated, "Because I got a little pain in my hand because I was typing so much." Subject 7 wrote, "because I wanted to do my school work". Subject 10 wrote, "That's all the money I want for today." As with the students in Group 1, none of the written responses by these 3 students seem to imply any recognition that reinforcement possibilities had ended after the first 20 min of the program.

Subject 8 ceased all computer-interactive behavior after the 3rd min, and Subject 9 stopped performing after the 8th min. However, neither of these students exited the program by typing the letter "N" to the prompt "CONTINUE?", apparently opting to simply watch the screen continue to provide noncontingent financial reinforcement approximately every 30 s. Prior to stopping problem solving, they averaged 7 and 13 correct problems/min, respectively. However, the program automatically ended after 5 min in which no key strokes were made. When the computer automatically terminated their sessions, subjects responded to the

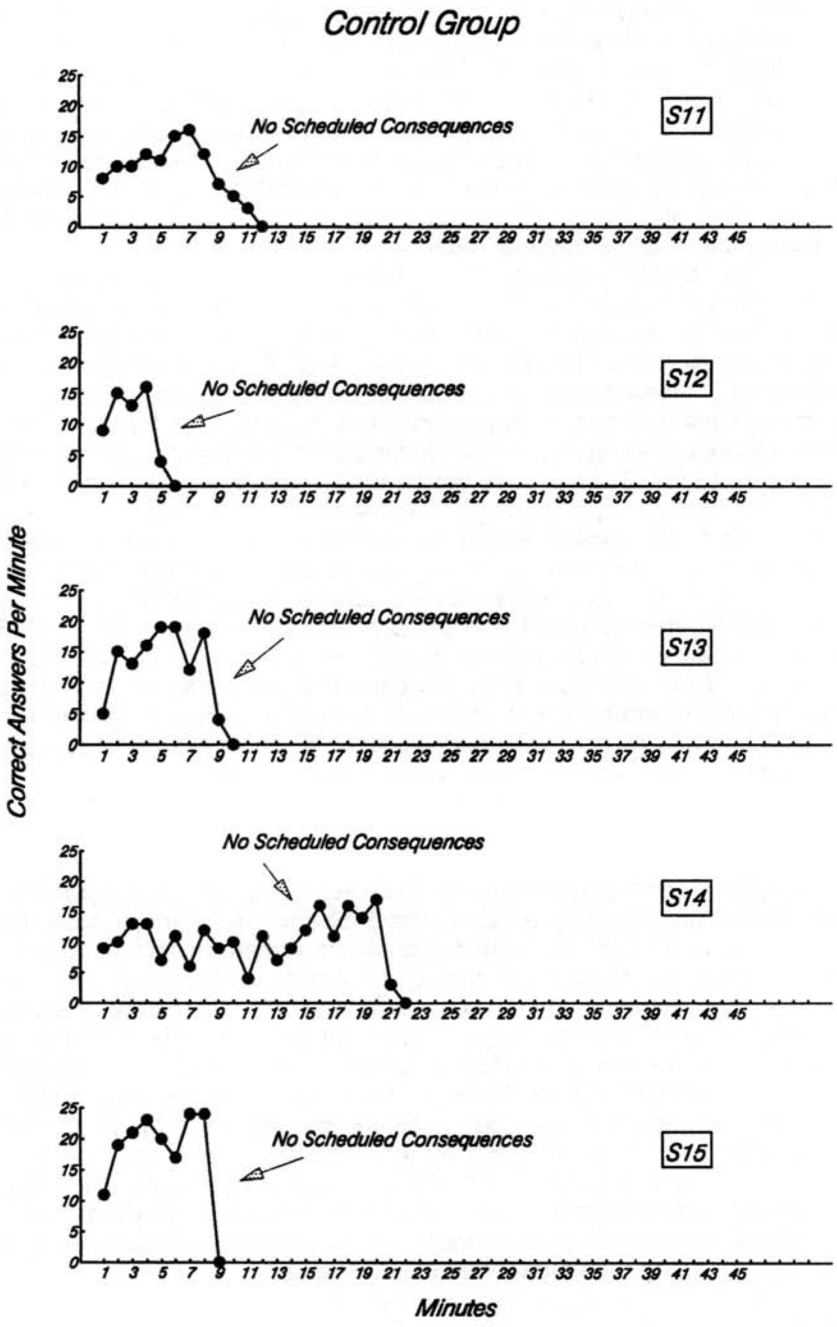

Figure 4. Frequency and duration of correct math problems for 5 subjects in the control group.

question regarding why they had stopped solving problems. Subject 8 demonstrated a clear understanding of the programmed contingencies by writing, "because I knew the problems and it was giving me money anyway". Subject 9 wrote, "I stopped because I got tired and some problems seem blurry." Although Subject 9 did not clearly specify in writing, her awareness of this ongoing noncontingent reinforcement, her failure to exit the program in favor of simply watching the screen deliver money according to the RT 30-s schedule suggests her appreciation of the program's "actual" requirements.

In the control group, 5 students did not have access to noncontingent financial reinforcement by way of the computer. Following the completion of every problem, the computer screen simply provided a continuing series of prompts to "CONTINUE?" followed by another problem if "Y" were typed. Data illustrated in Figure 4 suggest that these students were willing to perform problems at the computer for a period of time without benefit of any form of conspicuous "extrinsic" reinforcement. Subjects 11, 12, 13, 14, and 15 performed for respective durations of 12, 6, 10, 22, and 9 min, respectively, with means of 17.5, 9.5, 12.1, 10.85, and 17.66 correct problems/min, respectively. When the control group subjects exited the program, the computer screen posted, "WHY DID YOU STOP?", the subjects rendered comments suggesting that they were getting tired or bored with the process. For example, Subject 13 noted, "I can do these without any more practice." The rates and durations of problem solving by the control group students, as well as the closing commentaries of these students, suggest that doing multiplication problems, one after the other at the computer, may have *some* very limited "entertainment" value in and of itself.

Experiment 2

Experiment 1 demonstrated that even though no *response-dependent* contingency existed, the probabilistic relation between responding and RT reinforcement in conjunction with a coin toss graphic strengthened the efficiency of the reinforcement contingency. This was particularly conspicuous when comparing response rates and durations during the extinction conditions. Our earlier research (Ninness & Ninness, 1988) demonstrated increased resistance to extinction associated with FT time schedules; however, response-independent reinforcement was not arranged in conjunction with any form of second-order schedule in that study. Experiment 2 sought to analyze the effects of standard FT and second-order FT response-independent schedules. Based on the outcomes from Experiment 1, we anticipated one-directional increases in performance rates and durations associated with second-order response-independent reinforcement.

Method

Participants, setting, and apparatus. Six 5th-grade students, who did not participate in the first experiment, ranging from 10 to 11 years of age, were randomly assigned to one of two groups. Group 1 contained 1 male and 2 females. Group 2 contained 2 males and 1 female. No control group was employed; otherwise, the experimental preparations remained the same as those developed for Experiment 1.

Experimental design and procedures. Experiment 2 was designed to systematically replicate Experiment 1 by assessing the effects of second-order response-independent reinforcement when provided on FT schedules rather than RT schedules. As in Experiment 1, students were able to respond to multiplication problems by typing answers on the keyboard; however, for Group 1 students, response-independent reinforcement was delivered according to an RR 2 (FT 30-s:S). The probability of obtaining a match at the

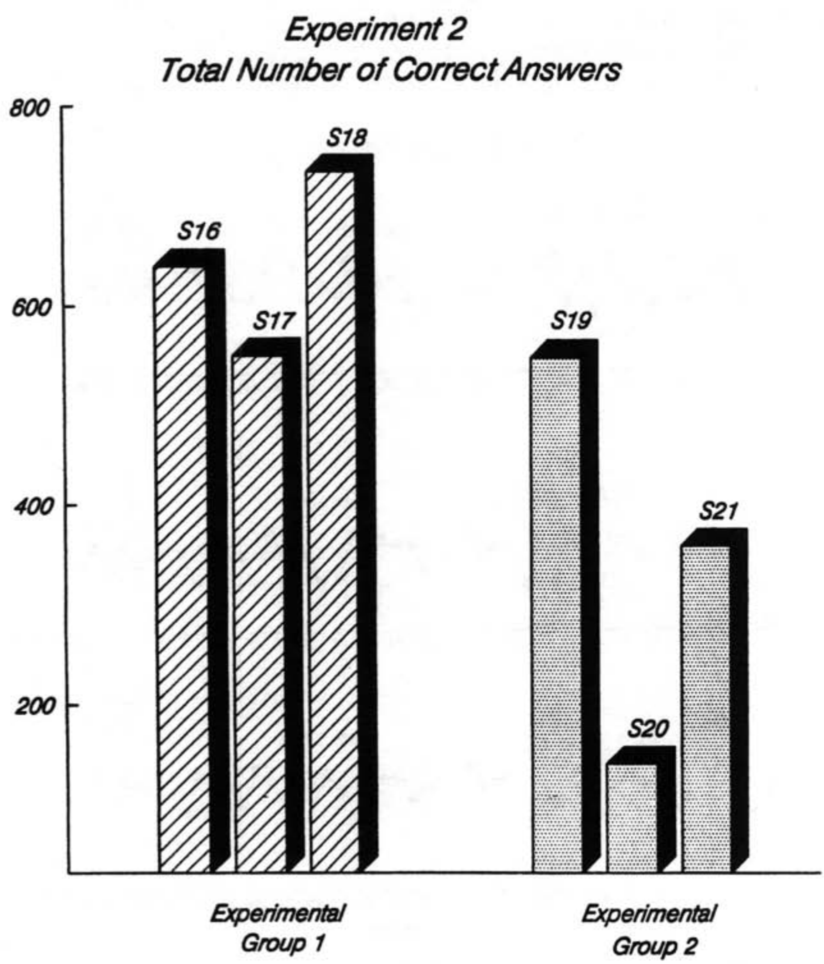

Figure 5. Total number of correct answers for subjects in both groups during Experiment 2.

end of every 30 s was 0.5 (mean reinforcement rate of 1/min). For Group 2 students, a standard FT 30-s schedule was employed (mean reinforcement rate of 2/min).

Results and discussion. As in Experiment 1, the group data were summarized by obtaining the total number of correct answers for each subject in each of the two experimental groups. Using randomization tests for nonrandom samples, a *t* test yielded a significantly reliable difference between groups ($p < .05$), with more problems solving in Group 1. Figure 5 illustrates the total number of correct answers for each subject in each group.

Individual-subject results were assessed in terms of problems-solving rate and duration within each student's experimental condition. Figure 6 displays data showing that all 3 students in experimental Group 1 performed multiplication problems at a relatively low rate during the first few minutes of RR 2 (FT 30-s:S) reinforcement. Because noncontingent reinforcement was provided every 30 s, it is very likely that relatively long intervals in which no responding occurred were

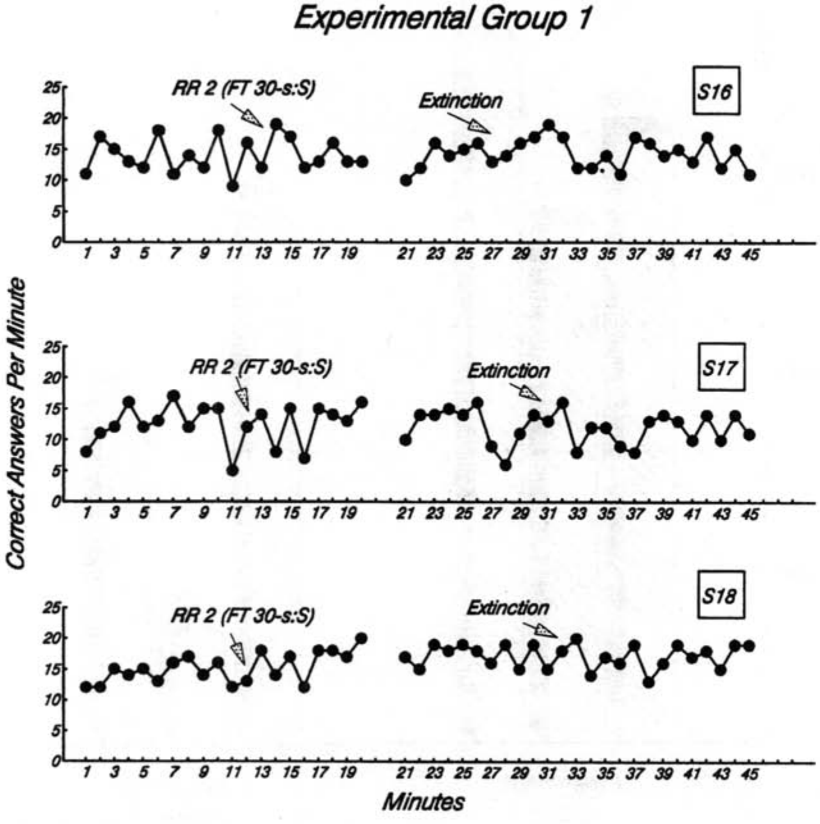

Figure 6. Frequency and duration of correct math problems for 5 subjects in Group 1 receiving second-order FT 30-s reinforcement.

correlated with the acquisition of financial reinforcement. However, as in Experiment 1, data from Group 1 students show fairly stable rates of responding, and some acceleration, across the first 20 min of RR 2 (FT 30-s) schedule (M = 14.05, 12.5, and 15.5 correct answers/min).

Student answers to the computer-posted questions at the end of the 10th min of the experiment are suggestive of their covert verbal impressions. When the computer posted the first question, "WHY ARE YOU DOING PROBLEMS?", Subjects 16 and 18 provided written responses alluding to a contingent relationship between problems solving and accessing to increasing monetary reinforcement. However, Subject 17 wrote, "I don't know." In response to the next question, "WHEN DID THE COMPUTER GIVE YOU MONEY?", all 3 subjects recounted the necessity of working math problems in order to get a chance at matching "heads" and "tails." In response to the third question, "DOES WORKING PROBLEMS QUICKLY SEEM TO HELP?", all students in Group 1 wrote brief answers in the affirmative. As in Experiment 1, written responses from Group 1 students seemed to superstitiously attribute the acquisition of reinforcement to the solving of multiplication problems.

Performance rates for Subjects 16 and 17 dropped slightly during the 11th min that followed questioning from the computer. All 3 students performed at relatively stable rates during the next 10 min of RR 2 (RT 30-s:S) schedule, and all 3 continued over the duration of the following 25 min in which the computer program had terminated the possibility of obtaining a match on HEADS or TAILS. As in Experiment 1, during this extinction period, the simulated coins flips continued according to the FT 30-s, but the acquisition of noncontingent monetary reinforcement ended. During this extinction phase of the experiment, Group 1 students only stopped performing multiplication problems when the computer program ended their sessions (M = 14.32, 12, and 17.2, correct answers/min, respectively). In response to the questions provided by the computer at the close of the sessions, all 3 subjects provided answers indicating that they stopped because the program ended. The written responses by Group 1 students seem to reflect the presumption that some form of response-based contingency had been in effect throughout the duration of the program. Likewise, their behavior appears to have followed this interpretation of the programmed contingencies.

Students in experimental Group 2 exhibited stable rates of problems solving during FT 30-s reinforcement (see Figure 7).

Subject 20 gradually slowed his performance rate (M = 10 correct problems/min) as he came into contact with noncontingent reinforcement. This student stopped all responding without exiting the program on the 15th min of FT 30-s reinforcement. Thereafter, he did not exit the program by typing "N" to the prompt "CONTINUE?" but simply allowed the computer to continue providing response-independent reinforcement at the end of every 30 s. This subject rendered an unequivocal recognition of the programmed contingencies in reply to the closing question, "WHY DID YOU STOP?". To this he stated, "because I was getting tired and I found out it gave me money anyway."

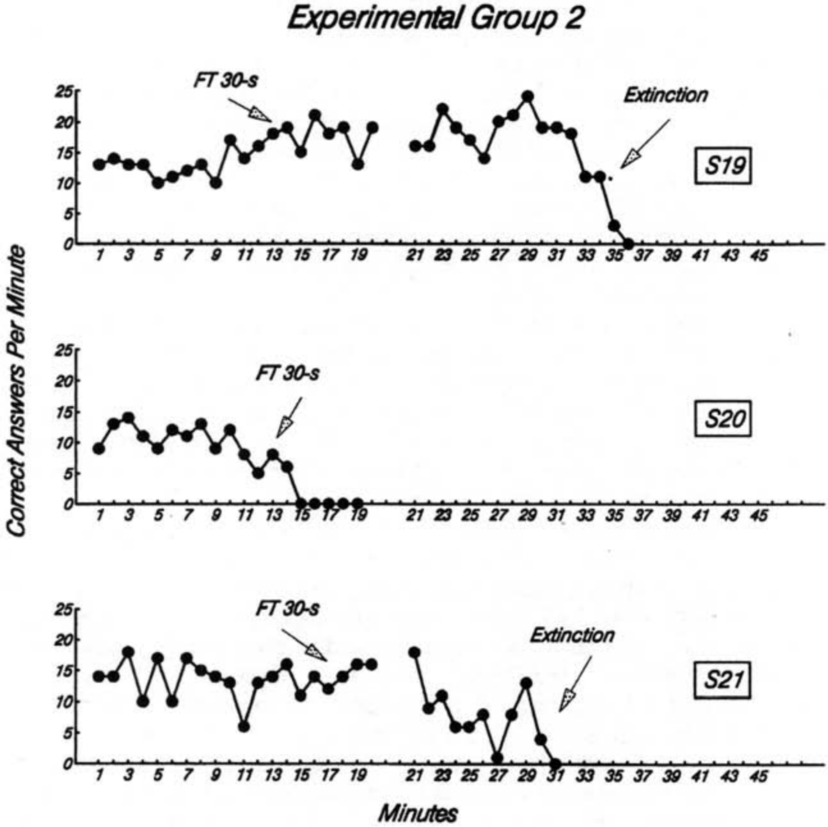

Figure 7. Frequency and duration of correct math problems for 5 subjects in Group 2 receiving FT 30-s reinforcement.

Subjects 19 and 21 averaged 14.9 and 13.7 correct answers/min during this time. At the end of the 10th min, these students provided answers to the computer-posted question, "WHY ARE YOU DOING PROBLEMS?". Apparently, Subject 19 did not completely understand the question when he responded by writing, "because I got faster." Subject 21 did not respond to this question. Replying to the second question, "WHEN DID THE COMPUTER GIVE YOU MONEY?", Subject 19 provided a more complex interpretation of the contingencies by writing, "after I completed a family of facts." Subject 21 rendered a somewhat distinctive explanation by writing, "when we go at a certain speed." Both of these accounts of the controlling variables represent the subjects' generation of "idiosyncratic" rules. Although these self-generated rules allude to different contingencies of reinforcement during the experiment, they are, nevertheless, consistent with the ways in which each of these students performed during the experiment.

Following computer questioning, data from Subject 21 demonstrates a brief decrease in her rate of responding during the 11th minute. Both Subjects 19 and 21 recovered their relatively stable rate of responding for the duration of the remaining 10 min of FT 30-s reinforcement. During extinction, these 2 students continued performing problems accurately for another 16 and 11 min (M = 15.63 and 7.64 correct problems/min), respectively, before exiting the program by typing "N" to the prompt "CONTINUE?". In response to the final question, "WHY DID YOU STOP?", Subject 19 responded, "because I had enough of these." Subject 21 wrote, "I was tired of doing this."

General Discussion

Although it is clear that some of our experimental subjects were able to identify the relatively subtle response independent-reinforcement contingencies, our results suggest that elaborate second-order response-independent reinforcers may have engendered elaborate and especially compelling interpretations of the programmed adventitious contingencies. Written responses from students in both experiments, obtaining reinforcement according to RR 2 (RT 30-s:S) and RR 2 (FT 30-s:S) schedules, during and after the experimental sessions, suggest that they "believed" that there was a "cause and effect" relationship between their performances and the likelihood of accessing monetary reinforcement via the coin toss graphic. The written responses from these students often detailed their anticipation of gaining access to reinforcement based on being able to match HEADS or TAILS as they performed multiplication problems. Of more empirical interest, both RR 2 (RT 30-s:S) and RR 2 (FT 30-s:S) schedules generated relatively higher rates and longer durations of unnecessary responding than standard RT or FT schedules. These outcomes were particularly dramatic during the extinction phase of both experiments. Four of the 5 students receiving RR 2 (RT 30-s:S) and all 3 of the students receiving RR 2 (FT 30-s:S) sustained performances over 25-min extinction conditions. Concluding comments by many of these students suggest that they might have been willing to continue working even longer if the program had not terminated. Indeed, our outcomes do not appear to indicate any distinction between the appetitive effects of RR 2 (RT 30-s:S) versus RR 2 (FT 30-s:S) schedules.

By comparison, most students in Group 2 of both experiments performed over shorter durations during the extinction phases that followed simple FT or RT schedules. Two of the students in Group 2 (Experiment 1) who obtained standard RT 30-s reinforcement and one of the students in Group 2 (Experiment 2) who received FT 30-s reinforcement ceased responding, without exiting the program, while these time-based reinforcement schedules were still active. After stopping their computer-interactive behavior and watching the screen deliver noncontingent reinforcement for 5 min, 2 of these 3 students provided written comments suggesting that they had "determined" that responding was unnecessary in order to gain access to an increasing amount of money provided by the computer. This outcome is consistent with the findings of Ninness and Ninness (1988) for subjects who had received reinforcement according to a FT 60-s schedule. Nevertheless, the remaining students who obtained standard RT 30-s or FT 30-s reinforcement did not appear to "identify" the programmed contingencies. Although they performed for shorter durations during extinction, their written comments during response-independent reinforcement do not suggest discrimination of the time-based reinforcement schedules while performing problems on the computer.

Outcomes from the control group speak to the limited but conspicuous demand functions of our experimental preparations. All 5 students in the control group of Experiment 1 performed at a gradually accelerating rate after the 1st min of the program. However, this was sustained for a comparatively brief period of time. Only 1 student continued correct problem solving for 22 min. The others all exited the program within 12 min.

Several caveats present themselves. To some extent, our results might be attributed to behavioral momentum (Mace, Hock, Lalli, West, Belfiore, & Brown, 1988). For example, Belfiore et al. (1997) have recently demonstrated that latency between more complex, low-preference (3-digit) multiplication problems could be reduced by having students initiate sessions with less complex, high-preference (1-digit) problems. Because our software generated a random series of multiplication problems requiring 2-digit responses, it is possible that any given subject might have initially encountered a series of relatively high-preference (comparatively effortless) problems that established some level of momentum. Nevertheless, baseline rates and durations for control subjects in Experiment 1 suggest that for most subjects, this was not sufficient to sustain problem-solving behavior over any extended period of time. Second, our standardized questions may have interacted with the generation of subjects' rules and responding; again however, these questions did not appear to enhance control subjects' performances. Indeed, the idiosyncratic and highly diversified content of student rules suggests limited interaction with the demand characteristics of our standardized questions. Nevertheless, *talk-aloud* protocols (e.g., Dixon & Hayes, 1998) might be used to rule out potential interactions in future research. Third, it may be argued that the coin toss graphic might function as well even without monetary exchange for winning. Whereas our preliminary findings from follow-up research do not support such an assumption, an alternative finding would not alter the apparent efficiency of reinforcers (monetary or symbolic) delivered via second-order response-independent reinforcement. Moreover, although winning with or without monetary exchange may be a reinforcing event, public response to state lotteries seems to suggest that winning *with money* is a somewhat more enticing contingency.

We anticipate that the extended durations and relatively high rates of problem solving demonstrated by Group 1 subjects in both experiments may be attributed to the rule-governed effects emerging from the second-order schedules. Such outcomes have long been recognized in nonverbal organisms. For example, Zimmerman (1957, 1959) shaped a FR 15 lever press to the sound of a buzzer as a discriminative stimulus that also functioned as a reinforcer for running an alleyway to obtain food. By incorporating this FR 15 lever press as a second-order operant, rats emitted thousands of lever presses and continued responding for over 20 hr during extinction. *Analogously*, long durations of problem solving by Group 1 students (in both experiments) may have been a function of the second-order relation between problem solving RR 2 (FT 30-s:S) and RR 2 (RT 30-s:S) established via the second-order, coin-toss graphic procedure. Interestingly, although Group 1 subjects in both experiments obtained only half as much reinforcement per unit of time as did Group 2 students, they performed an average of 287 more responses (nearly a factor of 2) over the course of their experimental sessions. Even though no *response-dependent* contingency existed, the probabilistic relation between responding and time-based reinforcement in conjunction with the second-order coin-toss graphic seems to have augmented the strength of the reinforcement contingency. Based on the comments of our subjects, at the very least we can reasonably assume that this procedure made reinforcement acquisition more enticing (see Ninness, Glenn, & Ellis, 1993, for a discussion).

It is noteworthy that, as with the findings of Ono (1993), even though the students' verbal interpretations of the programmed contingencies were not always consistent with the actual programmed contingencies, their interpretations of these contingencies were usually consistent with the way in which they interacted with the computer. Our results seem to suggest that more complex and enticing second-order response-independent consequences may engender elaborate and more compelling interpretations of "cause and effect" relationships that *are not* in effect. Future research might assess the effects of higher-order and multifaceted consequences on the generation of rules, decisions, and performances across a wider range of computer and natural environments.

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