Extinction after partial reinforcement: Predicted vs. judged persistence

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The partial reinforcement extinction effect (PREE) (i.e., increased persistence following partial reward) is one of the most important generalizations from experimental studies of learning. Many theories of PREE assume that it involves cognitive and emotional mechanisms, but investigations of PREE have focused almost exclusively on behavioral measures. Four experiments with human adults investigated whether PREE is also reflected in cognitive measures. Independent groups of subjects learned an instrumental response under CRF vs. PRF contingencies, and then predicted (Experiments 1, 2, and 3) and/or judged (Experiments 3 and 4) their own persistence under extinction conditions. Predictions of persistence were unrelated to prior continuous or partial reinforcement contingencies (Experiments 1, 2, and 3), but subsequent judgments of persistence behavior were accurate (Experiments 3 and 4). These results indicate that increased persistence due to occasional reward is not well represented cognitively prior to its behavioral manifestation, but it is well represented after that manifestation. Possible explanations and implications of this apparent behavior–cognition dissociation are discussed.

Key words: Judgment of persistence, prediction of persistence, persistence, extinction, PREE.

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When reinforcers have been distributed intermittently rather than continuously during training, subsequent extinction persistence is typically enhanced. This is the partial reinforcement extinction effect (PREE), first described by Skinner (1938) and Humphreys (1939a) and later confirmed in a large number of studies (e.g., Mackintosh, 1974). PREE most reliably occurs in comparisons of separate groups of subjects exposed to continuous or partial reward contingencies (e.g., Capaldi, 1994), and has been observed in a number of species, including humans (e.g., Pittenger, Pavlik, Flora & Kontos, 1988; Svartdal, 2000a).

In experimental studies of PREE, persistence has been measured in terms of behavioral indices such as running speed (e.g., Capaldi, 1994), response rate (Skinner, 1938), or slope of response rate reduction (Nevin, 1988). However, while such measures are convenient in studies using non-human subjects, a wider range of measures is available for human studies. Many influential theories of PREE (e.g., Amsel, 1958, 1994; Capaldi, 1967, 1994; Lawrence & Festinger, 1962; Weiner, 1986) assume that cognitive and emotional mechanisms are involved in persistence effects. It may therefore be of great interest to explore alternative measures that focus on cognitive or emotional states. Such alternative measures of persistence effects should be expected to reflect differential effects of learning contingencies in the same manner as behavioral measures. One might even argue that measures that focus more directly on cognitive and emotional mechanisms assumed to be involved in PREE may be more sensitive than behavioral measures, and that they therefore should be preferred when feasible. However, at present we do not know whether alternative measures of PREE in fact correlate with behavioral measures, or even whether such measures reflect differential learning contingencies at all. The present study therefore explored these issues.

In humans, cognitive and emotional measures might focus either on the assumed processes or states specifically (e.g., perceived frustration during acquisition), or on the outcomes of such processes or states (e.g., the effects of frustration on perceived persistence). The present experiments chose the latter strategy, and attempted to measure persistence in simple judgments and predictions. Independent groups of subjects learned an instrumental response under continuous reinforcement (CRF) or partial reinforcement (PRF) contingencies, and then estimated their own persistence under no-reward conditions. Persistence estimates can be given following acquisition, but before extinction onset (i.e., predictions of persistence), or following extinction (i.e., judgments of persistence). The present experiments included both strategies. Since the learning contingencies used in these experiments reliably generate a between-groups behavioral PREE (Svartdal, 2000a), differential effects of these contingencies should also be expected in predictions and judgments. "Cognitive sensitivity" to those contingencies would imply that subjects predict or judge persistence in accordance with behavioral persistence observed in corresponding situations; insensitivity would imply that predictions and judgments are not correlated with behavioral persistence.

The presence or absence of cognitive sensitivity to differential persistence effects of learning contingencies is of considerable interest. For example, demonstration of a cognitive PREE would undoubtedly strengthen the assumption that cognitive mediation is important in behavioral adaptation to learning contingencies (e.g., Shanks & St. John, 1994). If adaptation to learning contingencies is regularly associated

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with verbalization of the contingency, crucial aspects of the learning process are available to conscious apprehension (e.g., Chatlosh, Neunaber & Wasserman, 1985; Shanks & Dickinson, 1991). Hence, reliable behavioral effects of contingencies, including extinction effects, should also be reflected in cognitive and verbal measures.

Cognitive sensitivity to learning contingencies is of interest even if explicit verbalization is not involved in contingency adaptation. Cognitive sensitivity to learning contingencies need not be a consequence of explicit awareness of those contingencies, and cognitive sensitivity need not be explicit. Just as many measures of cognitive processes are of assumed, non-observable constructs or processes rather than of consciously available content (e.g., Nisbett & Wilson, 1977), cognitive sensitivity to learning contingencies may well be unavailable to explicit report. Thus, predictions and judgments of contingency effects should be sensitive as a measure of extinction effects regardless of whether subjects are able to verbalize the learning contingency or not. For example, following partial reinforcement, a subject might demonstrate both increased behavioral persistence *and* increased cognitive persistence, and both effects may be measured without the person being able to explicitly report this persistence.

Very few investigations have actually attempted to measure subjects' extinction persistence in terms of cognitive measures. Humphreys (1939b) performed one of the few relevant studies. In a classical conditioning procedure with 24 trials, subjects wrote down, for each trial, whether the unconditioned stimulus (US) would occur following the conditional stimulus (CS). The verbal anticipation of the US thus served as the conditioned response (CR). Two reinforcement conditions, 100% or 50%, were arranged. Under 12 subsequent extinction trials, the 50% group demonstrated slower extinction of the anticipation response than the 100% group. Although it may be questioned whether the CR in this situation was "cognitive" or not, these results indicate that cognitive measures in terms of predictions of the PREE are feasible.

In indirect studies of this question, Svartdal (2000b) tested "cognitive sensitivity" to manipulations of reward information in judgments of persistence under instrumental contingencies. Naïve subjects read scenarios of simple reward situations, and were informed that behavior generated in those situations was now no longer rewarded (i.e., extinction). Information about frequency of reward (continuous vs. partial) was manipulated over independent groups. If experience from natural reward situations generates extinction effects comparable to those observed in experimental studies, we should expect subjects reading scenarios describing continuous reward outcomes to judge extinction persistence as lower than subjects reading scenarios describing partial reward outcomes. However, naïve subjects did not reveal sensitivity to contingency information manipulations in their persistence judgments. Regardless of information about reward rate, extinction persistence judgments were identical across groups.

Since the Svartdal (2000b) study assumed the existence of persistence effects from extended experience with natural reward contingencies, the negative finding from that study can be interpreted as either the absence of cognitive representations of accumulated experience with reward situations, or as the absence of the relevant experience itself. Clearly, if subjects had explicit experience with relevant learning contingencies, and still did not demonstrate a cognitive PREE, the latter interpretation could be excluded. The experiments of the present study provided subjects with such experience and therefore represent a more direct test of a cognitive sensitivity hypothesis. Independent groups of subjects learned an instrumental response under CRF vs. PRF conditions, and then predicted (Experiments 1, 2, and 3) and/or judged (Experiments 3 and 4) their own persistence under subsequent no-reward conditions. Given the common finding that behavioral sensitivity to learning contingencies is closely correlated with cognitive measures (e.g., Chatlosh *et al.*, 1985; Shanks & Dickinson, 1991), it is reasonable to expect that a between-groups cognitive PREE should appear both in predictions and judgments. On the other hand, the negative findings from experiments on persistence judgments (Svartdal, 2000b) indicate the opposite expectation.

EXPERIMENT 1

Experiment 1 exposed independent groups of subjects to continuous vs. partial reward contingencies. Immediately after the learning phase, subjects predicted their own persistence under no-reward conditions. Behavioral extinction data from this experimental situation demonstrate a reliable between-groups conventional PREE (e.g., Svartdal, 2000a, Experiment 2).

Method

Subjects. Participants were 31 students at the University of Tromsø. The subjects were recruited at the university campus and randomly allocated to experimental conditions prior to arrival in the laboratory.

Apparatus. The experiment took place in a sound-attenuated room containing a table with stimulus-presentation and response-recording equipment. Two push-buttons mounted on force-sensitive transducers (Hottinger Baldwin U1 Z6-4) recorded subject responses. The push-buttons were located 10 cm apart on a console (30 cm by 30 cm) located on a small computer table (60 cm by 60 cm), with force transducers hidden under the table. A computer sampled the output from the transducers and computed the location of the individual responses (left or right button) from the peak force applied to the buttons during specified response periods.

A vertical metal console (33 cm by 33 cm) with two transilluminated keys (used as lamps) was located on the table behind the response buttons. The three colors of each key (red, green, and orange) were under computer control and signaled the start of a trial (orange light on both keys), the schedule component (green or red lights), and feedback of the correct solution (flashing orange light on both keys). The room further contained a loudspeaker located to the right of the subject. The experiment was controlled, and all data recorded and analyzed, by custom-made ASYST software (Svartdal & Flaten, 1993) run on a personal computer located in an adjacent room.

Procedure. Subjects were instructed to learn and apply a response sequence rule based on feedback for correct and incorrect responding. In each trial, two computer responses were first presented on the right or left lamps on the vertical console. In specified response periods following the two computer responses, subjects then emitted two presses, either of which could occur on either of the right and left subject response buttons. Correct sequences were followed by feedback messages according to the schedule in operation; incorrect sequences had no consequences. The subjects were asked to obtain as many feedback messages as possible.

Two orange lights on the keys of the console for 0.6 s signaled the beginning of each trial. After a 1 s pause, the two computer responses were presented. Each lasted 0.5 s, with 0.5 s pauses between, and was accompanied by a 1,000 Hz tone. After a 0.7 s pause, the first subject response was prompted by the 1,000 Hz tone for 1 s, and then, after a 0.5 s pause, the next response was prompted for 1 s. The feedback message consisted of five flashes (each lasting 0.5 s) of the orange light on both keys, accompanied by five 500 Hz sine tones (each also lasting 0.5 s). Each trial lasted about 7 s. The experimental session consisted of 180 trials with 3 s pauses between each trial, and lasted about 40 minutes.

Two different computer responses alternated throughout the experiment. One was indicated by green computer responses, the other by red computer responses. The significance of the red and green computer responses was explained by telling the subject that "each color may signify a particular solution method." However, in the present experiment the red and green computer responses implied feedback presentation with the same probability, and the same rule was functional under both components.

The response–outcome contingency always related to the position of button presses (i.e., left or right presses) and required that the two subject button presses reversed (transposed) the sequence of the two computer responses within the same trial. For example, the subject response sequence LR would satisfy the criterion if the initial computer responses were RL. Similarly, if the computer-generated responses were RR, the appropriate presses would be LL. The computer responses for all trials were generated according to a random algorithm from the same seed, and all subjects thus received the same sequence of computer responses. Since the computer sequences varied throughout the experiment, formulation and application of the functional rule required sustained attention.

The probability of feedback for correct responding was manipulated between groups. Different groups of subjects received feedback for correct response sequences with probabilities of 100% (CRF) and 60% (PRF). The 60% value for the PRF condition was chosen because it is reliably associated with increased extinction persistence (Svartdal, 2000a).

Behavioral data. Response sequences that matched the feedback criterion – trial *n* reversals – were summed over blocks of five trials. Since there were four possible combinations of L–R sequences within each trial (LL, LR, RL, and RR), responding would satisfy the criterion by a chance probability of 0.25 within a given trial. Over five trials, random responding would translate into a hit rate of 1.25; perfect adaptation to the criterion would result in a hit rate of 5. These data were subjected to ANOVA according to a condition (CRF vs. PRF) × trial blocks (18) design; predicted differences in asymptotic levels were tested by contrast analysis (Keppel, 1991).

Questionnaire data. Immediately following the acquisition trials, the subject was asked to answer the following question: *"How many rewards for correct responses did you receive during the experiment?"* This question was included to measure any group differences in estimated reinforcer rate, and thus represented a manipulation check as well as a contingency sensitivity measure. Subjects selected from a fixed number of alternatives (10–100, 10 options in increments of 10) for each of the two red and green schedule components. Separate questions for the two green and red contingencies were asked to make sure that subjects in fact judged the reinforcer rates under both contingencies as equal.

Subjects then were asked the following question: *"We stopped the experiment after a short period in which you did not receive the usual feedback for correct answers. How many times do you believe that you would continue your ordinary correct answer until you would give up and turn to alternative response patterns?"* Because acquisition and extinction data have been analyzed in blocks of five trials in previous research applying this experimental situation (Svartdal, 2000a), a similar "resolution" for the persistence judgments was used. Thus, persistence predictions were given by selecting a response number from 5 to 40 (in increments of 5).

Results

Acquisition

Examination of the acquisition data revealed that subjects established functional responding in a gradual manner, with a lower asymptotic level in the PRF condition. The ANOVA showed a significant effect of condition, $F(1, 29) = 7.45, p < 0.05$, of trial blocks, $F(17, 493) = 18.07$, $p < 0.001$, and of their interaction, $F(17, 493) = 1.96, p < 0.05$. The acquisition data are shown in Fig. 1. A planned comparison of the PRF vs. CRF condition asymptotic response levels (final ten acquisition trial blocks) indicated a significant difference, $F(1, 29) = 7.59$, $p < 0.025$; the means were 4.3 in the CRF condition, and 3.2 in the PRF condition. These analyses demonstrate that the feedback manipulation produced reliable effects, and that there was a reliable group difference in asymptotic response rates.

Subjects correctly judged the reinforcer rates under the red and green component schedules to be identical. Since the questions were formulated as judgments of separate components, judgments of reinforcer rates on each component were summed to represent an overall judgment of reinforcer rate.

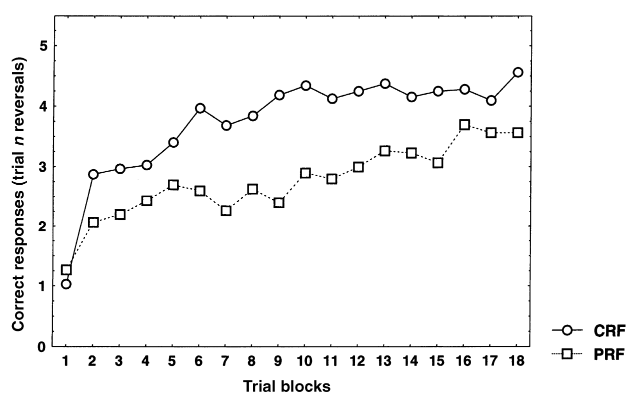

Fig. 1. Acquisition of the instrumental response (trial *n* reversals) over trial blocks in the CRF and PRF conditions in Experiment 1.

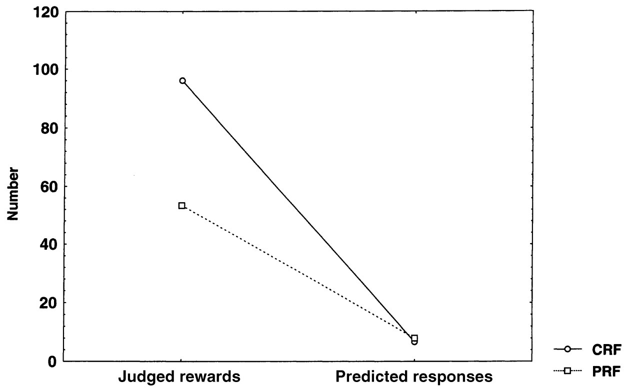

Fig. 2. Judged number of rewards under acquisition (left) and predicted number of responses under extinction (right) following exposure to CRF and PRF contingencies in Experiment 1.

An ANOVA of these data revealed a significant effect of the rate manipulation, $F(1, 29) = 11.35$, $p < 0.005$, reflecting that subjects in the CRF condition judged the reinforcer rate to be higher (mean = 95.0) than subjects in the PRF condition (mean = 53.3). The actual reinforcer rates were higher in the CRF condition (mean = 134.1) but almost identical to the judged rates in the PRF condition (mean = 56.3). Thus, although subjects in the CRF condition somewhat underestimated the reinforcer rates, sensitivity of judgments to the rate manipulation was evident over the two groups.

Predicted extinction persistence

In response to the persistence question, there were no group differences. The respective means were 6.7 in the CRF condition vs. 8.0 in the PRF condition, $F(1, 28) = 1.00$, $p > 0.33$. Thus, all subjects judged persistence to be low, but the immediately preceding learning history did not affect their predictions. These data are shown in Fig. 2.

Discussion

The main finding of the present experiment was that subjects did not demonstrate cognitive sensitivity to the effect of CRF vs. PRF contingencies when they predicted their own persistence under no-reinforcement conditions. Comparable behavioral data from this experimental situation (Svartdal, 2000a) show that subjects respond in accordance with a conventional PREE. Such between-group behavioral differences emerge reliably even with small groups, and are observed regardless of analysis method (i.e., absolute number of extinction responses; slope of the extinction curve). Thus, while button-pressing behavior in this situation conforms to a standard PREE, there were no parallel extinction effects in predictions.

The lack of sensitivity of persistence prediction to learning history contrasts with the sensitivity of judgments and behavior to the reinforcer rate manipulation. First, subjects exposed to the CRF condition correctly judged the number of reinforcers during training to be significantly higher than subjects in the PRF group. Second, subjects demonstrated a significantly higher acquisition response rate in the CRF condition compared with that observed in the PRF condition. Both measures also correlated well with arranged contingencies. The insensitivity of persistence predictions to the reward rate manipulation deviates from this pattern and indicates that subjects made their persistence predictions with no apparent reference to the preceding learning experience. The present data therefore suggest a dissociation between behavioral and cognitive measures of extinction persistence.

This conclusion hinges on the validity of the prediction measure of persistence. By its very nature, this measure must be of a possible but not yet demonstrated response "reserve." But measurement of this hypothetical reserve may easily be affected by the description of changed contingencies. Thus, when subjects were asked to predict persistence under no-reward conditions, it may be that description of those changed conditions determined predictions equally over conditions. Also, the changed conditions were only implicitly related to the prior learning conditions. Hence, if subjects interpreted the prediction task in terms of reinforcement being discontinued, lack of sensitivity of predictions to the preceding learning contingencies may simply reflect a common understanding among subjects of that fact. Thus, low persistence is the logical outcome, regardless of prior learning history. Experiment 2 therefore replicated Experiment 1 with improvements and expansions in the prediction measure.

EXPERIMENT 2

Method

Subjects. Participants were 30 students (mean age = 24 years) at the University of Tromsø. None had previous experience with the experimental task. The subjects were randomly allocated to experimental conditions prior to arrival in the laboratory.

Apparatus and procedure. The apparatus and procedure were identical to those of Experiment 1, except that inquiry about extinction persistence was now formulated as follows: *"We terminated the experiment when you had acquired a functional rule. Imagine now that the experiment had continued just like before, but that there was no feedback for correct answers. You did not know why; what happened was that feedback stimuli were no longer presented when you gave your answers. How many times do you think that you would have repeated your correct response?"*

In this manner, predictions were explicitly related to the preceding learning history, and it was emphasized that participants should take into account that changed conditions were detected over successive trials. Further, because the extinction prediction data of Experiment 1 tended to demonstrate low persistence, the "resolution" for the persistence judgments was increased. Subjects now selected a response number from 2 to 20 (in increments of 2) for each of the red and green component schedules in answer to this question. In addition, subjects were asked to estimate the number of responses emitted, and the number of feedback stimuli received (10–90, increments of 10, for each component schedule).

The questionnaire further asked subjects to rate their agreement (1 = agree totally; 6 = disagree totally) to the following sentences: *"When I work on a task, I do not give up easily"; and "When I worked on this task, I felt that I would not give up easily."* The first question was intended to measure general persistence in solving problems, and the second to measure persistence specifically in relation to the present task. It was reasoned that if the reinforcement schedule affected persistence in this situation, group differences should emerge on the latter, task-related question, but not on the first, trait-related question.

Results and discussion

Acquisition

The acquisition data corresponded well to the acquisition data of Experiment 1. The ANOVA indicated a significant effect of condition, $F(1, 25) = 10.33$, $p < 0.01$, and of trial blocks, $F(17, 425) = 23.60$, $p < 0.001$. The interaction effect was not significant, $F(17, 425) = 1.38$, $p > 0.10$. A planned comparison of the response rates over the final ten acquisition trial blocks indicated a significant difference, $F(1, 25) = 10.29$, $p < 0.005$; the respective means were 4.7 (CRF condition) and 3.8 (PRF condition).

An ANOVA of the judged reinforcer rates (i.e., sum of rates under the green and red component schedules) showed a significant effect of the rate manipulation, $F(1, 25) = 10.43$, $p < 0.005$, reflecting that subjects in the CRF condition judged the reward rate to be higher (mean = 114.7) than subjects in the PRF condition (mean = 55.0). The actual rate means were 152.9 and 72.1. Thus, although subjects somewhat underestimated the overall number of reinforcers presented during acquisition, they demonstrated sensitivity to the reinforcer rate manipulation in judgments.

Persistence predictions

In response to the first persistence question, there were no group differences in predicted persistence (the respective means were 14.9 in the CRF condition vs. 16.2 in the PRF condition), $F(1, 25) = 0.07$. These data are shown in Fig. 3. It should be noted that overall predicted persistence appeared to be higher in Experiment 2 than in Experiment 1. This apparent difference is caused by differences in the way the persistence measures were taken and analyzed. In Experiment 1, subjects predicted overall persistence. In Experiment 2, separate persistence judgments were made to the red and green component schedules and then summed for analysis. Thus, a direct comparison between the overall (Experiment 1) and separate component (Experiment 2) predictions is not meaningful. Nevertheless, both measures agree perfectly in that they indicate no sensitivity to the reward rate manipulation.

In responses to the trait persistence question (*"When I work on a task, I do not give up easily"*), there was no group difference, $F(1, 25) = 2.52$, $p > 0.13$. Similarly, in responses to the task persistence question (*"When I worked on this task, I felt that I would not give up easily"*), there was no significant group difference, $F(1, 25) = 2.43$, $p > 0.13$. Both measures tended to show increased persistence in the CRF group (i.e., opposite to that expected from a conventional PREE), and there were no differences between the trait and task measures.

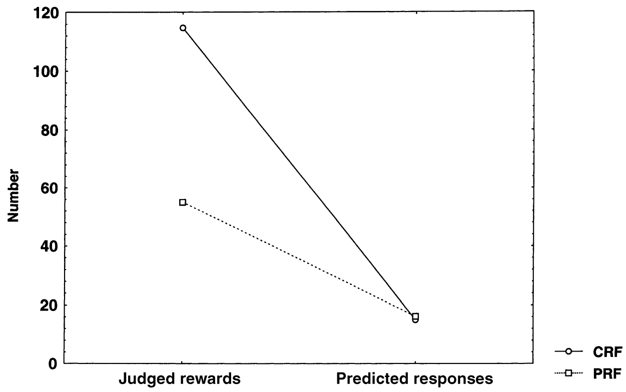

Fig. 3. Judged number of rewards under acquisition (left) and predicted number of responses under extinction (right) following exposure to CRF and PRF contingencies in Experiment 2.

EXPERIMENT 3

Experiments 1 and 2 indicate that predictions of persistence under no-reward conditions were unaffected by reward rate manipulations during the immediately preceding learning conditions. This result is somewhat surprising, since other estimates obtained in this situation (i.e., judgments of reinforcer and response rates) correlated well with actual rates. However, the judgments were of past events, while predictions related to something yet to happen. Experiment 3 intended to explore the interrelationship between those measures. By obtaining estimates at the end of the acquisition phase (predictions of persistence) and at the end of the extinction phase (judgments of actual persistence), further information about the interrelationship between these measures and actual behavior should emerge.

Method

Subjects. Participants were 25 students (mean age = 22.6 years) at the University of Tromsø. None had previous experience with the experimental task. The subjects were randomly allocated to experimental conditions prior to arrival in the laboratory.

Apparatus and procedure. The apparatus and method were identical to those used in Experiments 1 and 2, except that subjects now performed the complete learning and extinction phases of the experiment, and that predictions and judgments were obtained following both the acquisition and extinction phases. The acquisition phase consisted of 180 trials, and the extinction phase of 40 trials. During extinction, no feedback stimuli occurred.

Predictions. Following Trial 160, the experiment paused and subjects were asked to predict their own persistence under no-reward conditions in the same manner as in Experiment 2. In addition, judgments of responses emitted and feedback stimuli received during acquisition were obtained as in Experiment 2. Following the completion of these questionnaire items, the experiment continued.

Judgments. Following the extinction phase, all subjects were asked to estimate the number of responses emitted the during the extinction trials (2–20, in increments of 2, on each component schedule), and the number of feedback stimuli they received in the acquisition phase (10–90, in increments of 10, on each component schedule). The questionnaire also included the two trait vs. task persistence questions used in Experiment 2.

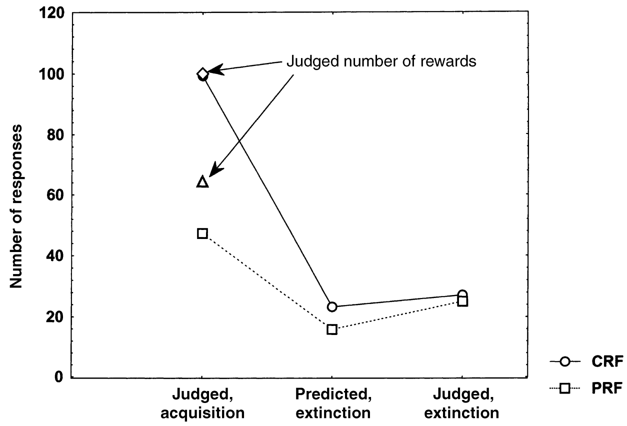

Fig. 5. Judged number of responses under acquisition (left), predicted number of responses under extinction (middle), and judged number of responses under extinction (right) in Experiment 3. Judged number of rewards is also indicated.

Results

Behavioral data

The ANOVA indicated significant effects of condition, $F(1, 23) = 14.48$, $p < 0.001$, trial blocks, $F(17, 391) = 16.59$, $p < 0.001$, and their interaction, $F(17, 391) = 2.27$, $p < 0.005$. A planned comparison showed that the asymptotic level in the CRF group was significantly higher than in the PRF group over the final ten trial blocks, $F(1, 23) = 10.89$, $p < 0.005$. Since the interruption of acquisition trials (questionnaire administration) could affect performance, within-groups response levels of the two trial blocks before vs. after interruption were compared. There were no significant changes ($F < 0.60$ in both comparisons). Thus, the acquisition data conformed well to prior data, and there were no behavioral effects of questionnaire administration. The acquisition data, along with the extinction data, are shown in Fig. 4.

The extinction data showed that both groups continued to respond at relatively high response levels, and that no conventional PREE appeared. Extinction performance was assessed in late extinction trial blocks, i.e., when extinction performance had stabilized (Svartdal, 2000a). Thus, a comparison between the CRF and PRF groups on the final three extinction trial blocks demonstrated a non-significant difference, $F(1, 23) = 1.24$. Fig. 4 indicates that extinction response levels tended to be higher in the CRF group. Contrast analyses demonstrated a significant change from asymptotic level (final ten trial blocks during acquisition) to average level of the final three extinction trial blocks in the CRF group, $F(1, 23) = 4.92$, $p < 0.05$, but not in the PRF group, $F(1, 23) = 1.43$. Inspection of Fig. 4 also indicates that the response levels during extinction were well above chance levels (1.25) in both groups.

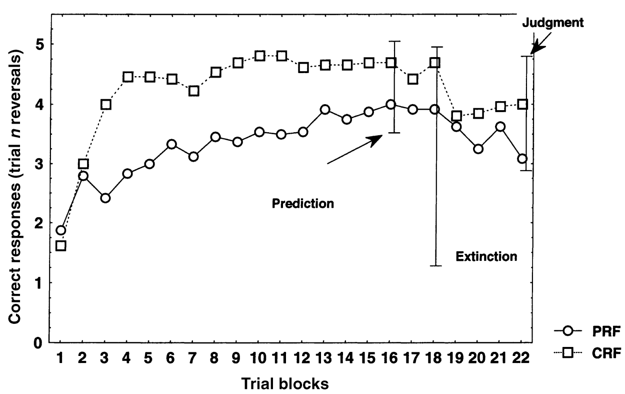

Fig. 4. Acquisition and extinction performance in the CRF and PRF groups in Experiment 3. Predictions were made following trial 160, judgments following the extinction session. Note the absence of the conventional PREE.

Questionnaire data

The predictions of extinction persistence did not differ significantly between groups, $F(1, 23) = 1.96$, but Fig. 5 indicates that the CRF group tended to give higher persistence predictions (23.3 in the CRF group vs. 15.8 in the PRF group). This trend is contrary to the pattern expected under a conventional PREE, but it was consistent with actual behavior. Thus, this result indicates that the between-groups reward manipulation had no effect on persistence predictions.

All other estimates correlated well with behavior and reward rates. Judgments of response rate during acquisition differed between the groups, $F(1, 23) = 6.25$, $p < 0.025$, as did judged number of rewards, $F(1, 23) = 18.16$, $p < 0.001$ (see Fig. 5). Within the PRF group, only 60% of the correct responses resulted in feedback presentation. Subjects judged this difference correctly, $F(1, 23) = 7.18$, $p < 0.025$. Finally, since the actual response rates during extinction did not differ between groups, such a difference should not emerge in judgments, and it did not, $F(1, 23) = 0.27$.

Only 16 subjects answered the trait vs. task persistence questions. The estimates did not indicate any difference in persistence trait vs. task persistence, and no difference between groups emerged, $F(1, 14) = 0.00$, in either comparison.

Discussion

The prediction data of Experiment 3 conformed well to those of Experiments 1 and 2. The between-group reward rate manipulation did not create any difference in predictions of extinction persistence. In addition, Experiment 3 demonstrated that those predictions seemed to affect behavioral persistence, since the usual between-groups PREE disappeared in the subsequent extinction phase. Since behavioral between-groups PREE has been reliably demonstrated in this situation, the absence of this effect here must be attributed to the prediction estimate given late in acquisition. Acquisition performance was not affected (performance was stable in pre- and post-estimate comparisons); only subsequent extinction performance was affected. This indicates that it was not the interruption per se that created changed extinction performance, but rather the content of the questions asked during that interruption. The actual predictions did not differ between groups, and subsequent extinction performance conformed well to predictions. Note also that judgments made after the completion of the extinction phase corresponded well to the behavioral, and therefore to the prediction, data.

EXPERIMENT 4

Experiments 1–3 showed that (a) predictions were unaffected by between-group manipulations of reinforcer rates during learning, (b) predictions seemed to disrupt the behavioral PREE, and (c) judgments of behavior, in both the learning and extinction phases, were remarkably accurate. However, since the predictions disrupted the behavioral PREE in Experiment 3, we do not know whether subjects in fact are able to describe a behavioral PREE when it actually occurs. This question is important for several reasons, but principally because it is a premise for the experiments of this report. If a "cognitive" PREE is not measurable even when subjects demonstrate PREE behaviorally, the feasibility of cognitive estimates of persistence effects must be doubted. Hence, Experiment 4 tested whether subjects in fact are able to describe behavioral PREE in their own behavior.

Method

Subjects. Participants were 37 students (mean age = 24.1 years) at the University of Tromsø. None had previous experience with the experimental task. The subjects were randomly allocated to experimental conditions prior to arrival in the laboratory. One subject was excluded because of failure to understand the task.

Apparatus and procedure. The apparatus and method were identical to those used in Experiment 3, except that the acquisition phase was run without interruption. Thus, all subjects received 180 acquisition and 40 extinction trials. During extinction, no feedback stimuli were presented. Immediately following the extinction phase, the second part of the questionnaire used in Experiment 3 was administered.

Results

Behavioral data
The ANOVA showed significant effects of condition, $F(1, 34) = 87.36$, $p < 0.001$, trial blocks, $F(17, 578) = 21.77$, $p < 0.001$, and their interaction, $F(17, 578) = 4.50$, $p < 0.001$. A planned comparison revealed that asymptotic response levels (final 10 acquisition trial blocks) differed significantly between groups, $F(1, 34) = 85.14$, $p < 0.001$. These data again demonstrated reliable effects of the feedback manipulation, and also a reliable group difference in asymptotic response rates.

During extinction, the CRF group demonstrated a rapid drop in response level, while that drop was much less pronounced in the PRF group. A comparison of the final three extinction trial blocks showed that the response levels had reversed from the acquisition phase between groups, with the higher level in the PRF group (2.63 vs. 1.65). This difference was significant, $F(1, 34) = 13.05$, $p < 0.001$, and represents a conventional behavioral PREE. The acquisition and extinction data are shown in Fig. 6.[1]

Judgment data
Judgments of response rate during acquisition were significantly different between the CRF and PRF groups (85.3 vs. 50.0, respectively), $F(1, 34) = 11.69$, $p < 0.005$. Similarly, judgment of feedback rates during acquisition differed between groups (91.8 vs. 41.7), $F(1, 34) = 22.41$, $p < 0.001$.

Of primary interest here are the estimates of extinction response rates. The mean estimate for the CRF group was 9.9, while that of the PRF group was 16.9, $F(1, 33) = 12.50$, $p < 0.005$. Thus, the estimates of response rates during extinction conform well to the behavioral data and represent a conventional between-groups PREE. These data are shown in Fig. 7.

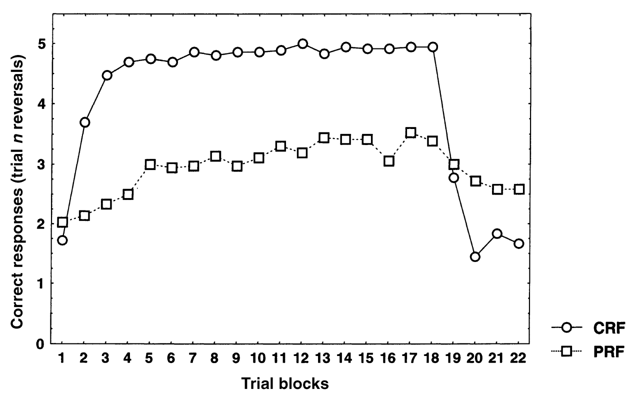

Fig. 6. Acquisition and extinction performance in the CRF and PRF groups in Experiment 4. Note the conventional PREE.

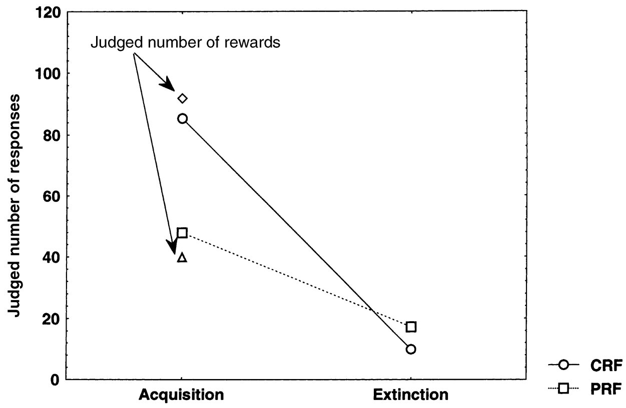

Fig. 7. Judged number of responses under acquisition (left) and extinction (right) in the CRF and PRF groups in Experiment 4. Judged number of rewards is also indicated.

Since subjects in the PRF group received feedback in only 60% of the trials with correct responses, the judged number of feedback stimuli should be lower than the judged number of responses. The ANOVA confirmed this expectation, $F(1, 34) = 5.51$, $p < 0.025$. Within the CRF group, however, these estimates should not differ, and they did not, $F(1, 34) = 3.31$, $p > 0.05$. These data are also shown in Fig. 7.

In response to the trait persistence question, there was no group difference, $F(1, 35) = 1.05$. Similarly, in responses to the task persistence question, there was no significant group difference, $F(1, 35) = 2.94$, $p > 0.09$.

Discussion

Experiment 4 demonstrated that subjects were capable of judging their own persistence behavior. Thus, the behavioral data and judgments corresponded well and conformed to a conventional PREE. This suggests that the "cognitive" measure used here – judgment of response rate during extinction – is indeed sensitive as a measure of PREE. However, since judgments were obtained following the subjects' own persistence behavior, this measure cannot be taken as evidence that subjects demonstrated a "cognitive PREE". The present data only permit the conclusion that subjects can accurately describe their own behavior under extinction conditions.

A second conclusion that can be drawn from the data of Experiment 4 is that subjects were very accurate in describing both behavior and reward contingencies. Thus, subjects in the PRF group correctly indicated that their response levels during acquisition had been higher than the reward rate, and the between-groups comparisons reflected the actual differences between the two groups.

GENERAL DISCUSSION

The conventional PREE – increased persistence following partial reward – is a reliable outcome when separate groups of subjects are exposed to CRF vs. PRF contingencies. The present experiments, using human adult subjects, investigated alternative measures of PREE and asked whether the conventional PREE occurs in persistence predictions and judgments. Experiments 1–3 exposed separate groups of subjects to CRF vs. PRF contingencies and asked subjects, immediately after the acquisition phase, to predict their own persistence under no-reward conditions. There were no indications that predictions of extinction persistence were related to the immediately preceding learning contingencies. These results indicate that people have no explicit or implicit cognitive representation of increased or decreased persistence after exposure to CRF vs. PRF schedules.

Experiment 4 tested the possibility that failure to predict persistence according to a conventional PREE is due to a general inability to perceive persistence differences in behavior. Independent groups of subjects were exposed to CRF vs. PRF contingencies, then to extinction. Extinction behavior conformed to a conventional PREE, as did subsequent judgments of persistence behavior. Thus, subjects seem to be cognitively sensitive to differences in persistence caused by reward rate manipulations, but only after this sensitivity has been demonstrated behaviorally. Whether this cognitive sensitivity is based on previous learning history, observation of persistence behavior, or both, is not clear, but given the results of Experiments 1–3 it is likely that observation of persistence behavior is crucial.

Together, these findings suggest that persistence effects following reward rate manipulations are robust if measured behaviorally. However, if measured cognitively, the conventional PREE is more fragile. The most surprising result of the present study is that predictions of persistence are not affected by prior reward conditions. This finding is surprising because many investigations, including the present one, demonstrate close correspondences between behavioral and cognitive measures during *acquisition* of the instrumental response. For example, Shanks and Dickinson (1991) showed that judgments and free operant behavior were equivalently affected by different response–outcome contingencies; in fact, judgments matched actual contingencies even better than behavioral indices. Such findings indicate that behavioral adaptation to instrumental contingencies is mediated by cognitive apprehension of those contingencies. We should then expect that robust extinction effects following such contingencies be mediated in a similar way. The present results indicate that this may not be the case. Persistence predictions seem to be unrelated to previous learning history, indicating that extinction persistence behavior is not mediated cognitively. Thus, these results support previous studies that demonstrate insensitivity of persistence predictions to contingency information (Svartdal, 2000b).

The insensitivity of predictions to learning history shown in Experiments 1–3 cannot be due to lack of relevant information. The present experiments show that subjects are very competent in judging and remembering reward and response rates. The absence of persistence effects in predictions therefore must reflect a failure to apply relevant information. Other data (Svartdal & Breivik, 2001) indicate that such a dissociation between knowledge of reward history and extinction performance may be quite general. For example, when subjects are given relevant contingency information (e.g., high vs. low probability of obtaining a desired outcome in an instrumental task) and then perform the task with no outcomes (i.e., "extinction"), contingency information seems to have no effect on subjects' persistence in performing the task.

The present data indicate that the conventional PREE may be disassociated from cognition until it is expressed behaviorally. An obvious objection to this conclusion is that subjects do not demonstrate PREE in predictions because the information provided about changed contingencies affects subjects equally over conditions. Experiment 2 was performed to exclude this possibility. Nevertheless, it can be argued that any description of no-reward contingencies may override prior history and affect persistence predictions. However, data from a recent series of experiments (Svartdal & Silvera, 2002) undermines this objection. Subjects performed the instrumental task used in the present experiments. Following the acquisition phase, subjects gave a number of successive predictions. No information about changed contingencies was given; subjects simply indicated the likelihood of emitting the response they had learned, given that feedback did not occur in the *preceding* trial. There were no group differences in persistence predictions over a sequence of such predictions. These data indicate that even when subjects are not informed about changed contingencies, persistence predictions are not sensitive to reward rate manipulations during acquisition.

Several factors may explain why predictions of persistence in terms of number of responses are not affected by prior learning history. First, because increased or decreased persistence is not an immediate and salient outcome of specific contingencies (but rather an effect of those contingencies under no-reward contingencies), persistence effects may be difficult to apprehend subjectively. Another issue is that increased or decreased persistence is manifested in gradual rather than distinct behavioral changes. Such changes may be difficult to detect and describe (Svartdal, 1995), and therefore to capture in predictions. Third, since the PREE is a relatively transient phenomenon, its cognitive representation may be weak. For example, studies that have demonstrated PREE in humans (e.g., Pavlik & Flora, 1993; Pittenger *et al.*, 1988; Svartdal, 2000a) indicate that group differences dissipate over relatively few trials. It should be noted, however, that these factors should be expected to negatively affect judgments of persistence behavior as well, but they did not (Experiment 4). This indicates that the prediction measure is especially insensitive as a measure of persistence.

Even if the PREE is not reflected in predictions of persistence, this does not mean that prior learning contingencies are not represented cognitively. The present report focused on possible cognitive *outcomes* of mechanisms associated with extinction persistence. Alternative measures that focus more directly on relevant mechanisms might prove more successful. For example, given that the pattern of rewarded and non-rewarded trials under acquisition affects extinction persistence (e.g., Capaldi, 1994), the appropriate cognitive persistence measure might be of subjects' representations of patterns of rewarded and non-rewarded trials. Similarly, if causal attributions affect persistence (e.g., Weiner, 1986), differences in attributions following regular vs. occasional reward might be useful as a cognitive measure of extinction persistence. If such direct measures should prove more sensitive than the indirect prediction measures explored in the present studies, it would then be interesting to explore why the translation to cognitive outcomes (as measured in the present experiments) apparently is slower and/or less reliable than the corresponding translation to behavioral outcomes.

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NOTES

[1] There is no consensus as to whether persistence should be expressed in terms of relative change from asymptote or initial extinction level (e.g., Nevin, 1988), or in terms of absolute number of responses (e.g., Pavlik & Flora, 1993). In the present context this issue is not crucial, since the observed extinction effects conform to the conventional PREE regardless of analysis method (cf. Svartdal, 2000a).

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