[1]A LABORATORY STUDY OF FLUENCY TRAINING: EVALUATING EFFECTS OF OPERANT CONTINGENCIES ON CHOICE REACTION TIME.

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Practice on choice-reaction-time (CRT) tasks was used as a laboratory analogue to fluency (accuracy plus speed) training. The use of CRT tasks comprising well-learned stimulus-response relations allowed for the study of the acquisition of response speed without having to train response topography. In this systematic replication of Baron, Menich and Perone (1983), instruction-based and contingency-based procedures were compared as tools for promoting fluent responding on simple CRT tasks. Five female-undergraduate psychology students were trained first under instruction-based procedures, where they received response-by-response accuracy and end-of-trial accuracy and latency performance feedback. Next, all were switched into the contingency-based phase, where decreasing response latencies were progressively shaped. Subjects received both response-by-response and end-of-trial accuracy and latency performance feedback during this training phase. In the last stage of training, monetary reinforcement was added to the shaping procedure. Contrary to Baron et al. (1983), but consistent with the CRT literature, relatively large increases in rate-correct-per-minute (RCPM) were found under instruction-based training conditions. However, consistent with Baron et al., switching subjects into the contingency-based procedure resulted in increases in RCPM of a magnitude greater than was predicted had subjects continued training under instruction-based conditions. Also, RCPM continued to increase when monetary reinforcement was added to the contingency-based procedure. Overall, contingency-based training procedures appeared to most effectively promote fluent responding.

In mainstream education, slow, accuracy-intensive practice is the practice of choice for many reasons. One reason, for example, is that many educators believe that appropriate response speed develops with prolonged practice, and that by encouraging rapid, error-filled responding early in training, they are teaching poor study habits to their students that will be difficult to unlearn (Leonard & Newman, 1965). Similarly, teachers of learning disabled students strongly favour training students on "easy" tasks. With reading, for example, some educators advocate training learners to read material where they can maintain 95-98% accuracy. These educators argue that successful completion of a given task builds the student's "self-esteem" and increases their "motivation" to continue learning (Mercer & Mercer, 1989; Scott, Stoutimore, Wolking & Harris, 1990).

Precision teachers, a group of educational researchers and practitioners in the behavior analytic community, have challenged the assumptions behind accuracy-intensive practice. Precision teachers assert that response speed is a property of behavior, and, therefore, appropriate response speed should be directly trained (Lindsley, 1991; Binder, 1993). In fact, training, they assert, should continue until the task can be performed automatically or *fluently*. Behavioral fluency is defined as accuracy in combination with appropriate response speed (Binder, 1993). Fluent performance is making the appropriate response "smoothly and without hesitation" (Binder, 1995). Among the benefits produced by training to fluency, claim precision teachers, are greater retention of skill or learned material, higher resistance to distraction, and application (i.e., transfer of training)(Binder, 1993; Johnson & Layng, 1991). Precision teachers regularly report educational gains made by their students that are well above those typically found in mainstream education (e.g., see Johnson & Layng, 1991). The present experiment is a laboratory analogue to fluency training, which is typically conducted in the classroom. Our goal was to define an effective and efficient procedure for training fluency on a simple laboratory task. We chose to study the acquisition of fluency on *choice reaction time (CRT)* tasks (e.g., pressing one of three adjacent response keys in response to the presentation of one of three stimuli on a computer screen). By using relatively simple, overlearned S-R relations in a CRT paradigm, we were able to eliminate the acquisition of initial stimulus control of each stimulus over the correct response and to reduce the variability arising from both this source and that resulting from errors in typing words.

A number of CRT studies (e.g., Ackerman, 1988; Hale, 1969; Kristofferson, 1977; Pashler & Baylis, 1991; Rabbitt & Banerji, 1989; Schneider & Fisk, 1984) have demonstrated clear improvement in response latency (while accuracy was maintained at or above some minimum level) as a result of practice. However, because of procedural differences in duration of training, feedback contingencies, instructions, monetary incentives, to name a few, it was difficult to determine which variable(s) contributed meaningfully to fluent performance.

Baron, Menich and Perone (1983) observed that one important difference between human and animal reaction-time research is that animal researchers use contingency-based procedures (i.e., the target response is differentially reinforced), whereas human researchers use rule-governed procedures (e.g., giving verbal instructions) to promote rapid responding. To address this deficiency in the human CRT literature, they conducted an experiment to compare the relative effectiveness of instruction-based (I.B.) and contingency-based (C.B.) procedures for promoting fluency on a 2-choice CRT task. In this experiment, subjects trained first under I.B. procedures and were then switched into a C.B. training phase, where faster speeds were progressively shaped. Baron et al. reported that although response speeds increased during initial I.B. practice, greater relative improvement occurred during C.B. practice, when time limit contingencies were in place. Overall, these results suggested that the C.B. training was superior to I.B.

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training for promoting fluent performance, at least with CRT-type tasks. Unfortunately, however, instructional (S^D) and reinforcement (S^{R+}) effects may have been confounded, in that provision of reinforcement for slow responses during I.B. training may have inadvertently cued subjects to respond slowly, despite instructions to the contrary. The present experiment, a systematic replication of Baron et al. (1983), was conducted to make an unconfounded comparison between I.B. and C.B. procedures as tools for promoting fluency on simple CRT tasks.

METHOD

Subjects. Five female-undergraduate psychology students participated in this experiment.

Apparatus. CRT training occurred on an IBM-compatible computer using a program called ***Speeded Discrimination Training*** or ***SDT***.

CRT Tasks. There were two CRT tasks. The *number* CRT task was comprised of three stimuli ("zero," "four," and "nine"), each of which was paired with a different response key (3-key response box). The *category* CRT task was comprised of 15 stimuli, five exemplars from each of three semantically unrelated categories (see Table 1); thus five stimuli were paired with each response key.

Procedure.

Trials and Sessions. A training trial consisted of 20 seconds of stimulus presentations and responses to stimuli. Each day subjects completed three 15-trial blocks of training. Subjects completed five (daily) training sessions per week for between six and eight weeks.

Training. Three subjects trained on the category CRT task (S1, S2, & S3), while the remaining two subjects (S4 & S5) trained on the number CRT task. Prior to training, subjects received a general overview of CRT training. Subjects were told that a series of stimuli would be presented to them on the computer screen, and they had to learn to press the key (on the 3-key response box) paired with each stimulus. Training occurred in three phases:

Phase A - Instruction-based training. During this initial training phase, subjects were instructed to always be trying to decrease their response latency while keeping their percent of correct responses above 90%. They received response-by-response accuracy and end-of-trial accuracy and latency feedback.

Phase B - Contingency-based training I. During this phase, shorter (i.e., faster) response latencies were progressively shaped. Here subjects were instructed to always be trying to decrease their response latency while keeping the percent of correct responses that met the latency criterion above 85%. In addition to Phase A feedback, subjects received response-by-response latency feedback.

Phase C - Contingency-based training II. During this final training phase, monetary reinforcement was introduced and made contingent upon the percentage of correct responses (above 85%) that met the latency criterion. In addition to Phase B feedback, end-of-trial earnings were scored.

Reversals. In order to determine the effects of the removal of the shaping procedure, two subjects (S2 & S5) experienced reversals (ABAB) before moving into the final training phase.

Data analysis.

Dependent variable: The relative effectiveness of the I.B. and C.B. procedures for training fluency on CRT tasks was determined by studying changes in each subject's ***rate-correct-per-minute*** (**RCPM**) across training. **RCPM** was calculated by dividing the number of correct responses per trial by the total response time (calculated by summing the latencies across all correct and incorrect responses and converting this value to seconds) and multiplying that value by 60.

To make an unconfounded comparison between I.B. and C.B. training, it was necessary to study log-log transformed RCPM data in addition to looking at the raw RCPM scores.

Why log-log transformed data? According to the power law of learning, which applies to reaction time data, large practice effects develop early in training followed by progressively smaller improvement as training continues (Anderson, 1995; Newell & Rosenbloom, 1981). Given the nature of reaction time data, then, it is not appropriate to compare the relative effectiveness of different training procedures by comparing the rate of improvement across different training phases, because rate of improvement during later training phases will *necessarily* by smaller than that found earlier in training. However, because log-log transformations of CRT data fall on a straight line (Newell & Rosenbloom; Stevens & Savin, 1962), it was possible to assess the relative effectiveness of I.B. and C.B. training procedures by comparing the actual rate of improvement during C.B. training with the rate of improvement predicted under continued I.B. practice (Kazdin, 1982, p. 333-336). That is, having log-log transforming the raw (nonlinear) RCPM data, it became possible to make an assessment of the relative effectiveness of I.B. and C.B. training procedures by projecting the regression line which described the rate of improvment under I.B. conditions through the C.B. data and assessing how well this regression line described the C.B. data. The premise was that if training under C.B. procedures has had no effect on performance, then the resultant data should follow the same linear trend as that evident under I.B. conditions. If, alternatively, the C.B. procedure has affected performance on the CRT task, then the resultant data should deviate from the linear trend which describes the I.B. data. To summarize, the following analysis was done (separately for each subject) to assess the relative effectiveness of the I.B. and C.B. training procedures:

- the RCPM data were log-log transformed
- a regression line was "fit" through I.B. data and then projected through the C.B. data
- conclusions were drawn based upon the "goodness-of-fit" of the I.B. regression line to the C.B. data.

RESULTS

The following is a summary of findings across all subjects in this experiment. Raw and log-log transformed RCPM data for the category subjects are located in Figure 1; those for the number subjects are located in Figure 2. Looking at the raw RCPM data, clearly, all subjects demonstrated greatest

improvement very early in the I.B. training phase. (Notice the large increase in RCPM over the initial 2-3 days of training.) Also, continued though more gradual increases in RCPM were found throughout the remainder of I.B. training. Next, as illustrated by the log-log transformed RCPM data, when switched into the initial C.B. training phase, all subjects demonstrated better-than-predicted performance (i.e., C.B. data fell above the I.B regression line). Thus, for all subjects, RCPM scores increased at a faster rate than that predicted under continued I.B. practice. Specifically, one subject (S4) demonstrated greater-than-predicted improvement immediately; three subjects (S1-S3) demonstrated greater-than-predicted improvement early in the phase; and, the remaining subject (S5) demonstrated greater-than-predicted improvement towards the end of the C.B. training phase. Although the duration of the reversal phases was too brief to allow conclusions to be confidently drawn from the data, there was some suggestion that the removal of the shaping procedure disrupted performance (e.g., S5's RCPM began decreasing towards the end of the *return-to-Phase-A* training phase). Finally, the addition of monetary reinforcement to the C.B. training procedure, while appearing to increase subject "motivation" (Ss expressed a willingness to continue training beyond the predetermined duration of training), did not meaningfully affect the rate-of-increase of RCPM. That is, RCPM continued to increase, but at a rate comparable to that found during the initial C.B. training phase.

CONCLUSION

In this experiment, instruction- and contingency-based procedures were compared as tools for promoting fluent performance on simple CRT tasks. The following conclusions were drawn from the data. First, the present data confirm the assertions made by CRT researchers that I.B. practice on simple CRT tasks produces large initial, followed by continued though more gradual improvement in performance as training continues. Second, the present data also confirm Baron Menich and Perone's (1983) finding that, relative to I.B. procedures, C.B. procedures more effectively promote fluency on CRT tasks. That is, when switched from I.B. to C.B. training, all subjects demonstrated *greater* improvement than was theoretically predicted to occur under continued I.B. practice.

As discussed earlier, training to fluency on academic and non-academic tasks is necessary and worthwhile, producing many additional benefits to the learner beyond simple proficiency on the trained task. The present experiment confirms the assertion that C.B. procedures, like shaping speed, are effective tools for promoting fluent performance, at least on CRT-type tasks.

Recall that despite our stringent accuracy requirements (e.g., 90% correct in Phase A), clear and continued increases in response speed were demonstrated by all subjects throughout training. These data, in combination with our pilot data (where emphasis was place on speed of responding, and level of improvement for all subjects was poor), suggest that, at least for CRT training, it may appropriate to stress both speed and accuracy throughout training. Interestingly, this assertion is contrary to the arguments made by some precision teachers (e.g., Lindsley, 1990; Lindsley, in Potts, Eshleman, & Cooper, 1993; Bower & Orgel, 1981) that placing too much emphasis on accuracy impedes the acquisition of fluency.

Clearly, this study has contributed to the precision teaching literature by offering evidence to support the assertion that contingency-based procedures, like shaping speed, are effective tools for promoting fluent performance, at least on CRT-type tasks. In addition, and perhaps of greater importance, the present study has raised awareness of the potential benefits of moving some of the fluency research from the classroom into the laboratory (see also Grabavac, Goldwater & Acker, 1996B).

Table 1
Category task stimuli.

Animal	Colour	Sport
deer	blue	golf
tiger	green	track
horse	white	tennis
sheep	purple	hockey
rabbit	yellow	soccer

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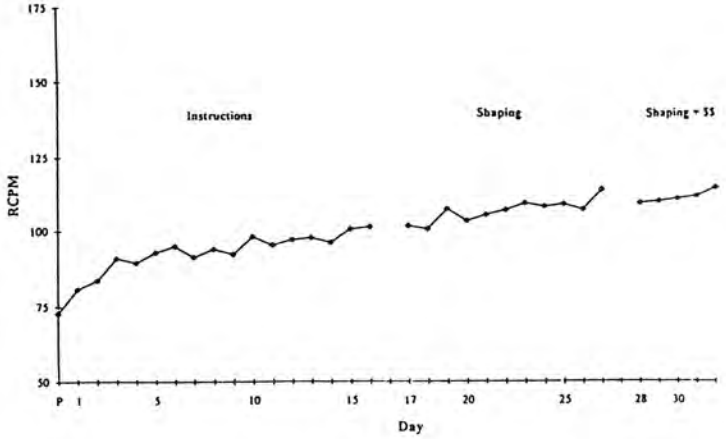
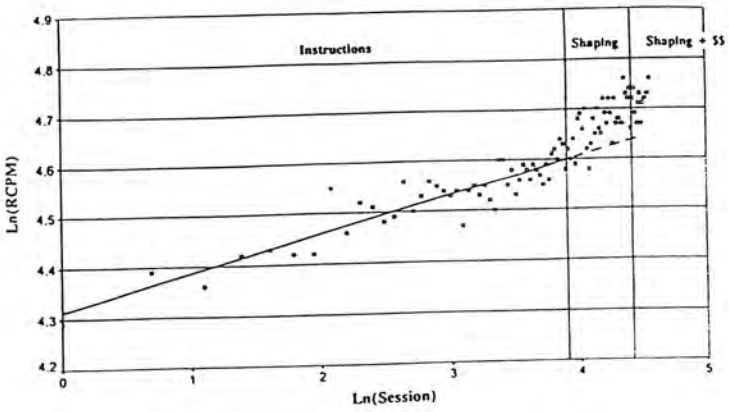


Subject 1's raw RCPM data



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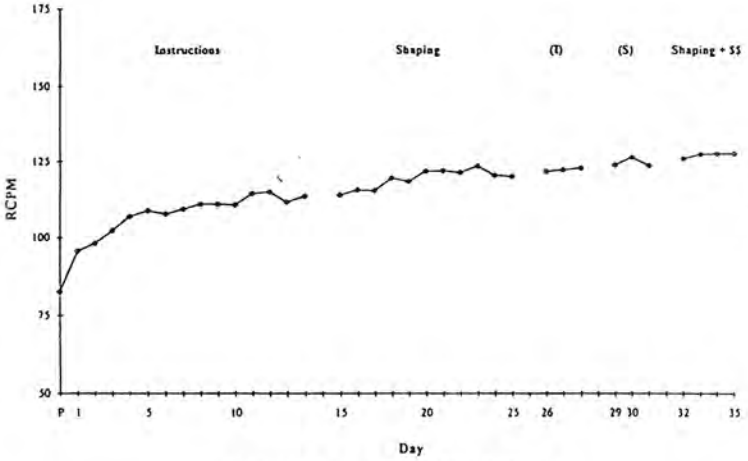

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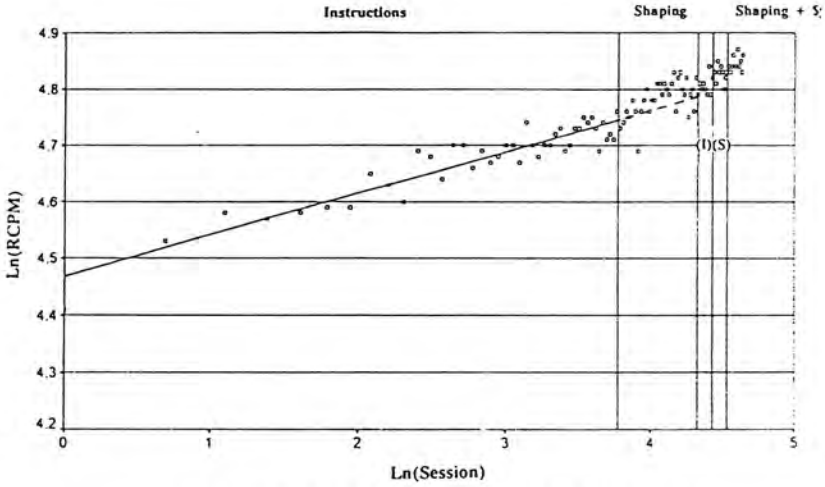

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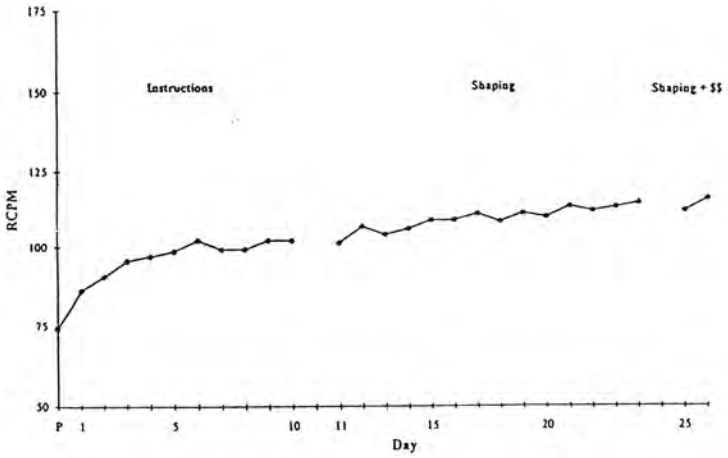

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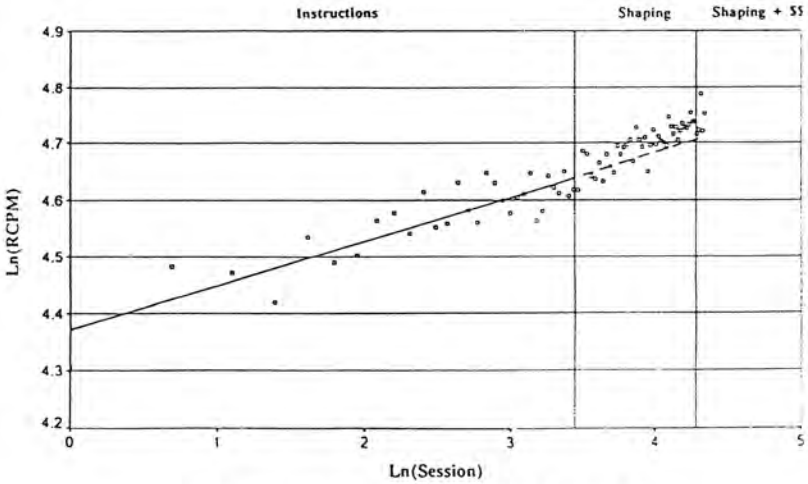
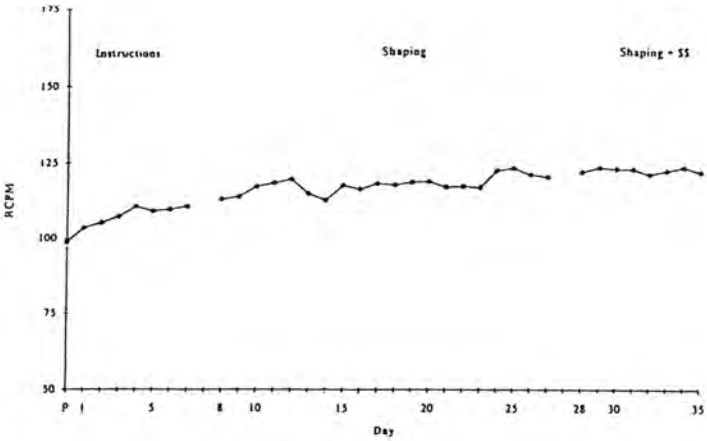
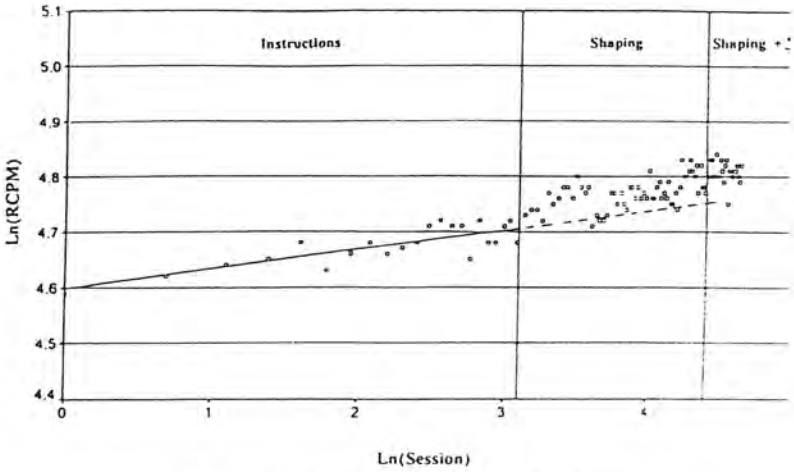


Subject 3's log-log transformed RCPM data

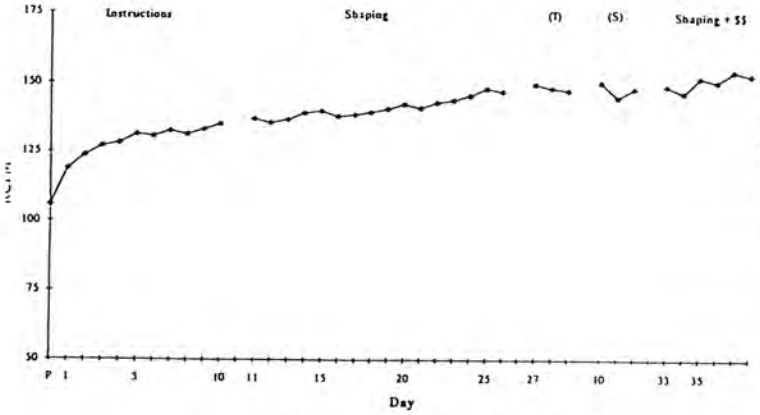
Figure 1. Raw and log-log transformed rate-correct-per-minute data for S1-S3, who trained on the category task. The raw RCPM data illustrate the large initial improvement found under early I.B. training. The log-log transformed RCPM data demonstrate that subjects made greater relative improvement under C.B. conditions (i.e., C.B. data points fall above the I.B. regression line) relative to performance under I.B. training conditions.



Subject 4's raw RCPM data



Subject 4's log-log transformed RCPM data



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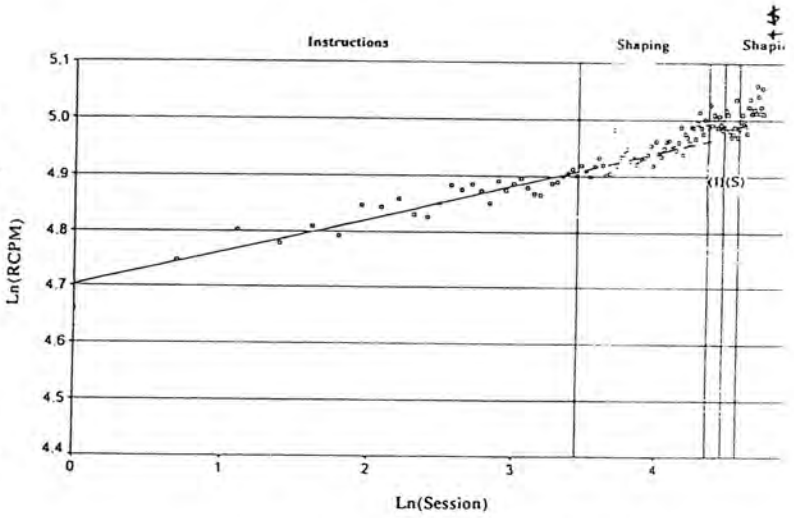

Subject 5's log-log transformed RCPM data

Figure 2. Raw and log-log transformed rate-correct-per-minute data for S4-S5, who trained on the number task. The raw RCPM data illustrate the large initial improvement found under early I.B. training. The log-log transformed RCPM data demonstrate that subjects made greater relative improvement under C.B. conditions (i.e., C.B. data points fall above the I.B. regression line) relative to performance under I.B. training conditions.