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VARIABLES CONTROLLING THE RESURGENCE
OF PREVIOUSLY REINFORCED BEHAVIOUR
IN HENS

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Abstract

Resurgence is defined as the occurrence of previously reinforced behaviours when reinforcer delivery ceases for a recently reinforced behaviour. In five experiments, variables suggested to control the degree of occurrence of a first-trained behaviour during the extinction of a second-trained behaviour (resurgence) were investigated. All experiments used hens and behaviours were selected from door push, key peck, and head bob. In Experiment 1, using 6 naive hens, Behaviour 1 was reinforced on a random-interval (RI) 60-s schedule followed by two sessions of extinction. Each occurrence of Behaviour 2 was then reinforced followed by another period of extinction. The degree of occurrence of Behaviour 1 during the final extinction was less than that which occurred during the period of Behaviour 1 extinction, suggesting that the extinction of Behaviour 2 did not increase the occurrence of Behaviour 1. This result failed to support the idea that resurgence is induced by the extinction of Behaviour 2. In Experiment 2, using the same hens and an additional hen, Experiment 1 was repeated five times and then there were either 0 or 9 sessions of Behaviour 1 extinction in a further five conditions. The degree of resurgence was generally less when there were 9 sessions than when there were no sessions but not consistently different from either when there were 2 sessions. Experiment 3 used six naive hens. Two first-trained behaviours were initially reinforced on RI 45-s schedules under a multiple schedule. One first behaviour then received a period of extinction and then each occurrence of two second behaviours was reinforced under the multiple schedule followed by extinction. The sequence from training of the first behaviours to the extinction of the second behaviours was repeated 10 times with the number of occurrences of the component for which extinction was in effect for the first behaviour varying across conditions from 12 to 0. The degree of resurgence was an inverse function of the amount of Behaviour 1 extinction. Experiment 4 used six naive hens. In a multiple schedule two first behaviours were reinforced on RI 20-s schedules and then two second behaviours were reinforced followed by extinction. This was repeated 8 times with the RI schedule in effect for one of the second behaviours varying from 80 s to 10 s across conditions while the other remained at 40 s. The degree of occurrence of Behaviour 1 when Behaviour 2 was reinforced was a direct function of the varied RI schedule of Behaviour 2. The degree of

resurgence of Behaviour 1 in extinction was an inverse function of the varied RI schedule of Behaviour 2. The degree of resurgence was also inversely related to the degree of occurrence of this Behaviour 1 when Behaviour 2 was reinforced. Experiment 5 used five naive hens and one hen from Experiment 3 in a multiple-schedule design where the length of training of the second behaviours varied from 124 to 0 occurrences of a component over three conditions. No effect of this was found on the degree of resurgence. The results are consistent with the hypothesis that resurgence is the result of the prevention of extinction of Behaviour 1 by the reinforcement of Behaviour 2, but they are not definitive proof that this hypothesis is correct. Models derived from the Generalised Matching Law and Behavioural Momentum are also proposed as descriptions of resurgence.

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Changes in the probability of occurrence of a behaviour that are correlated with changes in the stimuli that follow occurrences of this behaviour have been termed operant relations (Catania, 1973). In one such operant relation the consequent stimuli (termed reinforcers) function to increase the probability of a behaviour occurring (reinforcement). When such stimuli (reinforcers) cease to follow occurrences of the behaviour, the probability of the behaviour occurring will decline. This procedure is called extinction. It has been found that when extinction is in effect, many aspects of the reinforced behaviour become more variable (e.g., Antonitus, 1951; Eckerman & Lanson, 1969; Margulies, 1961; Millenson & Hurwitz, 1961; Millenson, Hurwitz, & Nixon, 1961; Notterman & Mintz, 1965; Stokes, 1995). Additionally, when extinction is introduced previously reinforced behaviours sometimes occur (e.g., Enkema, Slavin, Spaeth, & Neuringer, 1972; Epstein, 1983; Epstein, 1985; Hull, 1934; Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Mulick, Leitenberg, & Rawson, 1976; Pryor, Haag, & O'Reilly, 1969; Rawson & Leitenberg, 1973; Rawson, Leitenberg, Mulick, & Lefebvre, 1977).

Reoccurrence of behaviour in extinction is often reported but there is some confusion as to how it is best described. Mechner, Hyten, Field, and Madden (1997) define the term “resurgence” as the reoccurrence of a behaviour after a period of time since its last occurrence. Defining resurgence in this way, however, means that any delayed occurrence of the same topography after the first occurrence of a behaviour might be termed resurgence. This is because there must be a period of time between the two occurrences otherwise there would be only one occurrence and not a reoccurrence. Resurgence, then, by this definition, would encompass almost all operant phenomena—such as behaviour produced under intermittent schedules of reinforcement—and hence be of little use. A more restrictive description is required that isolates particular reoccurrences of behaviour for study.

Epstein (1985) proposed a principle of “extinction-induced resurgence”: “When, in a given situation, recently reinforced behaviour is no longer reinforced, behaviours that were previously reinforced under similar circumstances tend to recur” (p. 144). As a principle it states the relation between a behavioural phenomenon and the conditions which control its occurrence, it does not, however, independently define the phenomenon. The condition that controls the

reoccurrence of previously reinforced behaviours for Epstein's principle of extinction-induced resurgence is the introduction of extinction for the recently reinforced behaviour (Behaviour 2), with no other obvious changes in the contingencies that control the previously reinforced behaviour (Behaviour 1). Whether the introduction of extinction for Behaviour 2 does, in fact, induce the reoccurrence of Behaviour 1 is an empirical question which will be examined below. In any event, extinction-induced resurgence is not a term that can be used a priori to describe the reoccurrence of a previously reinforced behaviour when reinforcer delivery ceases for a recently reinforced behaviour because it requires that induction be shown. In spite of this, reoccurrence of behaviour even when induction by extinction has not explicitly been shown has sometimes been termed extinction-induced resurgence (e.g., Dixon & Hayes, 1998). There appears to be some confusion between the principle, which states a controlling variable of reoccurrence, and the particular reoccurrence studied. A clear description of the reoccurrence under study is required to avoid confusion.

While Epstein (1985) mostly writes about extinction-induced resurgence, which we have seen is a principle and not a definition of a phenomenon, at one point he states that:

A special case of resurgence would seem to be Freud's (1920) concept of regression, though the concepts differ in several respects. Regression refers to a psychodynamic mechanism that is supposed to underlie changes in behavior. The principle of resurgence, in contrast, is purely descriptive; no mechanism is implied. Regression is said to proceed to points of fixation which are established during childhood; hence emerging behaviors are said to be infantile and primitive. The principle of resurgence makes no such restriction. Finally, regression is usually understood to be a response to punishment—to "powerful external obstacles"—rather than simply to nonreinforcement (though Freud himself seems not to have made the distinction). Consequently, most laboratory studies of regression used punishment rather than extinction to induce earlier forms (p. 144).

One interpretation of this passage is that Epstein is allowing resurgence to be the occurrence of previously reinforced behaviours with the inductive event

determining the membership in a subclass, for example, extinction-induced resurgence. As we have seen, induction is an empirical question and cannot serve *a priori* to define a phenomenon. We are again left with resurgence being the reoccurrence of previously reinforced behaviours. Wilson and Hayes (1996) likewise suggest that resurgence in Epstein's view "merely describes a shift in response probabilities" (p. 267). Resurgence defined in both these ways is similar in breadth to that defined by Mechner et al. (1997) and is thus open to the same criticisms.

To avoid problems of this sort a strictly operational definition will be used here. The term "resurgence" will be used to describe the occurrence of previously reinforced behaviour (Behaviour 1) when reinforcer delivery ceases for a recently reinforced behaviour (Behaviour 2). The cessation of reinforcer delivery for Behaviour 2 defines whether the reoccurrence of Behaviour 1 will be termed resurgence, and it is presumed that Behaviour 1 has no other (obvious) source of control. The definition therefore limits the range of events that might be termed resurgence. Reoccurrence when response requirements are increased (e.g., Mechner et al., 1997) and when responses are punished (e.g., Wilson & Hayes, 1996) would not be considered resurgence here. In addition, the present definition excludes the occurrence of previously reinforced behaviours after reinforcer cessation when a second behaviour was not explicitly trained. For example, Lindblom and Jenkins' (1981) demonstration of recovery of responding after negatively contingent or noncontingent reinforcement would not be considered resurgence here. This use of the term resurgence names a particular phenomenon and leaves the controlling variables of the phenomenon open to experimental investigation—there is sometimes a response probability increase in an earlier behaviour when a later behaviour is put on extinction, but we still need to investigate the wide range of possible controlling variables.

For consistency, this operational definition of resurgence will be used throughout the present thesis when referring to the results of other researchers' studies. The reader is warned, then, that a statement here of the nature of "resurgence was found in a study by x" means that x's results showed that previously reinforced behaviours occurred when reinforcer delivery ceased for a recently reinforced behaviour. This statement does not mean that x termed these results resurgence as defined here.

There are many reasons why resurgence should be studied. Resurgence during extinction has been introduced in text books (e.g., Chance, 1994; Guerin, 1994) and has also been used to help account for other phenomena, most commonly problem solving (e.g., Epstein, 1987; 1991; Epstein, Kirshnit, Lanza, & Rubin, 1984; Nakajima & Sato, 1993). Although resurgence has been widely used as an explanation, it is a poorly understood phenomenon.

Lerman and Iwata (1996) also note that understanding extinction phenomena like resurgence may help in changing behaviour in applied settings. Of particular interest in this regard is the procedure termed differential reinforcement of alternative behaviour (DRA). In this procedure, an alternative behaviour (Behaviour 2) is reinforced to reduce the occurrence of a problem behaviour (Behaviour 1). If reinforcer delivery for the alternative behaviour were to cease then the problem behaviour might reoccur, which would be termed resurgence. Given that reinforcer delivery cannot always be guaranteed in the natural environment, this is clearly an important area. Much of the early work on resurgence appears to have been aimed at assessing whether the effects of DRA persist after the procedure has ceased and at examining variables that might improve the effectiveness of DRA (e.g., Enkema et al., 1972; Leitenberg et al., 1970; Leitenberg et al., 1975).

Understanding resurgence also has implications for assessment in applied settings. Iwata, Dorsey, Slifer, Bauman, and Richman (1994) proposed that the effectiveness of behaviour-change techniques might be improved by identification of the function of the problem behaviour, that is, of the reinforcers that maintain the problem behaviour. They proposed that stimuli that function as reinforcers could be identified by making them contingent upon problem behaviour for brief periods and observing the rate of that behaviour (Iwata et al., 1994). The phenomenon of resurgence suggests that the withdrawal of such stimuli might also yield information useful in planning behaviour change. When reinforcer delivery ceases, behaviours previously maintained by the same reinforcer may occur. These previously reinforced behaviours occurring during the extinction of a recently reinforced behaviour may be desirable or undesirable. If desirable behaviours occurred these might be useful in decreasing the time required to train a new alternative behaviour. If the behaviours that occurred were undesirable then it may be advantageous to plan to place contingencies on these behaviours during

the intervention. For such an approach to be useful, however, the variables that influence resurgence need to be understood.

This thesis aimed to investigate variables that might control resurgence using nonhuman animals, and took as its starting point the previous studies investigating this question. While investigations involving resurgence have been conducted using human subjects (e.g., Dixon & Hayes, 1998; Fitzsimons & Hyten, 1996; Hyten, Fitzsimons, & Neff, 1996; Mechner et al., 1997; Morgan & Lee, 1996; Pittenger, Pavlik, Flora, & Kontos, 1988), there are some problems with interpreting the results of these human studies. Galizio and Buskist (1988) pointed out that the choice of a consequence to function as a reinforcer when using human subjects is not easy because control over the events that establish stimuli as reinforcers (see Marr, 1993) is often not available. In addition, Galizio and Buskist (1988) note that there are a number of factors that may affect whether experimental stimuli function as reinforcers for human behaviour. The definition of resurgence here requires that the behaviours are under the control of reinforcement. Thus evidence of whether a particular consequence functioned as a reinforcer is required before reoccurrence of a behaviour could be termed resurgence as defined here.

Consequences used in human resurgence studies have included points (e.g., Morgan & Lee, 1996), points exchangeable for money (e.g., Hyten et al., 1996; Mechner et al., 1997), and verbal statements (e.g., Dixon & Hayes, 1998). However, because a reinforcer is defined by its effect on behaviour, it cannot be equated with consequence delivery nor can extinction be equated with the absence of consequence delivery. None of these studies investigated whether or not the delivery of these stimuli functioned as reinforcers. Thus it is not known whether the reoccurrence of behaviour in these human studies was resurgence as defined here (the occurrence of previously reinforced behaviour during the extinction of recently reinforced behaviour) or not. For this reason, these studies do not help clarify the variables that influence resurgence.

Epstein (1983) noted that many of the studies in which resurgence has been found did not set out to investigate resurgence specifically (e.g., Hull, 1934; Pryor et al., 1969). While Epstein (1983) stated that this meant that critical procedural controls were not implemented it may have also resulted in little investigation into the controlling variables of resurgence. In addition, there are

several confounds even in experiments which have studied resurgence that make the interpretation of the results more complicated than has been presented previously. These will be examined next.

Epstein (1983), using six pigeons, reinforced pecking of one of two lit keys (Behaviour 1) on a variable-interval (VI) 60-s schedule until the response rates were stable. Variable-interval schedules deliver reinforcers for the first response after a variable time, that averages to a certain predetermined value, has elapsed from the start of the schedule until the first reinforcer is delivered, and from then on the time is measured from when the last reinforcer was delivered. Epstein (1983) then ceased reinforcer delivery for between 1 and 15 sessions (an average of 6 sessions). A test session was then conducted in which, after 10 min of no key pecking, a second behaviour (Behaviour 2) was selected (e.g., wing raise) and this was reinforced on its next 20 occurrences. When reinforcement for Behaviour 2 ceased, pecking the key which had previously been associated with reinforcement occurred between 25 and 575 times across pigeons during the remainder of the test session. For each pigeon this degree of resurgence was far greater than the occurrence of this behaviour in the extinction period prior to the training of Behaviour 2. Epstein (1983) argued that the training and extinction of Behaviour 2 resulted in this increased rate of Behaviour 1. This resurgence of Behaviour 1, he said, was due to the extinction of Behaviour 2, and Epstein (1983) termed this effect extinction-induced resurgence.

In Epstein's (1983) study, Behaviour 2 was reinforced during the test session. As Epstein (1983) noted, one possible confound of this is that reinforcer delivery may have made the stimulus conditions in the test session more like those during the previous training of Behaviour 1. This factor alone may reinstate responding (e.g., Hollis, 1968; Mulick et al., 1976; Reid, 1958; Spradlin, Giradeau, & Hom, 1966) and, therefore, could have caused the resurgence observed.

When discussing the possibility that reinforcer delivery reinstated responding, Epstein (1983) referred to an unpublished study, also using pigeons, which is described in Epstein (1985). In this study, pecking a key (Behaviour 1) was reinforced on a VI 60-s schedule then reinforcement ceased for pecking this key at the same time that pecking another key (Behaviour 2) was reinforced on a VI 60-s schedule, this was followed by extinction. Resurgence did not occur until

40 min into the extinction of Behaviour 2, but when it did occur it was reasonably large. Epstein (1983) suggests that this seems to rule out the reinstatement effects of reinforcer delivery as being a major confound for the results of the Epstein (1983) study. Even if we accept that reinstatement effects of reinforcer delivery are temporary, Epstein's (1983) conclusion may be incorrect. Because there was no specific period of extinction for Behaviour 1, the effect of the training and extinction of Behaviour 2 on the occurrence of Behaviour 1 in the study described in Epstein (1985) cannot be assessed. In addition, a rival hypothesis predicts such reoccurrence without induction by Behaviour 2 extinction under the conditions described in Epstein (1985). This rival hypothesis will be discussed later. It would therefore appear, as Cleland (1996) argued, that it is not possible to conclude from Epstein's (1983) data that resurgence is extinction induced.

In the only other known study directly investigating the effects of the extinction of Behaviour 2 on resurgence, Cleland (1996) attempted to systematically replicate the Epstein (1983) study with naive hens. In Cleland's (1996) study the possibility of reinforcer delivery reinstating responding was reduced by not delivering reinforcers in the test sessions. Cleland (1996) found that during the extinction of Behaviour 2, Behaviour 1 occurred for all hens. However, the degree of occurrence was similar to that expected if Behaviour 2 had not been trained and extinguished (Cleland, 1996). This suggested that the resurgence was not extinction induced. Cleland (1996) suggested that his results might have been confounded as Behaviour 2 was trained for an extended period. Leitenberg et al.'s (Experiment 4, 1975) results suggest that extended training of Behaviour 2 may reduce the degree of resurgence.

Leitenberg et al. (Experiment 3, 1975), using naive pigeons, reinforced pecking a key under a VI 2-min schedule and then both ceased reinforcer delivery for this behaviour and started reinforcing the pecking of another key. Pecking this other key was reinforced either under a VI 30-s schedule or under a VI 4-min schedule for ten sessions for two groups of subjects. Reinforcer delivery then ceased for pecking this second key. They found that during the training of Behaviour 2, the occurrence of Behaviour 1 was less when Behaviour 2 was reinforced at a high rate (VI 30 s) than when it was reinforced at a low rate (VI 4 min). During the extinction of Behaviour 2, however, the reoccurrence of Behaviour 1 was greater when Behaviour 2 had been reinforced at a high rate (VI

30 s) than when it had been reinforced at a low rate (VI 4 min). This experiment supported a suggestion by Leitenberg et al. (1975) that resurgence occurs because the reinforcement of Behaviour 2 merely prevents the occurrence of Behaviour 1, and hence the exposure of Behaviour 1 to the extinction in effect. In other words Behaviour 1 had not been exposed to extinction in the first place and so resurgence occurred when Behaviour 2 was under extinction. This was termed the “Response Prevention Hypothesis” (Leitenberg et al., 1975; Rawson et al., 1977). This hypothesis might be used to account for the resurgence observed in the study described in Epstein (1985) because reinforcement of Behaviour 2 might have prevented the extinction of Behaviour 1 in that study.

As will be described below, some data suggest that a behaviour can occur when extinction is programmed for that behaviour but still not contact the extinction contingency for it because of the occurrence of reinforcers for another behaviour. Catania and Cutts (1963) showed that a behaviour can be adventitiously maintained by the contingencies in effect for another concurrent behaviour. Thus Behaviour 1 might occur during the training of Behaviour 2 and not contact the extinction contingency but, instead, be maintained by adventitious reinforcement. If it were the case that Behaviour 1 would be adventitiously maintained, then whether occurrences of Behaviour 1 are prevented or not is irrelevant to whether extinction is contacted. Therefore, the prevention of the occurrence of Behaviour 1 during Behaviour 2 training does not necessarily equate with the prevention of contact with the extinction contingencies in effect for Behaviour 1. Leitenberg et al. (1975) used a procedure to reduce the probability of adventitious reinforcement of Behaviour 1 during the training of Behaviour 2. In their study, therefore, the prevention of the occurrence of Behaviour 1 during the training of Behaviour 2 might be considered synonymous with the prevention of contact with the extinction contingencies, but this might not always be the case. To avoid confusion, Leitenberg et al.'s (1975) hypothesis that resurgence results from preventing Behaviour 1 contacting the extinction contingencies in effect for that behaviour will be termed the “Prevention of Extinction Hypothesis” here. Consistent with Leitenberg et al.'s (1975) hypothesis the occurrence of Behaviour 1 during the training of Behaviour 2 (as long as the possibility of adventitious reinforcement has been controlled) will be taken as the primary measure of the degree of contact with the extinction contingencies.

Leitenberg et al. (1975) noted that their results might also be accounted for by assuming that the correlation of the cessation of reinforcement of Behaviour 1 with the delivery of reinforcement for Behaviour 2 means that the removal of reinforcement for Behaviour 2 will function to indicate that Behaviour 1 is again reinforced. Subsequent research, however, has suggested that this is not the case (Rawson et al., 1977).

It should be noted that the term extinction has been used here to mean the procedure of ceasing reinforcer delivery. Hearst (1988) notes that this term has also been used both to describe the resulting reduction in behaviour following reinforcer cessation and to mean the theoretical underlying process. To avoid confusion, a procedural definition will be used here. That is, extinction is defined simply as the cessation of reinforcer delivery. When extinction is put into effect the previously reinforced behaviour should occur (because the probability of that behaviour has been increased by the prior reinforcement) and thus the behaviour will come into contact with extinction, all else being equal. The data of Leitenberg et al. (1975), however, suggest that when another variable is changed (such as the training of Behaviour 2) in addition to reinforcer cessation for Behaviour 1, the extent to which the programmed contingencies contact Behaviour 1 may be affected. In an extreme case, Behaviour 1 might never occur after reinforcer cessation for Behaviour 1 and hence this behaviour would never contact the extinction contingency. The expression “degree of extinction” is used here to refer to the extent to which behaviour has contacted the extinction contingencies. Because behaviours must occur to contact the extinction contingencies, just as they must occur to contact reinforcement contingencies, the extent to which extinction has been in effect might be best measured by the number of unreinforced occurrences of behaviour.

In the Leitenberg et al. (1975) experiment, the degree of extinction of Behaviour 1 was manipulated by varying the schedule under which Behaviour 2 was trained. It is possible that this schedule difference, rather than the degree of extinction of Behaviour 1, might be responsible for the different degrees of resurgence obtained. Furthermore, both the schedule under which Behaviour 2 was trained and the rate of Behaviour 2 varied with the occurrence of Behaviour 1 during the training of Behaviour 2. So it is not possible to determine from that experiment whether the occurrence of Behaviour 1 during the training of

Behaviour 2 was the result of the reinforcement rate for, or the response rate of, Behaviour 2.

Leitenberg et al. (Experiment 4, 1975), using rats, found a greater degree of resurgence when Behaviour 2 was trained for a short period than when Behaviour 2 was trained for a long period. However, Behaviour 1 appears to have occurred at a low rate throughout the training of Behaviour 2. Thus it is likely that Behaviour 1 occurred more during the training of Behaviour 2 when this was a long period than when this was a short period. Because of this, the Behaviour 1 associated with the longer Behaviour 2 training period may also have come in contact with extinction to a greater degree. If so, the different degrees of resurgence might be the result of different degrees of extinction of Behaviour 1 as suggested by the Prevention of Extinction Hypothesis.

The studies of Epstein (1983) and Leitenberg et al. (1975) suggest a number of variables that might influence resurgence. Among these are the extinction of Behaviour 2, the degree of extinction of Behaviour 1, the rate of reinforcement of Behaviour 2, and the length of training of Behaviour 2. The research described above used a basic paradigm consisting of the training of Behaviour 1 followed by the training and then extinction of Behaviour 2. By definition, however, the term resurgence implies that an action at one point in time (i.e., reinforcing Behaviour 1) affects behaviour at a later point in time (i.e., resurgence of Behaviour 1 during the extinction of Behaviour 2). Resurgence is thus a case of one variable (reinforcement of Behaviour 1) acting over time on behaviour. If one variable can act over time upon behaviour then other variables may also act over time. If so, these other variables may affect the findings of a resurgence study.

It is possible that the organism's history might influence resurgence over and above any effects of an independent variable. To help avoid this possibility, most resurgence studies have ensured that the organisms are naive with respect to the behaviours trained, stimuli used and independent variable of interest. Generally, this has been achieved by using group designs. In single-subject designs, where conditions may be repeated within subjects, experimental history itself may influence behaviour. Tatham and Wanchisen (1998) argue that historical effects can be assessed within subjects by comparing the behaviour in a condition that did not have the historical variable with the behaviour in a

condition that did. In a resurgence study the effects of experimental history should thus be able to be assessed by comparing the resurgence obtained when an organism is naive with respect to the experimental variables with that obtained later when it is not. The present studies started with experimentally naive subjects and studied the degree of resurgence under this condition. This was compared to the degree of resurgence after repeated exposure to the experimental conditions to investigate if the results were confounded by experimental history.

Resurgence refers to the occurrence of a previously reinforced behaviour (Behaviour 1) during extinction of a more recently reinforced behaviour (Behaviour 2). It is possible, however, that Behaviour 1 might be affected by the recent reinforcement of Behaviour 2. We need to be sure that the reoccurrence of Behaviour 1 during the extinction of Behaviour 2 is the result of the previous reinforcement of Behaviour 1, rather than the recent reinforcement of Behaviour 2, for the reoccurrence of Behaviour 1 to be termed resurgence. Thus, the reinforcers delivered during the training of Behaviour 2 should not reinforce Behaviour 1. There are two ways in which reinforcer delivery for Behaviour 2 might reinforce Behaviour 1. The probability of a response that occurs close in time to, but does not result in, reinforcement, may be increased (e.g., Catania & Cutts, 1963; Neuringer, 1970; Skinner, 1948). It is possible that if Behaviour 1 occurs immediately prior to the performance and reinforcement of Behaviour 2, the occurrence of Behaviour 1 might be adventitiously reinforced. A consistently high rate of occurrence of Behaviour 1 during the training of Behaviour 2 might suggest adventitious reinforcement. When this occurs any occurrence of Behaviour 1 during the extinction of Behaviour 2 may be because of this recent adventitious reinforcement, not as a result of previous reinforcement, and this reoccurrence should not be termed resurgence though in some cases it has (e.g., Eldridge, Pear, Torgrud, & Evers, 1988).

In an attempt to prevent such adventitious reinforcement, some researchers have used a change-over delay (COD), so that the occurrence of an effective behaviour would not be reinforced until after a specific time had elapsed from the occurrence of a behaviour not currently being trained (e.g., Cleland, 1996; Leitenberg et al., 1975). This should decrease the temporal contiguity between any occurrence of the first behaviour and reinforcement delivered for the second behaviour. Cleland (1996) found that Behaviour 1 was still occurring at the end of

the training of Behaviour 2 for 3 of the 11 hens when a 2-s COD was used. Thus a longer COD would seem to be required. In the present studies a COD of 6-s was used in all training phases.

Reinforcers may also affect behaviours that reinforcers are not contingent upon when these other behaviours are topographically similar to the reinforced behaviour (Catania, 1998; Skinner, 1938). It is possible that if Behaviour 1 and 2 are similar, the effects of reinforcement for Behaviour 2 might generalise to Behaviour 1 also. Hence, as in the case of adventitious reinforcement, any occurrence of Behaviour 1 during the extinction of Behaviour 2 may be the result of this recent reinforcement and should not be termed resurgence. In the case of adventitious reinforcement, Behaviour 1 needs to occur during the training of Behaviour 2 to be affected by the reinforcement of Behaviour 2. In the case of generalisation, however, recent reinforcement would affect Behaviour 1 because of topographical similarity to Behaviour 2. Thus Behaviour 1 does not necessarily need to occur during the training of Behaviour 2 to be affected. Because of this it is difficult to detect whether generalisation has occurred.

Using behaviours that are topographically distinct should help to avoid this problem by decreasing the common response properties. Leitenberg et al. (Experiment 1, 1975) however, found that the resurgence of a behaviour with rats during the extinction of a topographically similar response was not significantly different from the resurgence of a behaviour during the extinction of a topographically dissimilar response. The authors concluded that response topography may not alter the main result of a resurgence study (Leitenberg et al., 1975). It may be the case that generalisation does not substantially affect the results of a resurgence study. Given that it is difficult to detect whether generalisation has occurred, however, it would seem prudent to limit the probability of it occurring in resurgence experiments by using topographically distinct behaviours.

Previous research suggests that both key pecking (pecking a lit key) and door pushing (pushing two vertical door prongs) in hens can be independently reinforced (Cleland, 1996; Sumpter, Foster, & Temple, 1995). Investigations prior to Experiment 1 here established that a particular series of head movements termed head bobbing could also be reinforced and measured by automated means. The present research used all three of these behaviours at various times.

Additionally, in all experiments, some subjects were trained with one response while others were trained with another to check whether the topography of behaviour might itself be a variable that affects resurgence.

It was stated previously that Behaviour 1 might be adventitiously reinforced during the training of Behaviour 2. If so this may increase the probability of Behaviour 1 occurring during the extinction of Behaviour 2. As described above, however, the results of Leitenberg et al. (Experiment 3, 1975), suggest that the occurrence of Behaviour 1 during the reinforcement of Behaviour 2 might reduce the degree of resurgence. Hence these occurrences should be controlled. The results of Leitenberg et al. (1975) suggest that the occurrence of Behaviour 1 during the training of Behaviour 2 may be reduced by reinforcing Behaviour 2 under a rich schedule. Thus Behaviour 2 was generally reinforced under FR 1 in the present experiments. The exception was where the rate of reinforcement of Behaviour 2 was investigated (Experiment 4).

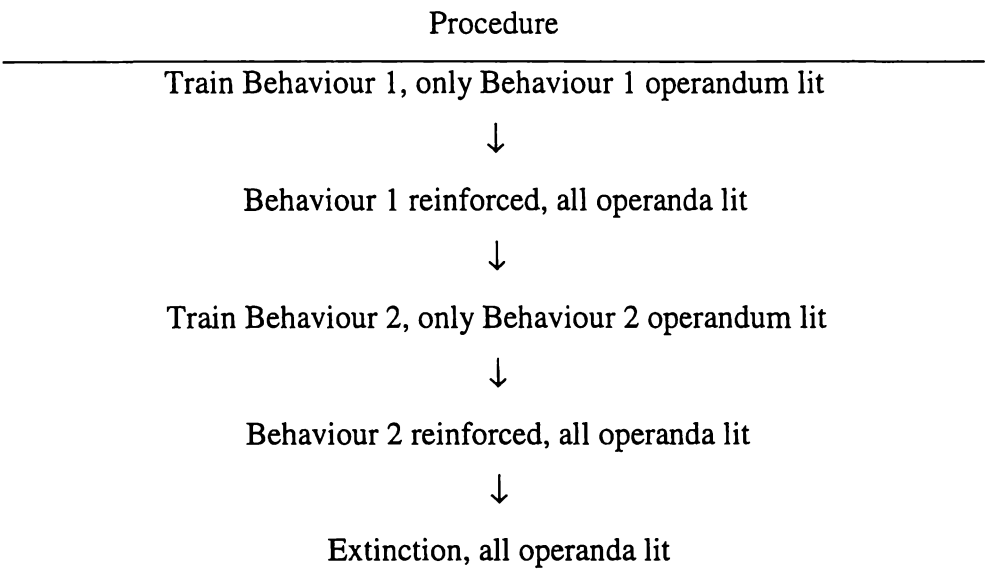
When Behaviour 1 has been trained it is associated with particular stimuli. If the training of Behaviour 2 takes place under the same stimulus conditions then Behaviour 1 may occur during this training. One way to reduce the occurrence of Behaviour 1 at this point would be to train Behaviour 2 under different stimulus conditions. In the resurgence studies described above the two behaviours were reinforced under similar stimulus conditions. Moreover, in Epstein's (1985) principle of extinction-induced resurgence it is implied that the stimulus conditions during extinction of Behaviour 2 need to be similar to the stimulus conditions during the reinforcement of Behaviour 1 for resurgence to occur. Whether this is, in fact, the case is an empirical question whose investigation is beyond the scope of this thesis so, for consistency with previous research, the behaviours should also be trained under the same stimulus conditions. In the present series of experiments each behaviour was trained in a distinct stimulus condition prior to being reinforced under a common stimuli condition. Extinction was in effect under the common stimuli also. In the distinct stimulus condition only the operandum light for the effective behaviour was lit. In the common stimuli condition the operanda for both Behaviour 1 and Behaviour 2 were lit. Thus the general procedure consisted of training Behaviour 1 with only that operandum lit, reinforcing Behaviour 1 with the operandum for Behaviour 2 also lit, training Behaviour 2 with only that operandum lit, reinforcing Behaviour 2

with the operandum for Behaviour 1 also lit, followed by extinction as shown in Table 1. The particular procedure used depended upon the variable being investigated.

The following series of experiments investigate some of the possible variables affecting resurgence suggested by the literature reviewed above, using single-subject design. Experiment 1 investigates whether resurgence is induced by the extinction of Behaviour 2 as suggested by Epstein (1985).

Table 1

Outline of the general procedure of the experiments.



Experiment 1

It was noted previously that Cleland (1996) failed to replicate Epstein's (1983) finding of extinction-induced resurgence and that this may have been the result of the length of training of Behaviour 2 (Leitenberg et al., 1975). The purpose of the present experiment was to eliminate this possible confound by training Behaviour 2 for only a brief period but otherwise keeping the procedure similar. Briefly, Behaviour 1 was first trained with only its operandum lit then with all operanda lit followed by a period of extinction as shown in Table 2. Then Behaviour 2 was trained with only its operandum lit then with all operanda lit followed by another period of extinction. If the occurrence of Behaviour 1 during the final extinction (resurgence) was greater than the occurrence of Behaviour 1 during its own extinction then the training and extinction of Behaviour 2 would have increased the occurrence of Behaviour 1. Such a result would thus indicate induction of resurgence by the extinction of Behaviour 2.

Method

Subjects

Five experimentally naive ISA Brown hens, numbered 81 to 85, served as subjects. They were three years of age at the start of the experiment, and were obtained from a free-range farm approximately four months before the start of the experiment. The subjects were maintained at 80% (+ or - 5%) of their free-feeding body weights by the provision of supplemental feed (commercial laying pellets) outside the experimental session. They were housed in standard wire hen cages (30 cm wide x 45 cm deep x 43 cm high) where water was freely available. Grit and vitamins were also provided weekly.

Apparatus

The experimental chamber was constructed of 2-cm thick particle board with the inside painted white. The internal dimensions were 57 cm x 40 cm x 54 cm and it contained a metal wire-grid floor in a removable metal tray. A fan provided both ventilation and masking noise. Attached to the front panel of the chamber was a response key, a wire frame door that could be pushed forward, and an operandum that was used to define and count head bobs. The key was back-lit by a red light emitting diode (LED), measured 3 cm in diameter, and was situated

Table 2

Outline of the procedure for each phase of Experiment 1.

Phase	Procedure
1	Train Behaviour 1, only Behaviour 1 operandum lit
2	Behaviour 1 reinforced, all operanda lit
3	Extinction, all operanda lit
4	Train Behaviour 2, only Behaviour 2 operandum lit
5	Behaviour 2 reinforced, all operanda lit
6	Extinction, all operanda lit

9 cm from the top of the chamber and 13 cm from the left side of the chamber. It required a force of approximately 1 N to operate a microswitch and produced a feedback beep on operation (when required by the procedure).

The head-bob operandum (Figure 1) consisted of a box attached to the front of the chamber (a) containing three infrared sensors and an aluminium "T" shaped structure that protruded down from the top of the chamber (b) which contained three infrared LEDs. The resulting infrared beams (shown as white lines in Figure 1) were 8 cm in length and ran parallel with the left side of the chamber at a distance of 8.5 cm. The top (c), middle (d), and bottom (e) beams were situated 6 cm, 8.4 cm and 10.4 cm from the top of the chamber respectively. An effective head bob consisted of the hen breaking the bottom, then the top, and then the bottom beam again. A maximum of 1.5 s was allowed between each beam break before a new response had to be started. The breaking of the bottom beam was not effective unless the top and middle beams were unbroken. Effective beam breakings delivered feedback beeps. The head-bob operandum was lit by a LED positioned 4 cm from the left and 9 cm from the top of the chamber, recessed 9 cm into the response panel to avoid it being pecked during head bobbing.

The door (Figure 2) was similar to that described in Sumpter et al. (1995). The two vertical aluminium prongs of the door were situated 4 cm back from the front panel and 11 cm up from the grid floor. They were located 27 cm and 33 cm from the left side of the chamber respectively. A hole in the front of each chamber in line with the door prongs was covered with a box that was lit by a red LED. A microswitch was activated when the prongs were pushed 5 cm towards these boxes. The force required to activate the microswitch was 0.6 N when measured 2 cm from the bottom of the door prongs. A vertical infrared beam was positioned 8 cm in front of the door prongs. Door pushes were not effective unless this beam was broken. The door prongs had to be lowered back to the vertical position after each effective door push before another effective door push could be made. Effective door pushes delivered feedback beeps. The chamber also contained a magazine that presented wheat and which was lit by a 1-W bulb when activated. An infrared beam was generated across the magazine opening to record access times to the magazine.

The experimental chambers were controlled and data were recorded by a

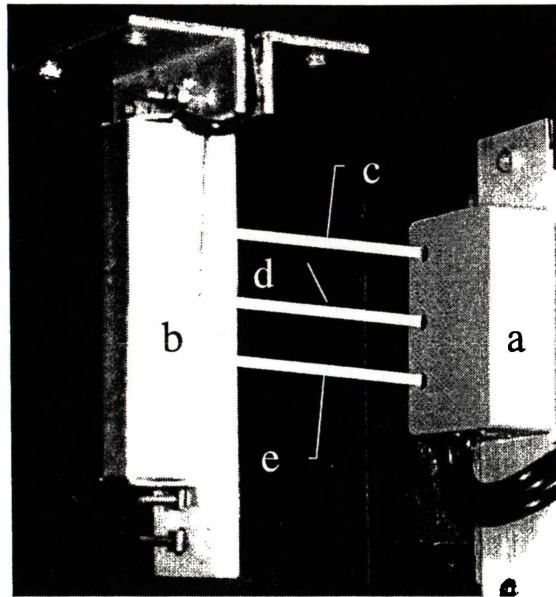


Figure 1. The head-bob operandum. See text for details.

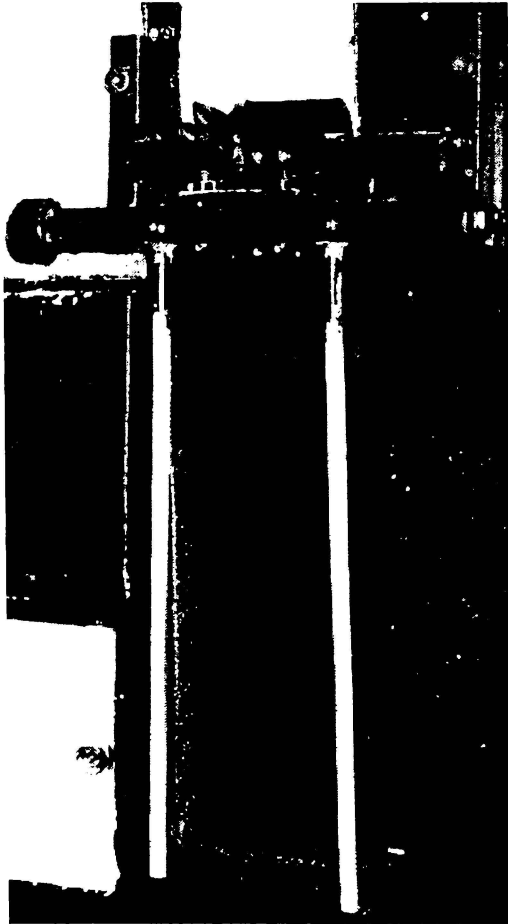


Figure 2. The door-push operandum. See text for details.

Compaq DX66 MHz PC running programs written in MED-PC Version 2 that implemented the experimental procedures.

Procedure

The experiment consisted of six phases. Table 3 shows when responses were reinforced and the stimulus conditions in effect for each phase. Hens 81-83 were first trained to head bob (Behaviour 1) and then to door push (Behaviour 2) while Hens 84-85 were first trained to door push (Behaviour 1) and then to head bob (Behaviour 2). Each of these behaviours was trained over two phases, one when only its operandum was lit and the other where all operandum were lit. Following the final training phase for each behaviour there was a period of extinction with all operandum lit. Table 4 shows the number of sessions of each phase for each hen. Head bobs, key pecks and door pushes were recorded in all phases. In all phases for which reinforcers were delivered, a COD of 6 s was in effect after any response on a noneffective operandum.

Phase 1: Behaviour 1 trained, effective apparatus lit. Each subject was placed in the experimental chamber with the appropriate response apparatus lit (Table 3) and was then trained to eat from a magazine. The other operandum were not lit, and responding on either of these was ineffective. The reinforcer was 3-s access to grain. In this, and all other sessions, a session terminated when 30 reinforcers had been delivered or 2400 s had elapsed, whichever occurred first. Following magazine training, subjects were trained to perform Behaviour 1 by hand shaping. The topography of the behaviour trained (i.e., head bobbing or door pushing) varied between Hens 81-83 and Hens 84-85. Each effective response initially resulted in 7 s of magazine operation. Subsequent magazine operation times were obtained by subtracting any access to the magazine in excess of 1.5 s from the previous magazine operation time. If less than 1.5 s access to the magazine was obtained then magazine operation time was increased by 0.1 s to a maximum of 7 s. The condition was changed for a subject when that subject obtained 30 reinforcers in at least one session in under 10 min. At this point magazine operation time for each subject was changed to the average of the time taken for that subject to get to the magazine plus 1.5 s.

The trained behaviour was then placed under a random-interval (RI) schedule of reinforcement using an auto-adjusting procedure similar to that of

Table 3

Stimulus and reinforcement conditions for each phase of Experiment 1.

Hens 81-83 (Head-bob-first subjects)						
Phase	Behaviour 1		Behaviour 2		Key	
	Head bob		Door push			
	Rft	Light	Rft	Light	Rft	Light
1	✓	✓				
2	✓	✓		✓		✓
3		✓		✓		✓
4			✓	✓		
5		✓	✓	✓		✓
6		✓		✓		✓
Hens 84 and 85 (Door-push-first subjects)						
Phase	Door push		Head bob		Key	
	Rft	Light	Rft	Light	Rft	Light
1	✓	✓				
2	✓	✓		✓		✓
3		✓		✓		✓
4			✓	✓		
5		✓	✓	✓		✓
6		✓		✓		✓

Rft = when reinforcement was delivered for the response.

Light = when the operanda LED was on and feedback was provided.

Table 4
Number of sessions of each phase for all Experiment 1 subjects.

Head-bob-first subjects						
Hen	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
81	26	7	2	3	4	7
82	26	7	2	4	3	7
83	26	7	2	3	4	7
Door-push-first subjects						
Hen	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
84	26	7	2	3	4	7
85	26	7	2	3	4	7

Stahl, Gonzalez, and Swift (1996). RI schedules deliver reinforcers for a response after a variable time that averages a preselected value has elapsed since the start of the schedule for the first reinforcer and since the previous reinforcer delivery for subsequent reinforcers. Under these schedules, reinforcers are programmed randomly with a preselected probability of occurring after a particular time interval. In the RI schedules used here, reinforcers continued to be programmed even if a previously programmed reinforcer had yet to be obtained. This was done because preliminary research by the present author suggested that the auto-adjusting procedure functioned better when this was the case. The auto-adjusting procedure increased the RI value (from an initial RI 10 s) by 2.5% of the RI in effect if the rate of responding in the previous two 30-s intervals was 90% or greater than the rate of responding for the entire session up to this point. The RI value was not changed if the rate of responding in the previous two 30-s intervals was between 71% and 89% of the rate of responding for the entire session up to this point. The RI value was decreased by 2.5% if the rate of responding in the previous two 30-s intervals was 70% or less than the rate of responding for the entire session up to this point. This condition was changed when the RI value for all subjects appeared to be fluctuating around a value of 60 s.

Phase 2: Behaviour 1 reinforced, all apparatus lights lit. At this point the noneffective operanda were lit and feedback beeps were delivered on their operation (Table 3). This phase was maintained until graphs of the effective response rates for each hen for the last four sessions were deemed to be stable by visual inspection by at least two observers experienced in the visual judgement of stability. Rate of responding was deemed stable when the last sessions' rate was not markedly different from that of the previous three sessions. Rate of responding was calculated, here and elsewhere, by dividing the total responses made per session by total session time minus magazine-operation time.

Phase 3: Extinction of Behaviour 1, all apparatus lights lit. At the start of this phase reinforcer delivery ceased. This was maintained until the response rate on the previously effective apparatus for each hen was less than 25% of the median of the last five sessions of the previous condition.

Phase 4: Behaviour 2 trained, effective apparatus lit. At this point Behaviour 2 was hand shaped as outlined in Phase 1 with only the effective operandum lit (Table 3). Following shaping each response was reinforced

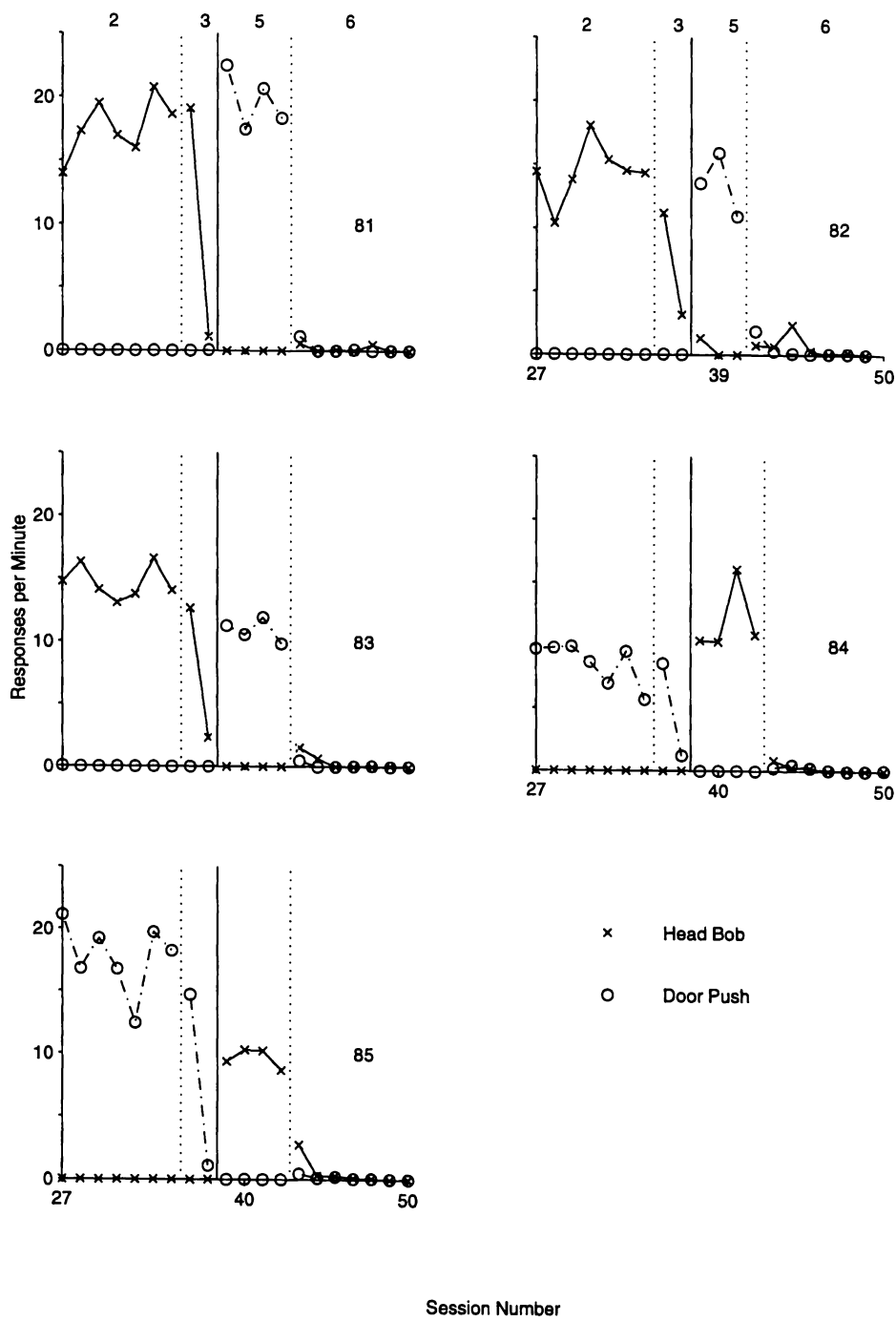


Figure 3. Experiment 1. The rate of occurrence of head bobs (crosses) and door pushes (circles) in Phases 2, 3, 5 and 6.

spontaneously recover at the start of an extinction session (Kimble, 1961) a session is the smallest period that can be used for comparison of the levels of responding. Behaviour 1 thus needs to occur more over a session during the extinction of Behaviour 2 (Phase 6) than it did over the last session of extinction of Behaviour 1 for resurgence to be the result of the extinction of Behaviour 2.

Figure 4 shows the rates of Behaviour 1 from both the Behaviour 1 (Phase 3) and Behaviour 2 (Phase 6) extinction sessions divided by the response rate in the last session when 30 reinforcers were obtained for Behaviour 1 (Phase 2), for all hens. The measure shown equalises any differences in response rate across hens and responses. The data are plotted against the number of sessions of formal extinction. In no case was the relative rate of occurrence of Behaviour 1 during the extinction of Behaviour 2 (i.e., during Phase 6) more than the relative rate of Behaviour 1 during the last session of the extinction of Behaviour 1 (i.e., during Phase 3). These findings suggest that, as in Cleland (1996) who had a longer period of Behaviour 2 training, the present resurgence was not the result of the extinction of Behaviour 2. It should be noted, however, that because the rate of Behaviour 1 declined over the two sessions of Behaviour 1 extinction it is possible that the response rate in any following extinction sessions would be lower still. The rate of occurrence of Behaviour 1 in the last session of extinction may thus overestimate the likely occurrence of Behaviour 1 in any following sessions of extinction without the training and extinction of the second behaviour. This might have masked a small inductive effect but should not have masked the large effect shown by Epstein (1983).

Epstein (1983) found that the extinction of Behaviour 2 resulted in increases in the rate of occurrence of Behaviour 1 whereas the present experiment did not. This may be because in the present experiment reinforcer delivery did not occur in the extinction sessions and, therefore, could not reinstate responding; whereas in Epstein's (1983) study this was not the case. Additionally, the findings may be the result of other differences between the experiments such as the species used. This seems unlikely, but if it were the case then extinction-induced resurgence would still be a valid, if limited, principle. To find if this was so, as Sidman (1960) suggested for such cases, requires a direct replication of Epstein's (1983) study using hens. However, it is difficult to interpret Epstein's study because, as previously mentioned, there is a possible confound and so data from a

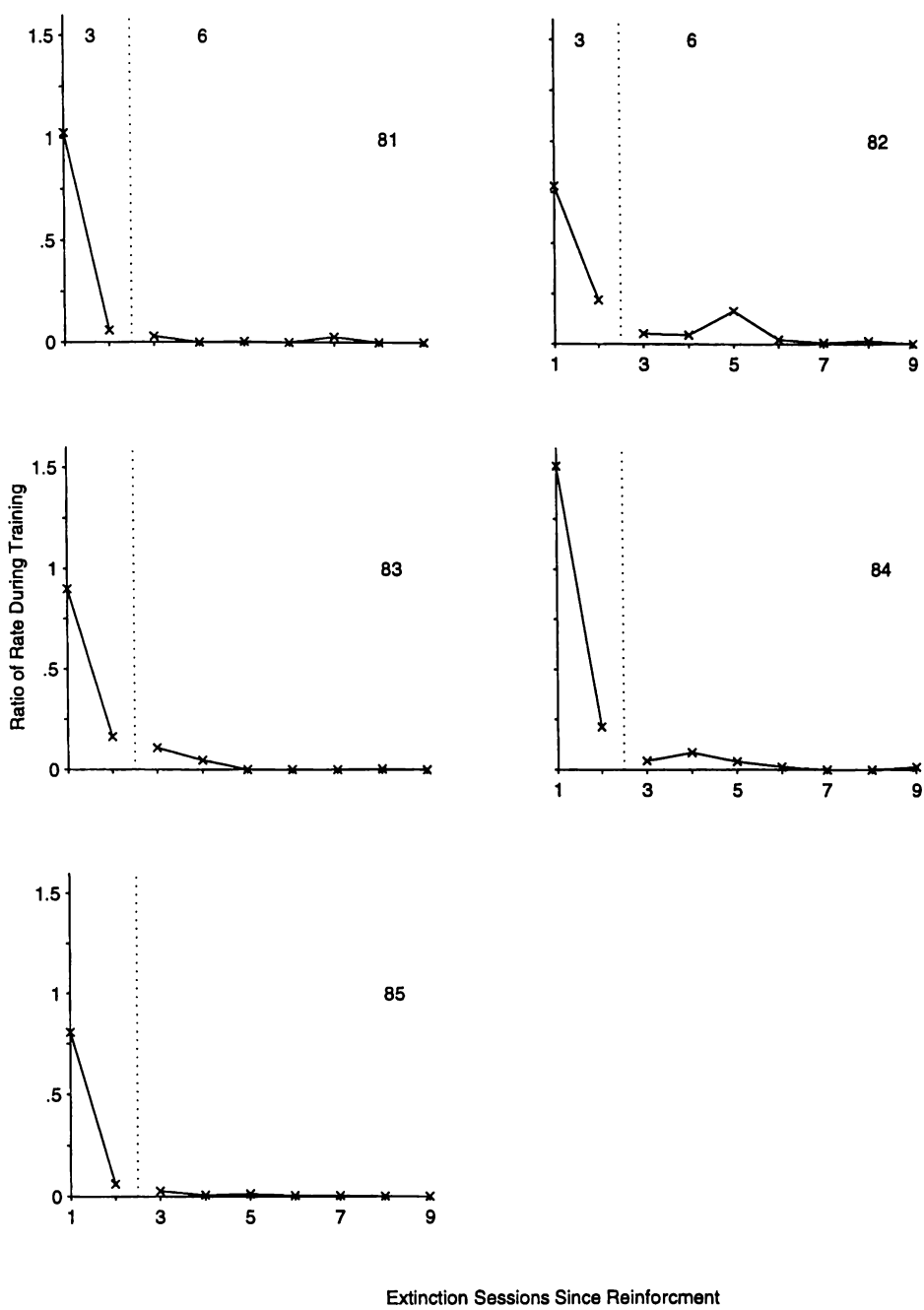


Figure 4. Experiment 1. Rate of occurrence of Behaviour 1 as a ratio of the rate of Behaviour 1 in the last session where 30 reinforcers were obtained (Phase 2) plotted against the number of extinction sessions since reinforcer delivery ceased for this behaviour. The data in sections 3 and 6 are from Phase 3 and 6 respectively.

direct replication, which would include that confound, would be equally difficult to interpret. A better way of investigating the role of species here would be to replicate Experiment 1 using pigeons, or another species. However, of more concern than the generality of the results across species is the finding that the median number of occurrences of Behaviour 1 during the entire Behaviour 2 extinction phase was quite small (i.e., <50). Rather than systematically replicating Experiment 1, a reason for the small degree of resurgence found here was investigated in the next experiment.

Experiment 2

The Prevention of Extinction Hypothesis predicts that the degree of resurgence should be a function of the degree of extinction of Behaviour 1. If this is the case then the small amount of resurgence found in Experiment 1 may have been the result of the 80 min period of extinction of Behaviour 1. However, the results on which Leitenberg et al. (1975) base the Prevention of Extinction Hypothesis are not clear cut. In their study the number of unreinforced occurrences of Behaviour 1 was manipulated by training Behaviour 2 under different schedules. Thus there is a possibility that this training difference, independent of the degree of occurrence of Behaviour 1, may have been responsible for the differing degrees of response recovery observed. One purpose of Experiment 2, therefore, was to investigate whether the degree of resurgence is a function of the amount of extinction of the first behaviour when the training schedule for the second behaviour is held constant.

An investigation into whether the degree of resurgence was a function of the amount of extinction of the first behaviour could be done using a group design as did the Leitenberg et al. (1975) study. However, as Sidman (1960) points out, group designs may not necessarily isolate the variables controlling the behaviour of individuals. One way to identify the controlling variables of the behaviour of individual subjects is to replicate conditions consecutively within subjects whilst varying the independent variable. For within-subject replication to be appropriate for investigating resurgence, the degree of resurgence in each condition should not be influenced by the previous experimental conditions. With replications, a potential confound is the repeated reinforcement and extinction of both the behaviours. There is some research that suggests that the number of responses in extinction may decline over repeated training and extinction conditions (e.g., Bullock, 1960; Bullock & Smith, 1953; Clark, 1964; Clark & Taylor, 1960; Perkins & Cacioppo, 1950; Schaeffer, Salzberg, Birkle, & Ryan, 1967). The extinction conditions of these studies consisted of fewer than five sessions. Anger and Anger (1976) reported that, when each extinction condition was eight sessions long, the repeated extinction effect did not occur for the total responding. They found that, over the repeated extinction conditions, responding in the first session of each extinction condition decreased, however this was counteracted by

increases in responding during the later sessions of each extinction condition.

The initial part of the present experiment replicated the procedure used in Experiment 1 within subjects with two sessions of extinction of Behaviour 1. The same conditions were replicated five times to evaluate the effect of repeated extinction, a possible historical confound. After this the length of extinction of Behaviour 1 was varied from 0 to 9 sessions over a series of conditions to examine any effect of the amount of previous extinction upon the degree of resurgence.

Method

Subjects

Six ISA Brown hens, numbered 81-86, served as subjects. They were approximately three years of age at the start of the experiment. Five (Hens 81-85) had served in Experiment 1. Subject 84 died during the experiment and was replaced with a hen numbered 86 at the start of Condition 6. Hen 86 had previously been trained to perform Behaviour 1 and Behaviour 2 on RI schedules of 30 s and 60 s respectively in a similar experiment. The hens were maintained and housed as in Experiment 1.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The experiment consisted of 10 conditions, and each condition consisted of either five or six phases that were similar to those of Experiment 1. The procedure was essentially 10 repetitions of the procedure used in Experiment 1 with varying lengths of Phase 3 extinction. Hens 81-83 were first trained to head bob (Behaviour 1) and then door push (Behaviour 2) while Hens 84-86 were first trained to door push (Behaviour 1) and then head bob (Behaviour 2). Exceptions to the procedures used in Experiment 1 are stated below. Conditions 1 to 5 involved two sessions of extinction of Behaviour 1 while Conditions 6 to 10 involved 9 or 0 sessions of extinction of Behaviour 1.

Phase 1: Behaviour 1 reinforced, effective apparatus lit. As all hens had experience with Behaviour 1 no initial training was required. The magazine operation times used during the RI auto-adjusting procedure were those used in

Experiment 1 with the exception of that used with Hen 84. The magazine operation time was decreased for Hen 84 because the average time taken by this hen to get to the magazine decreased. During the RI shaping in Condition 1 the RI value for Hen 84 dropped below the starting value of 10 s to 7.22 s over seven sessions. This hen was restarted in the next session with an RI value of 10 s. This phase terminated after 23 sessions of the auto-adjusting RI procedure. In all subsequent conditions, with the exception of Condition 9, Phase 1 consisted of one session of the auto-adjusting procedure with a starting RI value of 60 s. In Condition 9, all subjects received two sessions of the RI procedure.

Phase 2: Behaviour 1 reinforced, all apparatus lights lit. During Phase 2 Condition 8 Hen 85 (a Door-push-first hen) was exposed by accident to the program appropriate for Hen 82 (a Head-bob-first hen). Hen 85 received no reinforcers in that session and performed 197 door pushes.

Phase 3: Extinction of Behaviour 1, all apparatus lights lit. This phase was maintained for two sessions in Conditions 1 to 5, nine sessions in Conditions 6, 7, and 10, and did not occur in Conditions 8 and 9.

Phase 4: Behaviour 2 reinforced, effective apparatus lit. This phase terminated after two sessions for all subjects in Condition 1 and for Hens 81 and 82 in Condition 2. In all other conditions this phase terminated after one session. Hen 84 became ill during this phase of Condition 2.

Phase 5: Behaviour 2 reinforced, all apparatus lights lit. For this phase, the reinforcer times for Behaviour 2 were the same as those used for this behaviour in Experiment 1. This phase lasted for four sessions in all conditions. Hens 83 and 86 received one extra session of this phase in Conditions 8 and 10 respectively. Unbeknownst to the experimenter, the infrared sensor in the magazine ceased to function reliably during this phase of Condition 10. Repair to the sensor was not effected until after the conclusion of the experiment.

Phase 6: Extinction of Behaviour 2, all apparatus lights lit. After Session 1 of Phase 6 in Condition 7 the subjects were accidentally not fed the additional supplemental feed. Hen 81 received only six sessions of Phase 6 in Condition 9.

Results and Discussion

The present experiment was conducted to investigate whether the degree of resurgence was a function of the amount of extinction of Behaviour 1. Of concern

was whether the results were ~~going to be~~ confounded by ~~any effect of~~ repeating conditions. Figure 5 shows the rate of occurrence of Behaviour 1 (left panel) when Behaviour 1 was reinforced (Phase 2) and the rate of occurrence of Behaviour 2 (right panel) when Behaviour 2 was reinforced (Phase 5) for all hens over all conditions. The data from Experiment 1 are included, for comparison, and here and elsewhere are labelled Condition 0. There were no consistent trends in the rates of occurrence of behaviours across conditions. Thus both behaviours recovered, during the training phases, to their previous levels and so any changes in the degree of resurgence could not be attributed to changes in these response rates over conditions.

It was also possible that the first behaviour could be adventitiously maintained when the second behaviour was reinforced (Phase 5) by the reinforcers available for the second behaviour. Figure 6 shows the rates of occurrence of Behaviour 1 while Behaviour 2 was reinforced (Phase 5) for all subjects and conditions. Generally Behaviour 1 did not occur during Phase 5 and when it did occur it did not continue to occur over all sessions of a condition. The most consistent occurrence was over three consecutive sessions of Condition 9 for Hen 81 and the highest rate seen was in the last session of Condition 9 for Hen 86. In addition, these responses generally occurred at the start of a session prior to any reinforcer delivery. It would seem unlikely, therefore, that they were the result of reinforcer delivery for Behaviour 2 adventitiously maintaining Behaviour 1.

The major issue to be examined here, however, is the effect of repeated extinction conditions. Anger and Anger (1976) found that, over repeated extinction conditions, responding in the first session of each condition decreased while responding from the third session onwards of each extinction condition increased. In the present experiment data exist for both behaviours in extinction immediately following their exposure to reinforcement (simple extinction). Simple extinction data are available for Behaviour 2 (Phase 6) and for Behaviour 1 prior to training Behaviour 2 (Phase 3). Over the repeated extinction conditions for the second behaviour (Phase 6) most responding occurred in the first session, and it then reduced rapidly. In order to show responding from Session 1 and from Sessions 3 to 7 on the same figure for comparison, relative measures are presented in Figure 7. Circles show the number of occurrences of Behaviour 1 from the first session of extinction (Phase 3) in each condition divided by the number from this

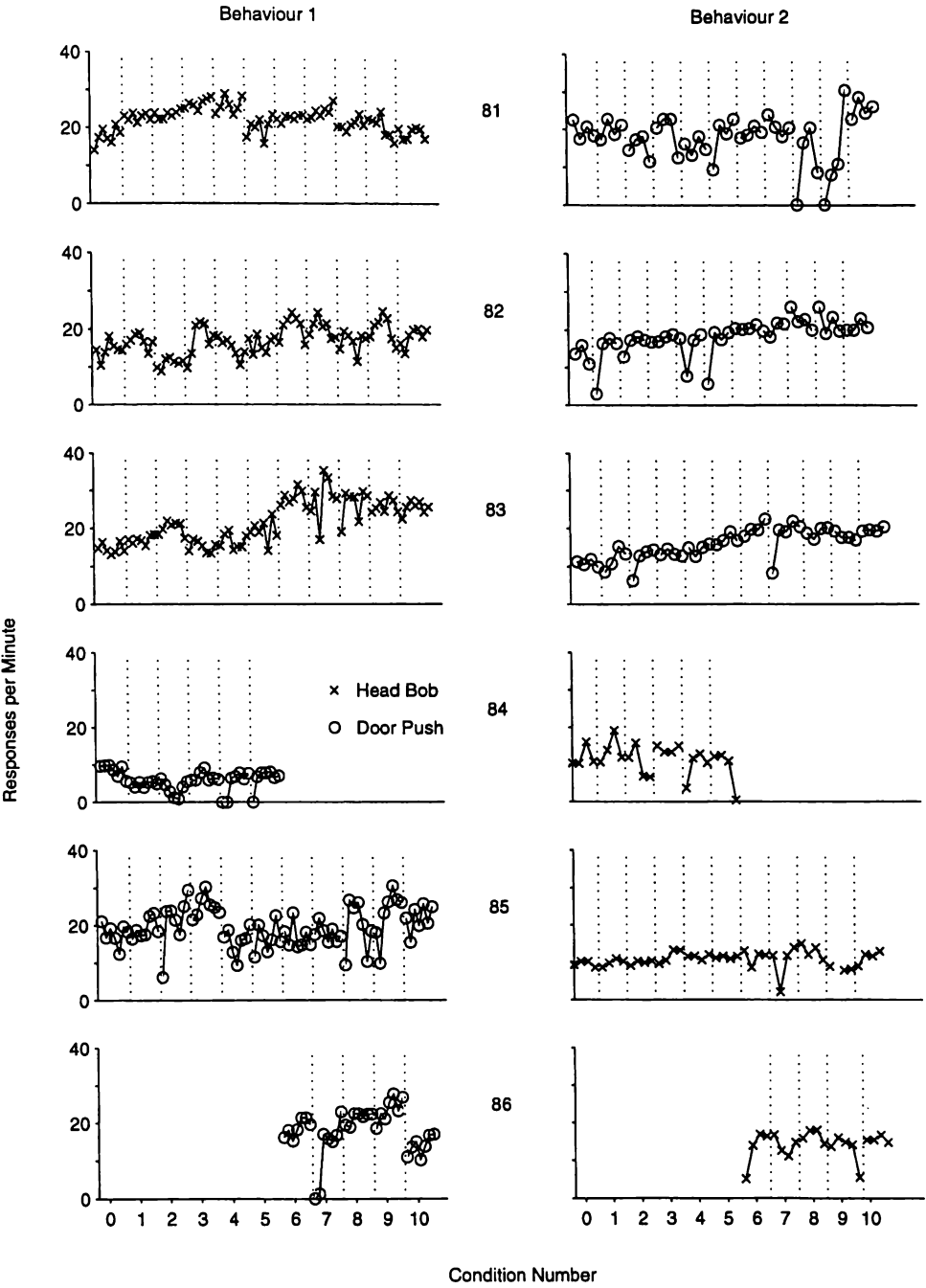


Figure 5. Experiment 2. The rate of Behaviour 1 (head bobbing for Hens 81-83 and door pushing for Hens 84-86) in each Phase 2 session for all conditions (left panel). Also shown is the rate of Behaviour 2 (door pushing for Hens 81-83 and head bobbing for Hens 84-86) in each Phase 5 session for all conditions (right panel).

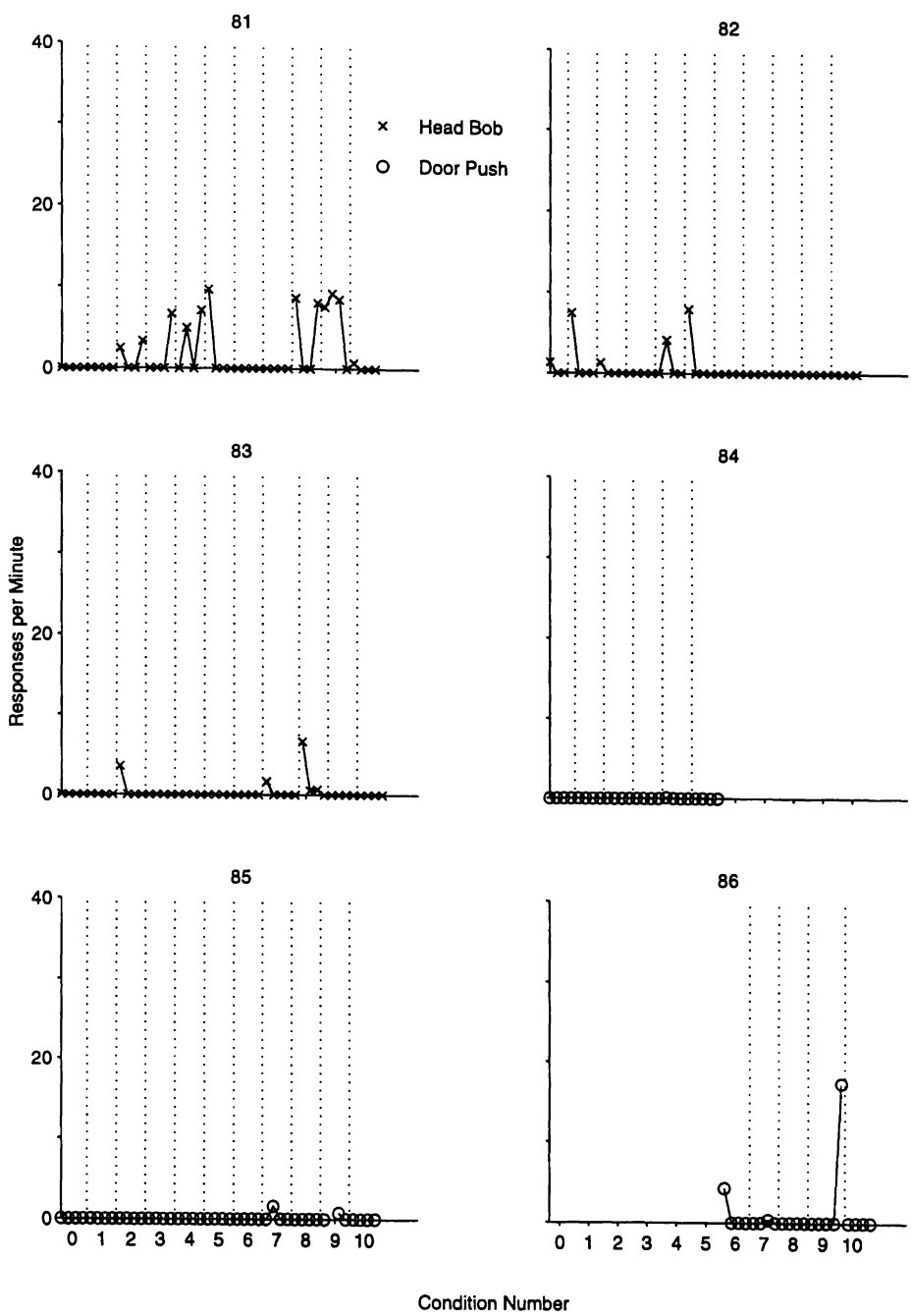


Figure 6. Experiment 2. The rate of Behaviour 1 in each session that Behaviour 2 was reinforced (Phase 5).

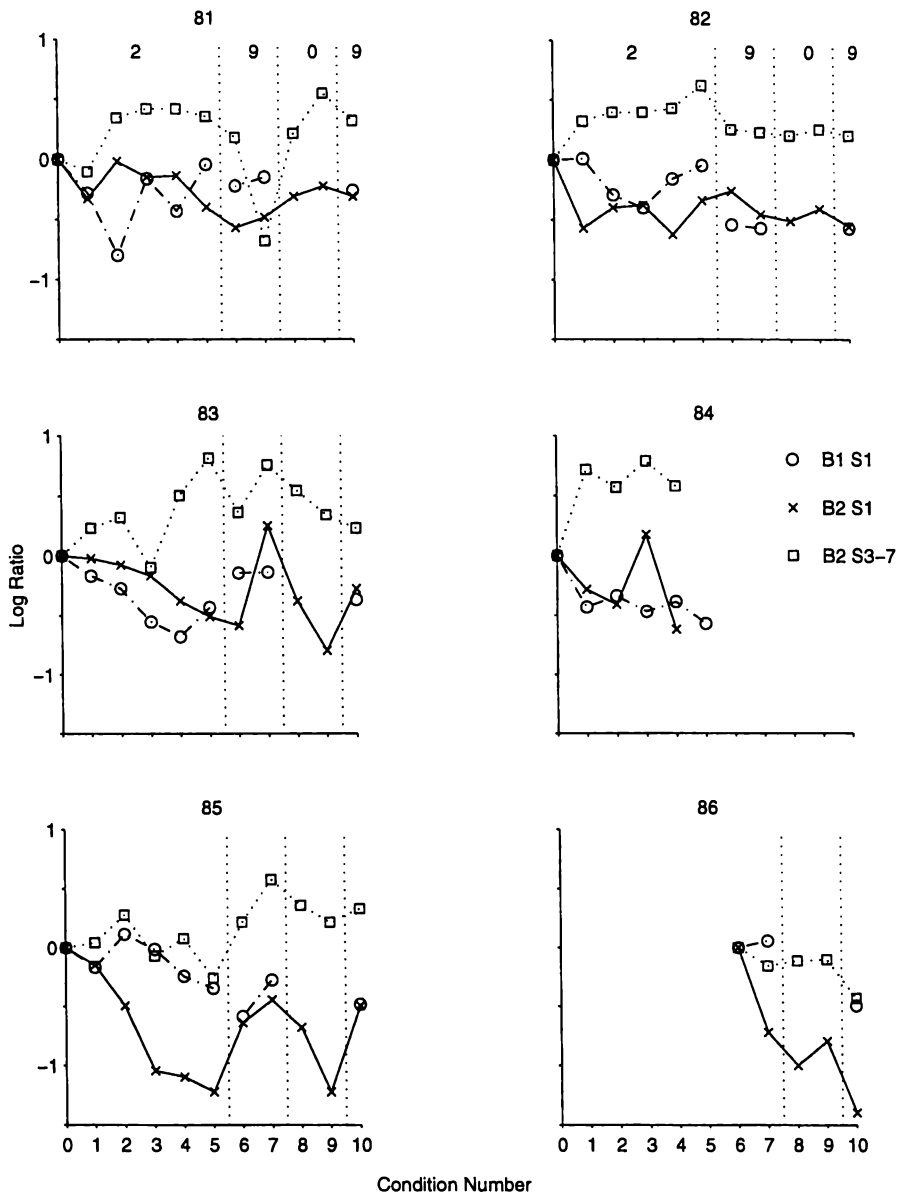


Figure 7. Experiment 2. The logarithms of the ratios of the number of first behaviours that occurred during the first session of extinction of that behaviour (Phase 3) to the number that occurred in the first session of extinction experienced by each subject under these conditions for all subjects (circles). Also shown are the logs for the same ratio of the second behaviours that occurred during the first session of extinction of the second behaviour (Phase 6, crosses) and of the average number of second behaviours over Sessions 3 to 7 of the extinction of the second behaviour (Phase 6, squares). The number of Phase 3 sessions are shown on the top graphs and condition breaks show where these changed.

session in Condition 0 (Experiment 1). Crosses are the number of occurrences of Behaviour 2 from the first session of its extinction (Phase 6) in each condition divided by the number in this session in Condition 0. Squares are the number of occurrences of Behaviour 2 from Session 3 to 7 of its extinction (Phase 6) in each condition divided by the number in the equivalent sessions in Condition 0. These ratios are shown as logarithms to give an equal-interval scale. Numbers greater than 0 mean that the number of responses increased and numbers less than 0 mean that they decreased, relative to Condition 0. The points for the second behaviour are joined across condition breaks because the conditions in effect for this behaviour did not change. For both behaviours, these measures for the first session generally decreased similarly over the experiment (circles and crosses decrease similarly across conditions).

Changes in the Behaviour 2 extinction responding in Sessions 3 to 7 were less consistent than those seen in the first-session data. It should be noted, however, that there was not a great deal of responding in Sessions 3 to 7 of extinction in both this and the previous experiment and so small changes in number give large changes in the ratios. In most cases the measure of responding in Sessions 3 to 7 of Conditions 1 to 10 was greater than zero suggesting that responding in this period increased with repeated conditions. Hen 86, a subject with prior experimental history, being the exception. These changes in early (Session 1) and late (Sessions 3 to 7) extinction responding across conditions provide some support for Anger and Anger's (1976) findings.

Anger and Anger (1976) suggested that the increase in later extinction responding (i.e., that from Session 3 onwards) was the reason that total extinction responding did not decrease across conditions. Figure 8 shows the total number of occurrences of Behaviour 2 during extinction across conditions. While the responding in Condition 10 for Hens 82, 85, and 86 is lower than that from the first extinction condition (Condition 0 for all hens excluding Hen 86) a decreasing trend is evident for Hen 86 only. It would appear that increases in responding in Sessions 2 to 7 was generally sufficient to offset the decrease in responding in the first session.

If the Prevention of Extinction Hypothesis, that resurgence is the result of the continuation of the extinction of Behaviour 1, is correct, then the pattern of the resurgence should be similar to that seen for a behaviour under simple extinction.

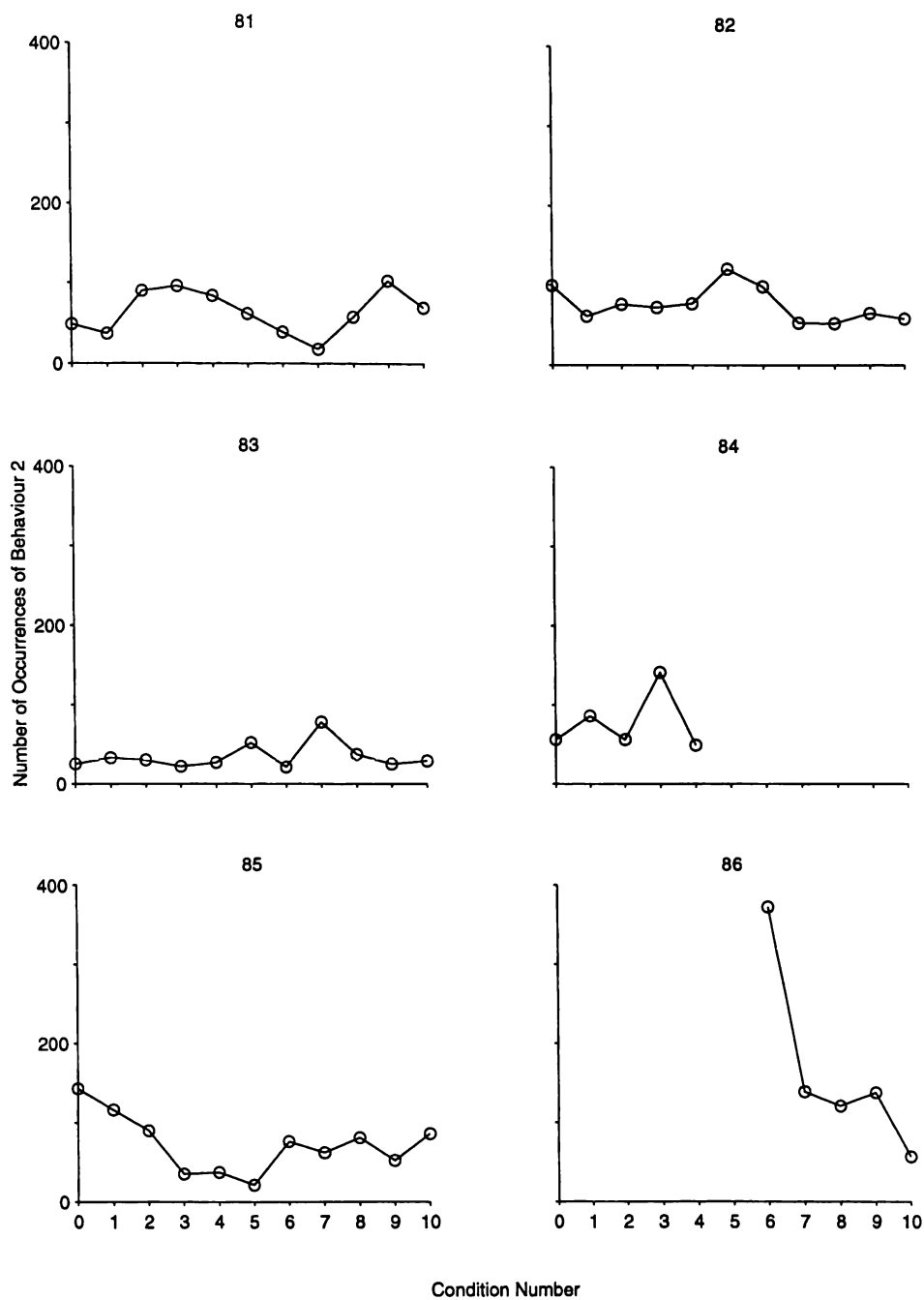


Figure 8. Experiment 2. Total number of occurrences of Behaviour 2 during extinction (Phase 6) in Experiment 1 (Condition 0) and Experiment 2 (Conditions 1 to 10).

This means that across repeated conditions it might be expected that the degree of resurgence would change depending upon the amount of previous extinction and on the number of previous conditions. There were two sessions of extinction following training of the first behaviour in Conditions 0 to 5. Because the occurrence of the first behaviour during Behaviour 2 training was generally small, the first session of extinction following training of the second behaviour (i.e., Phase 6) was effectively the third extinction session for the first behaviour after reinforcer cessation for Behaviour 1 in these conditions.

The first section of Figure 9 shows the number of occurrences of the first behaviour during the first session of Behaviour 2 extinction (circles) and during all the sessions of the Behaviour 2 extinction (crosses). It can be seen that both were variable and either generally increased or stayed roughly constant over the first six conditions. This pattern is more like the later sessions extinction responding for Behaviour 2 than the first session extinction responding observed across repeated conditions. Over these six conditions, the difference between the total number of occurrences of Behaviour 1 (crosses, Figure 9) during all extinction sessions in a condition and the occurrence of Behaviour 1 during the first session of extinction (circles) generally increased, Hen 82 being the exception. These findings are consistent with the resurgence here being equivalent to late extinction responding.

Figure 9 also shows the total number of occurrences of the first behaviour in both the first session and over all seven sessions of the extinction following Behaviour 2 training for the last five conditions. When there were nine previous extinction sessions for Behaviour 1 (Phase 3, Conditions 6, 7, and 10) this first session was effectively the tenth extinction session for this behaviour. It was effectively the first session of extinction when there had been no previous extinction for the first behaviour (i.e., Conditions 8 and 9). Both first session (circles) and total resurgence (crosses) when there were nine sessions of extinction of Behaviour 1 (i.e., Conditions 6, 7, and 10) were generally within the range found for two sessions of extinction (i.e., Conditions 0 to 5). For three of the five hens (Hens 82, 83 and 86) the total resurgence (crosses) in the conditions where there were no sessions of extinction (i.e., Conditions 8 and 9) was higher in both cases than the highest number that occurred with nine sessions of extinction (i.e., Conditions 6, 7, and 10). The degree of resurgence, measured by this total, was

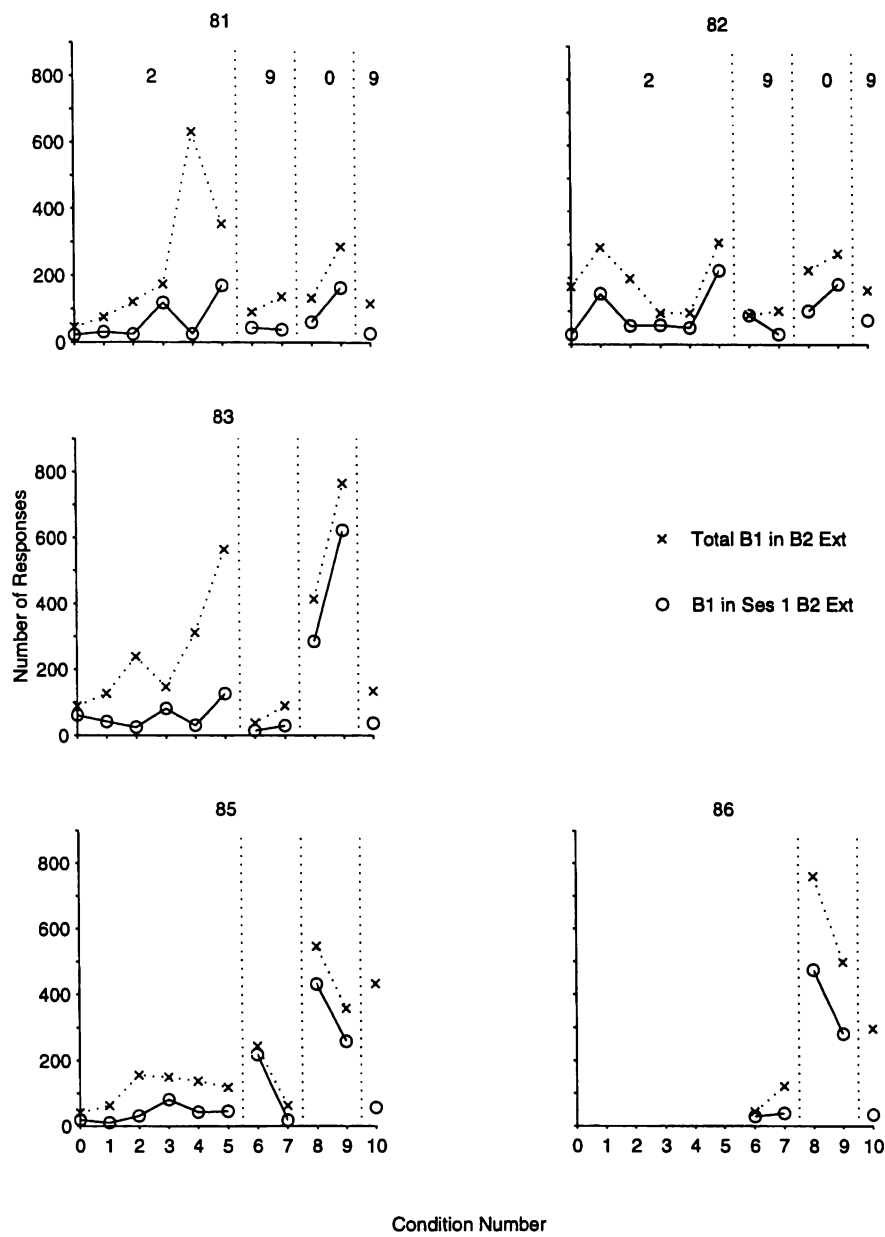


Figure 9. Experiment 2. The total occurrence of Behaviour 1 (crosses; head bobs for Hens 81-83 and door pushes for Hens 84-86) over the first 7 sessions of extinction of Behaviour 2 (Phase 6) for all conditions. Also shown is the occurrence of Behaviour 1 (circles) in the first session of extinction of Behaviour 2 (Phase 6) for all conditions. The numbers on the top of the top graphs show the number of extinction sessions of Behaviour 1 for those conditions.

somewhat variable. The total resurgence appears to have been higher when there was no extinction than when there was some but it was not a simple function of Behaviour 1 extinction. The resurgence in the first extinction session (circles) for the conditions where there was no initial extinction of Behaviour 1 (Phase 3, Conditions 8 and 9), was greater than the resurgence in the first extinction session that occurred with nine sessions of extinction (i.e., Conditions 6, 7, and 10) for all hens. These differences are small for Hens 81 and 82 but there are possible explanations for this.

Hen 81 performed Behaviour 1 approximately 400 times during the training of Behaviour 2 in both conditions where there was no programmed extinction of Behaviour 1. None of these responses was reinforced. This hen, therefore, could be seen to have experienced a greater period of extinction than programmed and this itself may explain the small effect found. Hen 82's first behaviour shows a greater early extinction drop over conditions than the other hens. For this hen, in later conditions (Conditions 6, 7, and 10) the number of responses in the first session of extinction of Behaviour 1 was around half that of Condition 1 (Figure 7) even though the rates of both behaviours during their training remained high. If the Prevention of Extinction Hypothesis were true then the first session of the final extinction for the conditions in which there was no extinction of Behaviour 1 (Conditions 8 and 9) is the first session of the extinction of Behaviour 1 in these conditions. Given the response rate drop during the first session of extinction of Behaviour 1 seen over conditions (Conditions 6, 7, and 10), a similarly low level of resurgence might be expected in the first session of the final extinction when this is the first session of extinction of Behaviour 1 (Conditions 8 and 9). Thus the data for these two hens appear to be influenced by factors other than the number of arranged extinction sessions.

Experiment 1 investigated Epstein's (1983) suggestion that resurgence was the result of the extinction of Behaviour 2. If this were so then the training and extinction of Behaviour 2 should have resulted in more Behaviour 1 occurring than otherwise would have occurred. This was not found to be the case. It was pointed out, however, that the estimation of the likely occurrence of Behaviour 1 without the training and extinction of Behaviour 2 may have been inaccurate. In the present studies, because there were some conditions where Behaviour 1 was under extinction before Behaviour 2 training, extinction data for the first

behaviour, without the training and extinction of the second behaviour, exist.

If Epstein (1983) is correct, it might be expected that the occurrence of Behaviour 1 in the first session of the final extinction (Phase 6) would be more frequent than its occurrence in the first session of its simple extinction (Phase 3). Figure 10 shows the occurrence of Behaviour 1 in the first session of extinction of Behaviour 1 (i.e., in Phase 3, crosses) for Conditions 0 to 7 and 10, for all hens except Hen 84. Also shown is the occurrence of Behaviour 1 in the first session of extinction of Behaviour 2 (i.e., Phase 6, circles) for Conditions 8 and 9. These latter data are not consistently higher than the former, with the exception of Hen 85 for whom the difference is small. Hence the extinction of Behaviour 2 did not result in greater occurrence of Behaviour 1 in the first session of extinction than would have occurred if Behaviour 2 had not been trained. As in Experiment 1, then, resurgence does not appear to be the result of the extinction of the second behaviour.

Overall then, the results of the present experiment suggest that the degree of resurgence that occurred early in each Behaviour 2 extinction phase depended on whether or not there had been a period of extinction of Behaviour 1. While the degree of this early resurgence was consistently related to whether or not there had been a period of extinction, the degree of total resurgence (over all of Phase 6) was somewhat less so. As previously mentioned, later extinction responding increased across repeated conditions for Behaviour 2. If this occurred for the first behaviour during the final extinction (i.e., for the resurgence) then total resurgence measured over all of the final extinction sessions would include more of this increase, while early resurgence would not include as much, and the amount included would change over conditions. Thus the total resurgence might be disproportionately affected by the repeated conditions. The repeated conditions may also have contributed to the variance in the degree of both total and early resurgence. This variability meant that whether or not the degree of resurgence was a simple function of the amount of extinction, as the Prevention of Extinction Hypothesis predicts, could not be assessed. Further research should aim to control the variability seen here.

The present experiment took approximately one year during which there were up to 312 sessions and 58 phase changes per hen. It is likely that extraneous sources of variability might have also affected the data over and above the

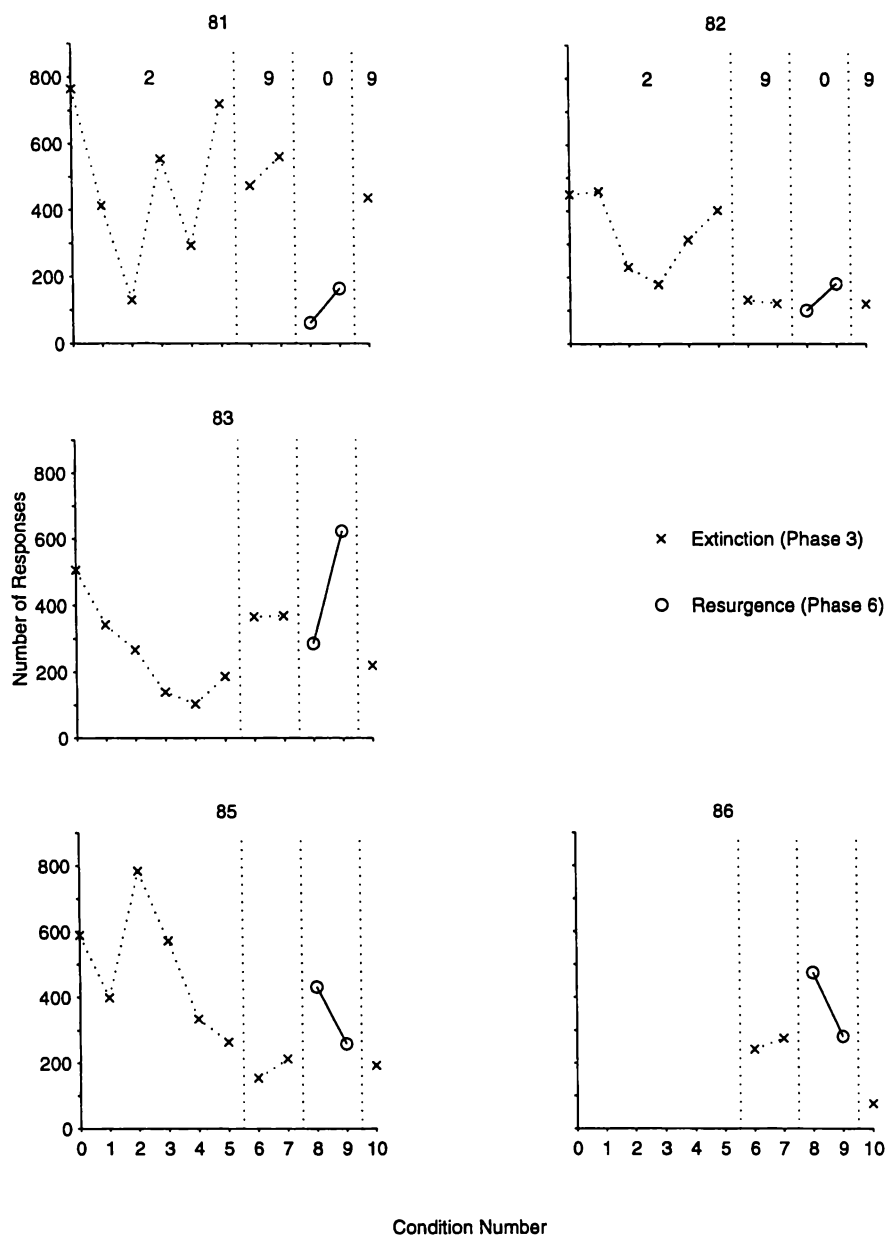


Figure 10. Experiment 2. The number of first behaviours that occurred in the first session of extinction of this behaviour (Phase 3; crosses) for Conditions 0 to 7 and 10 and the number of first behaviours that occurred during the extinction of the second behaviour (Phase 6; circles) for Conditions 8 and 9.

repeated conditions. If so, a more appropriate design to investigate whether or not the degree of resurgence is a function of the degree of extinction, would be one that allows behaviours to be compared over a similar time period, such as multiple-schedule design (Sidman, 1960). Such a procedure was used in the next experiment.

Experiment 3

The results of Experiment 2 suggest that a long period of extinction of a behaviour may reduce the resurgence of that behaviour. The variability in the degree of resurgence found meant that the only difference seen was between the degree of resurgence after no extinction and that after a long period of extinction. Whether the degree of resurgence of a behaviour is a function of the amount of extinction of that behaviour could not be ascertained. The variability may have been the result of the repeated training and extinction or of other uncontrolled variables that changed across conditions. One way of investigating and equalising for such effects is to use a multiple-schedule design in which behaviours under the control of different stimuli are compared within the same subject at similar points in time (Sidman, 1960).

A two-component multiple-schedule design to investigate resurgence might involve training two first behaviours, one under a red stimulus condition and the other under a green stimulus condition. Then one of the first behaviours might receive a period of extinction while the other would not receive extinction. Two second behaviours would then be trained, again one under the red stimulus condition and the other under the green stimulus condition, followed by extinction. In this final extinction the degree of resurgence of the first behaviour which had had some extinction and the first behaviour which had had no extinction could be compared. Because this design does not involve repeated conditions, the degree of resurgence would not be confounded by factors that varied across repeated conditions.

To investigate whether the degree of resurgence of behaviour is a function of the amount of extinction of that behaviour, however, requires more than two amounts of extinction of the first behaviour. This might be done by repeating the multiple schedule a number of times, varying the amount of extinction of one first behaviour while having no extinction of the other first behaviour. If the degree of resurgence changes across conditions as a result of a confound then, because the two first behaviours have similar history, the degree of resurgence of the first behaviours may change similarly across conditions. The degree of resurgence of the first behaviour which had no extinction could serve as a baseline to assess what changes in the degree of resurgence of the first behaviour which had prior

extinction were the result of this prior extinction.

Mulick et al. (1976) examined the recovery of one behaviour during the extinction of another behaviour using a multiple-schedule design. They reinforced bar pressing in four squirrel monkeys on intermittent schedules under three different stimulus conditions. Reinforcer delivery then ceased for this behaviour in all components but in one component pressing another bar was reinforced (DRA) and in another component not pressing the first bar was reinforced (DRO). The rate of pressing the first bar declined over sessions for all subjects in all components. All reinforcer delivery then ceased. No recovery of the first behaviour was observed. Then, for two of the subjects, pressing the first bar was again intermittently reinforced in one of the three components. This re-established pressing the first bar in all three components for both subjects. One interpretation of these results is that responding in the individual components was not under the separate control of the contingencies in effect in each component. To put it another way, the behaviours in the components were not independent.

Mulick et al. (1976) suggested that responding did not recover in extinction because there was a generalised avoidance of the first bar. If there was a generalised avoidance response then the behaviour in the components would not be independent. They then performed a second experiment using three monkeys in which the DRA and DRO components were similar but pressing the first bar in the third component was reinforced on an intermittent schedule throughout. The rate of bar pressing in this third component was reduced for two subjects when DRA and DRO were in effect in the other components. Because of this they suggested that the behaviours in the components were not independent at this point. Reinforcer delivery then ceased in the DRA and DRO components. In extinction the rate of pressing the first bar increased in the DRA component but decreased in the DRO component. Thus Mulick et al. (1976) suggested that pressing the first bar recovered after DRA but not after DRO. The rates of pressing the first bar in the DRO and DRA components in this last extinction, however, were similar. The difference in recovery noted by Mulick et al. (1976) was due to a lower rate in the DRA component than the DRO component when these procedures were in effect. Because there appears to have been no differentiation in the rate of bar pressing between the two components in extinction it is possible that bar pressing in these components was not independent

in extinction. Mulick et al. (1976) noted that the results may have been confounded by interactions between components and so no firm conclusions could be made about resurgence from these experiments.

For a multiple-schedule design to be useful in investigating resurgence the possibility that the results might be due to interactions needs to be eliminated. The results of Experiments 1 and 2 here suggest that the extinction of the second behaviour has little effect upon the degree of resurgence. Because of this, interactions between the second behaviours in a multiple-schedule design are unlikely to affect resurgence. It is the interactions between the first behaviours that need to be controlled.

Terrace (1966) suggested that differential reinforcement may be required for stimuli to control behaviour. Mulick et al. (1976) reinforced the pressing of the same bar under the same schedules across the components during training. As there was no requirement for differential responding across the components during training, the behaviours in the components may not have come under the control of the component stimuli. If this was the case then, by definition, a procedure applied to one component behaviour will affect the other component behaviours. Stimulus control by component stimuli would appear to be a necessary condition for behaviour in components to be independent. To establish this requires differential reinforcement across components. It is not clear at what point the first behaviours should be differentially reinforced for stimulus control to be established.

In the second Mulick et al. (1976) study, the rates of bar pressing in the DRA and DRO components, when these procedures were in effect, were different. It appears that differential reinforcement had established some stimulus control at this point. It might be argued that if stimuli control behaviour when DRO and DRA procedures are in effect then they should continue to control behaviour when these procedures are not in effect. If this was the case then Mulick et al.'s (1976) suggestion that bar pressing recovered after DRA but not DRO might be correct even though the rate of bar pressing was similar in both components at that point. However, it may also have been the case that the DRA and DRO schedules themselves were functioning as the discriminative stimuli instead of the component stimuli. If this were the case then when these procedures ceased the behaviours may have been under the control of the stimuli in the presence of

which they were originally trained. Thus, if bar pressing was not under differential stimulus control in training then it would not be under differential stimulus control in extinction. This might explain why similar recovery was observed for bar pressing in the DRA and DRO components when these procedures ceased, even though they resulted in different response rates when they were in effect.

To reduce the possibility that the same stimuli might control responding across components during extinction it would seem prudent that control by component stimuli be obtained as soon as possible during training. Thomas, Stengel, Sherman, and Woodford (1987) have shown that training behaviours under each of two different stimuli, each on alternate days, can result in differential stimulus control in a later extinction period. These authors found that under this procedure, stimulus control was not as good at the start of daily sessions as at the end but that there was stimulus control evident when the stimuli were alternated in extinction. These results suggest that stimulus control could be developed by training the first behaviours under their respective stimuli in separate sessions from the start of training, to avoid training under common stimuli across components, before introduction of the multiple schedule. A procedure in which the component behaviours are differentially reinforced in alternate sessions may help establish control of behaviour by component stimuli.

However, while such stimulus control is a necessary condition for the independence of behaviours in each component it is not sufficient to ensure that this is the case. A number of studies have shown that when contingencies are altered in one component of a multiple schedule the rate of responding in another component may also change (e.g., Reynolds, 1961a; 1961b). This is important because the results of any experiment where this is the case, while valid for the multiple-schedule situation, might not be valid for a situation such as simple schedules where these interactions do not occur.

In a review of relevant studies, Williams (1983) concluded that multiple-schedule interactions are most likely due to changes in relative rates of reinforcement between components. If this is the case then responding would not be independent when relative rates of reinforcement are constant between components, although no interaction would be evident until relative rates changed. Moreover, even when the same operation is conducted in both components at

similar times (i.e., extinction) the rates of responding in individual components may not be independent. Although a great many studies have investigated multiple-schedule interaction it is still not entirely clear how to avoid such interactions. It is possible, however, to ascertain whether such interactions have occurred.

Different schedules of reinforcement in each component might establish differentiation between component behaviours. However, using different schedules of reinforcement for the two first behaviours may itself affect resurgence in unknown ways. Differentiation between component behaviours might also be established by reinforcing different topographies of behaviour in the two components. Little difference was found in the resurgence of behaviours of different topographies in Experiment 1 and 2 so differentiation of component behaviours based on response topography should not substantially affect resurgence. Here, topographically different first behaviours were used. Specifically, head bobbing was the first-trained behaviour in the red component while door pushing was the first-trained behaviour in the green component. These behaviours were trained on alternate days to help establish control by the appropriate stimuli (house-light and operanda light). To decrease the probability that responses reinforced under the other stimuli would occur, only the operandum effective in that component was lit. The different stimulus conditions were then alternated within sessions in a multiple schedule with the light of the operanda for the second behaviour in each component also lit, as shown in Table 5.

After a period, reinforcement ceased for one first behaviour. The other first behaviour was still reinforced as a means of monitoring interactions between the components. Interactions would be shown by correlated changes in response rate or the occurrence of incorrect component behaviour at this point. Following this, key pecking (the second behaviour) was reinforced under the component stimuli, using a different key in each component. Then reinforcer delivery ceased.

There were a series of conditions, each with the same sequence, but each having different amounts of extinction of one first behaviour. These examined whether the degree of resurgence was a function of the amount of extinction of that behaviour. One first behaviour was never exposed to extinction prior to the training and extinction of the second behaviour so that any changes in the occurrence of the first behaviour could be assessed across repeated conditions.

Table 5

Outline of procedure used for half the subjects in Experiment 3 (Hens 21-23). The procedure for Hens 24-26 was similar except that in Phase 3 extinction was in effect for door pushing instead of head bobbing.

Phase	Component		Arrangement	Operanda lights
	Red	Green		
1	HB Rft	DP Rft	Alternate sessions	Only effective operanda lit
2	HB Rft	DP Rft	Multiple schedule	All operanda lit
3	Ext	DP Rft	Multiple schedule	All operanda lit
4	RK Rft	LK Rft	Alternate sessions	Only effective operanda lit
5	RK Rft	LK Rft	Multiple schedule	All operanda lit
6	Ext	Ext	Multiple schedule	All operanda lit

- HB = Head bob.
- DP = Door push.
- RK = Right-key peck.
- LK = Left-key peck.
- Rft = reinforcement delivered for response.
- Ext = no reinforcement delivered for any response (extinction).

The degree of resurgence of the first behaviour that had varied amounts of extinction was compared across conditions using the first behaviour that had no extinction as a baseline. The Prevention of Extinction Hypothesis predicts that the degree of resurgence will be an inverse function of the amount of prior extinction.

Method

Subjects

Six experimentally naive ISA Brown hens, numbered 21-26, served as subjects. They were two years old at the start of the experiment, and were obtained from a free-range farm approximately three months before the start of the experiment. The subjects were maintained and housed as previously described.

Apparatus

A chamber similar to that used in Experiment 2 was used, with the following alterations. The inside of the chamber was painted black. A key was added to the front wall of the chamber directly above the door push apparatus (i.e., 30 cm from the left and 7 cm from the top of the chamber). The operanda lights were replaced with LEDs that could be lit red or green. A house-light consisting of five red and five green LEDs was positioned in the middle of the ceiling of the chamber 31 cm from the front wall.

Procedure

The experiment consisted of 10 conditions, each with five or six phases. Table 6 shows which response was reinforced and the stimulus conditions in effect for each of the six phases. In each phase a house-light and some combination of operanda lights were lit either red or green, denoting which component was in effect. In all phases for which reinforcers were delivered, a COD of 6 s was in effect after any response on a noneffective operandum. The operation of an operandum, when lit, resulted in feedback beeps.

Phase 1: First behaviours trained and reinforced, effective apparatus lit.

In Condition 1, subjects were trained to eat wheat from a magazine and to head bob, in a similar fashion to Experiment 1, with the head-bob operandum and house-light lit red. When 30 magazine operations had occurred in at least one session for all hens, hens were trained to door push with this operandum and house-light lit green. Each door push was reinforced using a procedure the same

Table 6

Stimulus and reinforcement conditions for each phase of Experiment 3.

Hens 21-23								
Phase	Red				Green			
	Behaviour 1		Behaviour 2		Behaviour 1		Behaviour 2	
	Head Bob		Right-Key Peck		Door Push		Left-Key Peck	
	Rft	Light	Rft	Light	Rft	Light	Rft	Light
1	✓	✓			✓	✓		
2	✓	✓		✓	✓	✓		✓
3		✓		✓	✓	✓		✓
4			✓	✓			✓	✓
5		✓	✓	✓		✓	✓	✓
6		✓		✓		✓		✓
Hens 24-26								
Phase	Red				Green			
	Behaviour 1		Behaviour 2		Behaviour 1		Behaviour 2	
	Head Bob		Right-Key Peck		Door Push		Left-Key Peck	
	Rft	Light	Rft	Light	Rft	Light	Rft	Light
1	✓	✓			✓	✓		
2	✓	✓		✓	✓	✓		✓
3	✓	✓		✓		✓		✓
4			✓	✓			✓	✓
5		✓	✓	✓		✓	✓	✓
6		✓		✓		✓		✓

Rft = when reinforcement was delivered for the response .

Light = when the operanda LED was on and feedback was provided.

as that used for head bobbing when it was trained. When 30 magazine operations had occurred in at least one session for all hens, sessions with the red and green stimuli alternated each day until 30 magazine operations had occurred over two consecutive sessions for all hens.

At this point magazine operation time was changed to the average of the time taken for each subject to get to the magazine plus 1.5 s. In addition, the effective behaviour in each stimulus condition was placed under RI schedules of reinforcement using an auto-adjusting procedure similar to that used in Experiment 2. Unlike Experiment 2 however, reinforcers were not programmed if a previously programmed reinforcer had not been obtained. The auto-adjusting procedure increased the RI value from an initial value of 12 s to 45 s. During this phase the responding of Hen 24 became variable under both stimuli and, at one point, head bobbing was re-trained. This phase terminated when all hens had had at least one red and one green session at an RI schedule value of 40 s or above. Hens received 14 sessions under each colour stimuli in this phase of Condition 1. For all subsequent conditions, this phase consisted of two red and two green stimulus sessions with the RI auto-adjusting procedure starting at 45 s. The red and green stimulus sessions alternated daily starting with a red stimulus session on the first day.

Phase 2: First behaviours reinforced, all apparatus lights lit. In each session of Phase 2 a multiple schedule was in effect. There were four 360-s periods in which either red or green stimuli occurred, separated by 10-s blackout periods. The length of occurrence of these red and green components was exclusive of magazine operation time. The effective behaviour in each component was the same as that associated with the same colour in Phase 1. The schedule in effect for behaviour was RI 45 s. In this phase the right key was lit red in the red component and the left key was lit green in the green component (Table 6). Which component was in effect in any of the four occurrences per session was programmed quasi-randomly with two limiting conditions. Firstly, in each session, each component had to occur at least once. Secondly, the number of occurrences of each component, where the first behaviour was reinforced, had to be approximately equal over Phase 2 and Phase 3. Table 7 shows the number of occurrences of each component in this phase for the two first behaviours. In Session 10 of Condition 1 the head-bob light was accidentally disconnected for all

Table 7

Number of occurrences of components in which reinforcers were delivered or in which extinction was in effect over conditions for the first behaviours.

Hens 21-23								
Condition	Phase 2 (Rft)		Phase 3 (Rft)		Total Rft		Phase 3 (Ext)	
	HB	DP	HB	DP	HB	DP	HB	DP
1	25	17	0	12	25	29	12	0
2	26	14	0	12	26	26	12	0
3	26	14	0	10	26	24	10	0
4	22	18	0	4	22	22	4	0
5	24	24	0	0	24	24	0	0
6	23	21	0	3	23	24	1	0
7	23	21	0	3	23	24	1	0
8	25	23	0	2	25	25	2	0
9	23	21	0	3	23	24	.5	0
10	24	24	0	0	24	24	0	0

Hens 24-26								
Condition	Phase 2 (Rft)		Phase 3 (Rft)		Total Rft		Phase 3 (Ext)	
	HB	DP	HB	DP	HB	DP	HB	DP
1	17	25	12	0	29	25	0	12
2	14	26	12	0	26	26	0	12
3	14	26	10	0	24	26	0	10
4	18	22	4	0	22	22	0	4
5	24	24	0	0	24	24	0	0
6	21	23	0	3	21	26	1	0
7	21	23	3	0	24	23	0	1
8	23	25	2	0	25	25	0	2
9	21	23	3	0	24	23	0	.5
10	24	24	0	0	24	24	0	0

HB = Head bob , DP = Door push, Rft = Reinforcers available, and Ext = Extinction in effect.

subjects. Hens 22 and 25 received reinforcers for head bobbing in this session.

Phase 3: Extinction of one first behaviour, all apparatus lit. During this phase and in all but Conditions 5 and 10, extinction was in effect in the red component (i.e., for head bobbing) for Hens 21-23 and in the green component (i.e., for door pushing) for Hens 24-26. Contingencies in the other component (the green component for Hens 21-23 and the red component for Hens 24-26) continued as in Phase 2. This phase was omitted in Conditions 5 and 10. In the other conditions the number of occurrences of the component with extinction in effect varied from 12 to 0.5 (0.5 being a 180-s occurrence of the appropriate component). When there were more than two occurrences of the components with extinction in effect then there were two red and green components per session (therefore 12 occurrences of the extinction component occurred over 6 sessions). When there were less than two occurrences (i.e., 1 or 0.5) of the component with extinction in effect (i.e., Conditions 6, 7, and 9) there was one session of this phase with one occurrence of the component with extinction in effect and three occurrences of the other component. Table 7 shows the total number of occurrences of each component in this phase for the two first behaviours. Due to an error Hens 24-26 received an occurrence of extinction of head bobbing (red component) in Condition 6.

Phase 4: Second behaviours trained and reinforced, effective apparatus lit. At the start of this phase in Condition 1 subjects were placed in the chamber with the right key and house-light lit red and pecking the right key was shaped by hand. Each peck was reinforced. Once 30 magazine operations had occurred in a session as a result of right-key pecking for all hens then, in the next session, the left key and house-light were lit green and left-key pecking was reinforced. Then, in Condition 1 and all subsequent conditions, there was a session with a red house-light and right key followed the next day by one session with a green house-light and left key.

Phase 5: Second behaviours reinforced, all apparatus lit. There was one session in this phase in all conditions. In this session there were two occurrences of each component, each occurrence terminating when either 360 s had elapsed (excluding magazine operation time) or eight reinforcers had been obtained, whichever occurred first. Each occurrence was separated by 10 s of blackout of house-light and operanda. In the red component the house-light, head-bob

apparatus, and right key were lit red and right-key pecking was reinforced on a FR 1 schedule. In the green component the house-light, door-push apparatus and left key were lit green and left-key pecking was reinforced on FR 1. Component type alternated with the red component being presented first in the session.

Phase 6: Extinction of the second behaviours, all apparatus lit. At the start of this phase reinforcer delivery was stopped in all components. In all conditions occurrences of the red and green components alternated within sessions and which was the first presented alternated across sessions. The first component presented was red in the first session of this phase in all conditions. This phase ended after 13 sessions in Condition 1, and 10 sessions in all other conditions. Hen 24 received nine sessions of this phase in Condition 4. Hen 22 received an extra occurrence of the green component in Condition 2.

Results and Discussion

Evidence for Stimulus Control

One possible problem with the design used here is that the two first behaviours might not be independent, making the results difficult to interpret. If the two first behaviours within a condition were independent, then the appropriate stimuli should have controlled the occurrence of these behaviours during reinforcement and extinction (Terrace, 1966). Head bobbing, which was trained with red house- and stimulus-lights, should not have occurred when the house- and stimulus-lights were green. Similarly, door pushing, which was trained with green house- and stimulus-lights, should not have occurred when the house- and stimulus-lights were red. Figure 11 shows the rates of the first behaviours in each component in each session where they were reinforced during Phase 2, for each condition. Graphs in the left panel show the data from the components where there was no initial extinction and graphs in the right panel show the data from the component where extinction varied. Crosses indicate the first behaviour for which there was no initial extinction and circles indicate the first behaviour for which extinction was varied. It can be seen that each first behaviour occurred at a moderate rate in the stimulus conditions under which it was reinforced and at a minimal rate in the stimulus conditions for the other first behaviour. Hence the component stimuli controlled the occurrence of the first behaviours when they were reinforced.

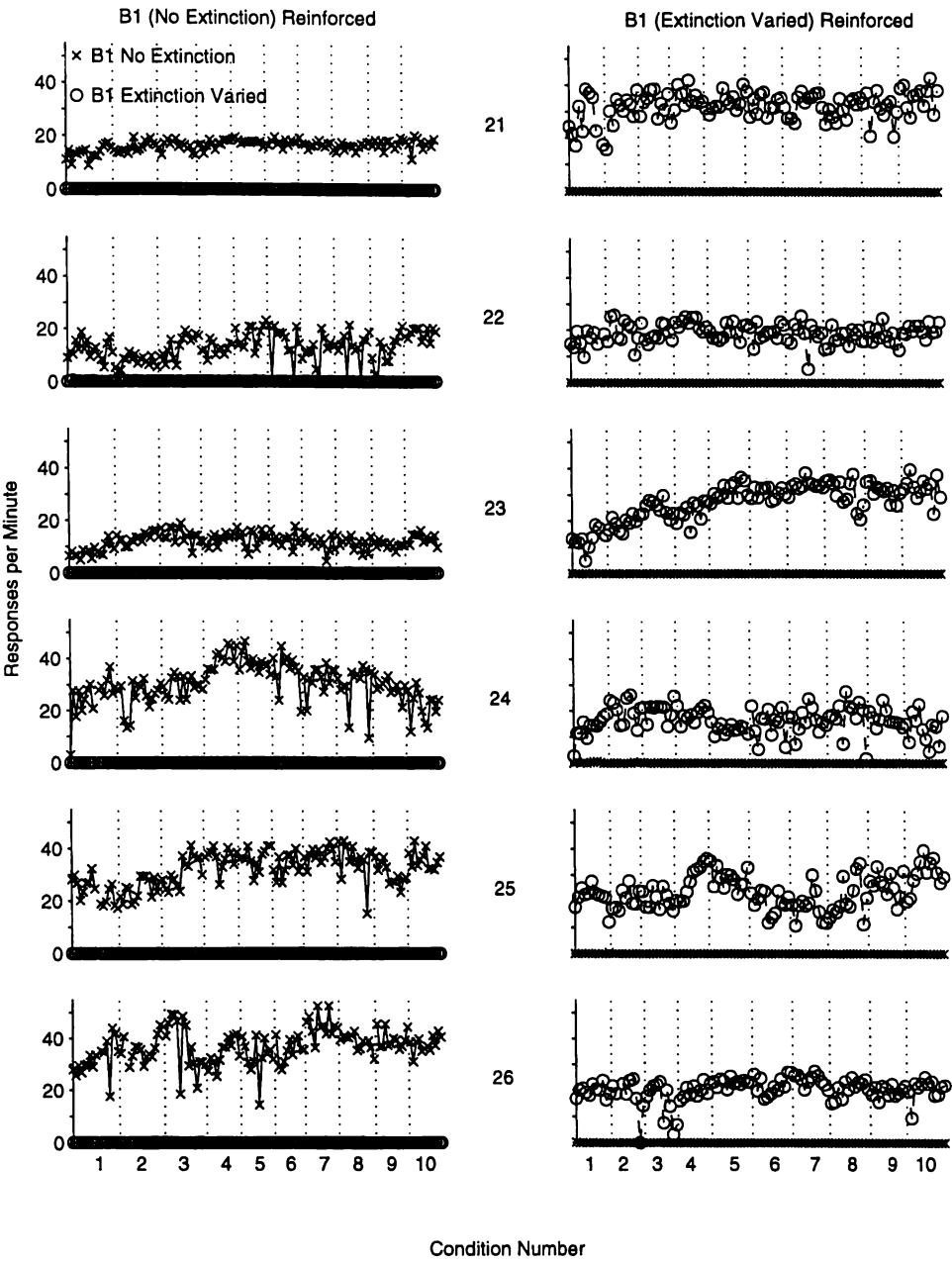


Figure 11. Experiment 3. Rates of the first behaviours when they were reinforced under the multiple schedule (Phases 2 and 3) for all sessions and conditions. Crosses show the data for the first behaviour that had no extinction. Circles show the data for the first behaviour that had varied extinction. The left panel shows the data from the component where there was no extinction; the right panel shows the data from the component where extinction varied.

Figure 12 shows the rate of the second behaviours in each component in each session when reinforced in Phase 5 for each condition. Graphs in the left panel show the data from the components where there was no initial extinction and graphs in the right panel show the data from the component where the amount of extinction varied. Triangles show the rate of the second behaviour associated with the first behaviour that had no extinction. Squares show the rate of the second behaviour associated with the first behaviour that had varied amounts of extinction. It can be seen that each second behaviour occurred at a moderate rate in the stimulus conditions under which it was reinforced and at a minimal rate in the stimulus conditions for the other second behaviour. As for the first behaviours, the component stimuli controlled the occurrence of the second behaviours when they were reinforced.

Figure 13 shows the rates of the first behaviours (left panel) and second behaviours (right panel) in the stimulus condition under which they were not trained, during the extinction of the second behaviour (Phase 6). It can be seen that rates of the first behaviours were low, the exception being the rate of Behaviour 1 for which there was no extinction for Hen 25 (head bobbing) in the first three sessions of Condition 1. This may have been because head bobbing was reinforced for this hen without the head-bob operandum lit (due to an equipment fault) and the head-bob operandum was not lit in the green condition. It can be seen that the rates of the second behaviour were low, the exception being the rate of Behaviour 1 for which there was no extinction for Hen 24 (right-key pecking) in the first two sessions of Condition 1. Because the rates of each behaviour under its untrained stimulus condition was generally small, it would appear that the occurrence of the component stimuli generally controlled the occurrence of both the first behaviours and the second behaviours during the extinction of the second behaviours.

Generally, then, there was good stimulus control over the first and second behaviours in this multiple schedule. Prior to the introduction of the multiple schedule in each condition, the two first behaviours were trained in separate sessions under their respective stimuli in a procedure similar to that used by Thomas et al. (1987). The minimal occurrence of the first behaviours under the other component stimuli during the multiple-schedule phases suggests that this

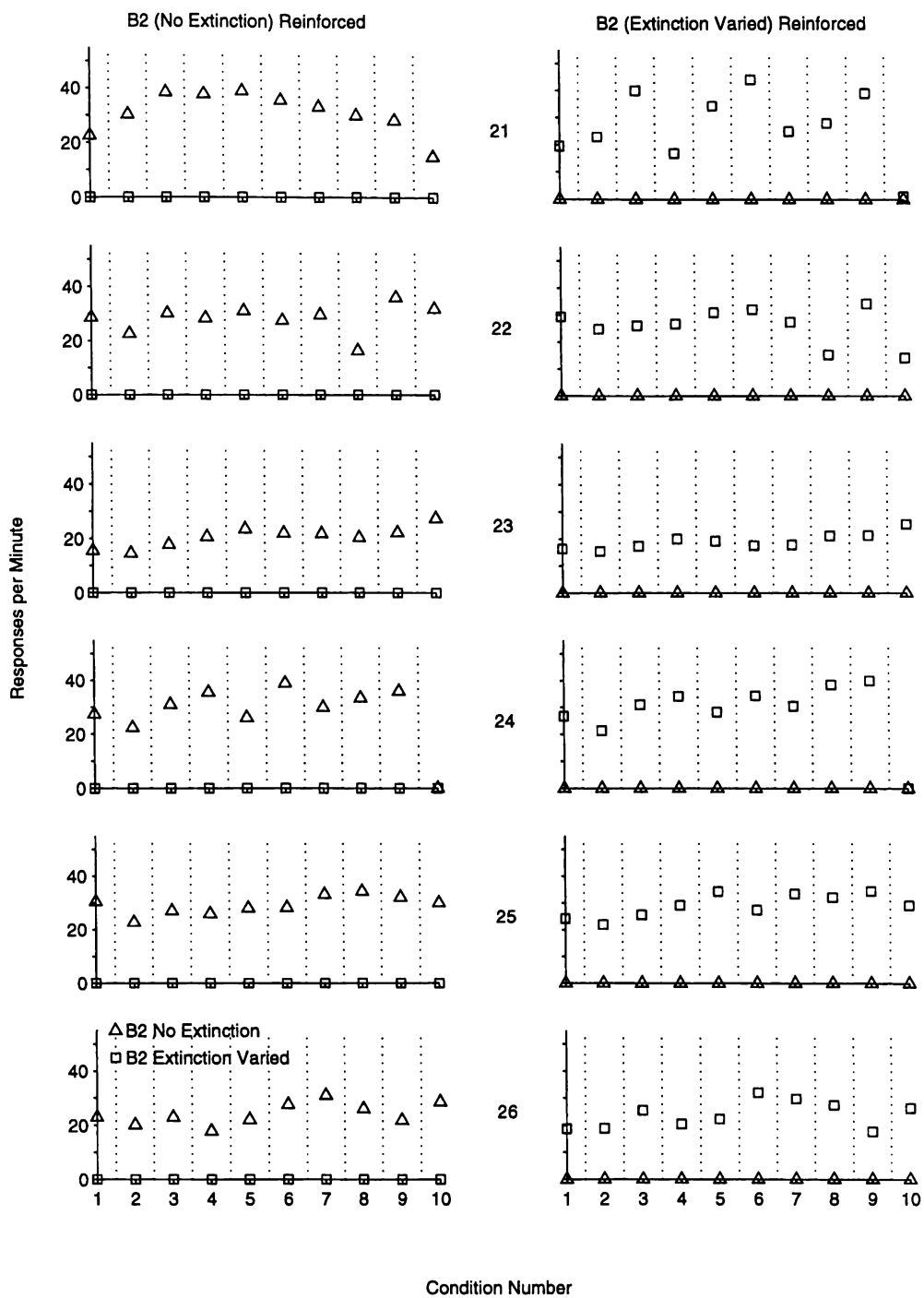


Figure 12. Experiment 3. Rates of the second behaviours when they were reinforced under the multiple schedule (Phase 5) for all sessions and conditions. Triangles show the data for the second behaviour associated with the first behaviour that had no extinction. Squares show the data for the second behaviour associated with the first behaviour that had varied extinction. The left panel shows the component where there was no first behaviour extinction; the right panel shows the component where first behaviour extinction varied.

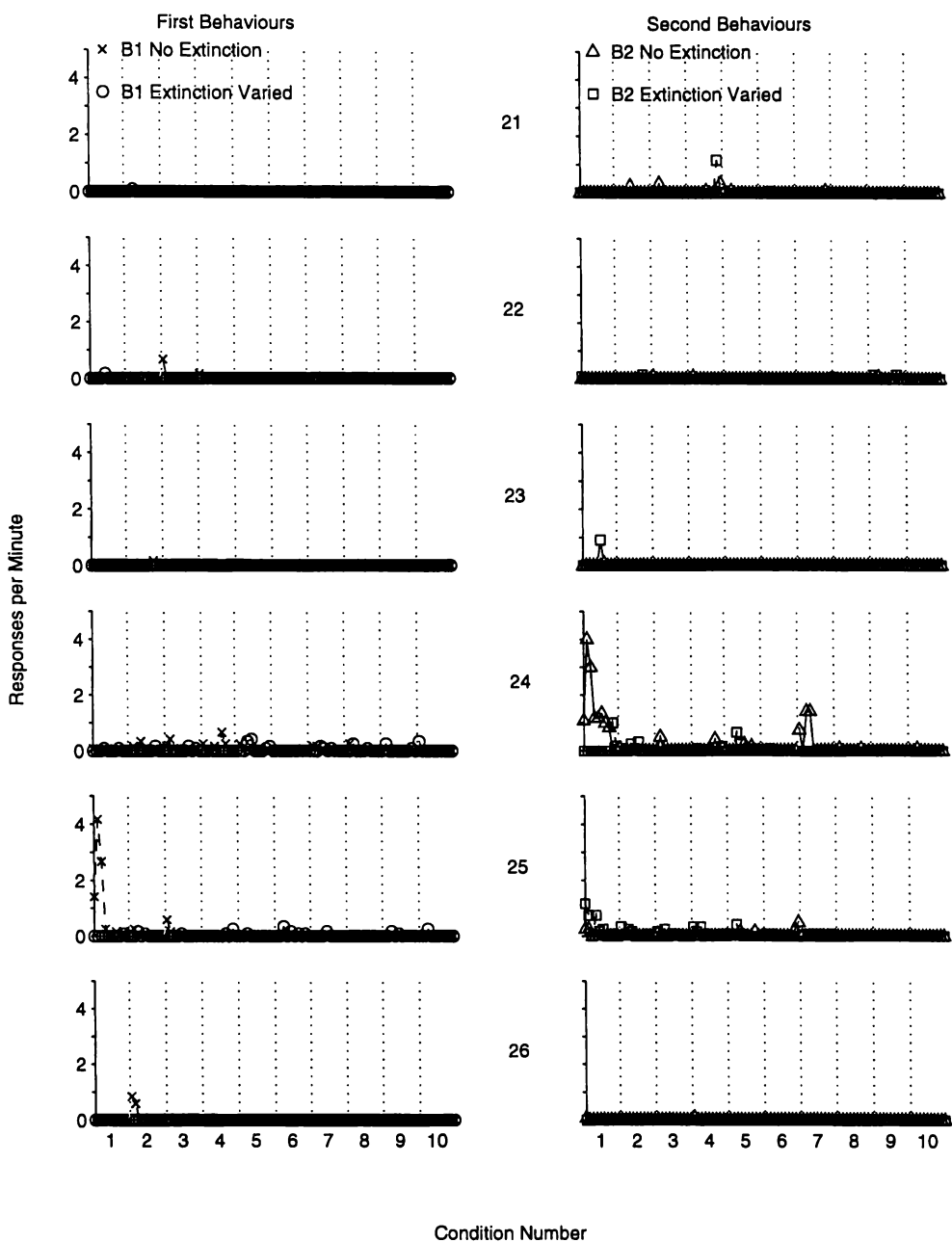


Figure 13. Experiment 3. The left panel of graphs show the rate of the Behaviour 1 that had no extinction under the stimuli for the Behaviour 1 that had prior extinction (crosses). Also shown is the rate of the Behaviour 1 that had prior extinction under the stimuli for the Behaviour 1 that had no extinction (circles). The rates are from all sessions of extinction of the second behaviour (Phase 6) and are shown across conditions. The right panel of graphs show the rate of the second behaviours associated with the first behaviours that had no extinction (triangles) and that had prior extinction (squares), also under each other's stimuli for all sessions of extinction of the second behaviour (Phase 6) across conditions.

procedure helped develop stimulus control. The present results provide support for the finding of Thomas et al. (1987) that such procedures can produce good stimulus control.

Independence of the First Behaviours

If the first behaviours were independent, then an expectation would be that the rate of occurrence of one of these behaviours should not have changed when the contingencies changed for the other first behaviour. Figure 14 shows the average rates of the first behaviour, for which there was no prior extinction, when reinforced in the multiple schedule for Conditions 1 to 4. Dots show the average rates when the other first behaviour was also reinforced (Phase 2) and triangles show the average rates when the other first behaviour was in its first extinction (Phase 3). Standard deviations from these average rates are also shown. When one first behaviour was placed under extinction (in Phase 3) and the other first behaviour was still reinforced there were no consistent increases or decreases in the rate of the reinforced behaviour within subjects. There would appear to be no consistent interactions here and so it is likely that these behaviours were independent. Therefore it is unlikely that the results of this experiment were due to interactions between the first behaviours.

The design of the present experiment does not allow the variables responsible for the independence of the first behaviours to be isolated. One feature of the experiment was the use of head bobbing and door pushing as the first behaviours. The effect of these specific response topographies upon multiple-schedule interactions is not known. Davison and Ferguson (1978), however, showed that the degree of interaction between components differed depending on whether pigeons treadle pressed or key pecked in the components. There was less interaction when treadle presses were required in both components than when key pecks were required. Interestingly, the interaction when key pecking was reinforced in one component and lever pressing in the other was intermediate between key-key and lever-lever values. Davison and Ferguson (1978) note that this suggests that particular topographies of response might be affected differently by relative rate of reinforcement. It is possible that the independence of the first behaviours in the present experiment was the result of the response topographies used.

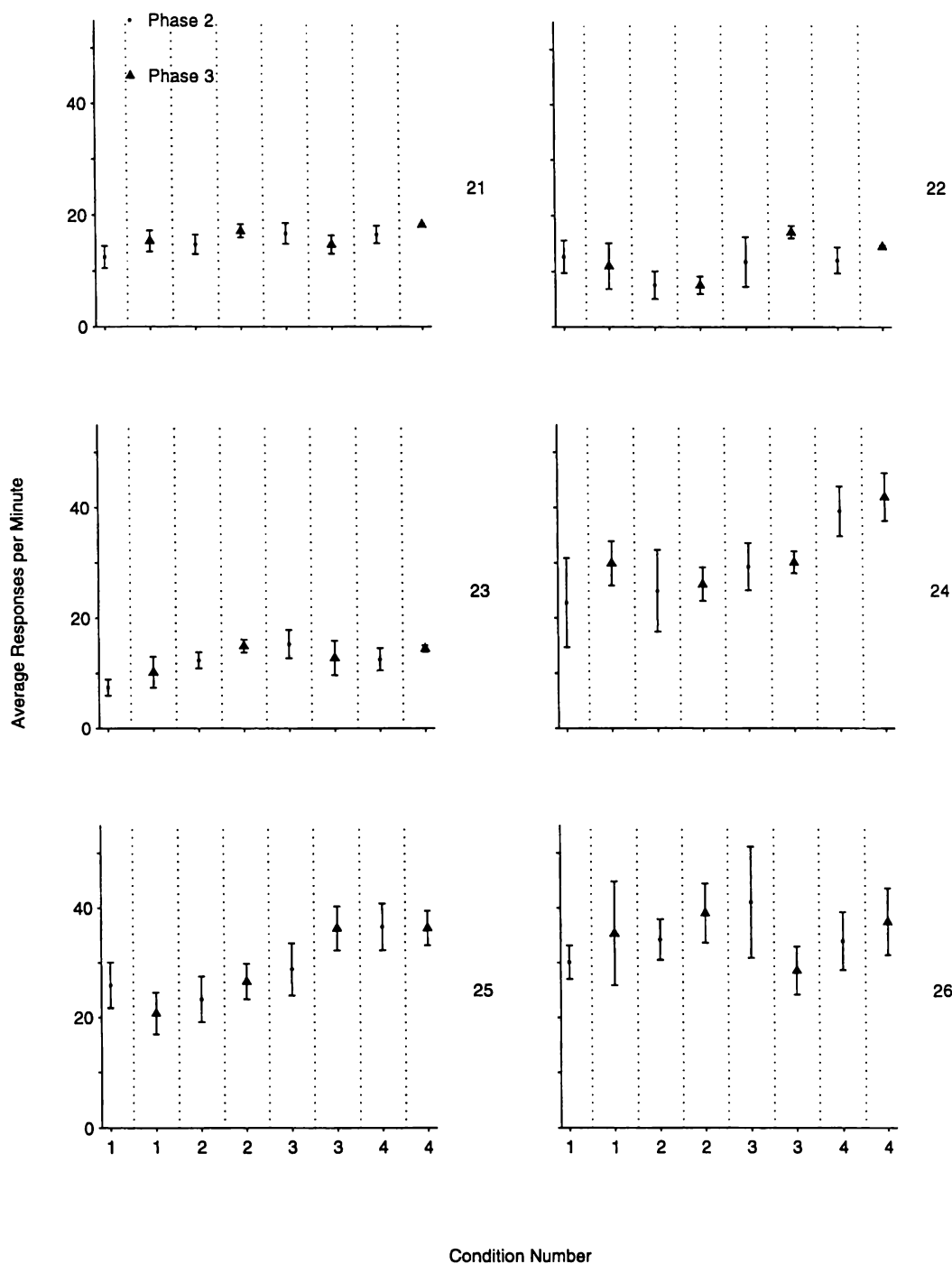


Figure 14. Experiment 3. Average rates of the first behaviour, for which there was no extinction, when reinforced in the multiple schedule for the first four conditions. Standard deviations of these rates are also shown. Dots show the data during the periods when the other Behaviour 1 was reinforced (Phase 2); triangles show the data during the periods when the other Behaviour 1 was not reinforced (Phase 3).

Adventitious Reinforcement

A potential confound here, as mentioned in the earlier studies, is that reinforcers delivered for the second behaviour may have adventitiously maintained the first behaviour, although the use of a 6-s COD makes this unlikely. Any adventitious reinforcement would make occurrences of the first behaviours during the extinction of the second behaviours difficult to interpret with respect to what variables affect the occurrence of previously reinforced behaviour (resurgence). Figure 15 (right panel) show the rates of the first behaviours in the sessions when the second behaviours were reinforced under the multiple schedule (Phase 5). It can be seen that first behaviours, generally, did not occur when the second behaviour was reinforced. In the cases when the first behaviours did occur they generally occurred at the start of a session prior to reinforcer delivery for the second behaviour. It would seem unlikely that the reinforcement delivered for the second behaviour adventitiously maintained the first behaviour. Also shown in Figure 15 (left panel) are the rates of the second behaviours in the sessions when the first behaviour was reinforced under the multiple schedule (Phases 2 and 3). It can be seen that the occurrence of the second behaviours when the first behaviours were reinforced was low and did not trend over conditions. It would appear that the second behaviour was also not maintained by reinforcement delivered for the first behaviour.

Effects of Prior Extinction Within Condition 1

We will now look at the resurgence of the first behaviours in the first condition. Figure 16 shows, for each hen, the rates of the first behaviours during the extinction of the second behaviours (Phase 6) in Condition 1 expressed as a ratio of the median response rate when the first behaviour was reinforced (in Phases 2 and 3) over all conditions. This measure normalises baseline response rate differences and thus allows comparison across both behaviours and subjects. It can be seen that the first behaviour which had prior extinction (in Phase 3, crosses) occurred less than the first behaviour which had no prior extinction (circles) in most cases. Within Condition 1, as shown across repeated conditions in Experiment 2, resurgence appears to have been a function of whether there was a period of extinction. The multiple schedule used here appears to generate similar results within a condition to those generated over repeated conditions

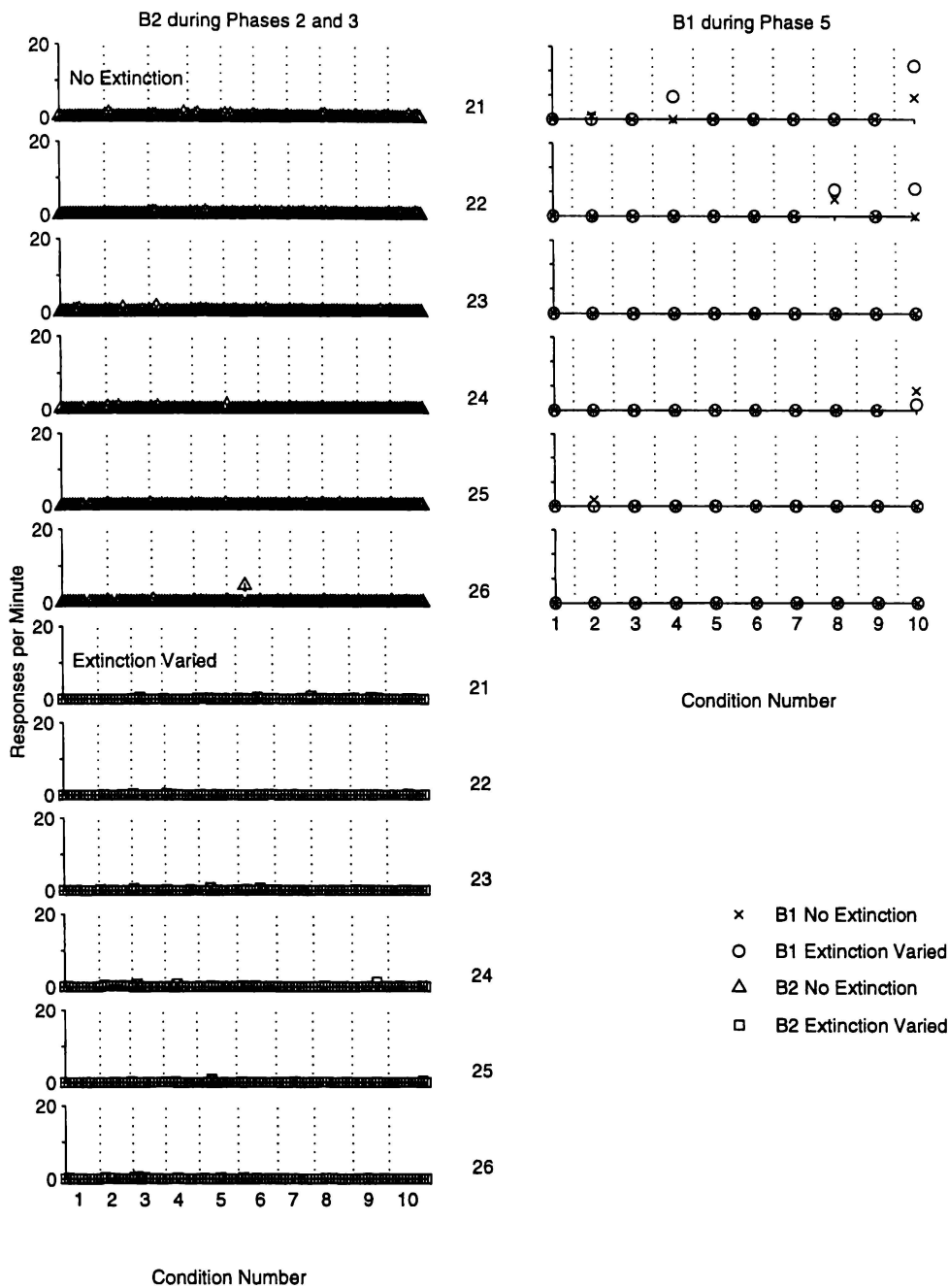


Figure 15. Experiment 3. Rates of the second behaviours in each session during the reinforcement of the first behaviours (Phases 2 and 3) across all conditions. Top left graphs show the second behaviour associated with the first behaviours that had no extinction (triangles). Bottom left graphs show the second behaviour associated with the first behaviour that had prior extinction varied (squares). Right graphs show the rate of the first behaviours that had no extinction (crosses) and that had prior extinction (circles, right graphs) in each session during the reinforcement of the second behaviour (Phase 5) across all conditions.

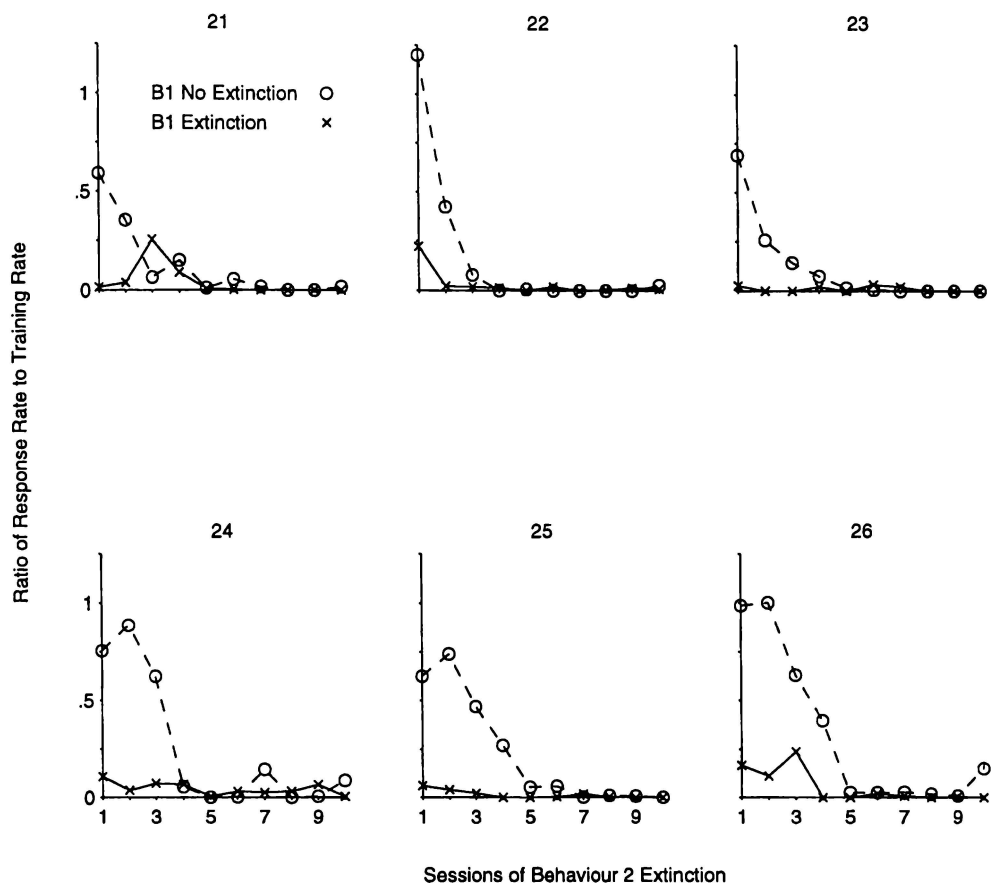


Figure 16. Experiment 3. Rates of the first behaviours from each session during Condition 1 of the extinction of Behaviour 2 (Phase 6). These are expressed as a ratio of median respective response rate when reinforced (Phases 2 and 3). Crosses show the data for the first behaviour that had prior extinction; circles show the data for the first behaviour that had no prior extinction.

(Experiment 2). This similarity is important as it implies that conclusions drawn from the data generated using such multiple schedules can be generalised to simple schedules.

Effects of Repeated Conditions

Repeated training. If resurgence is the result of the prevention of extinction of a behaviour, then the degree of resurgence should be an inverse function of the amount of extinction of that behaviour. To see if this was so, for the present experiment, requires comparison of the degree of resurgence across the repeated conditions where the number of components of extinction was varied. One concern here was that response rates would vary unsystematically across repeated conditions and make this comparison difficult. However, Figure 11 shows that the rates of the first behaviours when they were reinforced (Phases 2 and 3) were fairly consistent across sessions and conditions and generally did not trend. The rates of the second behaviours when reinforced, shown in Figure 12, were also consistent across sessions and conditions and also did not trend. It is unlikely that any changes in the degree of resurgence across conditions were the result of changes in the general levels of responding.

Repeated extinction. Anger and Anger (1976) found that, across repeated extinction conditions, responding in the first session of each extinction condition decreased but total responding was constant due to an increase in responding in later sessions of each extinction condition. Resurgence is an extinction effect and thus it is possible that changes in the degree of resurgence across repeated extinction conditions might also occur. Effects of repeated extinction can be assessed by examining the pattern of extinction of the first behaviour for which there was no prior extinction. The pattern in extinction of the second behaviours is also of interest as it indicates the pattern of simple extinction in the present experiment.

To equalise for overall response rate differences the response rates are presented here in Figures 17, 18, and 19 relative to the training response rates, as in Figure 16. Each figure shows the relative response rates plotted against both the session and condition in which they occurred for all hens. Figures 17, 18, and 19 show these measures for the second behaviour associated with the first behaviour that had earlier extinction, for the second behaviour associated with the

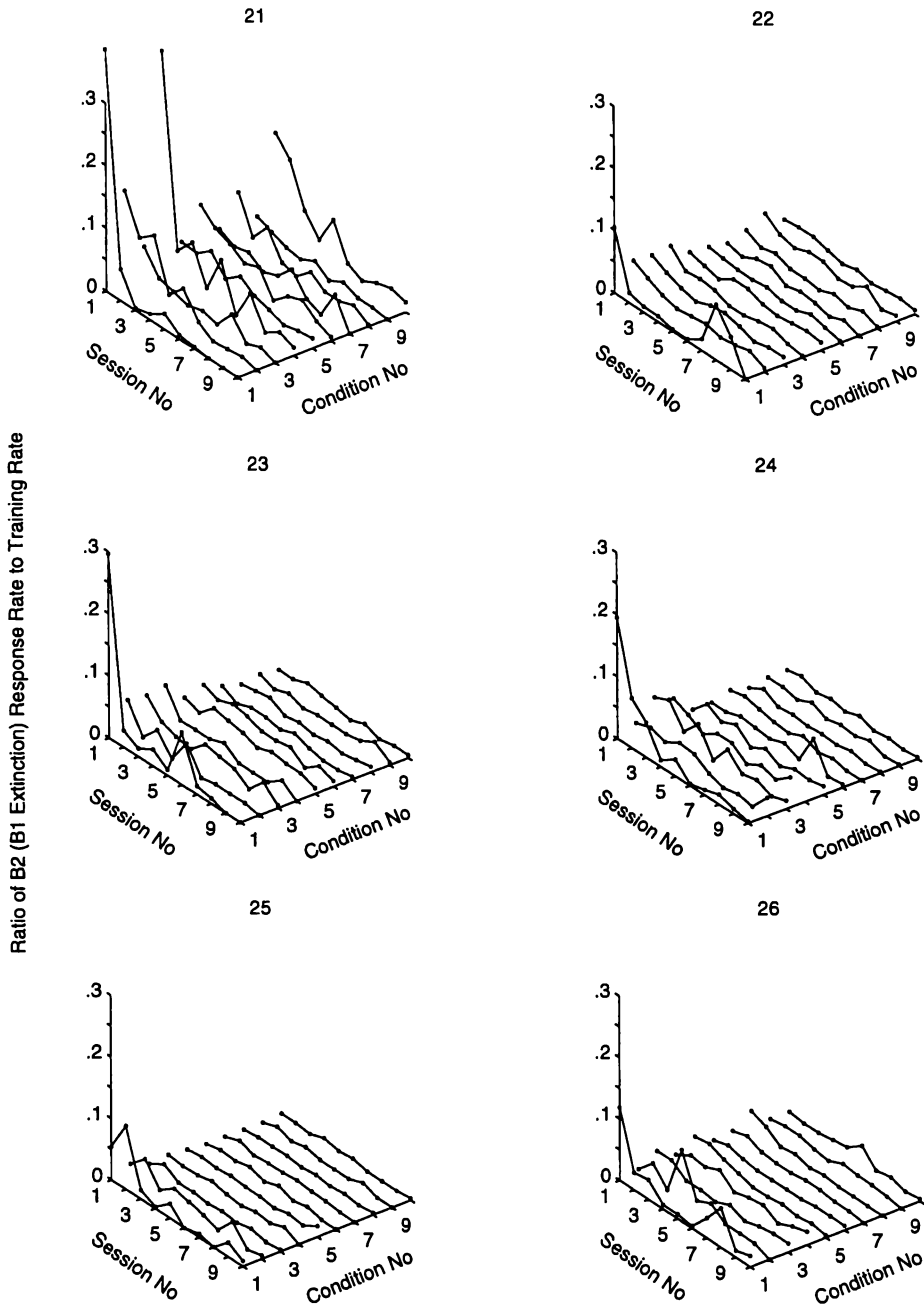


Figure 17. Experiment 3. Rate of the second behaviour, associated with the first behaviour for which extinction varied, during the extinction sessions of the second behaviour (Phase 6). This is expressed as a ratio of the rate of this behaviour when reinforced (Phase 5) for all conditions.

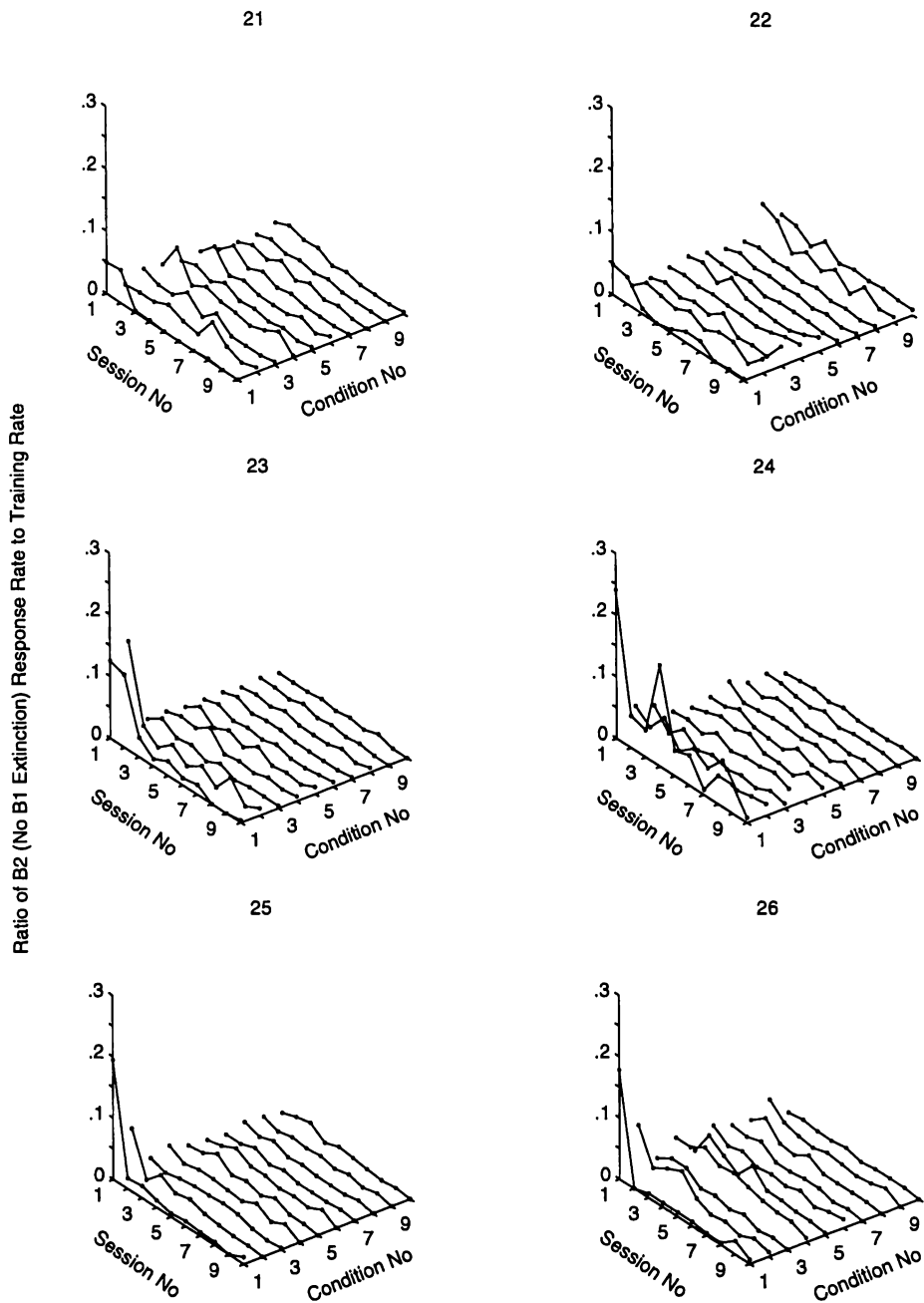


Figure 18. Experiment 3. Rate of the second behaviour, associated with the first behaviour that had no extinction, expressed as a ratio calculated as for the other second behaviour in Figure 17.

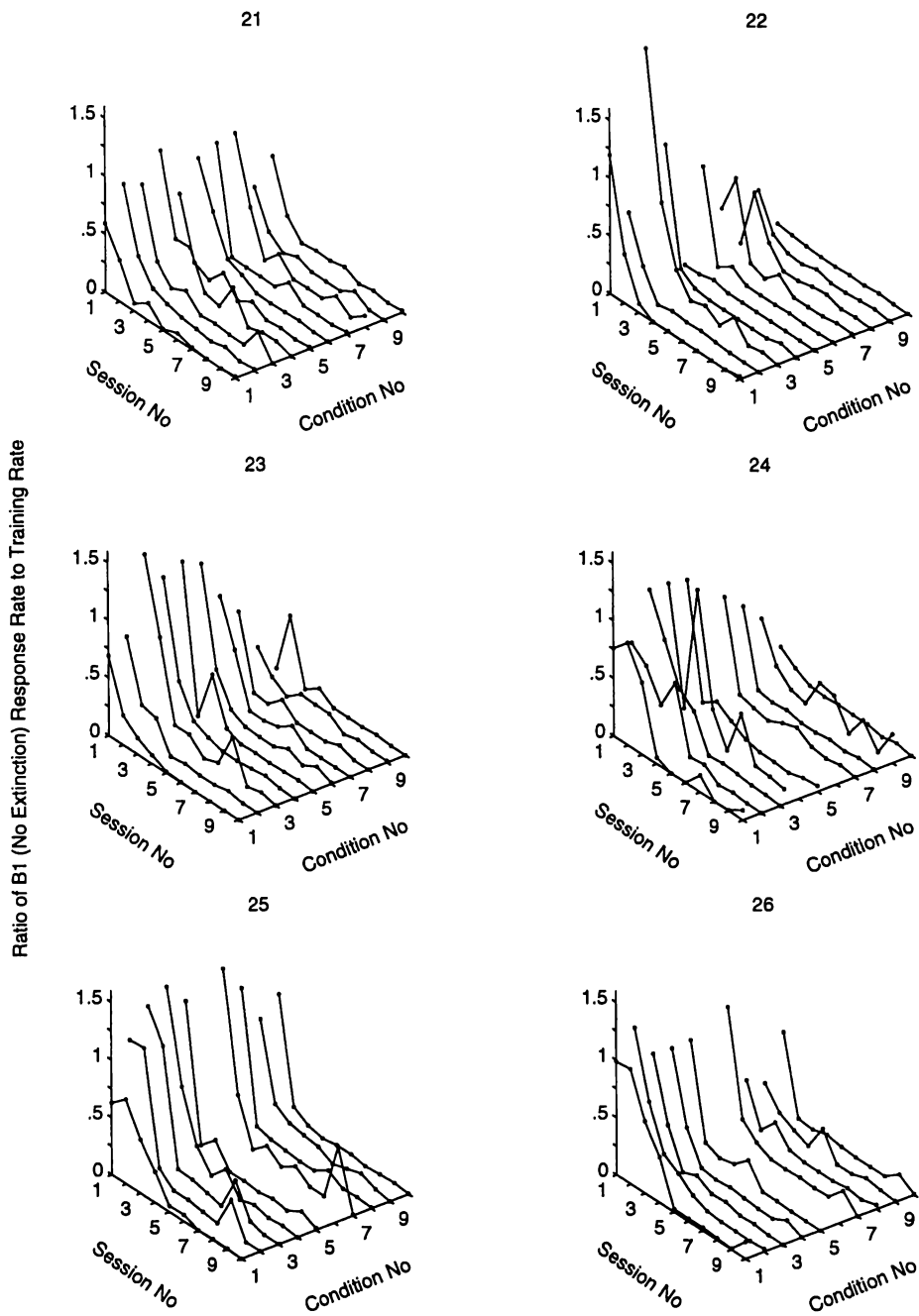


Figure 19. Experiment 3. Rate of the first behaviour, for which there was no extinction, expressed as a ratio calculated as for the second behaviour in Figure 17.

first behaviour that had no earlier extinction, and the first behaviour that had no earlier extinction, respectively. The points within each condition have been connected across consecutive sessions. It should be noted that the axes of Figures 17 and 18 are different from that of Figure 19.

It can be seen from Figures 17 and 18 that the relative rate of the second behaviour in the first session of each extinction condition generally decreased across conditions (shown as high points at the left of the graphs) as Anger and Anger (1976) found. Unlike Anger and Anger's (1976) results, however, there was no increase in responding in the later sessions of each condition across conditions (this would be shown as increases at the right of the graphs). Thus Anger and Anger's (1976) results for simple extinction are not replicated here for the second behaviours, although similar results to Anger and Anger (1976) were obtained in Experiment 2 for the second-trained behaviour. Procedural differences between Experiment 2 and the present experiment include the use of simple versus multiple schedules, 16800 s versus 7200 s of extinction for each second behaviour (spread over seven and ten sessions respectively), and the topography of responses (head bobbing and door pushing versus key pecking). Which, if any, of these factors are responsible for the lack of increase in later extinction responding cannot be determined from the present design.

Comparing Figures 17 and 18 with Figure 19 it can be seen that the first behaviour occurred relatively more than the second behaviours. One difference between the first and second behaviours was that the first behaviours were trained on a partial reinforcement schedule (RI 45 s) and the second behaviours were trained on a continuous reinforcement schedule (FR 1). Mackintosh (1974) notes that a well established finding is that more responses occur during extinction after partial than continuous reinforcement, so the different levels of occurrence of the first and second behaviours might be a product of the schedules used. From Figure 19 it can also be seen that the occurrence of the first behaviour in the first session of each extinction condition did not decrease consistently across conditions (high points at the left of the graphs did not change consistently across conditions). The pattern is not the same as those seen for the second behaviours across conditions (Figures 17 and 18). Like the second behaviours, however, there was no increase in responding in the later sessions of each condition across conditions (no increases at the right of the graphs).

The different patterns in the relative rates of the first and second behaviours in the first session of extinction are made clearer by replotting them together on the same graph in Figure 20. Circles show the data for the first behaviour for which there was no extinction and squares show the data for its associated second behaviour. Crosses show the data for the second behaviour associated with the first behaviour for which there was prior extinction. The second behaviours (squares and crosses) decrease across repeated extinction conditions to a very low level. The data pattern for the first behaviour (circles) resemble inverse U-shaped functions across conditions for three hens (23, 24, and 25) and there are some elements of this pattern for the remainder (21, 22, and 26). Assessment of any other patterns is complicated by the variability of the data. However, across subjects it can be seen that the data for the first behaviour (circles) in Conditions 2 and 3 are above that for Condition 1 in 9 of 12 cases while the data for its associated second behaviour (squares) in Conditions 2 and 3 are below that for Condition 1 in 11 of 12 cases. The increase in the relative rates of the first behaviour that had no earlier extinction (circles) over the first few conditions appears to correlate somewhat with a decrease in the relative rates of its associated second behaviour (squares). This raises the possibility that the two events are related. In this experiment Behaviour 1 and 2 could not be performed at the same time and session time was limited. The occurrence of one behaviour could have affected the degree of occurrence of the other behaviour. If this was the case, then any decrease in the occurrence of the second behaviour would allow more of the first behaviour to occur, accounting for the increase in the occurrence of the first behaviour. When the second behaviour was at a reasonably low level, however, the changes in the occurrence of the first behaviour as a result of changes to the occurrence of the second behaviour should cease. The occurrence of the first behaviour should then decrease across conditions as observed above for the simple extinction of the second behaviour. This is generally the case.

It would appear, then, that the pattern of resurgence of the first behaviour which had no earlier extinction across repeated extinction conditions might have been influenced by the pattern of the extinction of its associated second behaviour across these conditions. The pattern for the first behaviour may not have been fundamentally different from the pattern seen in simple extinction, with the exception that the point at which the first behaviour occurred was somewhat

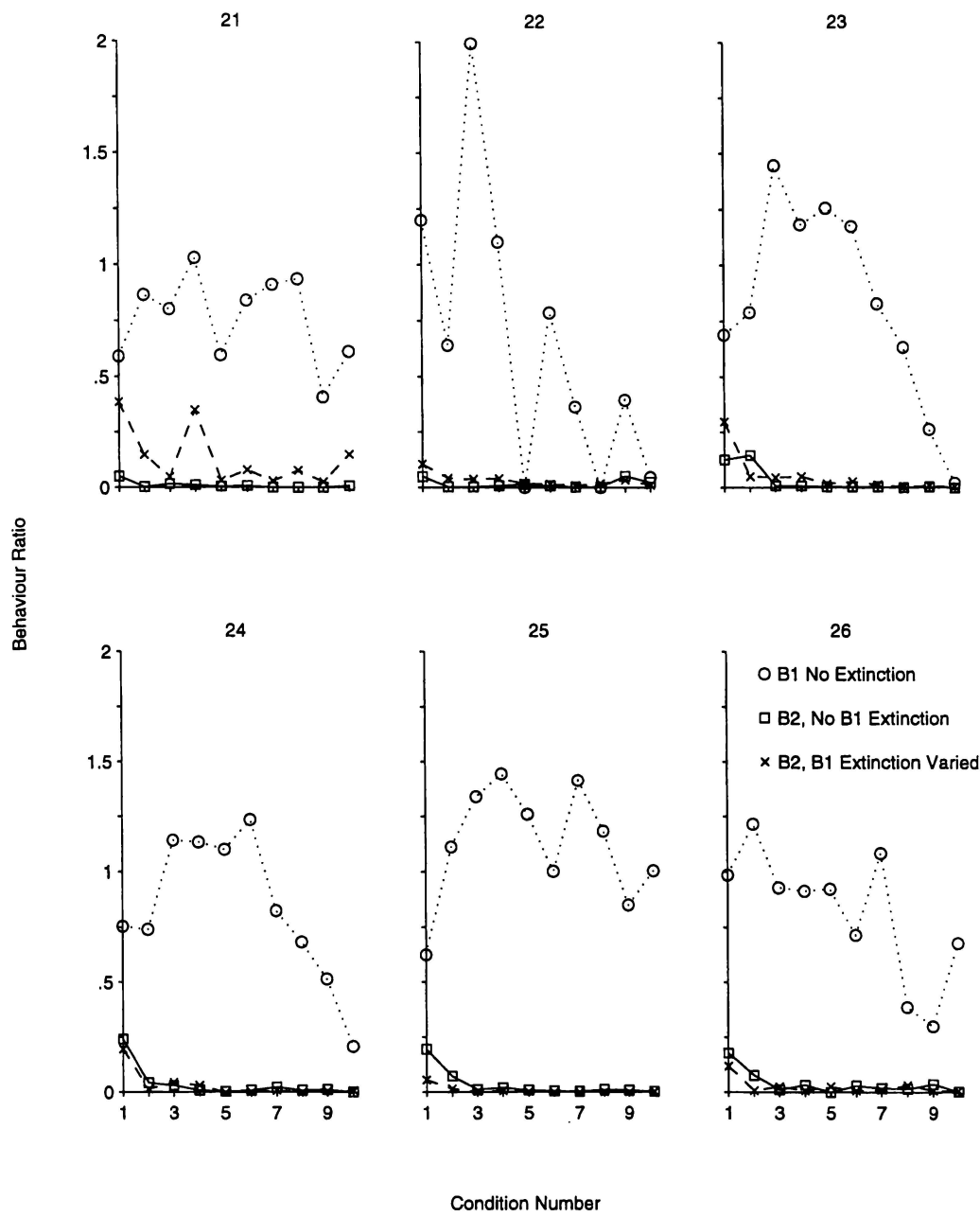


Figure 20. Experiment 3. Response rate in the first session of extinction of the second behaviour (Phase 6) across conditions, expressed as ratios as in Figures 17, 18, and 19. Circles show the data for the first behaviour for which there was no extinction; squares show the data for its associated second behaviour. Crosses show the data for the second behaviour that was associated with the first behaviour for which there was varied prior extinction.

dependent upon the second behaviour.

Control of Resurgence by Prior Extinction Across Conditions

It is possible that the resurgence of the first behaviour that had earlier extinction was also influenced by the occurrence of its second behaviour. Given that the degree of occurrence of the second behaviour varied across conditions, and that this may have affected the degree of resurgence at any particular point within the final extinction phase, it may be best to examine the total resurgence across repeated conditions rather than to examine responding at any particular point within the final extinction phase. The total numbers of occurrences of the first behaviour over the entire extinction of the second behaviour (Phase 6) are shown in Figure 21. These are plotted against the number of occurrences of the component in which extinction was in effect in Phase 3. It can be seen that there was a general tendency for the number of responses to decrease as the number of occurrences prior to Phase 6 increased, however, there was considerable variation in the response rates not accounted for by the number of occurrences of the component. Hence, generally, the degree of resurgence was an inverse function of the amount of extinction but the data are reasonably variable. Experiment 2 varied the amount of extinction of the first behaviour across conditions using simple schedules and also found variability in the degree of resurgence. That the present multiple-schedule data replicate the previous work with simple schedules is important for the generality of these results to simple schedules.

One possibility here, and the reason for using a multiple-schedule design, is that some of the variability across conditions was from factors that would also affect another similarly trained behaviour occurring in the same session. Two first behaviours were trained in the present experiment. It is possible that factors that affect the occurrence of one first behaviour across repeated conditions also affect the occurrence of the other first behaviour by the same proportion across repeated conditions. If so, then expressing the degree of resurgence of one first behaviour (that had varied amounts of prior extinction) relative to the resurgence of the other first behaviour should negate the effects of these confounding factors. Figure 22 shows the occurrences of the first behaviour (extinction varied) as a proportion of the total number of occurrences of both first behaviours during the final extinction (Phase 6). These are plotted against the number of occurrences of the component

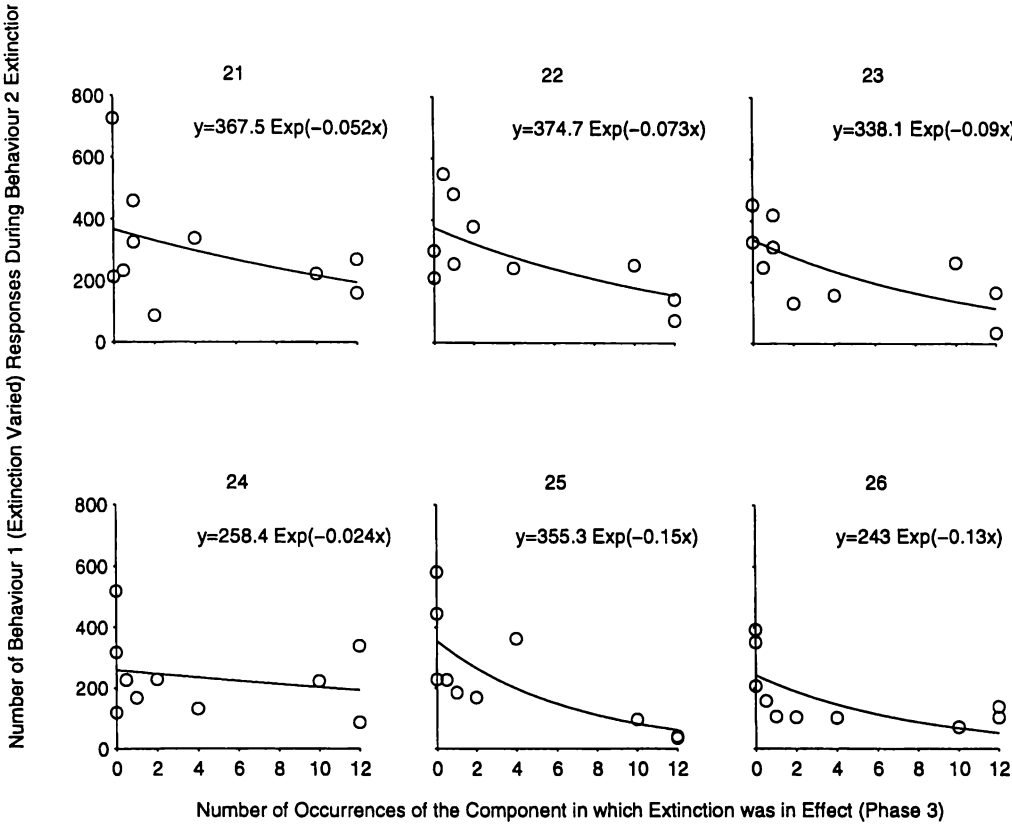


Figure 21. Experiment 3. Number of the first behaviours, for which prior extinction varied, that occurred during the extinction of Behaviour 2 (Phase 6). These are plotted against the number of occurrences of the component in which extinction was in effect (Phase 3). The negative exponential curves were fitted by non-linear regression and the equations are shown.

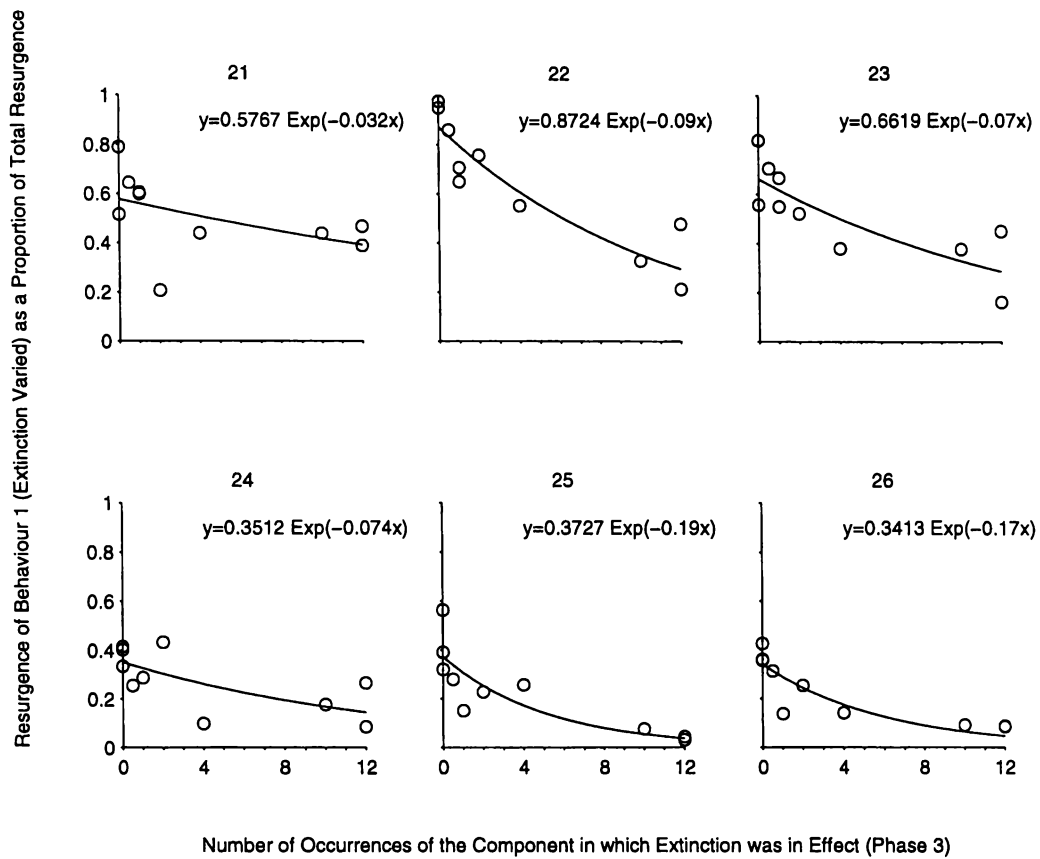


Figure 22. Experiment 3. Proportions of the first behaviours, for which prior extinction varied, that occurred during the extinction of Behaviour 2 (Phase 6). These proportions are of the total occurrence of both first behaviours (extinction and no extinction) during the extinction of Behaviour 2. These are plotted as a function of the number of occurrences of the component in which extinction was in effect, as in Figure 21. The negative exponential curves shown were fitted by non-linear regression and the equations are shown.

in which extinction was in effect, as in Figure 21. It can be seen that, for all hens, the degree of resurgence indicated by this measure, although still variable, decreased as the number of occurrences of this component increased.

To assess whether this proportional expression of resurgence (Figure 22) resulted in a more orderly relation than the total number of responses did (Figure 21), negative exponential curves were fitted by non-linear regression to the data for each subject. This curve was chosen because the data for some subjects appeared curvilinear and because log transformation of the data was not feasible as a result of zero responding in some sessions. Both measures were divided by their respective standard deviations to equate the scales before the functions were fitted. This allows the variances accounted for and the standard errors, shown in Table 8, to be compared. It can be seen that expressing resurgence proportionally increased the variance accounted for and decreased the standard error of estimate in all cases and therefore increased orderliness in the data. The degree of resurgence expressed proportionally was a reasonably orderly inverse function of the degree of extinction for four hens (22, 23, 25, and 26) and a somewhat less orderly inverse function of the degree of extinction for the remaining two hens (21 and 24).

The Prevention of Extinction Hypothesis is that resurgence occurs because the reinforcement of the second behaviour prevents the extinction of the first behaviour (e.g., Leitenberg et al., 1975). As mentioned in the General Introduction, Leitenberg et al. (1975, Experiment 3) showed that resurgence varied when the prevention of extinction of Behaviour 1 was manipulated by reinforcing Behaviour 2 under different schedules. Because the amount of extinction of Behaviour 1 was indirectly manipulated by the schedule of reinforcement of Behaviour 2 in Leitenberg et al. (1975, Experiment 3) the present experiment manipulated the amount of extinction of the first behaviour directly using different length periods of extinction. The results showed that the degree of resurgence was an inverse function of the amount of extinction of Behaviour 1. This suggests that factors that might affect the amount of extinction of Behaviour 1, such as the training of a second behaviour, will also affect the degree of resurgence. The results of the present study are consistent with the Prevention of Extinction Hypothesis. Further research is required to isolate precisely what variables prevent the occurrence of the first behaviour during the period where the second

Table 8

The percentage of variance accounted for and the standard error of estimate of the negative exponential functions fitted to the occurrence of Behaviour 1 (extinction varied) during the extinction of Behaviour 2. The same measures are also shown for the functions fitted to this occurrence expressed as a proportion of the total occurrence of both the first behaviours during the extinction of Behaviour 2.

Hen	Number of Responses		Proportional Occurrence	
	% Variance	Standard	% Variance	Standard
	Accounted	error	Accounted	Error
21	15	0.979	22	0.939
22	42	0.807	84	0.419
23	46	0.782	66	0.619
24	4.3	1.04	46	0.781
25	51	0.741	70	0.581
26	37	.843	77	0.508

behaviour is reinforced. The present study also demonstrates that multiple schedules can be used to show orderly relations in the resurgence of single subjects within a condition and across conditions and might be of use in the study of the variables that prevent the extinction of the first behaviour.

Experiment 4

The results of Experiments 2 and 3 suggested that the degree of resurgence is a function of the amount of previous extinction of a behaviour. This is consistent with the Prevention of Extinction Hypothesis (Leitenberg et al., 1975) but raises the question of what might prevent the extinction of Behaviour 1 and hence increase resurgence. As previously reported, Leitenberg et al. (1975) used either a rich or a lean schedule of reinforcement when training Behaviour 2 and found that the occurrence of Behaviour 1 during this phase was greater under the lean schedule. In that study the occurrence of Behaviour 1 varied inversely with the rate of reinforcement of Behaviour 2 and so Behaviour 1 was exposed to the extinction contingencies more often when the lean schedule was used. However, the rate of occurrence of Behaviour 2 in this phase also varied with reinforcement schedule and was lower when there was a lean schedule. Thus it is not possible to determine whether the occurrence of Behaviour 1 during the reinforcement of Behaviour 2 was the result of the obtained reinforcer rate or a product of the rate of Behaviour 2.

When an experiment requires that a behaviour be maintained under a lean schedule of reinforcement, it is common practice to train that behaviour under a richer schedule and gradually lean out the schedule until the terminal value is obtained. Presumably this is because behaviour is maintained better with gradual rather than sudden increases in schedule value. Chance (1988) notes that the term “ratio strain” can be used to describe the disruption of responding caused by sudden increases in schedule value, even when the schedule of reinforcement used is an interval schedule. In the Leitenberg et al. (1975) study there was no such gradual introduction of the schedules and so the sudden increase in schedule value might have contributed to the lower rate of the second behaviour under the lean schedule. As the rich schedule value was lower than that previously experienced by the subjects, responding under the rich schedule should not have been disrupted. Gradual introduction of schedules might reduce any response rate differences between the second behaviour under the rich and lean schedules. The auto-adjusting RI procedure used in the previous experiments here is one method by which schedules might be gradually introduced.

Catania and Reynolds (1968) found that response rate was a negatively

accelerated function of reinforcement rate in single VI schedules. Some data suggests that such a relation is obtained in open economies, where subjects are maintained at a percentage of their free-feeding weights by post-session feeding, but not in closed economies where weight is maintained only by food delivered in the session (e.g., Hall & Lattal, 1990; 1999; Zeiler, 1999). Given that an open economy was used here the rate of the second behaviour should change with the rate of reinforcement, even with preliminary training. The response rates of three of Catania and Reynolds' (1968) six subjects increased as rate of reinforcement increased up to approximately 30 reinforcers per hour and then remained relatively constant. If the rate of reinforcement for the second behaviour was above 30 reinforcers per hour then the differences between second behaviour rates should be small. If the rates of the second behaviours were similar then it would be possible to assess the effects of the reinforcement schedule used to train the second behaviour on the occurrence of the first behaviour.

In this next study a systematic replication of Leitenberg et al. (1975) was used to assess whether the occurrence of the first behaviour during the training of the second behaviour varied with the reinforcement rate of the second behaviour, but using a repeated multiple-schedule design like that of Experiment 3. In the present experiment, the schedule maintaining one second behaviour was varied over conditions while that maintaining the other second behaviour was kept constant as shown in Table 9. In each condition initial training took place with only the operandum for the effective response and house-light lit. Once performance of the second behaviour had been established under the terminal schedules for that condition, all operanda were made available. It was thought that the preliminary training would result in similar Behaviour 2 rates prior to the availability of Behaviour 1. If this was so, the role of the rate of reinforcement of the second behaviour on the occurrence of the first behaviour could be assessed independent of the effects of the rate of the second behaviour.

The results of Leitenberg et al. (1975) suggest that the degree of occurrence of Behaviour 1 during the training of Behaviour 2 will be an inverse function of the rate of reinforcement for Behaviour 2. If this is the case, then the Prevention of Extinction Hypothesis predicts that the degree of resurgence of Behaviour 1 will be a function of the rate of reinforcement for Behaviour 2. A further prediction from the hypothesis is that the degree of resurgence will be an

Table 9

Outline of procedure used for half the subjects in Experiment 4 (Hens 81-83). The procedure for Hens 84-86 was similar except that in Phase 4 the schedule of reinforcement was varied across conditions for left-key pecking instead of right-key pecking.

Phase	Red Component	Green Component	Arrangement	Operanda lights
1	HB Rft	DP Rft	Alternate sessions	Only effective operanda lit
2	HB Rft	DP Rft	Multiple schedule	All operanda lit
3	RK Rft Varied RI across conditions	LK Rft Constant RI across conditions	Alternate sessions	Only effective operanda lit
4	RK Rft Varied RI across conditions	LK Rft Constant RI across conditions	Multiple schedule	All operanda lit
5	Extinction	Extinction	Multiple schedule	All operanda lit

- HB = Head bob.
- DP = Door push.
- RK = Right-key peck.
- LK = Left-key peck.
- Rft = Reinforcement delivered for response.

inverse function of the degree of occurrence of Behaviour 1 during the reinforcement of Behaviour 2. This can be tested only indirectly in the present study because the occurrence of Behaviour 1 during Behaviour 2 reinforcement will have been manipulated only indirectly by the rate of Behaviour 2 reinforcement.

Method

Subjects

Six experimentally naive ISA Brown hens, numbered 81-86, served as subjects. They were 2 years of age at the start of the experiment, and were obtained from a free-range farm approximately 8 months before the start of the experiment. It should be noted that although the hens were numbered the same as those used in Experiment 1 and 2, they were not the same hens. The subjects were maintained and housed as previously described.

Apparatus

This was similar to that used in Experiment 3 with the exception that the inside of the chamber was painted white.

Procedure

This was similar to the procedure used in Experiment 3 with head bobbing and door pushing the first behaviours and right and left key pecking the second behaviours in the red and green components respectively. Unlike Experiment 3 there were no extinction periods for either first behaviour. Instead the RI schedule used with one second behaviour was varied across eight conditions as shown in Table 10. The RI schedules used were 10 s (Conditions 1 and 4), 20 s (Condition 8), 40 s (Conditions 5 and 6), 60 s (Condition 7), and 80 s (Conditions 2 and 3). The varied schedule was associated with the right key for Hens 81-83 and the left key for Hens 84-86. A constant RI 40-s schedule was in effect for the other second behaviour, which was pecking the left key for Hens 81-83 and pecking the right key for Hens 84-86.

Phase 1: Behaviour 1 trained, effective apparatus lit. This phase of Condition 1 was similar to Phase 1, Condition 1, in Experiment 3 with the exception that the final schedules for the first two behaviours were both RI 20-s schedules. All hens received five sessions of auto-adjusting RI training for each

Table 10

Stimulus and reinforcement conditions for each phase of Experiment 4.

Hens 81-83										
Phase	Red					Green				
	Behaviour 1		Behaviour 2			Behaviour 1		Behaviour 2		
	Head Bob		Right-Key Peck			Door Push		Left-Key Peck		
	Rft	Light	Rft	RI	Light	Rft	Light	Rft	RI	Light
1	✓	✓				✓	✓			
2	✓	✓			✓	✓	✓			✓
3			✓	✓	✓			✓		✓
4		✓	✓	✓	✓		✓	✓		✓
5		✓			✓		✓			✓

Hens 84-86										
Phase	Red					Green				
	Behaviour 1		Behaviour 2			Behaviour 1		Behaviour 2		
	Head Bob		Right-Key Peck			Door Push		Left-Key Peck		
	Rft	Light	Rft	RI	Light	Rft	Light	Rft	RI	Light
1	✓	✓				✓	✓			
2	✓	✓			✓	✓	✓			✓
3			✓		✓			✓	✓	✓
4		✓	✓		✓		✓	✓	✓	✓
5		✓			✓		✓			✓

Rft = when reinforcement was delivered for the response.

Light = when the operanda LED was on and feedback was available.

RI = when the RI schedule was varied across conditions.

Behaviour 1 in Condition 1. In all subsequent conditions, there were two sessions of reinforcement for each Behaviour 1 on the RI 20-s schedule. The next phase then started.

Phase 2: Behaviour 1 reinforced, all apparatus lit. The 10 sessions in all conditions of this phase were similar to those in Phase 2 of Experiment 3 with the following exceptions. The schedule of reinforcement for each Behaviour 1 was RI 20 s. Each occurrence of a component terminated after the last of seven reinforcers or 600 s (not including magazine operation time).

Phase 3: Behaviour 2 trained, effective apparatus lit. In this phase of Condition 1 both second behaviours were shaped by successive approximation as in Phase 4, Condition 1, Experiment 3. These behaviours were then placed under RI schedules using the auto-adjusting procedure. The terminal value for the RI schedule associated with the right key for Hens 81-83 and the left key for Hens 84-86 varied across conditions. The terminal value for the RI schedule associated with the left key for Hens 81-83 and the right key for Hens 84-86 was RI 40 s in all conditions. If the terminal value for the RI schedule was higher than 10 s in a condition then the starting RI value was either 12 s or a value that had been used for that behaviour in a previous condition, whichever was highest. When the starting and terminal RI values were different for a behaviour (Conditions 1 and 2) this phase terminated when all hens had at least one session where the RI value at the end of the session was the terminal RI value. In Condition 2, Hen 83 did not meet this criteria. In all other conditions this phase terminated after a certain number of sessions. Table 11 shows the starting and terminal RI values, as well as the number of sessions, for each behaviour and condition. The number of sessions of this phase varied initially (Conditions 1 and 2) because of the different number of sessions taken to reach criterion and later (Conditions 3 and 4) to see if varying the number of sessions affected the degree of resurgence.

Phase 4: Behaviour 2 reinforced, all apparatus lit. In this phase all operanda were lit and each Behaviour 2 was reinforced under the terminal schedule of Phase 3 (shown in Table 11). In all conditions there were four sessions of this phase.

Phase 5: Extinction, all apparatus lit. This phase was similar to Phase 6 of Experiment 3 with all operanda lit and no reinforcers available. In the present experiment, however, each occurrence of a component was 600 s in duration and

Table 11

Starting and terminal RI values for each Behaviour 2 for which the schedule values were varied and for those which they were constant in Phase 3. Also shown are the number of sessions of this phase for each behaviour.

Condition	RI Varied		RI Constant		Sessions
	Start	Terminal	Start	Terminal	
1	10	10	12	40	11
2	12	80	40	40	31
3	80	80	40	40	5
4	10	10	40	40	11
5	40	40	40	40	5
6	40	40	40	40	5
7	60	60	40	40	5
8	20	20	40	40	5

there were seven sessions of this phase in each condition.

Results and Discussion

First Behaviours when Reinforced

Stimulus control. In Experiment 3 it was found that the first behaviours were under good stimulus control in the multiple schedule. In the present study, a first behaviour reinforced in one component occurred in 2.6% and 0.9% of the other components during reinforcement (Phase 2) and extinction (Phase 5) respectively, across all hens and conditions. There were a total of 180 of these responses during both of these phases, across all hens and conditions, resulting in an average of less than 0.06 responses per component. As in Experiment 3, the first behaviours appear to have been under good stimulus control.

Rates across conditions. Figure 23 shows the rates of the first behaviours when they were reinforced under the multiple schedule (Phase 2). Crosses show the rates of the first behaviour that was associated with the constant reinforcement schedule for the second behaviour; circles show the rate of the other first behaviour. These are shown during the components where the first behaviour, associated with the constant reinforcement schedule for the second behaviour, was reinforced (left panel) and where the other first behaviour was reinforced (right panel). It can be seen that while there were some changes in rate across conditions, whether the second behaviour was reinforced under a constant or a varied schedule did not result in any consistent differences in the rates of the first behaviours. Thus any differences in the degree of occurrence of the first behaviours during the reinforcement (Phase 4) and extinction of the second behaviour (Phase 5) are unlikely to be due to any effect of varying the second behaviour reinforcement schedule on the rates of the first behaviour when it was reinforced (Phase 2).

Second Behaviours during Preliminary Training

As previously described, both the rate of reinforcement for the second behaviour and the rate of the second behaviour covaried across groups in Leitenberg et al.'s (1975) study. Thus it was difficult to know whether the differential occurrence of the first behaviour during the training of the second behaviour was due to the response rate of, or the reinforcer rate for, the second

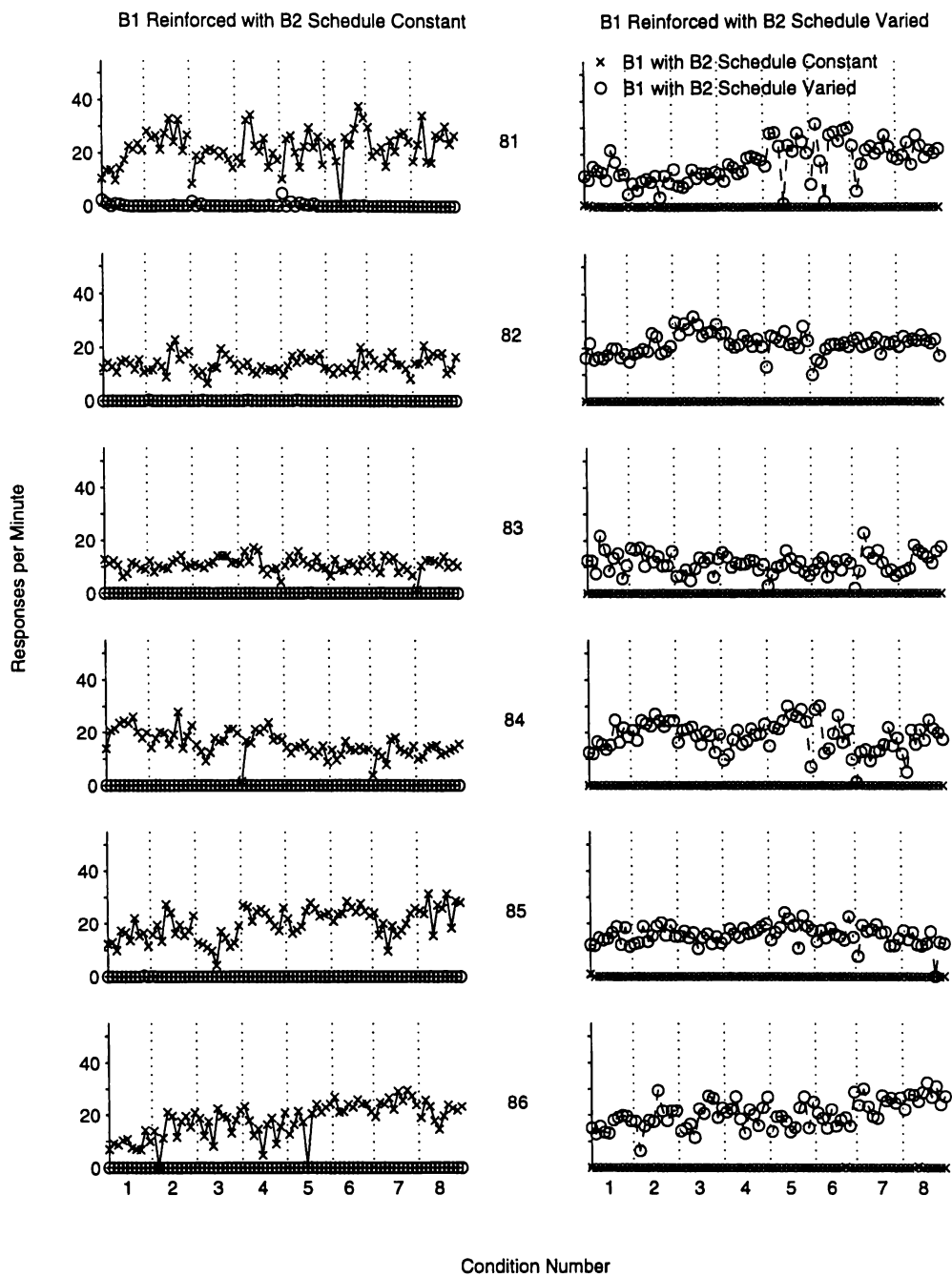


Figure 23. Experiment 4. Rates of the first behaviours for each session in which they were reinforced under the multiple schedule (Phase 2) for each condition. Crosses show the first behaviour associated with the second behaviour reinforced under the constant schedule. Circles show the first behaviour associated with the second behaviour reinforced under the varied schedule. The left panel shows the data from the component where the second behaviour schedule was constant; the right panel shows the data from the component where the second behaviour schedule varied.

behaviour. In the present experiment initial training of the second behaviour, in each condition, took place with only the operandum for the effective response and house-light lit and with components occurring on separate days (i.e., Phase 3). The purpose of this training was to establish the second behaviours prior to the introduction of the stimuli for the first behaviours. It was thought that if the second behaviours ended up being at similar rates during this preliminary training then any subsequent differences in the occurrence of the first behaviours when the first behaviour stimuli were lit (Phase 4) would be unlikely to be the result of the rate of the second behaviours. Any such differences might then be attributed to differences in Behaviour 2 reinforcement rate.

Response rates across conditions. Figure 24 shows the rates of the second behaviours from the phase where only the effective operandum was lit (Phase 3). Squares show the data for the second behaviour for which the reinforcement schedule was varied. Triangles show the data for the second behaviour for which the reinforcement schedule was kept constant. The numbers at the top of the graphs show the varied RI. The constant schedule was an RI 40 s in all conditions. It can be seen that the rates of the second behaviours were reasonably high at the end of this phase of each condition for all subjects, suggesting that the second behaviours were well established. In addition there was some variation in rate across conditions, including a tendency for the rates of both second behaviours for Hens 82, 84, and 85 to decrease during Condition 2. As Conditions 3 and 4 used the same schedules as Conditions 2 and 1 respectively, it is possible to see if this decrease had any effect on resurgence. This will be discussed later.

Response rate versus reinforcement rate. During the training of the second behaviour (Phase 3) the reinforcement rate was varied for one second behaviour only. To see if the response rates of both second behaviours were related to varied rate of reinforcement they have been plotted against this rate. Figure 25 shows the median rate of the second behaviours in the last five sessions of each Phase 3 condition. The left panel shows the data for the second behaviour for which the rate of reinforcement was constant. The right panel shows the data for the second behaviour for which the rate of reinforcement varied. In both cases the median response rates are plotted against the obtained rates of reinforcement for the varied behaviour during the selected session of the varied behaviour.

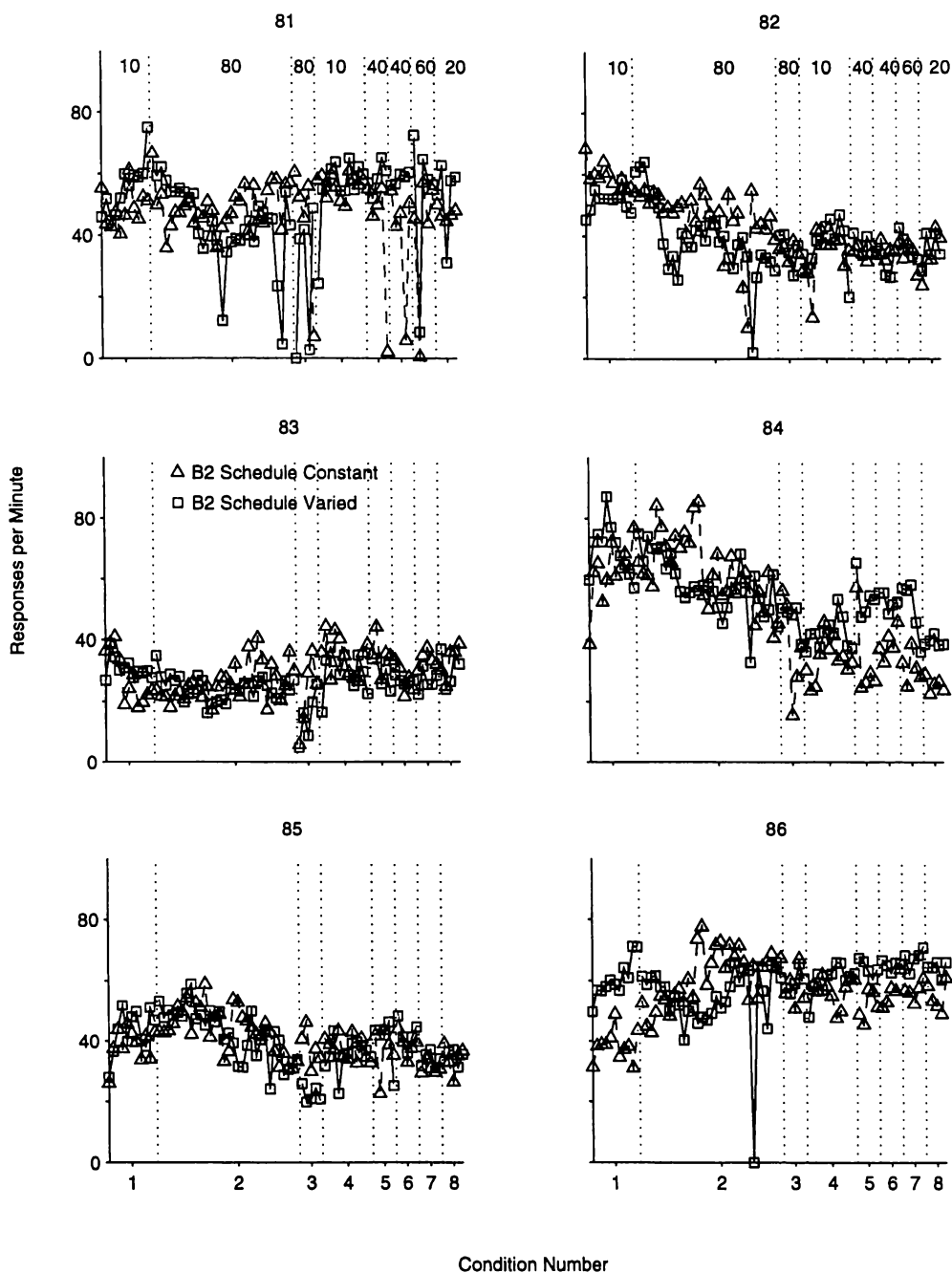


Figure 24. Experiment 4. Rates of the second behaviours for each session of preliminary training (Phase 3) for all conditions. Triangles show the data for the second behaviour for which the schedule was a constant RI 40 s. Squares show the data for the second behaviour for which the schedule was varied. The size of the varied schedule is shown on the top graphs.

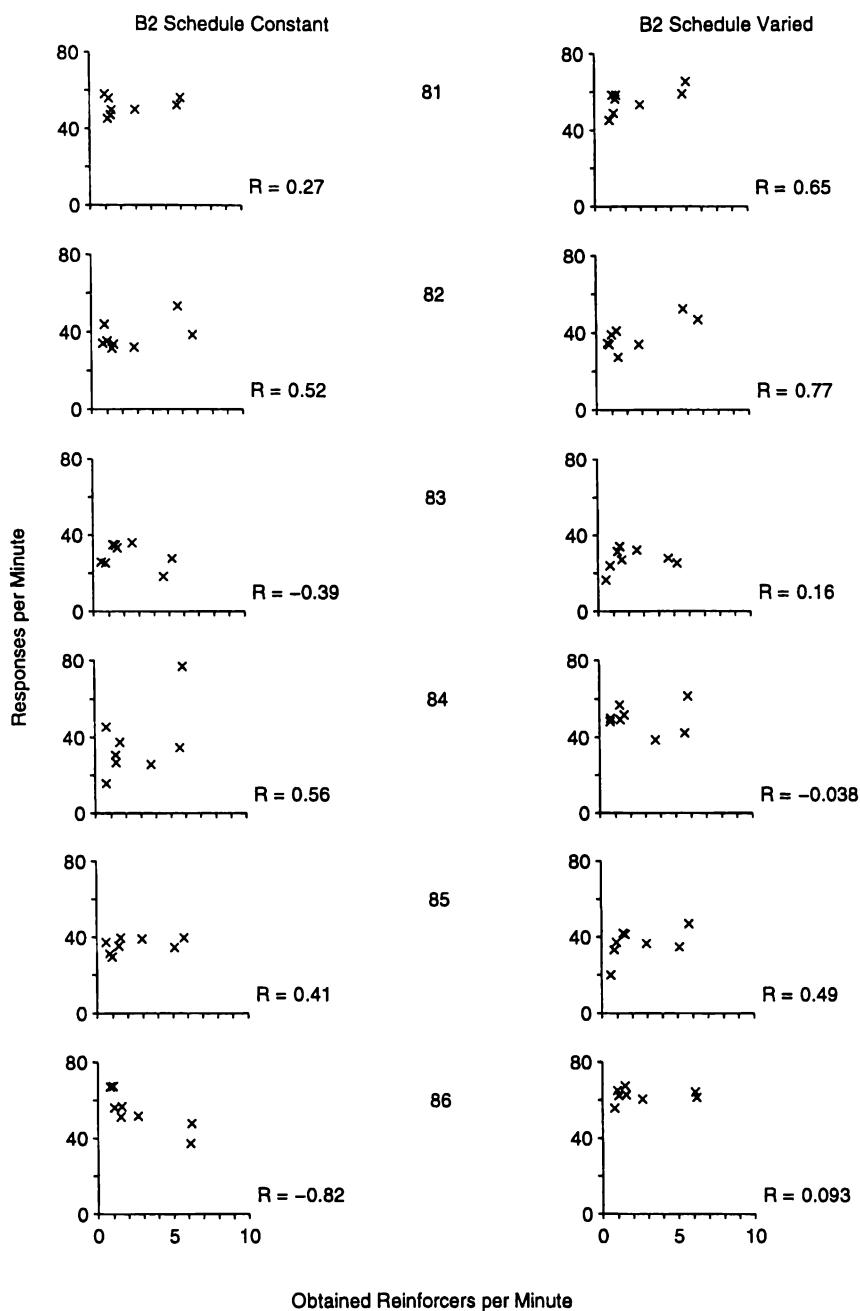


Figure 25. Experiment 4. Median rates of the second behaviours for the last five sessions of preliminary training (Phase 3) in each condition. The left panel shows the data for the first behaviour associated with the constant-second-behaviour schedule. The right panel shows the data for the second behaviour associated with the varied-second-behaviour schedule. In all cases these are plotted against the obtained reinforcer rate in the session in which the median response rate occurred for the first behaviour associated with the varied-second-behaviour schedule. Correlation coefficients (R) are shown on the graphs.

Correlation coefficients are also shown. It can be seen that there was no systematic relation between the rate of reinforcement for the varied behaviour and the rate of responding for either behaviour across subjects.

The data of Catania and Reynolds (1968) suggested that the relation between response and reinforcement rate is negatively accelerated with some tendency for the response rates to be relatively constant at reinforcer rates above 30 reinforcers per hour. For the sessions shown in Figure 25, reinforcer rate was never below 30 reinforcers per hour. That no systematic relation between response rate and reinforcer rate was found in the present results may be because the data fall on this constant part of the reinforcement rate and response rate function. In any event, the variation in Behaviour 2 rates across conditions was not consistently related to changes in the varied reinforcement schedule. This means that any systematic changes in the occurrence of Behaviour 1 during the reinforcement of Behaviour 2 cannot be attributed to the rate of the second behaviour during its prior training.

Second Behaviours during the Multiple Schedule

It is still possible that the rates of the second behaviour when reinforced in the multiple schedule (Phase 4) may have systematically varied with reinforcement rate. Previous research has found that the rates of a behaviour in one component of a multiple schedule may be influenced by the reinforcer rate in another component of a multiple schedule (Reynolds, 1961a; 1961b; Williams, 1983). Varying the rate of reinforcement across conditions, then, may have influenced the rate of both second behaviours when in the multiple schedule. These response rates will be examined below for systematic variation across reinforcement rates.

Response rate across conditions. First, the rates of the second behaviours over all conditions when reinforced in the multiple schedule are shown in Figure 26. This figure shows the rates of the second behaviours with the constant (triangles) and varied (squares) reinforcement schedules during Phase 4. The left panel shows the data from components where the second behaviour with the constant schedule was reinforced. The right panel shows the data from the components where the second behaviour with the varied schedule was reinforced. It can be seen that rates of the second behaviours were reasonably consistent

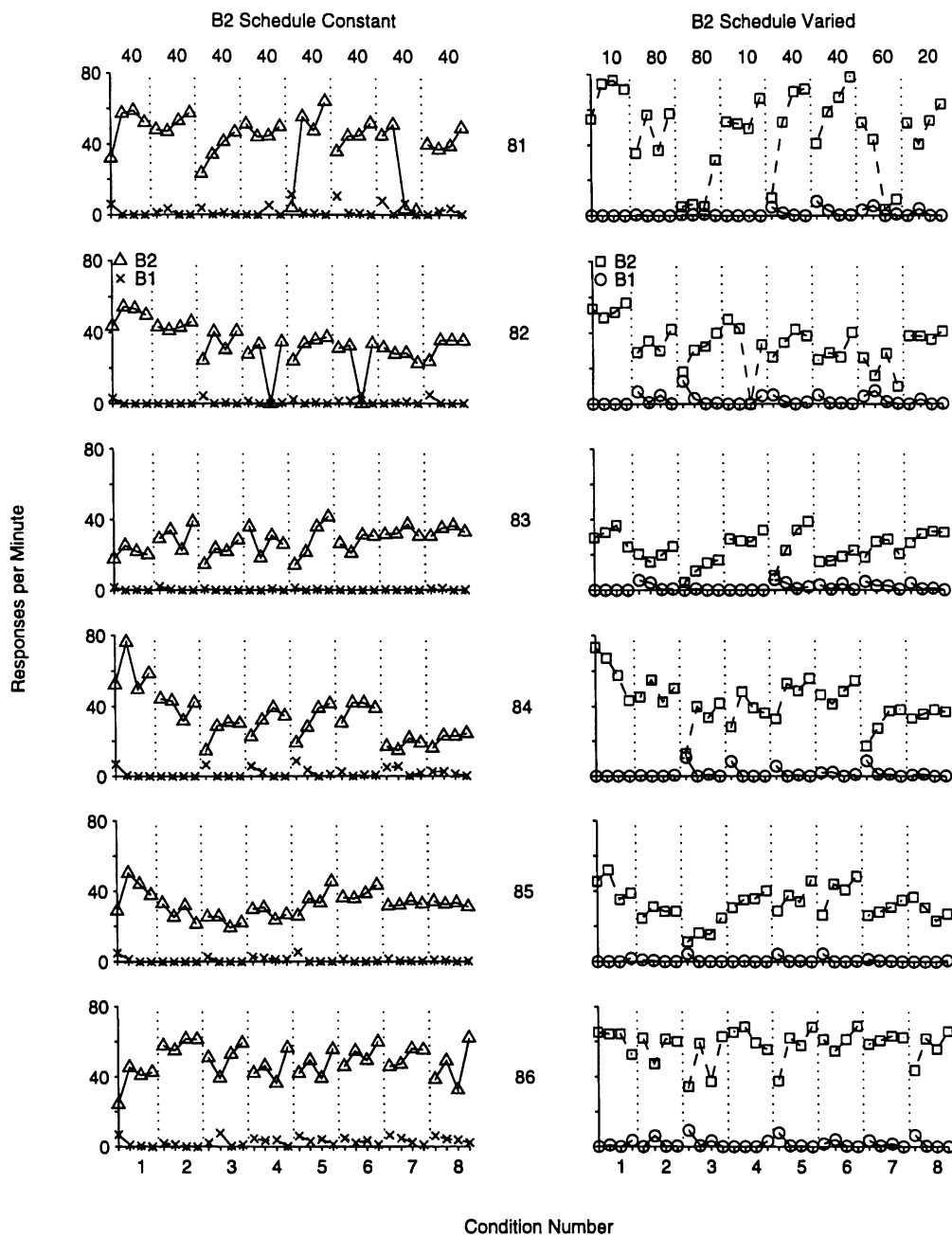


Figure 26. Experiment 4. Rates of the second behaviours and associated first behaviours when the second behaviours were reinforced under the multiple schedule for each session in Phase 4 for all conditions. Triangles and crosses show the second and first behaviours for which the second behaviour schedule was constant. Squares and circles show the second behaviour for which the second behaviour schedule varied. The left panel shows the data from the component where the schedule was constant. The right panel shows the data from the component where the schedule varied. Schedule size is on the top graphs.

across conditions for Hens 81, 83, 85 and 86 but tended to decrease across conditions for Hens 82 and 84. It was noted above that decreases in response rates for Hens 82 and 84 were also observed during the training of the second behaviour across conditions and it seems that the decreases have carried over into the multiple schedule. Because this is the case, the ratios of the rate of a second behaviour when under the multiple schedule (Phase 4) to its rate in training (Phase 3) should be more consistent across conditions than are these absolute rates.

Figure 27 shows these ratios logarithmically (i.e., the logarithms of the ratios of the response rates of each second behaviour during Phase 4 to the median rate of this behaviour in the last five sessions of Phase 3). Numbers greater than zero mean that response rate in Phase 4 increased and numbers less than zero mean that response rate decreased, relative to that occurring during Phase 3. It can be seen that while there are still occasional decreases in relative rate within a condition, relative response rate does not trend across conditions. Using these ratios appears to give more consistent data across conditions for Hens 82 and 84. This measure is also free of the effects of any changes in response rate that might have occurred as a result of reinforcer rate only (Figure 25) and is appropriate for the investigation of multiple schedule interaction here.

Response rate within conditions. Figure 26 also allows examination of the rates of the second behaviours within each condition of Phase 4. These were often not consistent across all sessions of a particular condition. The most common pattern within conditions was a tendency for response rate in the fourth session to be higher than that in the first session (74 of 96 cases, 77%). Where this pattern occurs, from Condition 2 onwards, the rate in the first session of that condition (e.g., Session 1 of Condition 3) was generally below the last session of this phase in the previous condition (e.g., Session 4 of Condition 2, 52 of 66 cases, 79%). Figure 26 also shows the rates of the first behaviours (circles and crosses) during Phase 4. When Behaviour 1 occurred it tended to occur early in this phase for each condition. Thus, the points at which the rates of the second behaviour are low tend to be those at which the rates of the first behaviour are high, although the rates of the first behaviour were generally much lower than the rates of the second behaviour. Hence it appears that the rates of the first and second behaviours varied inversely. To investigate this further a scatter plot of these response rates from all conditions and sessions during Phase 4 is shown in Figure 28, together

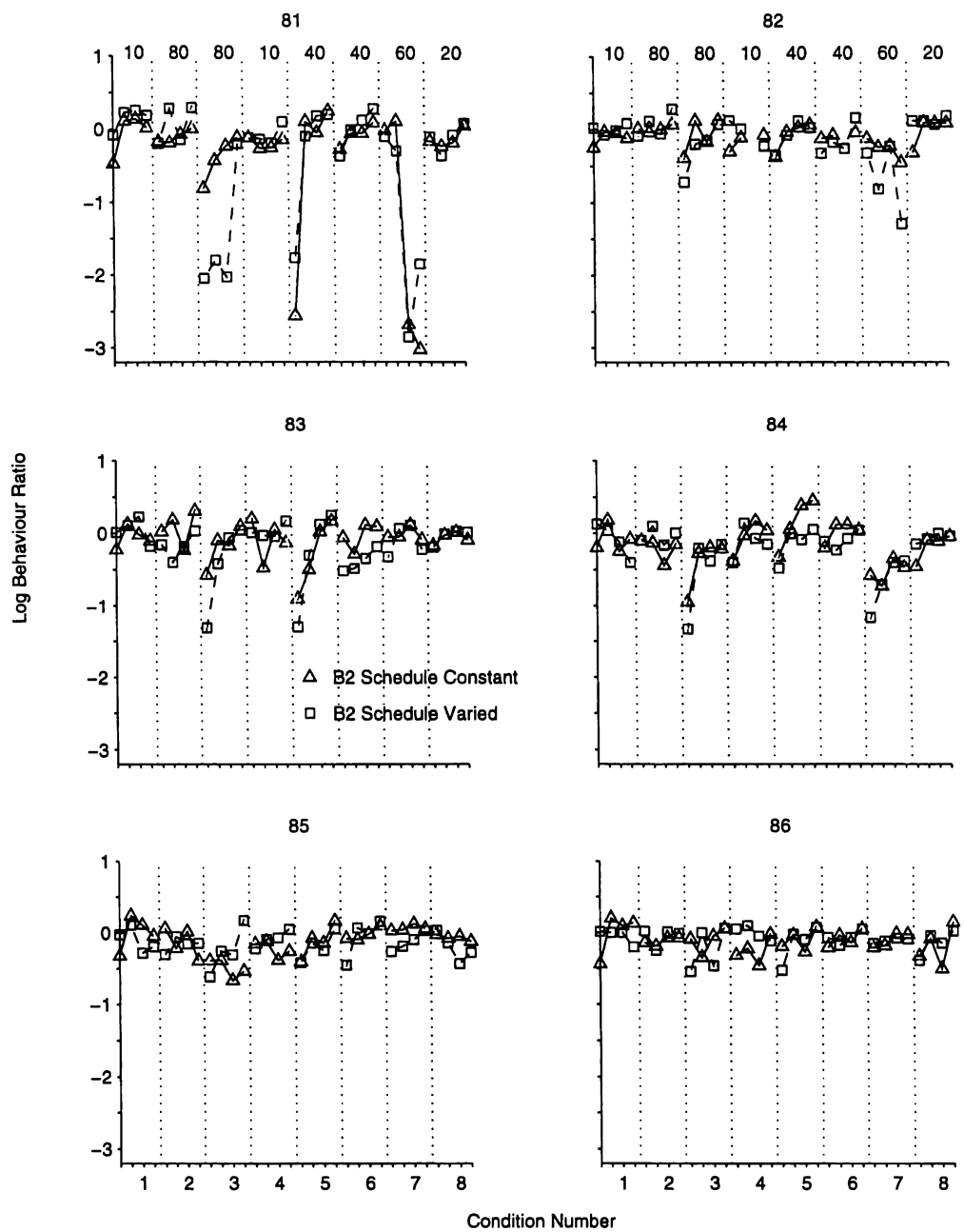


Figure 27. Experiment 4. Rates of the second behaviours when the second behaviours were reinforced under the multiple schedule (Phase 4) for all conditions, expressed as log ratios of the median response rate of each behaviour during the last five sessions of preliminary training (Phase 3) for each condition. Triangles show the second behaviour for which the schedule was constant. Squares show the second behaviour for which the schedule varied. The size of the varied schedule is shown on the top graphs.

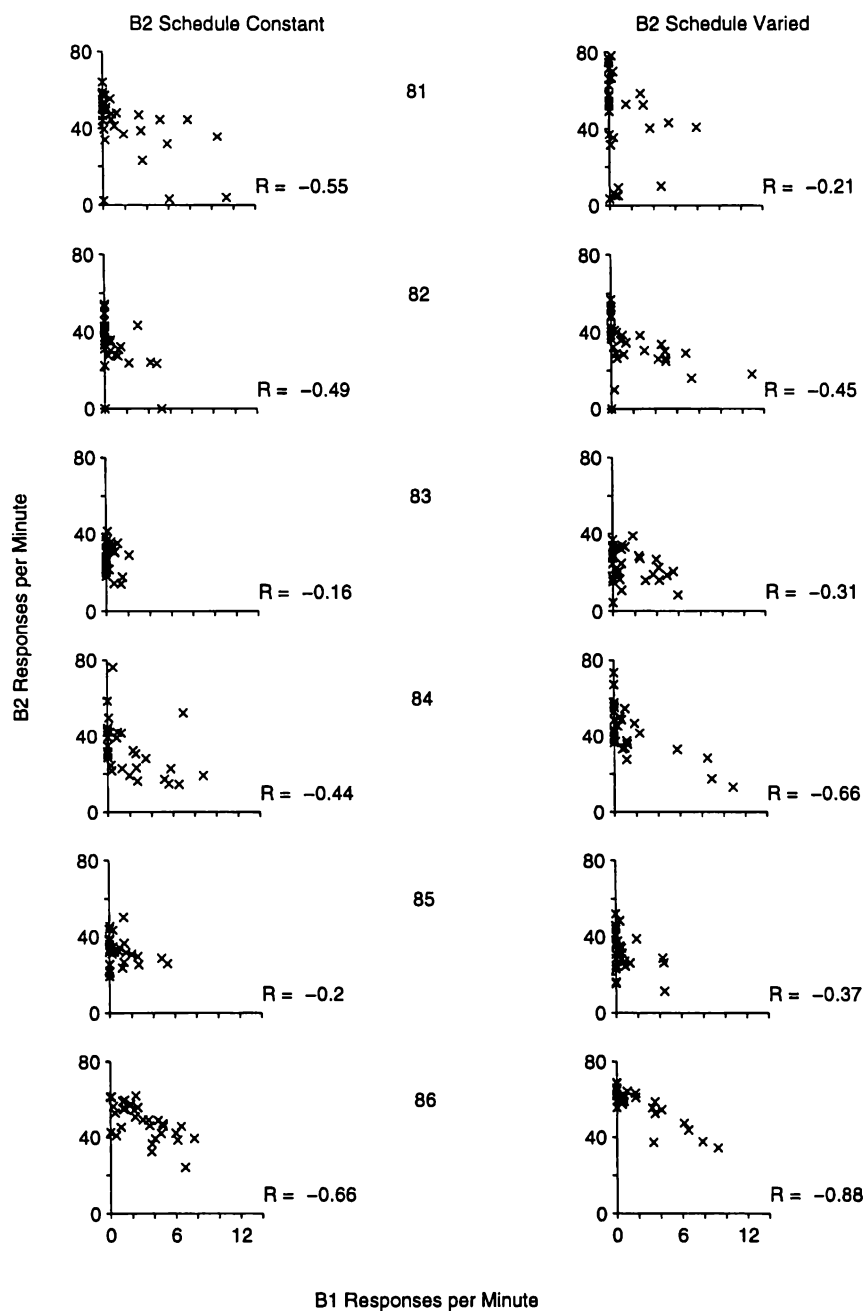


Figure 28. Experiment 4. Rates of the second behaviours plotted against the rates of the first behaviours for each session where the second behaviours were reinforced under the multiple schedule (Phase 4). The left panel shows the rate of the second behaviour with the constant reinforcement schedule plotted against the rate of its associated first behaviour. The right panel shows the rate of the second behaviour with the varied reinforcement schedule plotted against the rate of its associated first behaviour. Correlation coefficients (R) are shown on the graphs.

with their correlation coefficients. It can be seen that, although the strength of the relation varies widely across hens, there is generally a weak negative relation between the rate of the second behaviour and the rate of the first behaviour. As the first and second behaviours are concurrently available, and component time is limited, the rates of a second behaviour may be influenced by any occurrence of the first behaviour or vice versa.

Responding as a function of the varied schedule size. The present experiment ^{systemically} aimed to see whether the schedule for the second behaviour affected the rate of the first behaviour during the period where both were concurrently available in the multiple schedule (Phase 4). It was shown above that, during this period, the rates of the first and second behaviours within a component were somewhat inversely related. If the schedule was, in fact, affecting the rate of occurrence of the first behaviour, then this inverse relation would mean that the rate of the second behaviour would also covary with the schedule across conditions. Any covariance of second-behaviour response and reinforcer rates, in this case, can only be seen across conditions during periods where there was a variation in the occurrence of the first behaviour. Because most first behaviour occurred early in the phase this is where the second-behaviour reinforcer rates and response rates may covary across conditions. In addition, this relation should only be seen in the component in which the schedule was varied.

Responding in the first and last sessions when the second behaviour was reinforced under the multiple schedule (Phase 4) ^{was} will be examined. Figure 29 shows the relative rates of the second behaviours (as in Figure 27) during the first session of Phase 4 for all conditions. The left panel show the data for the second behaviour for which the schedule was constant. The right panel shows the data for the second behaviour for which the schedule varied. These are plotted against the varied RI schedule values. ~~It can be seen that~~ there is no consistent positive or negative relation for the second behaviour for which the RI schedule was constant (left panel). The relative rate of the second behaviour for which the RI schedule was varied (right panel), however, was negatively related to the varied RI schedule in all cases, though this is weak in some cases. Figure 30 shows the data for the last session of Phase 4 plotted as in Figure 29. It can be seen that there is no consistent positive or negative relation for either of the second behaviours during this session. It would appear that responding was systematically related to

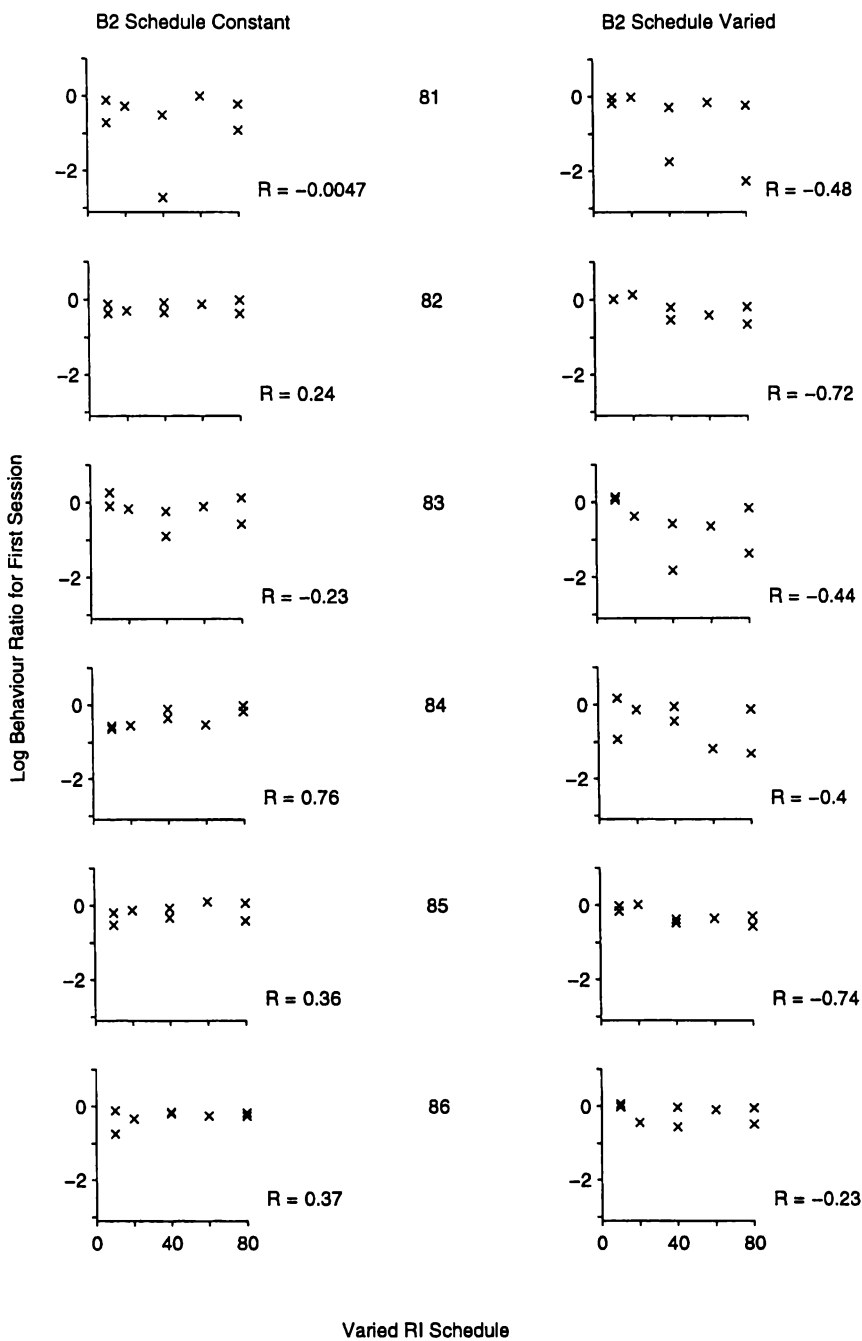


Figure 29. Experiment 4. Rates of the second behaviours in the first session when the second behaviours were reinforced under the multiple schedule (Phase 4) for all conditions, expressed as log ratios of the median rate of each behaviour during the last five sessions of preliminary training (Phase 3) for each condition. These are plotted against the varied schedule. The left panel shows the second behaviour for which the schedule was constant. The right panel shows the second behaviour for which the schedule varied. Correlation coefficients (R) are shown on the graphs.

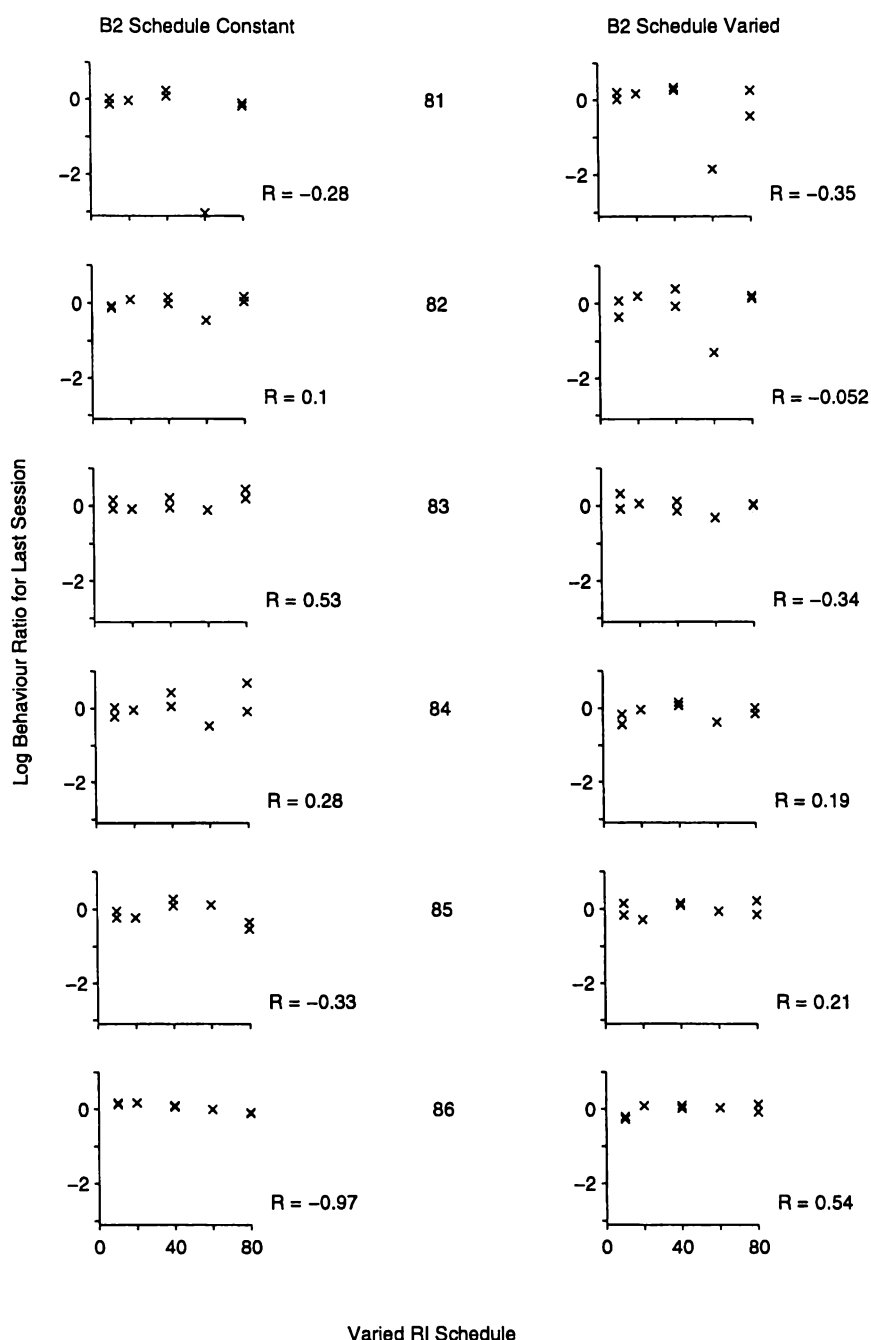


Figure 30. Experiment 4. Rates of the second behaviours in the last session when the second behaviours were reinforced under the multiple schedule (Phase 4) for all conditions. These are expressed as log ratios of the median rate of each behaviour during the last five sessions of preliminary training (Phase 3) for each condition and plotted against the varied schedule. The left panel shows the second behaviour for which the schedule was constant. The right panel shows the second behaviour for which the schedule varied. Correlation coefficients (R) are shown on the graphs.

reinforcement rate for only the second behaviour for which the schedule was varied and only in the first session of Phase 4.

If a multiple schedule interaction had occurred then correlations should have been obtained in all cases. As noted above, the relation between the rate of the second behaviour for which the schedule was varied and reinforcement rate, in the first session of Phase 4 across conditions, might be accounted for by the combination of : (1) a relation between the varied RI schedule and the occurrence of the first behaviour, and (2) the inverse relation between the rate of the first and second behaviours. Nevertheless, the data are correlational only and no firm conclusion about causation can be drawn. What can be concluded is that any effect of the RI schedule upon the relative rate of the second behaviours in the multiple schedule was not consistent across conditions when a within-condition relation was considered and as such it poses no threat to the interpretation of the results.

Summary of Behaviour 2 Results

Much of the analysis to this point has been concerned with whether changes in the rates of the second behaviour could have influenced the occurrence of the first behaviour during the training and reinforcement of the second behaviour. It was found that the rate of Behaviour 2 was not consistently related to reinforcement rate over conditions. Because of this, any systematic relation between the RI schedule and the occurrence of the first behaviour during the reinforcement of the second behaviour is unlikely to be the result of changes in the rate of the second behaviour. Unlike Leitenberg et al.'s (1975) experiment, then, any systematic differences in the occurrence of the first behaviour across varying second behaviour reinforcement schedules here can be attributed to the rate of reinforcement.

Occurrence of the First Behaviours during the Reinforcement and Extinction of the Second Behaviours

Independence of first behaviours. Experiment 3 showed that whether one first behaviour was reinforced or not did not affect the rate of occurrence of the other first behaviour. This enabled the resurgence of the two first behaviours in the multiple schedule to be viewed as independent events with respect to the independent variable in that experiment (prior extinction). In the present study the

independent variable was the RI schedule in effect for one second behaviour. It is possible that the RI schedule of one second behaviour may have affected the occurrence of the first behaviour associated with the other second behaviour. If so, the occurrence of each first behaviour would be a function of the schedules in effect in both components. In other words, the occurrence of the two first behaviours would not be independent with respect to the RI schedule. If this was so, then it would not be possible to draw conclusions here about the effect of varying the schedule of reinforcement for the second behaviour upon the occurrence of the first behaviour.

For the occurrence of the two first behaviours during both the reinforcement and the extinction of the second behaviours to be viewed as independent events, the occurrence of one first behaviour should not be affected by the schedule in effect for the second behaviour associated with the other first behaviour. Whether or not this was so here is examined in Figure 31, where the occurrence of the first behaviour associated with the constant schedule is plotted against the varied RI schedule for the reinforcement (Phase 4, left panel) and extinction (Phase 5, right panel) phases of the multiple schedule. It can be seen that the occurrence of this first behaviour was not consistently related to the varied RI schedule across subjects in either phase. Thus the occurrence of the two first behaviours can be considered to be independent with respect to the schedule for the second behaviour.

Within-condition comparisons. Of interest here is whether the occurrence of Behaviour 1 varied with the Behaviour 2 RI schedule. As previously mentioned Leitenberg et al. (1975) found that more of a first behaviour occurred when the second behaviour was reinforced under the lean schedule than under the richer schedule. They compared the occurrence of the first behaviours across groups of subjects for which the second behaviour schedule varied. The equivalent comparison here is between the occurrence of the first behaviours trained under lean and rich schedules within the same condition. In the present study the second behaviours were reinforced under different schedules in six conditions making a total of 36 possible within-condition comparisons across subjects. Figure 32 shows the number of occurrences of the first behaviours associated with the varied (circles) and constant (diamonds) Behaviour 2 schedules during the periods the second behaviour was reinforced in the multiple

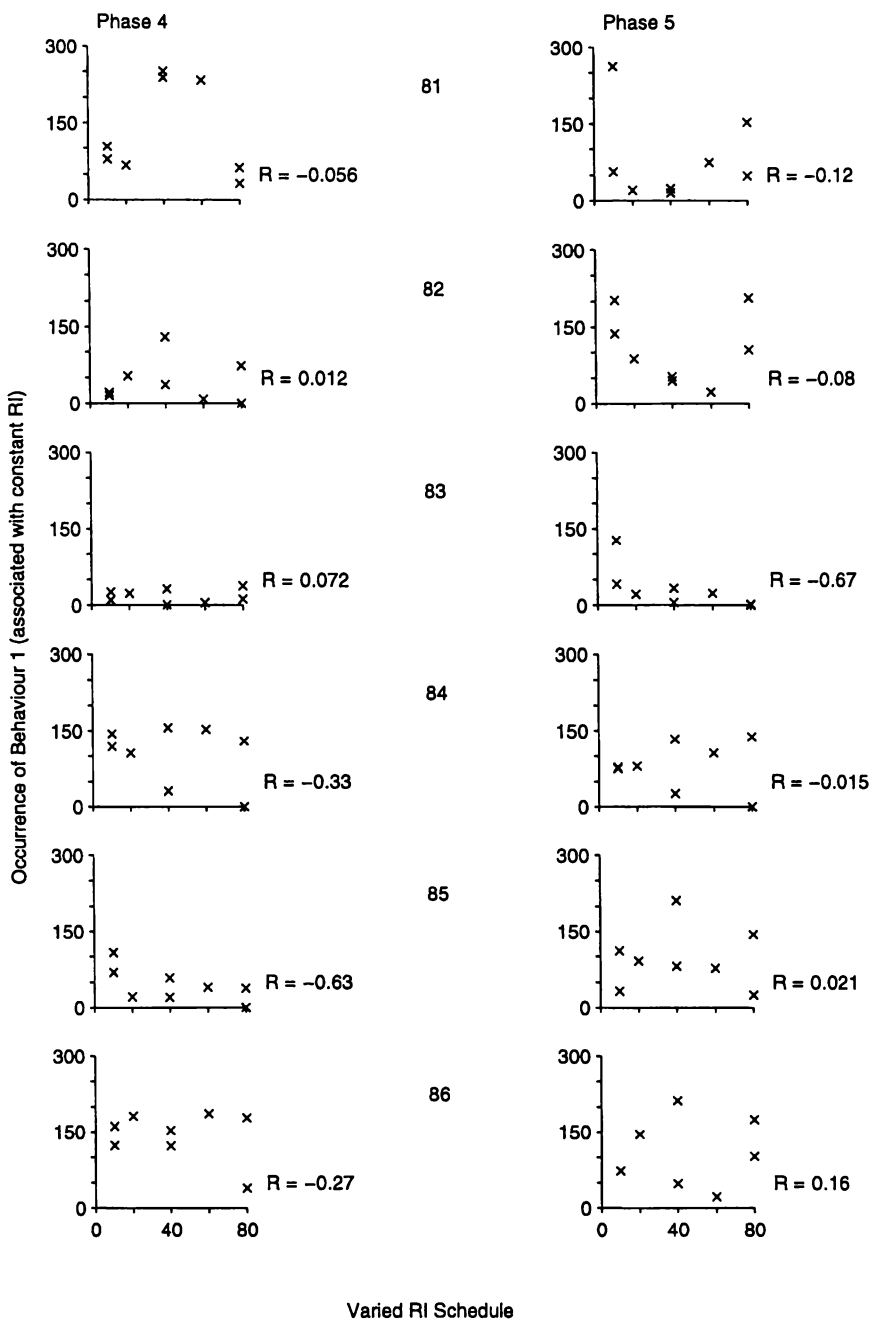


Figure 31. Experiment 4. The number of occurrences of the first behaviour associated with the constant-second-behaviour schedule. The left panel shows the number that occurred during the training of the second behaviour (Phase 4). The right panel shows the number that occurred during the extinction of the second behaviour (Phase 5). These are both plotted against the size of the varied-second-behaviour schedule. Correlation coefficients (R) are shown on the graphs.

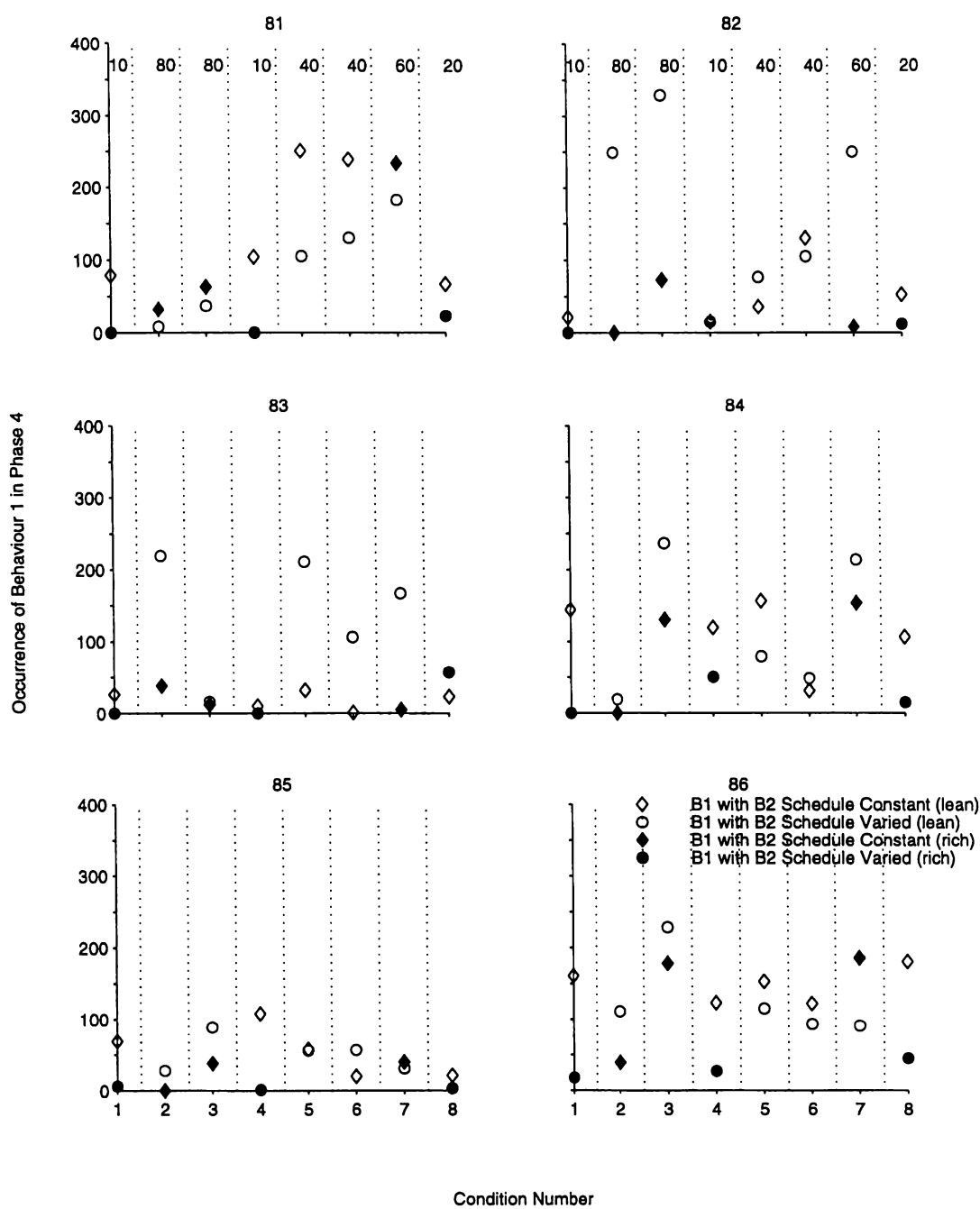


Figure 32. Experiment 4. Number of first behaviours occurring during the training of the second behaviour (Phase 4) for each condition. Diamonds show the first behaviour that was associated with the constant-second-behaviour schedule. Circles show the behaviour that was associated with the varied-second-behaviour schedule. The size of the varied schedule is shown on the top graphs. The behaviour associated with the rich and lean schedule in each condition is shown by the filled symbols and unfilled symbols respectively.

schedule (Phase 4). The varied RI schedules are shown on the figure and whether a behaviour was associated with the rich (filled symbols) or the lean (unfilled symbols) schedule in a condition is also shown. In 29 of the 36 cases (80%, Figure 32), the data were consistent with Leitenberg et al.'s (1975) findings in that the behaviour associated with the lean Behaviour 2 schedule (unfilled symbols) occurred more than the behaviour associated with the rich Behaviour 2 schedule (filled symbols). Leitenberg et al. (1975) also found that, during the extinction of the second behaviour, the first behaviour associated with the rich schedule occurred more than the first behaviour associated with the leaner schedule. Figure 33 shows the number of occurrences of the first behaviours from the final extinction (Phase 5) with the symbols being the same as Figure 32. In 25 of the 36 cases (69%) the data were consistent with Leitenberg et al.'s (1975) findings in that the behaviour associated with the rich Behaviour 2 schedule (filled symbols) occurred more than the behaviour associated with the lean Behaviour 2 schedule (unfilled symbols).

It appears then that the number of first behaviours that occurred when the second behaviour was reinforced was inversely related to the RI schedule for the second behaviour (Figure 32). In addition, the number of first behaviours that occurred during the final extinction (i.e., resurgence) was positively related to the RI schedule for the second behaviour (Figure 33). The Prevention of Extinction Hypothesis suggests that during both of these phases, the first behaviour was in extinction but was exposed to this contingency only when that behaviour occurred. In other words the more Behaviour 1 occurs during the training of Behaviour 2 the less it will occur during the extinction of Behaviour 2. Thus some first behaviours occur during the extinction of the second behaviour because the schedule of reinforcement of the second behaviour prevented their occurrence earlier. If this is so, the degree to which the first behaviour occurs during the extinction of the second behaviour should be an inverse function of the degree to which it occurred prior to this. In Experiment 3 the degree of prior extinction of the first behaviour was manipulated by inserting periods of extinction prior to the training of the second behaviour. As predicted by the Prevention of Extinction Hypothesis, the degree of resurgence was an inverse function of the degree of prior extinction. In the present study varying the RI schedule for the second behaviour resulted in different degrees of occurrence of the first behaviour during the training of the

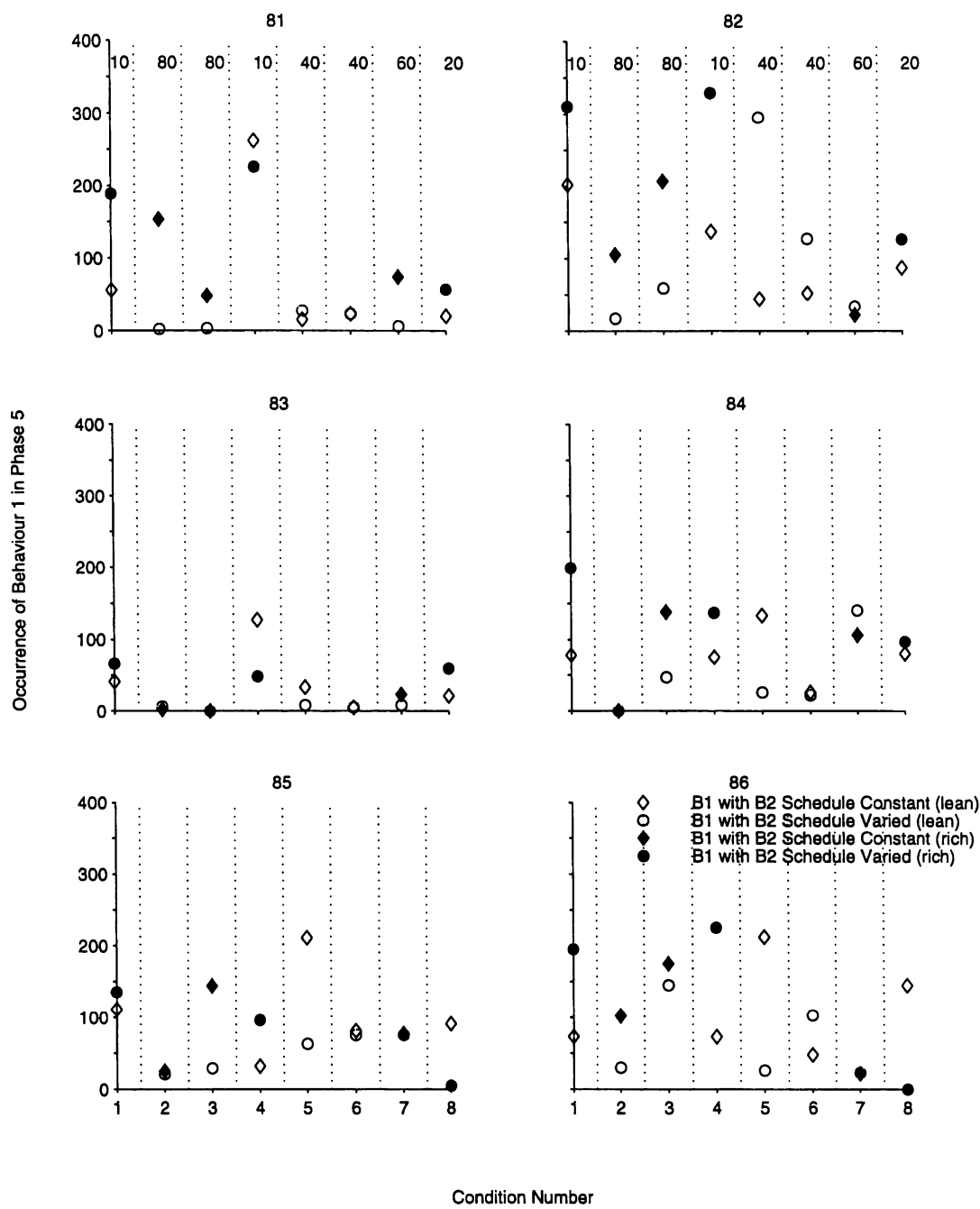


Figure 33. Experiment 4. Number of first behaviours occurring during the extinction of the second behaviour (Phase 5) for each condition. Diamonds show the first behaviour that was associated with the constant-second-behaviour schedule. Circles show the behaviour that was associated with the varied-second-behaviour schedule. The size of the varied schedule is shown on the top graphs. The behaviour associated with the rich and lean schedule in each condition is shown by filled symbols and unfilled symbols respectively.

second behaviour. As these first behaviours were not reinforced, and occurred prior to the extinction of the second behaviour, the same inverse relation that held for the degree of prior extinction and resurgence in Experiment 3 should hold here, all else being equal. Within each condition then, the first behaviour which occurred more during the reinforcement of the second behaviour (Phase 4, Figure 32) should occur less during the extinction of the second behaviour (Phase 5, Figure 33). Across all subjects and conditions this was the case in only 27 of the 48 cases (56%). Thus there is no clear support for the Prevention of Extinction Hypothesis, as interpreted here, from the within-condition data.

Across-condition comparisons. The questions investigated above within conditions can also be examined across conditions. Figure 34 shows the numbers of first behaviours associated with the varied-second-behaviour schedule in Phase 4 (left panel) and Phase 5 (middle panel) plotted against the varied RI schedule. The right panel shows the frequencies of this behaviour in Phase 5 plotted against those in Phase 4. Regression lines have been fitted by the method of least squares. It should be remembered that as the RI schedule value increases the rate of reinforcement decreases. It can be seen that the degree of occurrence of the first behaviour during the training of the second behaviour (Phase 4, left panel) was generally a function of the varied RI schedule, as suggested by the within-subject comparisons above and the results of Leitenberg et al. (1975). The degree of occurrence of the first behaviour during the final extinction (Phase 5, middle panel) is an inverse function of the varied RI schedule, also as suggested by the within-condition comparisons above and the data of Leitenberg et al. (1975). Unlike the within-condition comparisons, however, the total occurrence of the first behaviour in Phase 5 appears to be inversely related to the total occurrence of the first behaviour in Phase 4 (right panel). As noted above, the Prevention of Extinction Hypothesis predicts such a relation between the degree of prior extinction (responding in Phase 4) and the degree of resurgence (responding in Phase 5). However the data are somewhat variable. Figure 32 and Figure 33 show that the occurrence of the first behaviour associated with the constant-second-behaviour reinforcement schedule varied considerably in both Phase 4 and 5 across conditions. Because this first behaviour was not associated with the varied-second-behaviour schedule, the variability seen in the occurrence of this first behaviour is likely to be due to other factors. These other factors may also

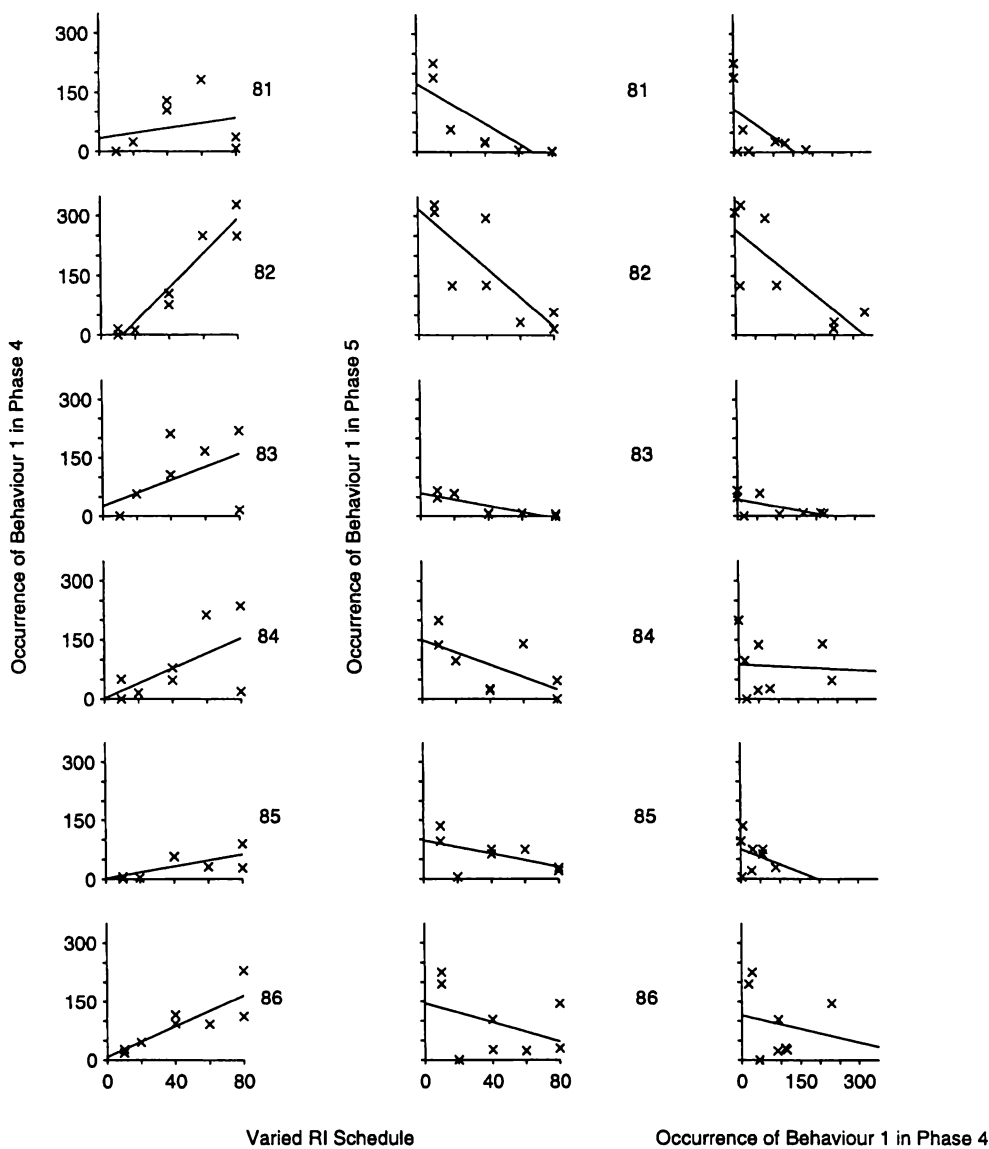


Figure 34. Experiment 4. The number of occurrences of the first behaviour associated with the varied-second-behaviour schedule for all conditions. The left panel shows the number of first behaviours that occurred during the training of the second behaviour (Phase 4) plotted against the varied schedule. The middle panel shows the number of first behaviours that occurred during extinction (Phase 5) plotted against the varied schedule. The right panel shows the number of first behaviours that occurred during Phase 5 (Y-axis middle panel) plotted against the number occurring during Phase 4 (Y-axis left panel). Linear regression lines have been fitted by the method of least squares.

affect the occurrence of the first behaviour associated with the varied-second-behaviour schedule. Variability across conditions was also found in Experiments 2 and 3 and may mask the shape of the relation between the degree of resurgence and the degree of prior extinction in Figure 34.

Possible confounds. In this study, the number of sessions of Behaviour 2 training (Phase 3) varied across conditions (Table 11). This phase was used to establish the second behaviours using the auto-adjusting procedure. In Condition 1, 11 sessions were required to reach the RI 40-s schedule. In Condition 2, there were 31 sessions before the RI 80-s schedule was reached. Fewer first behaviours (associated with the constant schedule) occurred once all behaviours were again available in Condition 2 (Phase 4, Figure 32) than in Condition 1 for 5 of the 6 hens. In addition there was less resurgence (Phase 5, Figure 33) in Condition 2 than in Condition 1 for 4 of the 6 hens. As previously noted, there are some data that suggest that the length of training of the second behaviour might affect the degree of resurgence (Leitenberg et al., 1975). Thus it is possible that some of the variation in responding here was a product of the length of training of the second behaviour. No firm conclusion can be drawn from the present data and so the next experiment investigated the effect of varying the length of training of the second behaviour.

During the preliminary training of the second behaviour (Phase 3) first behaviours occasionally occurred. First behaviours that occurred in Phase 3 were not reinforced. The effect of these responses is difficult to predict because the stimulus conditions in effect when they occurred were different from those during the final extinction (Phase 5). Figure 35 shows the number of these first behaviours associated with the constant (crosses) and varied (circles) second behaviour schedule that occurred during Phase 3. It can be seen that, with the exception of the behaviour associated with the varied schedule for Hen 81, few first behaviours occurred during this phase. For Hen 81 the number was reasonably constant across conditions after Condition 1 and so any effect upon the occurrence of the first behaviour in Phase 4 or 5 should also be relatively consistent for this hen. It would seem unlikely, therefore, that the variance in responding across conditions in Phases 4 and 5 was the result of responding in Phase 3.

It was noted earlier that the rates of the second behaviour when reinforcers

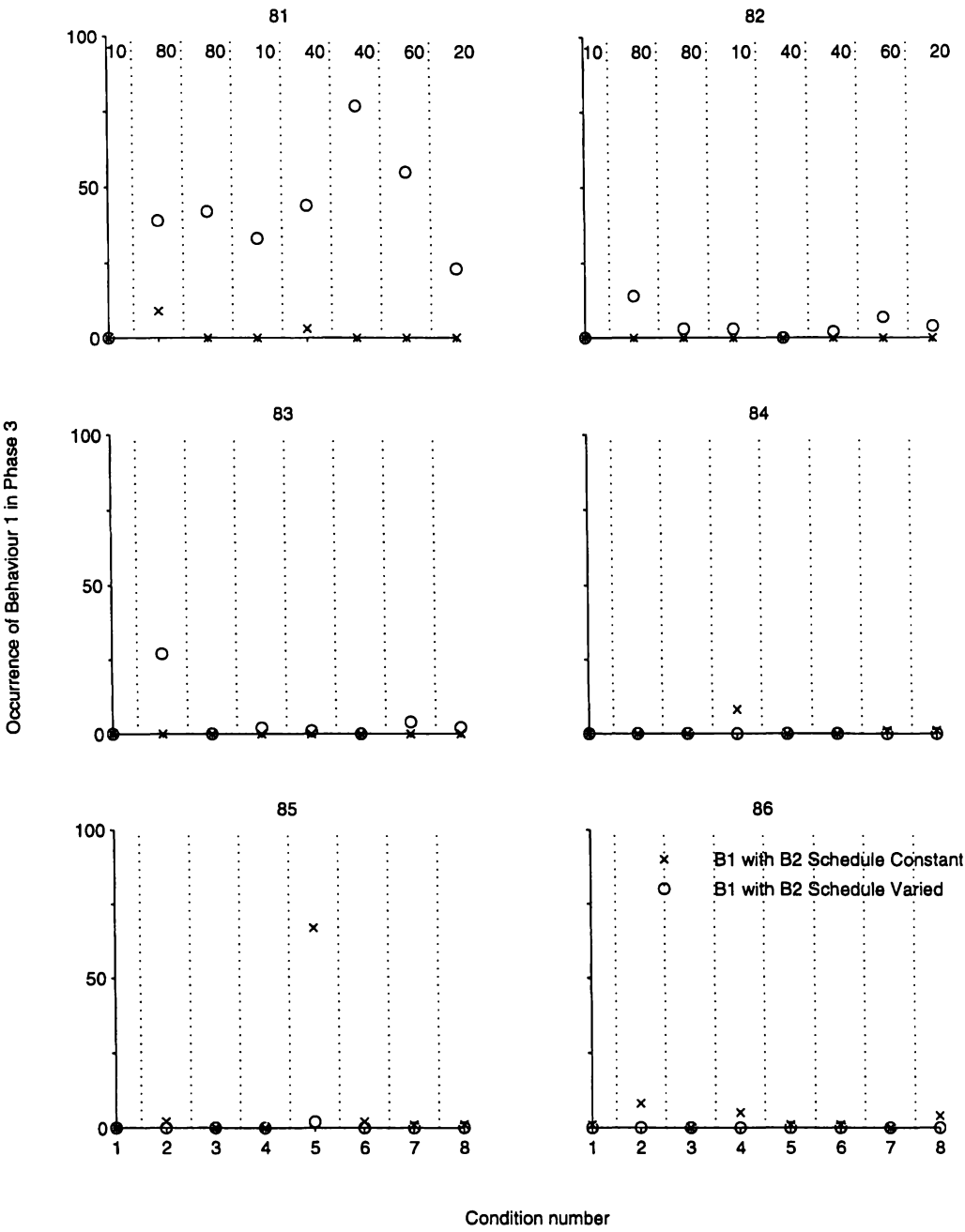


Figure 35. Experiment 4. Number of first behaviours that occurred during the preliminary training of the second behaviour (Phase 3) for all conditions. Crosses show the first behaviour associated with the constant-second-behaviour schedule. Circles show the first behaviour associated with the varied-second-behaviour schedule. The size of the varied schedule is shown on the top graphs.

were delivered during the multiple schedule (Phase 4) decreased for Hen 82, 84, and 85 across conditions. This was of concern because of the possibility that changes in the response rate of the second behaviour might affect the occurrence of the first behaviour. Figure 34 shows that the data for these hens (i.e., Hen 82, 84, and 85) are not systematically different from the other hens (i.e., Hen 81, 83, and 86). Thus it is unlikely that changes in the rate of the second behaviour contributed to the variance in the occurrence of the first behaviour across conditions.

Proportion of first behaviour that occurred within each phase. The degree of resurgence of the first behaviour, for which there was no extinction, was also found to be variable across conditions in Experiment 3. It was found there that the degree of resurgence of the first behaviour, for which the degree of prior extinction was varied, was an inverse function of the degree of prior extinction, but again the data were variable. When the resurgence was expressed as a proportion of the total of the occurrence of this behaviour and of the other first behaviour then it was a more orderly function of the degree of prior extinction. It is possible, then, that proportions may result in less variable data. Proportions can be calculated for responding from both the reinforcement phase and final extinction phase (Phases 4 and 5) here. Figure 36 (left panel) shows the occurrence of the first behaviour associated with the varied-second-behaviour schedule expressed as a proportion of the total of the occurrence of both first behaviours, during Phase 4. These are plotted against the varied schedule. The regression lines shown on the graphs in Figure 36 were fitted by the method of least squares.

For all hens the proportion of behaviour that occurred during the reinforcement of Behaviour 2 appears to be an increasing linear function of the varied schedule. Figure 36 (middle panel) shows the occurrence of the first behaviour associated with the varied-second-behaviour schedule expressed as a proportion of the total occurrence of both first behaviours, during Phase 5, again plotted against the varied schedule. For all hens, with the exception of Hen 83, the proportional occurrence of the first behaviour during the extinction of the second behaviour (i.e., the resurgence) appears to be an inverse function of the varied schedule. If, as the Prevention of Extinction Hypothesis predicts, the degree of resurgence is a function of the degree of prior extinction of the first

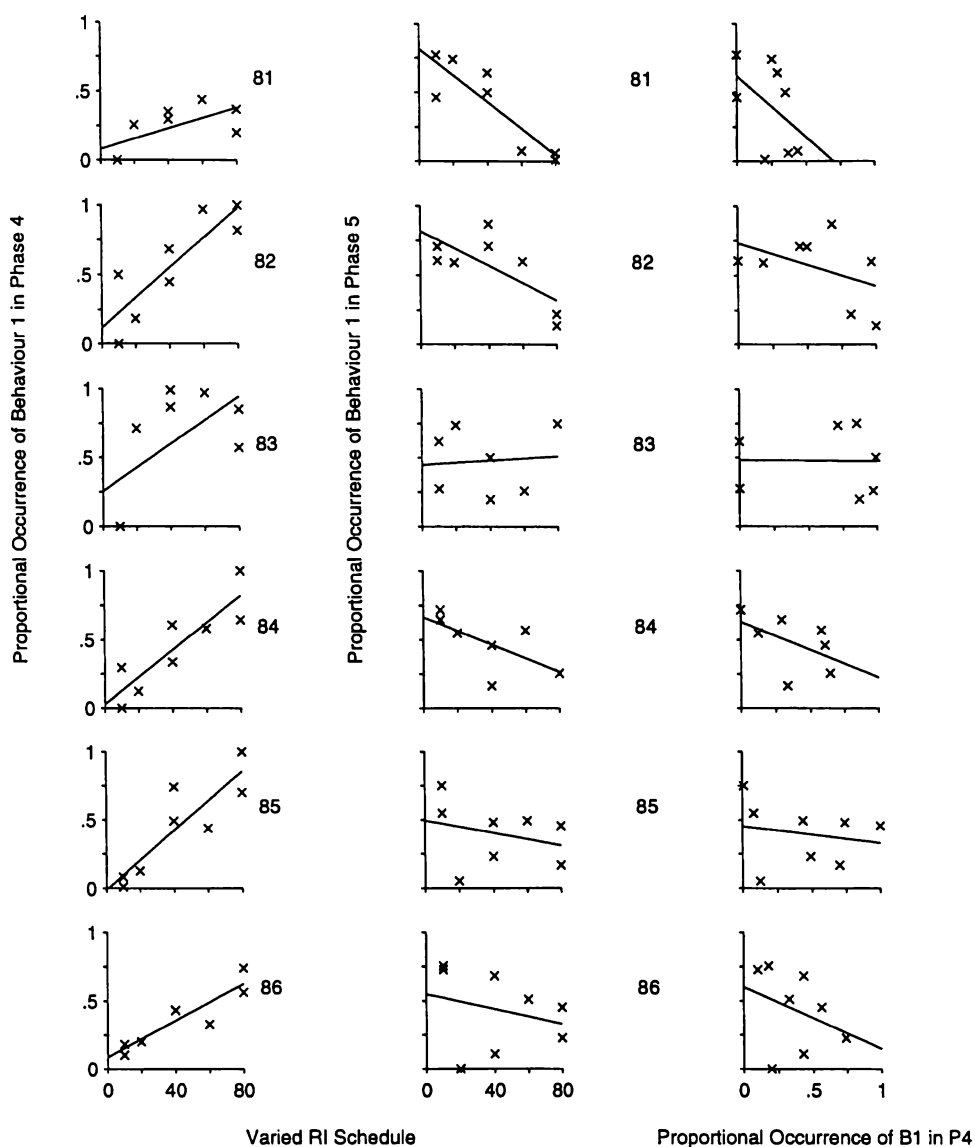


Figure 36. Experiment 4. The occurrence of the first behaviour associated with the varied-second-behaviour schedule for all conditions. This is expressed as a proportion of total occurrence of this behaviour and the other first behaviour. The left panel shows proportions during the training of the second behaviour (Phase 4) plotted against the size of the varied schedule. The middle panel shows the proportions during the final extinction (Phase 5) plotted against the size of the varied schedule. The right panel shows the proportions during Phase 5 (Y-axis middle panel) plotted against the proportions during Phase 4 (Y-axis left panel). Linear regression lines have been fitted by the method of least squares.

behaviour (Leitenberg et al., 1975) then the proportional occurrence of the first behaviour during Phase 5 (i.e., the resurgence, Figure 36, Y-axis of middle panel graphs) should be a function of the proportional occurrence of this behaviour during Phase 4 (the degree of prior extinction, Figure 36, Y-axis of left panel graphs). Figure 36 (right panel) shows these plotted against each other. It can be seen that, although variable, resurgence was inversely related to the degree of extinction for all subjects except Hen 83.

To see if expressing the number of first behaviours as a proportion (Figure 36) resulted in a more orderly function than using the numbers of behaviours (Figure 34), both measures were divided by their standard deviations and least squares regression lines were fitted. The variance accounted for by, standard errors of, and slopes of, these lines are shown in Table 12. It can be seen that some of the variances accounted for are quite low (i.e., the variance accounted for by the line relating proportion of responses in Phase 4 to those in Phase 5 for Hen 83 is only 0.036%). From Table 12 it can also be seen that the slopes of the lines were also low in such cases and this may have contributed to the low variances accounted for. For responding during second behaviour reinforcement (Phase 4) it can be seen that slightly more variance, on average, was accounted for by using the proportion than by using number of responses (65% compared to 47%), and the average standard error for the proportional measure was slightly smaller than that for the number (0.5 compared to 0.64). This suggests that expressing as a proportion resulted in a slightly more orderly function than using the numbers. For responding in the final extinction it can be seen that less variance is accounted for (31% compared to 48%) and the standard error is higher (0.75 compared to 0.65) when proportion is used than when numbers are used. This suggests that expressing as a proportion did not result in a more orderly function than using the numbers. For the function relating the degree of resurgence to the degree of previous extinction again less variance is accounted for (13% compared to 24%) and the standard error is higher (0.87 compared to 0.8) for when proportions are used than when numbers are used. Expressing the occurrence of the first behaviour as a proportion, then, did not consistently make the data more orderly.

This contradicts the results of Experiment 3, which found that expressing the occurrence of the first behaviour as a proportion increased the orderliness of the data with respect to the independent variable (prior extinction) in that

Table 12

The percentage of variance accounted for, the standard error of estimate, and the slopes of the least-squares regression lines fitted to the occurrence of the first behaviour associated with the varied-second-behaviour schedule during Phases 4 and 5. The same measures are also shown for the lines fitted to this occurrence expressed as a proportion (Prop) of the total occurrence of both the first behaviours during Phases 4 and 5.

Percent Variance Accounted For						
Phase 4			Phase 5		Phase 4 vs Phase 5	
Hen	Number	Prop	Number	Prop	Number	Prop
81	7.4	43	66	77	31	21
82	93	73	66	51	64	20
83	27	37	72	.75	39	.036
84	36	78	40	42	.38	25
85	48	77	31	8.2	8.1	3.6
86	71	82	16	7.2	3.2	11
M	47	65	48	31	24	13
Standard Error						
Phase 4			Phase 5		Phase 4 vs Phase 5	
Hen	Number	Prop	Number	Prop	Number	Prop
81	.9	.7	.54	.45	.78	.83
82	.25	.48	.54	.65	.56	.84
83	.8	.74	.49	.92	.73	.93
84	.75	.44	.72	.71	.93	.8
85	.68	.45	.78	.9	.9	.92
86	.5	.4	.86	.9	.92	.88
M	.64	.5	.65	.75	.80	.87

Slope						
Phase 4			Phase 5		Phase 4 vs Phase 5	
Hen	Number	Prop	Number	Prop	Number	Prop
81	.0095	.023	-.028	-.031	-.55	-.46
82	.034	.03	-.028	-.025	-.8	-.45
83	.018	.021	-.03	.0033	-.63	-.019
84	.021	.031	-.022	-.025	-.062	-.5
85	.024	.03	-.019	-.01	-.28	-.19
86	.029	.032	-.014	-.0094	-.18	-.33
M	.022	.028	-.024	-.016	-.42	-.32

experiment. It was proposed there that expressing the occurrence of one first behaviour relative to the occurrence of the other first behaviour may make the data more orderly because confounding factors might influence the occurrence of both behaviours similarly. The occurrence of the two first behaviours would covary across conditions, all things being equal. All things were not equal in the present experiment because varying the schedule affected the occurrence of one first behaviour (Figure 34). This might mask any covariation in the first behaviours during training or extinction of the second behaviours.

The Prevention of Extinction Hypothesis implies that all the occurrences of the first behaviour during the training and extinction of the second behaviour are the occurrence of the first behaviour in extinction. Thus, it is just how the occurrence of the first behaviour is distributed between training and extinction of the second behaviour that varies with the schedule of reinforcement for the second behaviour. Because of this, the total of the occurrences of the first behaviour during the training and extinction of the second behaviour should not be a function of the varied RI schedule. Hence this total responding can be used to see if there is any covariance between the first behaviours. Figure 37 shows the number of first behaviours associated with the varied-second-behaviour schedule plotted against the number of first behaviours associated with the constant-second-behaviour schedule. The left panel shows those that occurred during Phase 4, the middle panel shows those that occurred in Phase 5, and the right panel shows the total of those that occurred in Phases 4 and 5. It can be seen that, in general, there was little relation between the occurrence of the first behaviour associated with the varied-second-behaviour schedule and the occurrence of the other first behaviour, the exceptions being the Phase 4 responding of Hen 81 and the total responding of Hens 81 and 84. As there was little covariance any relative measure is unlikely to make the data more orderly. Instead it appears that the variations in the numbers of first behaviours occurring across conditions were not related.

It is not possible to say why this is the case in the present experiment. Comparing the results and procedure with Experiment 3, where a relative measure was useful, raises some possibilities. The length of occurrence of a component was a maximum of 600 s in the present experiment while this was a maximum of 360 s in Experiment 3. It may be the case that the longer occurrence gave rise to this difference by allowing the effect of short-acting confounds to be restricted to

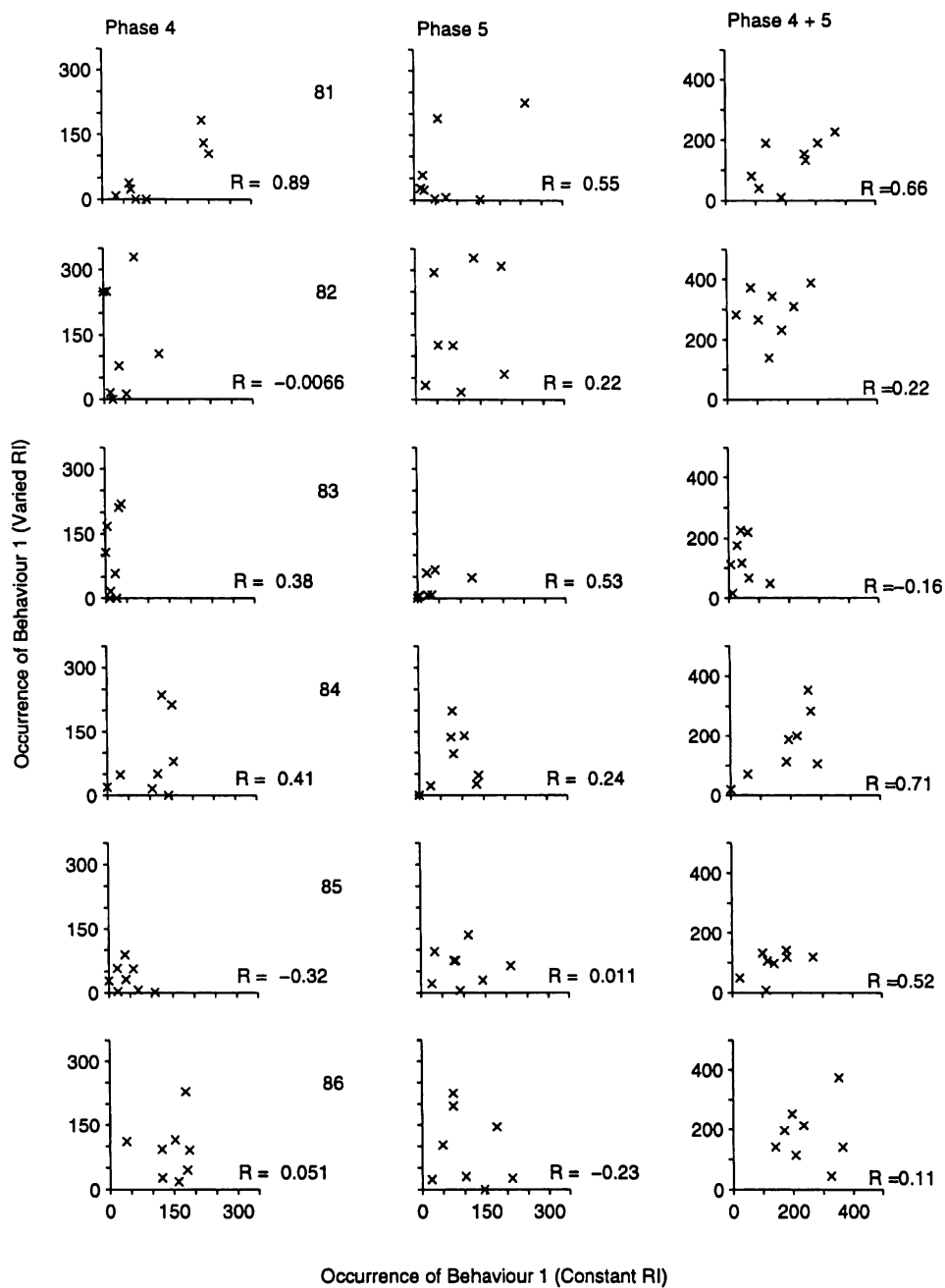


Figure 37. Experiment 4. The number occurrences of the first behaviour associated with the varied-second-behaviour schedule plotted against the number of occurrences of the first behaviour associated with the constant-second-behaviour schedule. The left panel shows the data from the training of the second behaviour (Phase 4). The middle panel shows the data from the final extinction (Phase 5). The right panel shows the data from both Phase 4 and Phase 5 summed. Correlation coefficients (R) are shown on the graphs.

one component. If, for instance, the effect of a confounding variable on behaviour occurred over 500 s then with a 600-s length of occurrence the effect on behaviour would be isolated to one component (e.g., red) whereas with a 360 s length of occurrence the behaviour in both components would be somewhat effected (e.g., both red and green). Additionally, it would appear from Figure 32 and Figure 33 that there was no general trend for responding to decrease across conditions, either in Phase 4 or Phase 5. In Experiment 3, decreases in the extinction responding were observed across conditions. It may be the case that the proportional measure increased the orderliness of the data because of this change in Experiment 3, and because such a trend did not occur here, the proportional measure did not make the data more orderly.

Summary of Occurrence of the First Behaviours

The following summarise the results so far: (1) the degree of occurrence of Behaviour 1 during the reinforcement of Behaviour 2 was an inverse function of the rate of reinforcement of Behaviour 2, (2) the degree of resurgence was generally a function of the previous rate of reinforcement for Behaviour 2, and (3) the degree of resurgence was somewhat inversely related to the degree of extinction of Behaviour 1 (i.e., the occurrence of this behaviour during the reinforcement of Behaviour 2). These results are consistent with those of Leitenberg et al. (1975) and might be taken to support the hypothesis that resurgence is due to the prevention of the extinction of a behaviour. However, the relation between the degree of resurgence and degree of prior extinction was generally less orderly than the relation between the degree of resurgence and the reinforcement rate in the varied-second-behaviour schedule (Table 12). As outlined above, the Prevention of Extinction Hypothesis does not suggest that this will be the case. It was proposed that the variability in the relation between the degree of resurgence and degree of prior extinction may have been because of the variability in the occurrence of the first behaviour across conditions. However, expressing the occurrence of one first behaviour relative to the occurrence of the other failed to make the data more orderly.

Analysis Predicated upon the Prevention of Extinction Hypothesis

It was noted above that the Prevention of Extinction Hypothesis suggests that the total frequency of the first behaviour during the training and extinction of

the second behaviour could be considered to be the total frequency of the first behaviour in extinction. If so, the frequency of Behaviour 1 during the training (Phase 4) and extinction (Phase 5) of Behaviour 2 should be inversely related. In the present study the occurrence of one first behaviour during the training of a second behaviour (Phase 4) varied as a function of reinforcer rate for a second behaviour (Figure 34, left panel) across conditions. The occurrence of one first behaviour during the extinction of a second behaviour (Phase 5) also varied as a function of reinforcer rate for a second behaviour (Figure 34, middle panel) across conditions. The total frequency of the first behaviour during both the training and extinction of the second behaviour should not have changed across conditions as a result of varying the reinforcer rate of a second behaviour but it may not necessarily have been constant. Figure 38 shows the total number of first behaviours that occurred in Phases 4 and 5 associated with the constant (crosses) and varied (circles) schedules. It can be seen that responding was variable but there were no general trends across conditions.

The fact that total responding varied across conditions, albeit inconsistently, is important here because, according to the Prevention of Extinction Hypothesis, it is the total frequency of the first behaviour in extinction that is distributed over Phases 4 and 5. Thus, if the distribution of the occurrence of the first behaviour between Phases 4 and 5 were constant across conditions, then the number of first behaviours occurring during Phases 4 and 5 would vary across conditions to the same degree. In other words, the number of first behaviours that occurred during the training (Phase 4) and extinction (Phase 5) of the second behaviour might be positively related across conditions to the degree that the total frequency of the first behaviour in extinction varied across conditions. This is precisely the opposite of the previously discussed relation predicted by the Prevention of Extinction Hypothesis when total extinction responding is constant across conditions: that the occurrence of the first behaviour during the training of the second behaviour (Phase 4) and extinction (Phase 5) would be negatively related across conditions. Thus the relation between Phase 4 and 5 responding found here (Figure 34, right panel) may be variable because of the contrasting effect of changes in total extinction responding across conditions.

It may be possible to separate out any effect of changes in total extinction responding with respect to the second behaviour schedule in the present

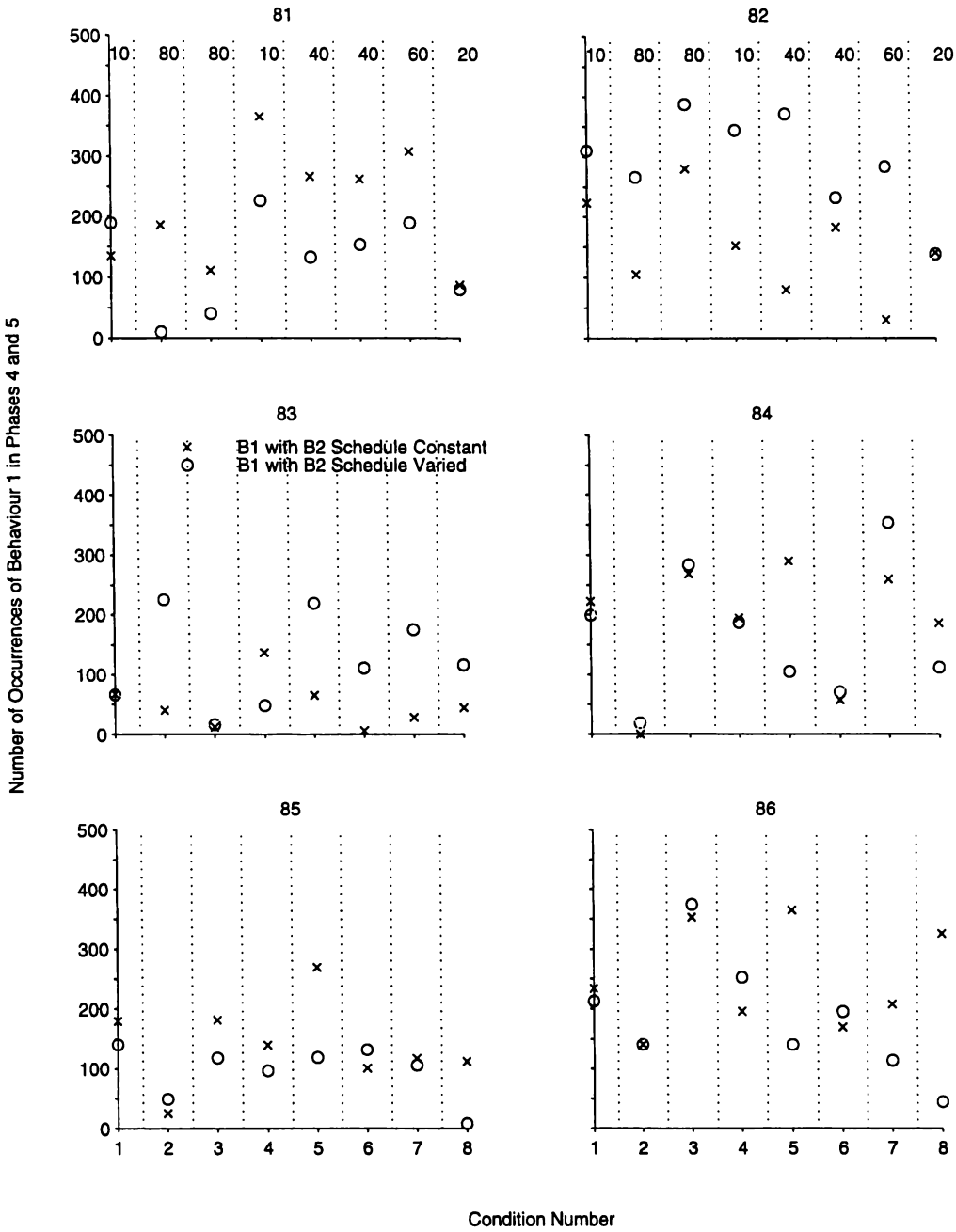


Figure 38. Experiment 4. Total number of first behaviours that occurred during the training (Phase 4) and extinction (Phase 5) of the second behaviour for all conditions. Crosses show the first behaviour associated with the constant-second-behaviour schedule. Circles show the first behaviour associated with the varied-second-behaviour schedule. The size of the varied schedule is shown on the top graphs.

experiment. If changes in the occurrence of the first behaviour during the training and extinction of the second behaviour were solely the result of changes in total extinction responding then the distribution of total responding between Phases 4 and 5 should remain constant across conditions. If, on the other hand, the changes in the occurrence of the first behaviour during the training and extinction of the second behaviour were not solely the result of changes in total extinction responding then the distribution should vary. In the present experiment the schedule in effect for one second behaviour was manipulated. If the RI schedule had an effect on the distribution of occurrence of this first behaviour during the training and extinction of the associated second behaviour then the distribution of this behaviour and RI schedule should covary. In addition, the distribution of the occurrence of the first behaviour associated with the constant-second-behaviour schedule across the training and extinction of the second behaviour should not covary with the varied RI schedule. This means of assessing the effect of the schedule of the second behaviour on the occurrence of the first behaviour will not be confounded by changes in the total frequency of occurrence of the first behaviour across conditions.

One measure of the distribution of responding is the number of first behaviours that occurred during extinction of the second behaviour (Phase 5) divided by the total number of first behaviours that occurred during the training (Phase 4) and extinction (Phase 5) of the second behaviour. These are shown in Figure 39 for the first behaviours associated with the constant (left panel) and varied (right panel) schedule plotted against the varied RI schedule. The proportional occurrence of the first behaviour associated with the constant schedule was variable (left panel) and there is no consistent positive or negative relation across hens. Thus the proportional occurrence of this behaviour did not vary systematically with the varied RI schedule. However, the proportional occurrence of the first behaviour associated with the varied-second-behaviour schedule is an inverse function of the varied RI schedule in all cases (right panel). Thus the rate of reinforcement for the second behaviour appears to have influenced the distribution of this first behaviour. This relation is better described by the negative exponential curves fitted by non-linear regression shown in the figure than by straight lines in all cases except Hen 82. It can be seen that there is generally high variance in the data accounted for suggesting that the relations are

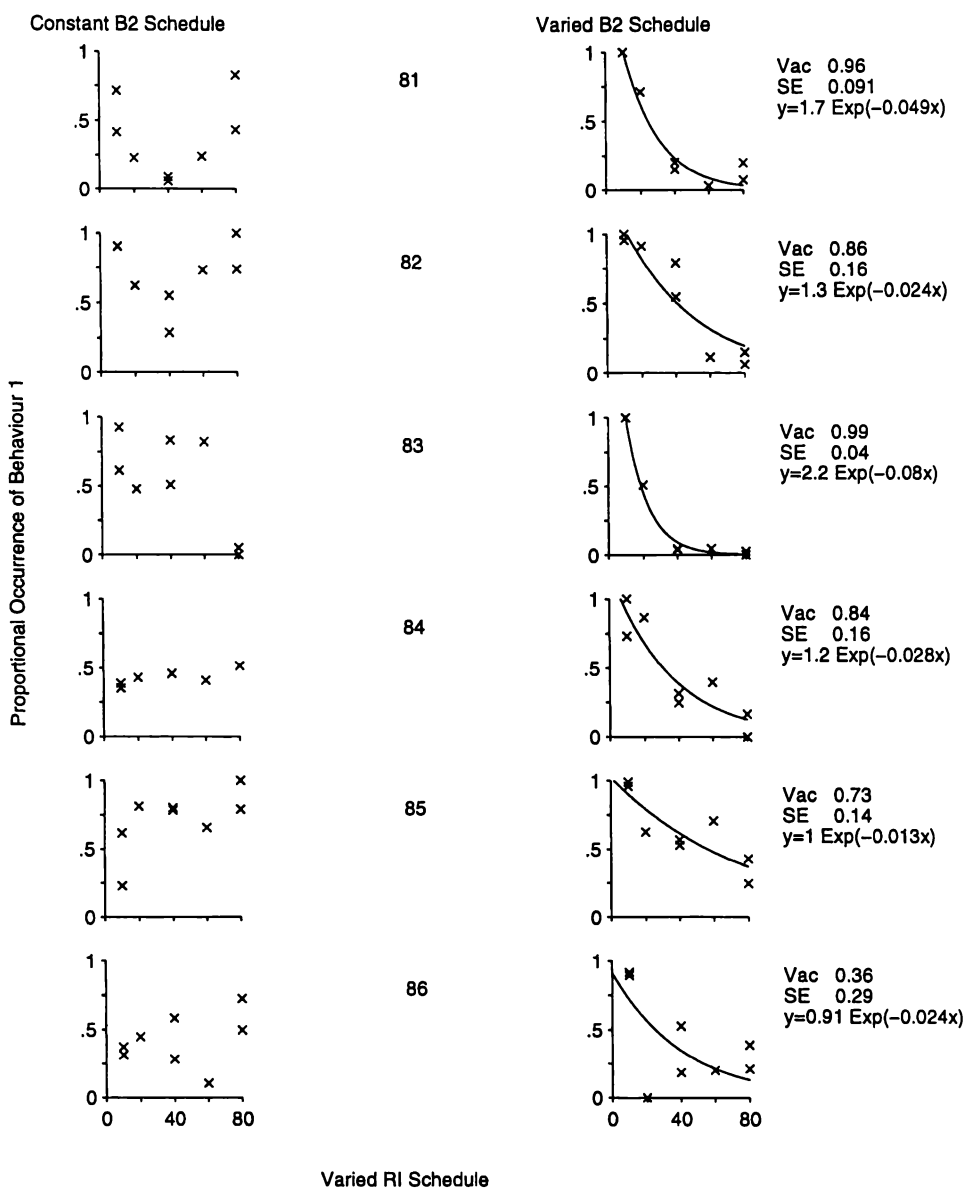


Figure 39. Experiment 4. Number of first behaviours that occurred during the extinction of the second behaviour (Phase 5) for all conditions. These are expressed as a proportion of the total occurrence of each behaviour during the training (Phase 4) and extinction (Phase 5) and are plotted against the size of the varied schedule. The left panel shows the first behaviour associated with the constant schedule. The right panel shows the first behaviour associated with the varied schedule. The negative exponential functions were fitted by non-linear regression. The proportion of variance accounted for (Vac) and standard errors (SE) of the lines are shown, as are correlation coefficients (R).

quite orderly. It would appear that negating the effect of changes in total frequency of the first behaviour across conditions made the data somewhat more orderly for the first behaviour associated with the varied-second-behaviour schedule.

Second Behaviours during Extinction

In the present experiment, there are data on both second behaviours in extinction. Of interest is whether the schedule of reinforcement for the second behaviours affected this. Figure 40 shows the total number of occurrences of the second behaviours during extinction (Phase 5). Squares show the total number of occurrences of the second behaviour associated with the varied schedule. Triangles show the total number of occurrences of the second behaviour associated with the constant schedule. It can be seen that the number of occurrences of both second behaviours were variable across conditions. This variability may have been due to a number of factors, including the number of second behaviour training sessions (i.e., Phase 3 sessions) and the effect of repeated extinction conditions. That responding across conditions was variable here suggests that within-condition comparisons may be relevant in assessing the effect of varying the RI schedule upon extinction behaviour.

Within-condition comparisons. There were six conditions for each hen where the second behaviours were reinforced under different schedules making a total of 36 possible comparisons. In 29 of the 36 cases (80%) the second behaviour that had been reinforced on the richer schedule in a condition (filled symbols) occurred more than the other second behaviour (Figure 40). From this it might be concluded that the degree of occurrence of a second behaviour in extinction is related to the rate of reinforcement for that behaviour. In addition, however, Figure 40 shows that the occurrence of the second behaviour associated with the constant schedule was greater when the other second behaviour had been reinforced on an RI 80-s schedule (Conditions 2 and 3) than when it had been reinforced on an RI 10-s schedule (Conditions 1 and 4) for all hens. This suggests that the occurrence in extinction of the second behaviour associated with the constant schedule was also influenced by the rate of reinforcement for the other second behaviour.

If it is the case that rate of reinforcement for one second behaviour affected

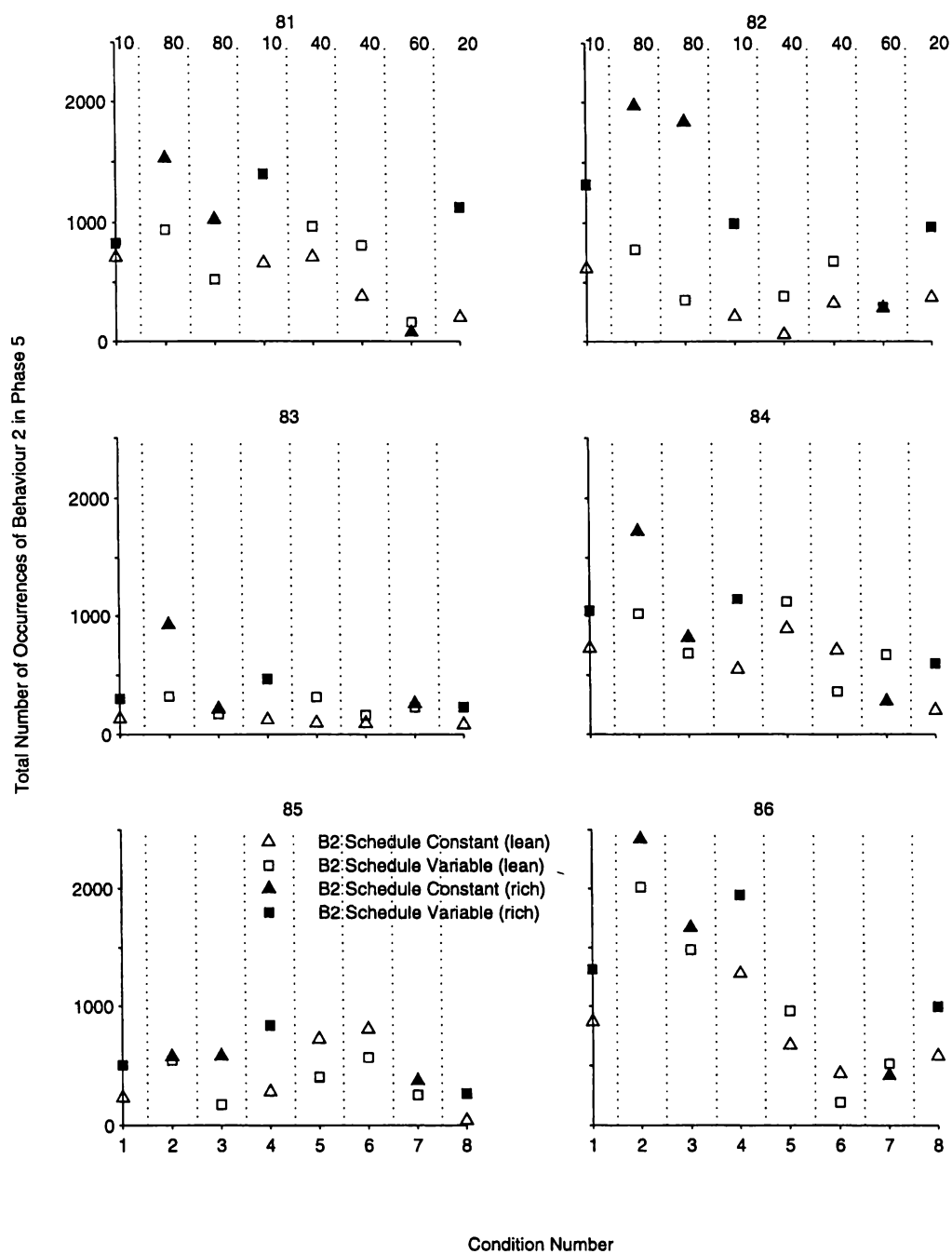


Figure 40. Experiment 4. Number of second behaviours that occurred during extinction of the second behaviour (Phase 5) for all conditions. Triangles show the second behaviour for which the schedule was constant. Squares show the second behaviour for which the schedule varied. The size of the varied schedule is shown on the top graphs. The behaviour reinforced under the rich and lean schedule in a condition is shown by filled symbols and unfilled symbols respectively.

the occurrence in extinction of the other second behaviour, then the relations between the number of occurrences of each of these second behaviours in extinction and the varied schedule should be in opposite directions. Figure 41 shows the number of second behaviours that occurred during extinction plotted against the varied RI schedule. The left panel shows the second behaviour for which the schedule was constant; the right panel shows the second behaviour for which the schedule was varied. It can be seen that there is considerable variability in both data sets. Nevertheless, the number of second behaviours associated with the constant schedule are positively correlated with the varied RI schedule. The number of second behaviours associated with the varied schedule, on the other hand, are generally negatively correlated with the varied RI schedule. Thus the number of either second behaviour that occurred in extinction were generally related to the reinforcement rate for that behaviour and for the other second behaviour.

Description using the Generalised Matching Law. Another way of describing the above data is that the occurrence of one behaviour relative to the occurrence of the other behaviour in extinction is a function of the past reinforcement rate for that behaviour relative to that of the other behaviour. This relation can be usefully described by the generalised matching law (GML):

$$\log\left(\frac{B1}{B2}\right) = a \log\left(\frac{r1}{r2}\right) + \log k \quad (1)$$

where B1 and B2 are the rates of the two behaviours, $r1$ and $r2$ the obtained rates of reinforcement for each behaviour, a is the slope and $\log k$ the intercept of the line relating the log behaviour ratio to the log reinforcement ratio (Baum, 1974). This equation describes any linear relationship between the logarithmic behaviour and reinforcement ratios, with the two parameters, a and k , allowing description of the relative occurrence of two behaviours when these do not necessarily strictly equal the relative rates of reinforcement obtained (Baum, 1974). The slope a is said to indicate the sensitivity of responding to the reinforcement contingencies; the intercept k is said to indicate any tendency for one response to occur more than another (i.e., bias) over and above reinforcer rate differences across all relative

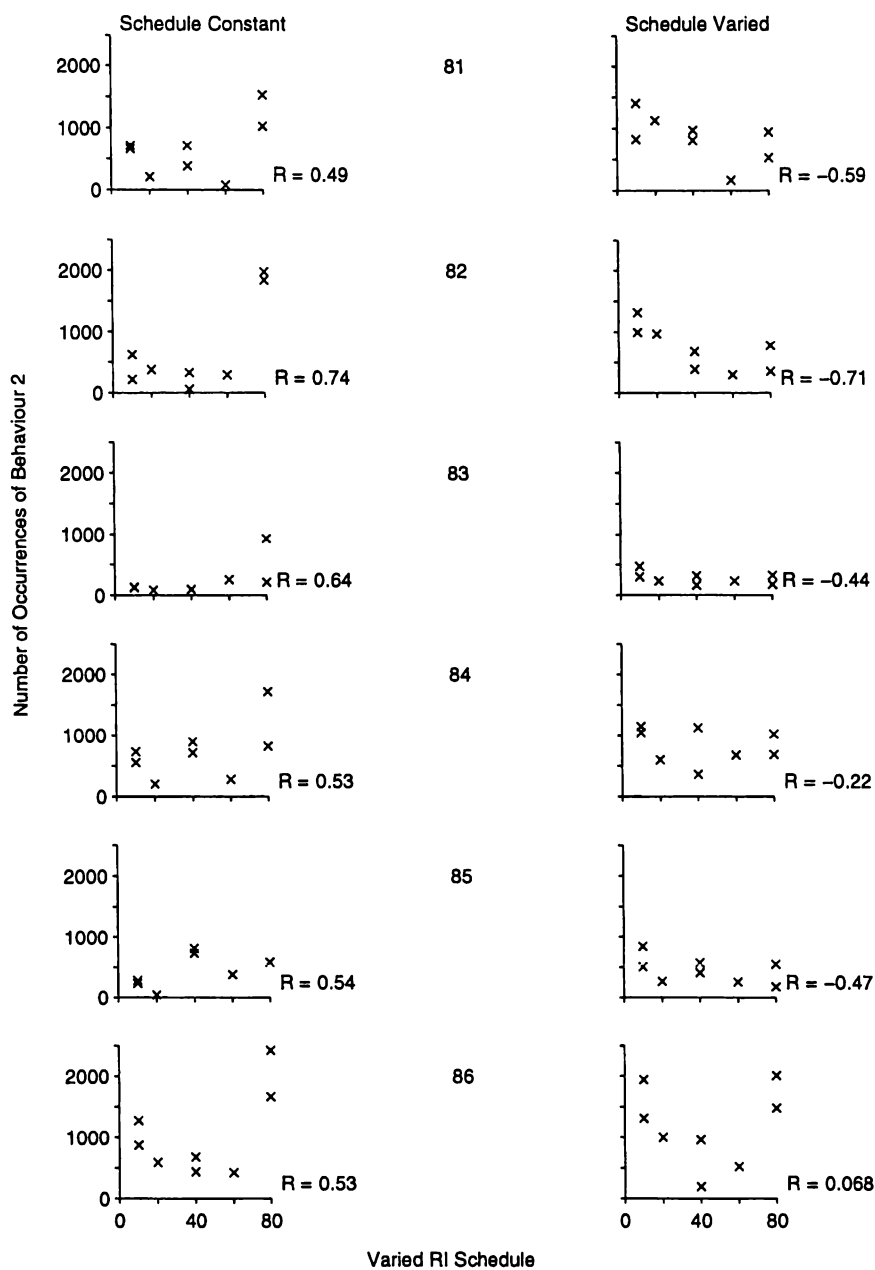


Figure 41. Experiment 4. Number of second behaviours that occurred during extinction of the second behaviour (Phase 5) plotted against the varied schedule. The left panel shows the second behaviour for which the schedule was constant. The right panel shows the second behaviour for which the schedule varied. Correlation coefficients (R) are shown on the graphs.

reinforcer rates (Baum, 1974).

The GML is usually used to describe the relation between the distribution of reinforcement and responding when behaviour has been maintained by reinforcement until deemed stable; this is termed steady-state behaviour (Sidman, 1960). When behaviour is no longer maintained by the same reinforcement contingencies in effect, behaviour may change. Behaviour during this change is termed transition behaviour (Sidman, 1960). As extinction introduces a change in reinforcement contingencies, behaviour after the introduction of extinction might be regarded as transition behaviour. It is possible that an equation that describes a relation that exists for steady-state behaviour might not apply to transition state behaviour. However, Myerson and Hale (1988) found that the relative occurrence of two concurrently available behaviours in extinction was the same as it had been when these two behaviours had been reinforced. In addition, the distribution of responding in extinction was closely related to the distribution of reinforcers during the steady state. Thus a function of the form as the GML can be used to describe the relative occurrence of concurrently available behaviours in extinction where the reinforcer ratio is the ratio of the reinforcer rates most recently used for each behaviour. In the present study, however, the two second behaviours were not concurrently available; they were instead available consecutively in a multiple schedule.

The GML has also been used, however, to describe the relation between relative rate of reinforcement and relative rate of responding in multiple schedules (e.g., Davison & Ferguson, 1978). In a review, Davison and McCarthy (1988) conclude that sensitivity to reinforcement is less in multiple schedules than in concurrent schedules with a values usually being between 0.3 and 0.5 in the former. There appears to have been no systematic attempt to describe the distribution of behaviour across a multiple schedule in extinction using the GML. In an early multiple-schedule study Gollub and Urban (1958) maintained key pecking in pigeons under a multiple VI 3-min VI 9-min schedule and then ceased reinforcement. During reinforcement, the ratio of the rate of responding in the rich component to that in the lean component over subjects was 1.39 to 1; in extinction this ratio was 3.6 to 1. The authors suggested that the magnitude of the interaction between components differs under reinforcement and extinction conditions. In addition to this, it can be seen that the behaviour ratio in extinction

of 3.6:1 is very close to the reinforcement ratio of 3:1. This suggests that the behaviour ratio in extinction was better described by the reinforcement ratio than the behaviour during the schedule. It seems a function similar to the GML might be used to describe the present data.

Figure 42 shows the logarithms of the ratios of the rates of the second behaviour with the varied schedule to the rate of the other second behaviour during reinforcement (Phase 4, left panel) and extinction (Phase 5, right panel). In both cases these are plotted against the logarithms of the ratios of the rate of reinforcement obtained under the varied schedule to the rate obtained under the other schedule during Phase 4. The regression lines were fitted by the method of least squares. It can be seen that the log ratio of responding during reinforcement (left panel) is a linear increasing function of the log reinforcer ratio for five of the six hens (average slope of 0.19 and intercept of 0.01). The log ratio of responding in extinction (right panel) is also generally a linear increasing function of the log reinforcer ratio (average slope of 0.63 and intercept of 0.08). Comparing the data from reinforcement and extinction for each subject it can be seen that in all cases α is greater in the latter case. Responding in extinction appears to be more strongly related to the previous relative reinforcement rate than responding during the multiple schedule was to relative reinforcement rate; a result similar to that of Gollub and Urban (1958).

It was noted previously that the rate of occurrence of the second behaviour when reinforced (Phase 4) was inversely related to the rate of occurrence of the first behaviour in that phase. Because the occurrence of the first behaviour during this phase was itself a function of the schedule in effect for the second behaviour, any change in the rate of the second behaviour might be a function of the occurrence of the first behaviour during this phase rather than a direct effect of the schedule upon the rate of the second behaviour. To see if this was the case, the relative rate of the second behaviour in a session where only the second behaviour occurred (i.e., in the last session of Phase 4, Figure 30) was compared to the relative rate in a session when the first behaviour generally occurred (i.e., in the first session of Phase 4, Figure 29). The relative rate of the second behaviour did not change with the reinforcement rate for that behaviour in the last session when the first behaviour did not occur. The relative rate of the second behaviour did change with the reinforcement rate for that behaviour in the first session when the

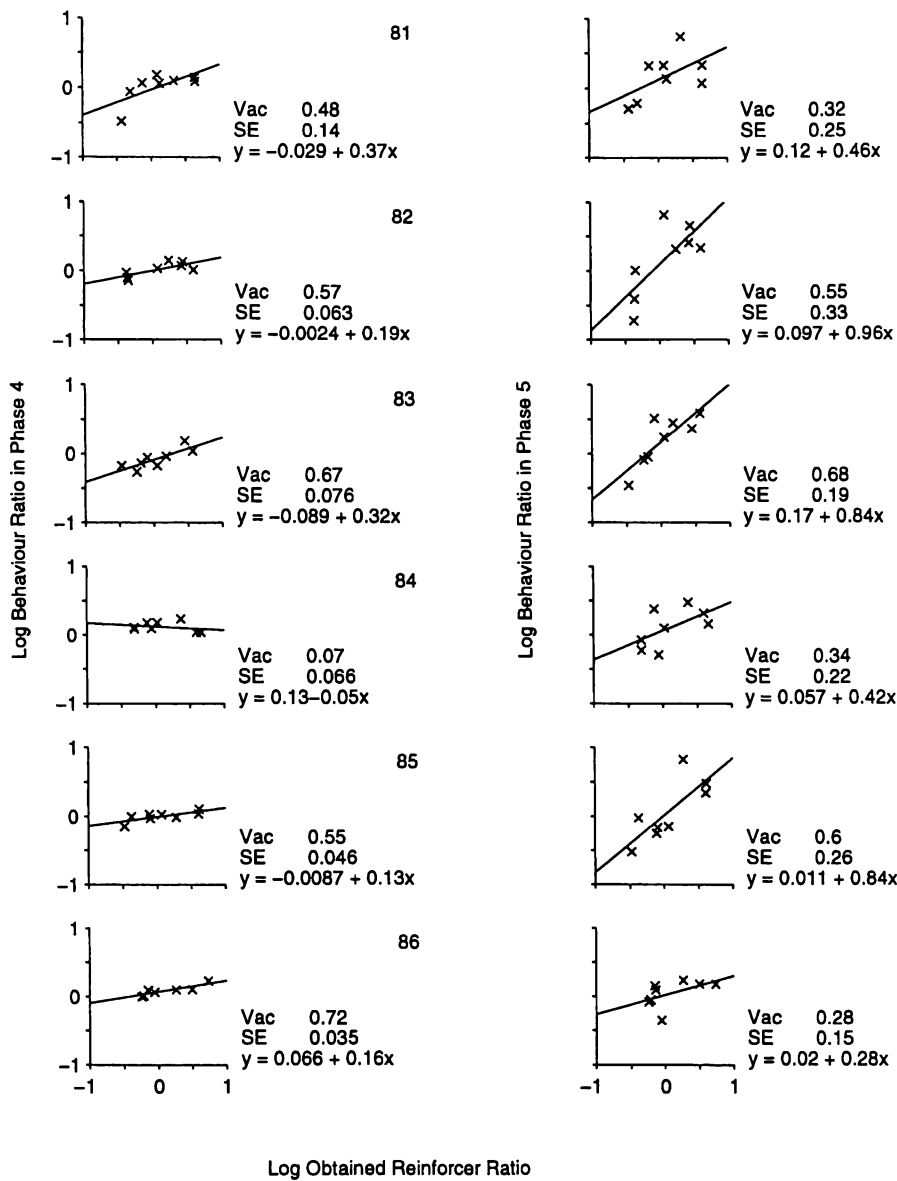


Figure 42. Experiment 4. Logarithms of the ratio of the rate of the second behaviour for which the reinforcement schedule varied to the rate of the second behaviour for which the reinforcement schedule was constant. The right panel shows the data from extinction (Phase 5). The left panel shows the data from reinforcement (Phase 4). In both cases these are plotted against the logarithms of the ratio of the obtained rate of reinforcement for the second behaviour for which the schedule was varied to the obtained rate of reinforcement for the second behaviour for which the reinforcement schedule was constant, during Phase 4. Linear regression lines fitted by the method of least squares, the proportion of variance accounted for (Vac), the standard errors (SE), and the equations of the lines are shown.

first behaviour occurred. This suggests that the sensitivity to reinforcement, found above for the second behaviour when reinforced, might also be affected by the differential occurrence of the first behaviour across reinforcement rates. To see if this was the case the log behaviour ratios and reinforcement ratios for these two sessions were compared. Figure 43 shows the log ratios for the first session in Phase 4 (left panel) and the last session in Phase 4 (right panel). The regression lines were fitted by the method of least squares. It can be seen that responding in the first session was somewhat sensitive to reinforcement (average $a = 0.32$, $k = -0.03$) while responding in the last session was not sensitive to reinforcement (average $a = 0.03$, $k = 0.04$). The sensitivity to reinforcement seen for the occurrence of the second behaviour during all of Phase 4 (Figure 42, left panel) might then be a product of the concurrent occurrence of the first behaviour in that phase. If so, this supports the suggestion made previously that there was little across-component multiple-schedule interaction when the second behaviours were reinforced.

The first behaviour almost always occurred during the extinction of the second behaviour (Phase 5). It might be argued that, if the degree of occurrence of the first behaviour helps to account for the sensitivity to reinforcement (a) of the second behaviour when reinforced (Phase 4), then perhaps it also accounts for the sensitivity to past reinforcement of the second behaviours in extinction (Phase 5). It was argued earlier that the inverse relationship between the occurrence of the first and second behaviours was a product of the organism being unable to perform the first and second behaviours simultaneously and of the limited component length. In extinction, however, responding decreased so that there was ample time for both behaviours to occur without the occurrence of one necessitating a drop in the occurrence of the other. The possibility that the occurrence of the first behaviour may have affected the occurrence of the second behaviour in extinction (Phase 5) cannot be ruled out, however. The data for the second behaviour in extinction have been usefully described by a function similar to the GML.

Description using Behavioural Momentum. The data may also be described by another model termed “Behavioural Momentum” (Nevin, Mandell, & Atak, 1983). Behavioural Momentum is defined as the product of response rate in the steady state and the resistance to change in the transition state (Nevin et al.,

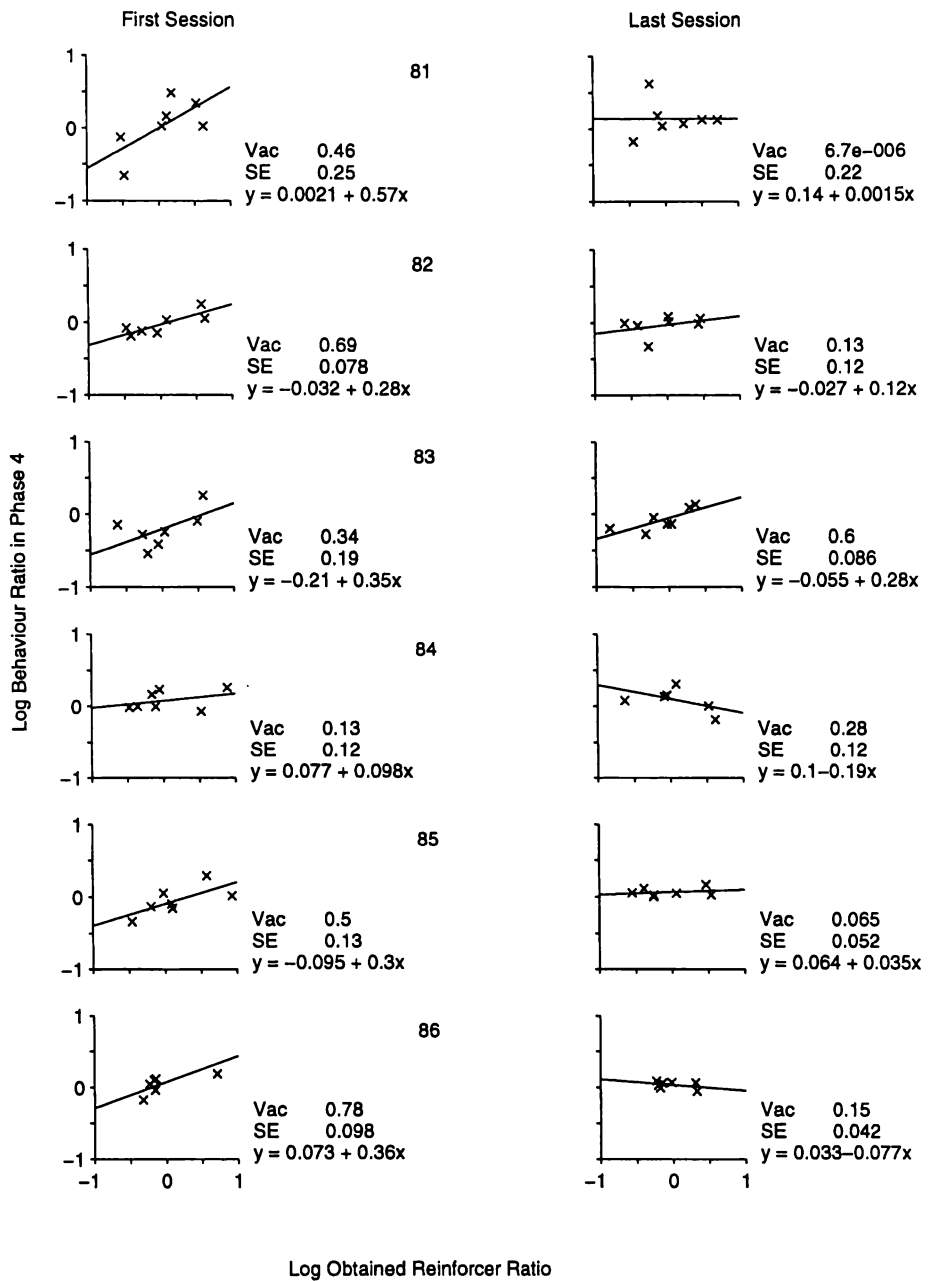


Figure 43. Experiment 4. Logarithms of the ratio of the rate of the second behaviour for which the reinforcement schedule varied to the rate of the second behaviour for which the reinforcement schedule was constant for all conditions. The left panel shows the data from the first session where the second behaviours were reinforced in the multiple schedule (Phase 4). The right panel shows the last session of Phase 4. These are plotted against the logarithms of the ratio of the rate of reinforcement obtained in the selected sessions. Linear regression lines fitted by the method of least squares, the proportion of variance accounted for (Vac), the standard errors (SE), and the equations of the lines are shown.

1983). As we are concerned here with transition-state behaviour, only resistance to change will be discussed here. Resistance to change (m) is given by the change in the independent variable (x) divided by the change in the response rate (ΔB) (Nevin, 1992), as in the following equation:

$$m = x / \Delta B \quad (2)$$

Nevin (1992) states that resistance to change is the reciprocal of the slope of the function relating response rate to the change in the independent variable. Relative measurement of resistance to change is provided by the resistance ratio, where 1 and 2 are different responses (Nevin, 1992) shown in the following equation:

$$\frac{m_1}{m_2} = \frac{x / \Delta B_1}{x / \Delta B_2} \quad (3)$$

Multiple-schedule research has found that the component with the higher rate of reinforcer delivery generally has the greatest resistance to change (Nevin, 1988). In the present experiment the rate of reinforcer delivery for one second behaviour varied across conditions, thus the resistance to change should also have varied. This can be assessed by comparing the slopes of linear regression lines of response rate over the extinction sessions (Nevin, 1992). To fit linear regression lines the data must first be converted to logarithms (Nevin, 1992). In the present data set there were often zero responses in later sessions of an extinction condition for some subjects. Lines fitted to logarithms of the individual subject data would thus be misleading. Aggregation of data across subjects avoids this problem. Average response rates per session across subjects were thus calculated, converted to logarithms, and linear regression lines fitted by the method of least squares. The logarithms and fitted lines are shown in Figure 44 plotted against the number of sessions in extinction for each condition. The size of the varied schedule for each condition is shown on the graphs. The constant schedule was an RI 40-s schedule in all conditions. Table 13 shows the intercepts, slopes, variance accounted for and standard errors of estimate for the lines. The slopes of the lines are shallower for the behaviour associated with the richer schedule within each condition. This pattern also appeared in the individual subject data. Thus

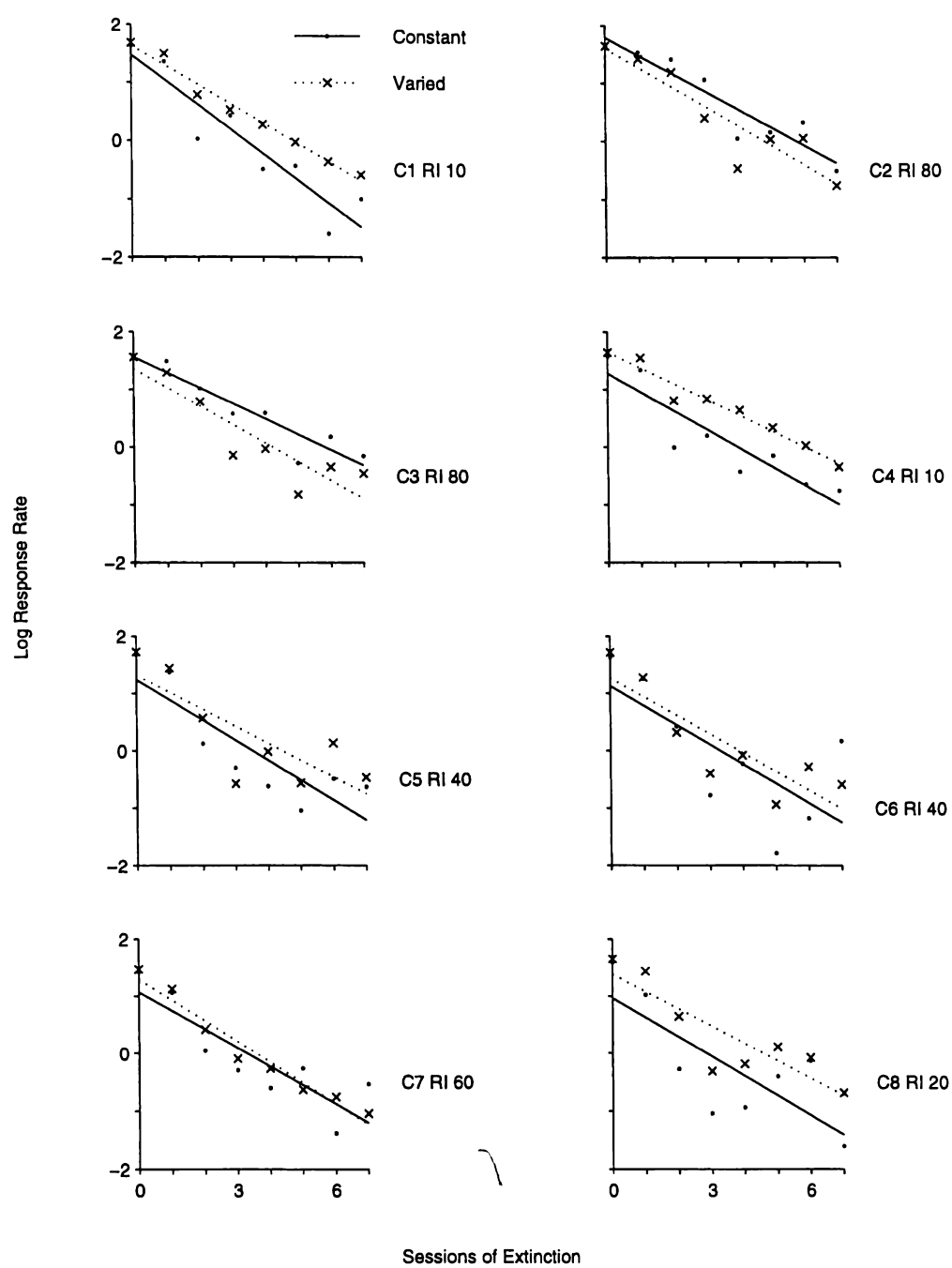


Figure 44. Experiment 4. The logarithms of the average second behaviour rates across subjects. These are shown for each session and condition during extinction (Phase 5). Linear regression lines were fitted by the method of least squares. Dots and solid regression lines show the data for the second behaviour for which the schedule was constant. Crosses and broken regression lines show the data for the second behaviour for which the schedule was varied. The size of the varied schedule is shown next to the graph of each condition.

Table 13

Y-axis intercepts (Y int), slopes, proportion of variance accounted for (R^2), and standard errors (SE) for the least-squares regression lines fitted to the logarithms of the average response rate across subjects over sessions of extinction for each condition.

Condition	Y int	Varied Schedule			Y int	Constant Schedule		
		Slope	R^2	SE		Slope	R^2	SE
1	1.63	-0.33	0.98	0.11	1.47	-0.42	0.87	0.38
2	1.60	-0.33	0.84	0.33	1.79	-0.31	0.88	0.26
3	1.35	-0.32	0.82	0.35	1.56	-0.27	0.88	0.23
4	1.65	-0.28	0.96	0.13	1.28	-0.33	0.83	0.34
5	1.31	-0.29	0.65	0.50	1.23	-0.35	0.74	0.47
6	1.27	-0.33	0.74	0.44	1.13	-0.34	0.50	0.77
7	1.29	-0.36	0.95	0.18	1.07	-0.32	0.75	0.42
8	1.38	-0.30	0.77	0.38	0.96	-0.34	0.60	0.63

resistance to change of the second behaviour within a condition appears to have been a function of the rate of reinforcer delivery which is consistent with the conclusions of Nevin (1988).

It has been suggested that this effect is not dependent upon whether reinforcer delivery was contingent upon the response or not but, instead, depends upon stimulus-reinforcer relations (Nevin, Tota, Torquato, & Shull, 1990). Because of this Nevin (1992) proposed that a model that relates the effectiveness of a conditioned stimulus to the ratio of the rate of reinforcer delivery in its presence (rc) to the session average rate of reinforcer delivery (rs), termed the contingency ratio, might account for resistance to change. The resistance ratio ($m1/m2$) would then be a function of the contingency ratio as given by the equation:

$$\log(m1 / m2) = a \log\left(\frac{rc1 / rs1}{rc2 / rs2}\right) \quad (4)$$

where a is a parameter indicating the sensitivity of the resistance ratio to the contingency ratio.

Whether this equation describes the data here can be assessed both within a condition and across conditions using the slopes of the lines for the aggregated data shown in Figure 44. Within a condition the resistance ratio is the log ratio of the reciprocal of the slope of the line relating the second behaviour, for which the schedule varied ($m1$), to the reciprocal of the slope of the line relating the second behaviour for which the schedule was constant ($m2$). The contingency ratio is the log ratio of the rate of reinforcement for the second behaviour, for which the schedule varied ($rc1$), to the rate of reinforcement for the other second behaviour ($rc2$). Because session average reinforcer rates ($rs1$ and $rs2$) are constant for both behaviours within a condition they do not need to be considered. Figure 45 (top left graph) shows the log resistance ratio plotted against the log contingency ratio for all conditions. Linear regression lines were fitted by the method of least squares for all graphs in Figure 45. The variances accounted for, standard errors, and the equation of the lines are also shown. It can be seen that the resistance ratio is a linear increasing function of the contingency ratio. The slope of the line gives the sensitivity of the resistance ratio to the contingency ratio (a). Nevin

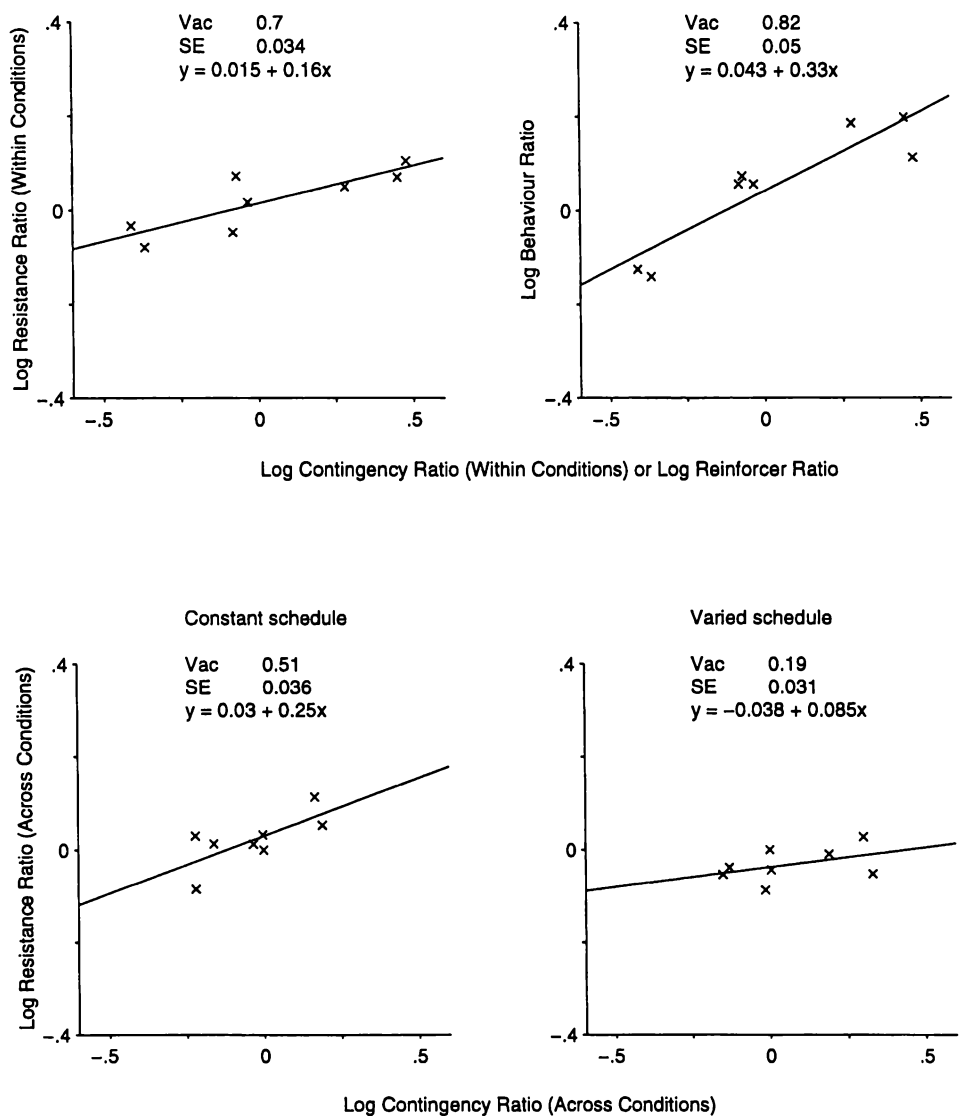


Figure 45. Experiment 4. The top panel shows the log within-condition resistance ratio (left) and the log behaviour ratio (right) plotted against the log contingency ratio or log reinforcer ratio. The bottom panel shows the log resistance ratio across conditions plotted against the log contingency ratio across conditions. The bottom left graph shows the data for the second behaviour for which the schedule was constant. The bottom right graph shows the data for the second behaviour for which the schedule was varied. Linear regression lines have been fitted to all graphs by the method of least squares. The equations, proportion of variance accounted for (Vac), and standard errors (SE) of these lines are shown. See text for a full explanation of how the ratios were calculated.

(1992) reported an a value of 0.35 for within-condition data while the a value here is 0.16. The sensitivity to the contingency ratio here, then, is approximately half what has been previously reported.

Across conditions, the resistance ratio is the log ratio of the reciprocals of the slope of a behaviour in one condition ($m1$) to that in another condition ($m2$). In the present experiment, comparisons can be performed for the second behaviour for which the schedule was constant and for the second behaviour for which the schedule varied. The data from Condition 5 was selected to be the denominator ($m2$) in the ratios because this was one of the conditions where the rate of reinforcement was the same in both components. The contingency ratio across conditions is the second term of Equation 4. As for the resistance ratio the data for the denominator came from Condition 5. The denominator was thus the ratio of reinforcer rate in a component in Condition 5 ($rc2$) to the session average reinforcer rate in Condition 5 ($rs2$). The numerator was the ratio of reinforcer rate in a component in a condition ($rc1$) to the session average reinforcer rate in that condition ($rs1$). The contingency ratio was the log ratio of these two. Figure 45 shows the resistance ratio plotted against the contingency ratio for the second behaviour for which the schedule was constant (lower left graph) and the second behaviour for which the schedule was varied (lower right graph). It can be seen that the resistance ratio of the second behaviour for which there was a constant schedule was moderately sensitive to the contingency ratio ($a = 0.25$). The resistance ratio of the second behaviour for which the schedule varied was relatively insensitive to the contingency ratio ($a = 0.085$). Both are below the a value of 0.35 reported by Nevin (1992) for across-condition data. What this analysis suggests is that resistance to change varied systematically across conditions for the behaviour for which the schedule was constant, but not for the behaviour for which the schedule varied. As noted above, effects of the occurrence of the first behaviour upon the occurrence of the second behaviour cannot be ruled out here. The low sensitivities of the contingency ratio to the reinforcer ratio might be accounted for by this variable.

Behavioural Momentum and GML analyses compared. The present study was not designed to compare Behavioural Momentum and matching accounts of extinction behaviour. Of interest here is a comparison of their use in quantifying the extinction data. The log obtained reinforcer ratio used in the GML analysis

(left panel, Figure 42) and the log contingency ratio used in the within-condition resistance-to-change analysis (top left graph, Figure 45) are the same measure. They differ only in that here the latter was aggregated across subjects. To compare with the within-subject resistance-to-change analysis, a matching analysis was performed using the average data, across subjects, for each condition. The top right graph of Figure 45 shows the log ratio of the average rate of the second behaviour, for which extinction varied, to the average rate of the other second behaviour. This is plotted against the log contingency/reinforcer ratio. A linear regression line is shown as well as the standard error, variance accounted for, and the equation of the line. Sidman (1960) noted that group functions do not necessarily represent the functions of individual subjects. It can be seen that the group function (top right graph, Figure 45) is more orderly than any of the individual subject functions (left panel, Figure 42). Because of this it might be argued that the group function does not truly represent all the individual subject data. Given this it is still interesting to compare the group functions for the Behavioural Momentum and matching analyses. The top graphs of Figure 45 show that both analyses describe the average data well and are essentially not different. Nevin (1988) argued that the use of total extinction responding, such as in the GML analysis here, may confound the effect of initial response rate after the steady state and the decrease in response rate in the transition state. In the present study this is unlikely as the response rates during reinforcement (Phase 4) did not systematically differ with reinforcer rate (Figure 30). Thus the similarity between the GML and momentum analyses here may be a result of the similar steady-state response rates. The convergence of the two analyses here might be a function of the similarity of baseline response rates but this cannot be concluded from the present data.

Summary of the Results of Experiment 4

In this experiment the schedule of reinforcement for one second behaviour was varied. It was found that the occurrence of the previously trained first behaviour during the training of this second behaviour was a direct function of the varied schedule size and the occurrence of the first behaviour during the extinction of this second behaviour was an inverse function of the varied schedule size. Both these relations are consistent with the findings of Leitenberg et al.

(1975) and the Prevention of Extinction Hypothesis. Also consistent with the Prevention of Extinction Hypothesis was that the occurrence of the first behaviour during the extinction of the second behaviour was inversely related to the occurrence of the first behaviour during the training of the second behaviour. There was considerable variability in the degree of occurrence of the first behaviour during the training and extinction of the second behaviour across conditions however, and this may have been the result of the different lengths of training of the second behaviours here. The next experiment examined this possibility. The occurrence of the first behaviour during the extinction of the second behaviour, as a proportion of the total number of occurrences of the first behaviour in both the training and extinction of the second behaviour, was an orderly function of the varied schedule size. This suggests that some of the variance in the degree of occurrence of the first behaviour during the training and extinction of the second behaviour across conditions was the result of changes in the total frequency of extinction responding across conditions. The occurrence of the second behaviour in extinction was also found to be a function of the varied schedule, and was quantitatively described by GML and Behavioural Momentum analyses equally well.

Experiment 5

Under the Prevention of Extinction Hypothesis, the training of Behaviour 2 may defer the extinction of Behaviour 1 until Behaviour 2 is under extinction (Leitenberg et al., 1975). If this is so Behaviour 1 should not occur more during the extinction of Behaviour 2 (resurgence) than it does during its own extinction. This was shown to be so in Experiment 2. In addition, periods of prior extinction should reduce the degree of resurgence. This was shown in Experiments 3 and 4. If resurgence is solely the result of the prevention of extinction of the first behaviour, however, then the training of a second behaviour, as long as the prevention of extinction of Behaviour 1 was total, should not result in fewer first behaviours occurring than would otherwise occur.

As previously mentioned, Leitenberg et al. (1975) found that the degree of resurgence was less when Behaviour 2 was trained for 27 days than when it had been trained for three or nine days. In that experiment the first behaviour may have continued to occur during the 27 days of training of Behaviour 2 and thus may have experienced more extinction than the first behaviour when Behaviour 2 was trained for three or nine days. As a result of this it might be argued that the Prevention of Extinction Hypothesis describes the smaller degree of resurgence found when the second behaviour was trained for 27 sessions.

Leitenberg et al. (1975) also compared the total number of first behaviours that occurred during the training and extinction of the second behaviour with the number that occurred during a similar period of extinction for another group of subjects when a second behaviour was not trained. More first behaviours occurred for the group for which a second behaviour was not trained than for the groups in which a second behaviour was trained. The Prevention of Extinction Hypothesis implies that the total number of first behaviours that occur during the training and extinction of the second behaviour should be equal to the total number of first behaviours that would occur in simple extinction of the first behaviour. Therefore the hypothesis cannot account for Leitenberg et al. (1975) results. These authors concluded from their results that the length of training of the second behavior can reduce the total occurrence of the first behaviour during the training and extinction of the second behaviour. This conclusion still allows the Prevention of Extinction Hypothesis to describe the distribution of the total frequency of the first behaviour

in the training and extinction of the second behaviour.

J. A. Mulick (personal communication, 6 July, 1999) suggested that a long period of training of Behaviour 2 can allow the occurrences of Behaviour 1 during the training of Behaviour 2 to be separated in time from each other. The distribution of Behaviour 1 responses over time during the training of Behaviour 2 results in greater “inhibition” of Behaviour 1 (presumably describing the observation of fewer first behaviours during the training and extinction of the second behaviour) than the contiguous occurrences of Behaviour 1. If this were the case then the variable responsible for the decrease in resurgence with long training of the second behaviour is not the length of training but rather the distributed extinction responding occurring during long training. This has yet to be investigated.

The effect of distributed and massed extinction in simple extinction has, however, been investigated. Although reviews of the varied literature suggest that, in simple extinction, behaviour may decline more quickly under massed extinction conditions than under distributed extinction conditions this is far from certain (Kimble, 1961; Mackintosh, 1974). If this were the case then the predictions from the simple extinction data would appear to be the reverse of that suggested by J. A. Mulick (personal communication, 6 July, 1999). Thus it may be that the training of the second behaviour has some effect over and above the simple deferment of extinction.

The J. A. Mulick (personal communication, 6 July, 1999) hypothesis is effectively the Prevention of Extinction Hypothesis with the added proviso that how the extinction of Behaviour 1 occurs (distributed or contiguous) will affect the later occurrence of the behaviour. As the first behaviour occurred during the training of the second behaviour in the Leitenberg et al. (1975) study, Mulick’s hypothesis cannot be ruled out. One clear way of showing that the length of training of the second behaviour affects resurgence would be to vary the length of training of the second behaviour while keeping the occurrence of the first behaviour to a minimum. Any change in the degree of resurgence could thus be attributed to the length of training of the second behaviour.

In the present experiment the length of training of Behaviour 2 was varied across subjects and conditions using the multiple-schedule design used in Experiments 3 and 4 as shown in Table 14. Behaviour 2 was reinforced under a

Table 14

Outline of procedure used in Experiment 5.

Phase	Component		Arrangement	Operanda lights
	Red	Green		
1	HB Rft	DP Rft	Alternate sessions	Only effective operanda lit
2	HB Rft	DP Rft	Multiple schedule	All operanda lit
3	RK Rft	LK Rft	Alternate sessions	Only effective operanda lit
4	RK Rft, TL varied	LK Rft, TL varied	Multiple schedule	All operanda lit
5	Ext	Ext	Multiple schedule	All operanda lit

- HB = Head bob.
- DP = Door push.
- RK = Right-key peck.
- LK = Left-key peck.
- Rft = Reinforcement delivered for response.
- TL = Training length (the number of occurrences of the training component).
- Ext = Extinction.

rich schedule to minimise the occurrence of Behaviour 1. The aim was to see if there were any changes in the degree of resurgence within or across conditions as a result of the length of training of Behaviour 2.

Method

Subjects

Six ISA Brown hens, numbered 21-26, served as subjects. All hens, with the exception of Hen 25, were 1.5 years of age at the start of the experiment, had been bought as chicks and reared in an aviary, and were experimentally naive. Hen 25 had previously served in Experiment 3. It should be noted that although the other hens were numbered the same as those used in Experiment 3, they were not the same hens. The subjects were maintained and housed as previously described.

Apparatus

The chamber and equipment was the same as was used in Experiment 3.

Procedure

This experiment consisted of three conditions. Each condition consisted of two training phases for Behaviour 1, two training phases for Behaviour 2, and a final extinction phase as shown in Table 15. These phases, labelled 1 to 5, were similar to those used in Experiment 3 with a major difference being that there was no extinction of Behaviour 1 prior to the introduction of Behaviour 2 in the present experiment (labelled Phase 3 in Experiment 3). Phase 1 of the present experiment is thus similar to Phase 1 of Experiment 3, Phase 2 to Phase 2, Phase 3 to Phase 4, and Phase 5 to Phase 6. In addition, the length of training (i.e., the reinforcement period) of one of the second behaviours was varied, using a crossover design, in Conditions 1 and 2 and there was no training for one second behaviour in Condition 3. In Phase 4 (second behaviours reinforced, all apparatus lit) the number of occurrences of red and green components varied across conditions as shown in Table 16. In Condition 1, there were 124 occurrences of the red component and 4 occurrences of the green component for Hens 21-23. For Hens 24-26 there were 4 occurrences of the red component and 124 occurrences of the green component. In Condition 2, there were four occurrences of each component in this phase for all hens. In Condition 3 there were no occurrences of

Table 15

Stimulus and reinforcement conditions for each phase of Experiment 5.

Phase	Red Component				Green Component			
	Behaviour 1		Behaviour 2		Behaviour 1		Behaviour 2	
	Head Bob		Right-Key Peck		Door Push		Left-Key Peck	
	Rft	Light	Rft	Light	Rft	Light	Rft	Light
1	✓	✓			✓	✓		
2	✓	✓		✓	✓	✓		✓
3			✓	✓			✓	✓
4		✓	✓	✓		✓	✓	✓
5		✓		✓		✓		✓

Rft = when reinforcement was delivered for the response.

Light = when the operanda LED was on and feedback was available.

Table 16

Number of occurrences of components in Phase 4 for each condition of Experiment 5.

Condition	Red Component		Green Component	
	21-23	24-26	21-23	24-26
	(Behaviour 1b)	(Behaviour 1a)	(Behaviour 1a)	(Behaviour 1b)
1	124	4	4	124
2	4	4	4	4
3	4	0	0	4

the green component for Hens 21-23 (left-key pecking) and no occurrences of the red component for Hens 24-26 (right-key pecking) for either Phase 3 (second behaviours trained and reinforced) or Phase 4. There were 4 occurrences of the red component for Hens 21-23 and 4 occurrences of the green component for Hens 24-26 in Phase 4 of Condition 3. Phase 5 consisted of seven sessions of extinction.

Results and Discussion

The response rates from the periods in which the first and second behaviours were reinforced (Phases 2 and 4) were similar to those presented in Experiment 3. Although they are not presented here they can be derived from Appendix D. The left panel of Figure 46 shows the number of occurrences of the first behaviours when the second behaviours were reinforced (Phase 4). The first behaviours have been labelled 1a (circles) and 1b (crosses). Behaviour 1a was door pushing for Hens 21-23 and head bobbing for Hens 24-26. Behaviour 1b was head bobbing for Hens 21-23 and door pushing for Hens 24-26. There were generally few occurrences of either first behaviour when the second behaviours were reinforced. Any effects of extinction of the first behaviour upon resurgence as a result of its occurrence in this phase should be small.

The middle panel shows the number of occurrences of the first behaviours during the extinction of the second behaviours (resurgence). If the length of training of the second behaviour had an effect upon the degree of resurgence then the occurrence of the first behaviour associated with shorter training of the second behaviour, or no training of the second behaviour, in each condition should be more than the occurrence of the first behaviour associated with the longer training of the second behaviour in that condition.

In Condition 1, the resurgence of the first behaviour associated with the second behaviour with 4 occurrences of the training component (circles) was greater than the resurgence of the first behaviour that was associated with the second behaviour with 124 occurrences of the training component (crosses) for 2 of the 6 hens (Hens 25 and 26) only. In Condition 2, when the number of occurrences of the training component for Behaviour 2 were similar, the response that occurred more in Condition 2 was the one that had occurred more in Condition 1, but the degree of difference between the data points is different from

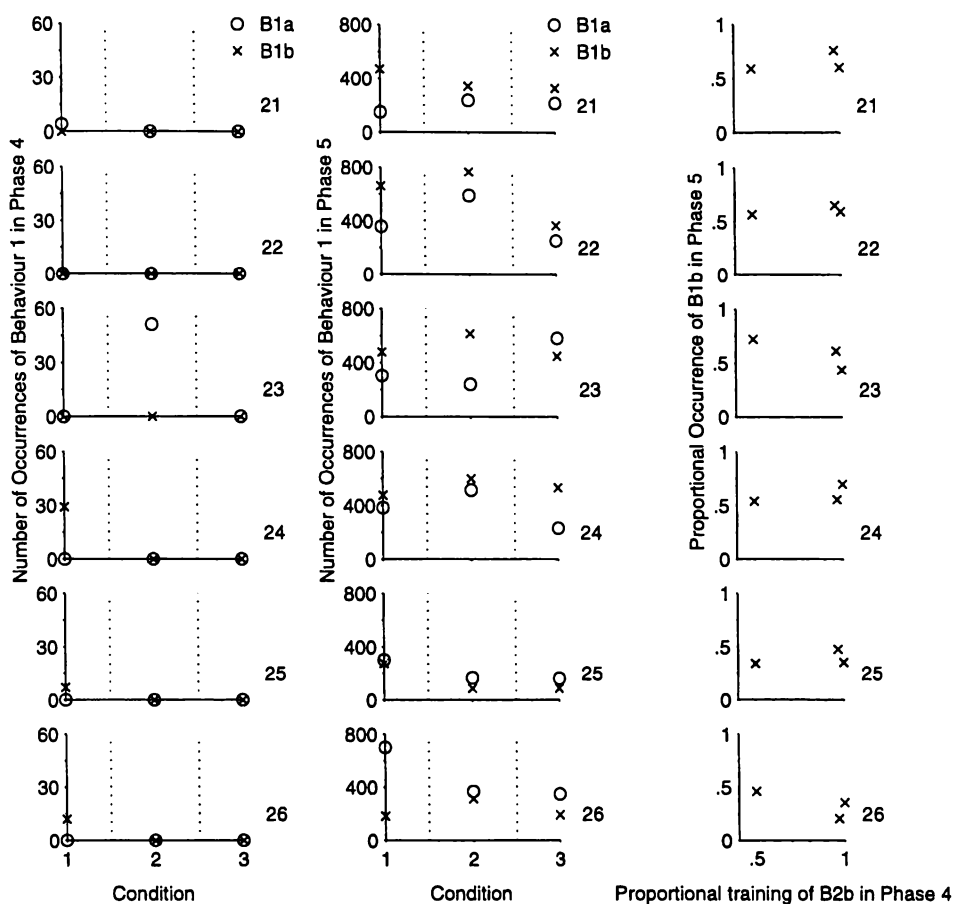


Figure 46. Experiment 5. The number of occurrences of the first behaviours when the second behaviours were reinforced (left panel) and when all behaviours were under extinction (middle panel) plotted against the condition number. For Behaviour 1a (circles, door pushing for Hens 21-23 and head bobbing for Hens 24-26) there were 4 occurrences of the second behaviour training component in Conditions 1 and 2 and no second behaviour training in Condition 3. For Behaviour 1b (crosses, head bobbing for Hens 21-23 and door pushing for Hens 24-26) there were 124 occurrences of the second behaviour training component in Condition 1 and 4 occurrences of the second behaviour training component in Conditions 2 and 3. The right panel shows the occurrence of Behaviour 1b as a proportion of the total occurrence of Behaviour 1a and 1b during the final extinction. This is plotted against the number of occurrences the training component for the second behaviour associated with the Behaviour 1b expressed as a proportion of the total number of occurrences of the training component for both second behaviours in that condition.

that for Condition 1 data points. In Condition 3 it can be seen that, for half the subjects only (Hen 23, 25, and 26), the occurrence of the first behaviour associated with the second behaviour that was not trained (circles) was above that of the first behaviour associated with the second behaviour that received four occurrences of the training component (crosses). In addition, with the exception of Hen 23, the behaviour that occurred most in Conditions 1 and 2 also occurred most in Condition 3, though the number of responses differ from those conditions. So within conditions there appears to be little evidence that the length of training of the second behaviour affected the resurgence of the first behaviour.

If the length of training of the second behaviour had an effect upon the degree of resurgence then it would be expected that the occurrence of a first behaviour would increase as the length of training of the second behaviour decreased across conditions. From Condition 1 to Condition 2, when the length of training for the second behaviour associated with Behaviour 1b changed from 124 to 4 occurrences of the training component, the occurrence of this behaviour (crosses) increased for four hens (Hens 22, 23, 24, and 26). When the length of training of the second behaviour that was associated with Behaviour 1a changed from four to zero occurrences of the training component, from Condition 2 to Condition 3, the occurrence of Behaviour 1b increased for Hen 23 only. Hence, of a possible 12 cases where the first behaviours might have increased as a result of a decrease in the length of training of the second behaviour, in only five cases did this occur. Thus comparison across conditions also suggests little effect of the length of training of the second behaviour upon the degree of resurgence of the first behaviour.

It was noted above that one of the two first behaviours generally occurred more than the other within subjects across all conditions here. Because a crossover design was used in the present experiment the role of response topography can be investigated. Door pushing was Behaviour 1a (circles) for Hens 21-23 and Behaviour 1b (crosses) for Hens 24-26. Head bobbing was Behaviour 1b (crosses) for Hens 21-23 and Behaviour 1a (circles) for Hens 24-26. For all hens except Hens 23 and 24 the occurrence of head bobbing was above that of door pushing in all conditions. For Hen 23 the occurrence of door pushing was above that of head bobbing in one condition only, and for Hen 24 it was higher in all conditions. It would appear that the tendency for one behaviour to occur more

across all conditions is only partly accounted for by a general tendency for head bobbing to occur more. It is possible, then, that the tendency for one behaviour to occur more across conditions may have obscured any effect of the training of the second behaviour.

The results of Experiments 3 and 4 suggest that relative measures of behaviour make data more orderly across conditions. The length of training of the two second behaviours can also be expressed relatively here. In the present case, the relative occurrence of the first behaviours and the relative length of training of the second behaviours have to be expressed as proportions rather than ratios as there was no training of one second behaviour in Condition 3. The right panel of graphs of Figure 46 show the proportional occurrence of the first behaviours during the extinction of the second behaviours (calculated as in Experiment 3) plotted against the proportional number of occurrences of the training component for the second behaviours. It can be seen that as the relative length of training of Behaviour 2 increased the relative occurrence of the first behaviours decreased for Hens 23 and 26 only, with the remainder either increasing or constant. It would appear that the length of training of the second behaviour in the present experiment had no consistent effect on the degree of resurgence.

In the present experiment the second behaviour was reinforced on an FR 1 schedule. To maintain the subjects' weight during Phase 4 each occurrence of a component ended after either 360 s had elapsed or 8 reinforcers had been obtained, whichever occurred first. The maximum number of reinforcers was obtained in each of these sessions and so 32 reinforcers in total were delivered when there were 4 presentations and 992 reinforcers were delivered in total when there were 124 presentations. When there were four occurrences of the components the average total time of training of the second behaviour across subjects, behaviours, and conditions, was 62 s, exclusive of magazine operation time, with a standard deviation of 45 s. When there were 124 occurrences of the components the average total time of training was 2080 s, with a standard deviation of 324 s. Although the numbers of reinforcers in the present study covered a wide range it could be argued that the time for which the second behaviour was trained did not cover such a wide range and may not have been long enough to have any effect on the degree of resurgence. Increasing the time for which the second behaviour is trained for within the two constraints of

reinforcer number and minimal occurrence of the first behaviour during the training of the second behaviour might be possible using different schedules of reinforcement or training procedures. The effect of training the second behaviour under schedules that deliver reinforcers after a variable number of responses with a probability less than 1, termed random-ratio schedules (RR), has yet to be investigated. If training the second behaviour on RR schedules results in few first behaviours occurring during second behaviour training then such schedules may be useful in allowing an increase in the training time for the second behaviour.

Having said this further research is required. The present study suggests that the length of training of the second behaviour had no effect on the degree of resurgence. It did not appear to matter whether a second behaviour was reinforced for 30 sessions or not at all. This supports the Prevention of Extinction Hypothesis by suggesting that if the extinction of the first behaviour is indeed prevented then the length of training of the second behaviour is irrelevant. As noted above, J. A. Mulick (personal communication, 6 July, 1999) has suggested that if the first behaviour occurs during the training of the second behaviour then where it occurs may be important. Specifically, Mulick proposed that contiguous occurrence of the first behaviour during the training of the second behaviour might result in more resurgence than the occurrence of the first behaviour distributed throughout the training of the second behaviour. This question awaits empirical testing.

General Discussion

This thesis investigated variables that the literature suggested might control the reoccurrence of a first trained behaviour during the extinction of a second trained behaviour (resurgence). The functional relations found have been reported in the results of the individual experiments. These relations were not as direct as might have been hoped and reasons for this have already been discussed. The purpose of the following discussion is to put the present results into the context of theories that may be applied to the study of resurgence and to note some possible implications of the results.

Descriptions

A variety of theories that might encompass the phenomena of resurgence are available in the literature. Some discussed here have been specifically derived from studies of resurgence, while others have been derived from the study of different, but related, phenomena. In any event, the theories covered here are not meant as an exhaustive list of possibilities; the present lack of data on resurgence allows for many of these at present.

Resurgence as Extinction Induced

Experiment 1 investigated Epstein's (1985) suggestion that the extinction of Behaviour 2 induces the resurgence of Behaviour 1. If this was the case then Behaviour 1 should have occurred more during the extinction of Behaviour 2 than it had occurred during a period of extinction prior to the training of Behaviour 2, as shown by Epstein (1983). This was not the case in Experiment 1. Furthermore, if the extinction of Behaviour 2 induces resurgence, then Behaviour 1 should occur more during the extinction of Behaviour 2 than it would do during extinction without Behaviour 2. The data from both Experiments 2 and 5 show that this, also, was not the case. Thus there is no evidence here of any direct induction of Behaviour 1 by the extinction of Behaviour 2. That there was no evidence of induction does not, of course, mean that induction might not occur under different circumstances, for instance, with pigeons rather than hens, but this seems unlikely. In any event, that substantial resurgence was obtained in other experiments here without any evidence of induction implies that induction is not a necessary condition for resurgence to occur.

A principle of behaviour should define a law of behaviour that is not already described by an existing principle. The extinction-induced resurgence principle stated, as previously quoted in the General Introduction, that: “When, in a given situation, recently reinforced behaviour is no longer reinforced, behaviours that were previously reinforced under similar circumstances tend to recur” (Epstein, 1985, p. 144). Epstein (1985) further stated that extinction-induced resurgence is an instance of a response interaction, with changes to one behaviour altering another. From Epstein's statements two things can be derived: first, that resurgence is a basic phenomenon that is not able to be described by existing principles, second, that resurgence is fundamentally under the control of a behavioural variable (because resurgence is induced by the extinction of *another behaviour*). Epstein's (1985) suggestion that extinction-induced resurgence can be used to explain other phenomena follows naturally from these derivations, as does the implication that environmental variables are of less importance than behavioural variables to resurgence (though Epstein, 1983, certainly did not eschew environmental influences). Thus it is unlikely that the principle of extinction-induced resurgence encourages investigation into possible environmental variables controlling resurgence. In this respect, it is interesting to note that in the fifteen years since Epstein (1985) there appear to have been no nonhuman animal studies published that investigated possible environmental controlling variables of resurgence whereas in the fifteen years before Epstein (1985) there were a number of studies (e.g., Enkema et al., 1972; Leitenberg et al., 1970; Leitenberg et al., 1975; Mulick et al., 1976; Rawson & Leitenberg, 1973; Rawson et al., 1977).

That induction does not appear necessary for resurgence allows for the corollary of the derivations from Epstein (1985) to be the case: that resurgence might be described by existing principles and that it might be under the control of environmental variables. It is possible then that existing principles of environmental control may apply to resurgence. This would have distinct advantages both in terms of conceptual economy and in terms of practical control over behaviour.

Resurgence as Described by the Prevention of Extinction Hypothesis

Experiments 3 and 4 investigated variables arising from Leitenberg et al.'s

(1975) suggestion that resurgence occurs because the training of Behaviour 2 prevents the extinction of Behaviour 1, termed by them the response prevention hypothesis but termed here the Prevention of Extinction Hypothesis. Experiment 3 showed that the degree of resurgence was a function of the period of prior extinction of Behaviour 1. While this finding is consistent with the Prevention of Extinction Hypothesis, whether it can be taken to support the hypothesis depends upon whether the prevention of extinction was directly manipulated. In the General Introduction it was stated that the phrase “degree of extinction” would be used here to refer to the extent to which behaviour had contacted the extinction contingencies. It was further noted that because behaviours must occur to contact the extinction contingencies, the extent to which extinction had been in effect may be best measured by the number of unreinforced occurrences of behaviour. In Experiment 3, the number of unreinforced occurrences of Behaviour 1 was only indirectly manipulated by the period of prior extinction. If the number of unreinforced occurrences of Behaviour 1 is the best measure of the contact with the extinction contingencies, a specific test of the Prevention of Extinction Hypothesis would require the number of unreinforced occurrences of Behaviour 1 to be manipulated directly. A potential problem with such a study is that the number of extinction responses may change over repeated extinction conditions as found by Anger and Anger (1976).

There is also, however, a problem with equating the degree of extinction with the number of unreinforced occurrences of Behaviour 1. Because the degree of extinction refers to the extent to which behaviour has contacted the extinction contingencies, the degree of extinction is dependent not only upon the unreinforced occurrences of Behaviour 1 but also on the contingencies previously in effect for Behaviour 1. This view characterises extinction as a contingency change that is only in effect when a behaviour contacts it. The implications of this view of extinction for the degree of extinction after different reinforcement contingencies will be discussed below.

The simplest contingency that might precede extinction is FR 1. As a reinforcer is always obtained by the subject after a response on this schedule, extinction would be contacted by the first response occurring during extinction. Each further response would also contact the extinction contingencies, in a similar way to the first response, so it would appear that the numbers of responses

occurring in extinction would be a good measure of the degree of extinction in this case. However, if the number of responses required for reinforcement was 10 instead of 1 (FR 10) then extinction would only be contacted by the 10th response occurring in extinction. This is because there had previously been 9 unreinforced responses prior to a reinforced response. How subsequent responses, such as the 11th response, are to be treated is not as clear. In one sense the 11th response is the second response in extinction. In this case a measure of the degree of extinction would be the numbers of responses occurring in extinction minus the 9 responses that occurred prior to extinction being contacted. In another sense, the 11th response is the first response of another FR 10 requirement, which, because it was never previously reinforced, is not contacting the extinction contingency. In this case the measure of the degree of extinction would be every 10th response occurring in extinction. As this latter measure counts the number of occasions reinforcers would have been delivered but were not, this measure appears to encompass the degree of contact with the extinction contingencies better. In practice which view is adopted may make little difference where the shape of a function is under investigation because the two measures will change in a similar way. For example consider the case where 506 responses are performed in extinction after an FR 10 schedule. Counting every 10th response, 50 responses occurred in extinction. Counting every response but subtracting the 9 first responses, 497 responses occurred in extinction. Dividing the latter measure by the FR value of 10 gives 49.7 which is not greatly different from 50. Thus, unless the absolute magnitude of extinction responding is required, either measure may suffice.

The situation becomes more complicated with a schedule in which reinforcer delivery is contingent upon both responding and time. In a fixed-interval (FI) schedule, a reinforcer is delivered for a response occurring after a certain interval has elapsed from the start of the schedule in the case of the first reinforcer, and then since the last reinforcer was delivered for subsequent reinforcers. For example, a reinforcer is delivered for the first response 60 s after the last reinforcer delivery in an FI 60-s schedule. As extinction can only be contacted when the extinction contingency differs from the contingency previously in effect, responses occurring prior to the first 60-s interval of extinction do not contact extinction. Extinction would be contacted by the first

response after this interval, say at 62 s into the session. As with the FR 10 schedule, the problem exists as to whether the second response after this first extinction response, say at 72 s into the session, is to be considered responding at the start of a fixed interval or responding 10 s into extinction. As is the case for the FR 10 schedule two measures are available: the first response after each 60-s interval and the total responding minus those responses occurring in the first 60 s of the session. These two measures are only necessarily related in that the former includes the latter. Because the degree of extinction has been defined as the degree of contact with extinction contingencies the first response after each 60-s interval, which would have been reinforced, may be the appropriate measure of the degree of extinction.

The situation becomes still more complicated when reinforcers are programmed to occur for responses after variable periods of time. The first behaviours in all of the experiments here were reinforced under RI schedules. In these schedules, reinforcers are programmed randomly with a preselected probability of a reinforcer occurring after a particular time interval. This random nature of the inter-reinforcer interval raises some questions. For instance, when behaviour has been reinforced under a RI 45-s schedule, is extinction contacted by the first response after the mean inter-reinforcement interval of 45 s, the first response after an interval longer than the longest inter-reinforcement interval previously experienced, or is extinction only contacted by the responses that would have been reinforced under the RI schedule? Given the usage of the degree of extinction mentioned previously, the most consistent measure here would be those responses which would have been reinforced had no extinction been in effect. In practice this would mean running the RI 45-s schedule during extinction and recording those responses which would have been reinforced. Furthermore, the number of these unreinforced responses would need to be manipulated to test the Prevention of Extinction Hypothesis. This was not done for Experiment 3. Without this measure of the degree of extinction the results of Experiment 3, although consistent with the Prevention of Extinction Hypothesis, cannot be taken as confirming this hypothesis. The conclusion that can be drawn from the results using this measure of the degree of extinction is thus the same as that which can be made using the total number of unreinforced responses.

That the data of Experiment 3 are consistent with the Prevention of

Extinction Hypothesis raises the theoretical question of whether the assumption that a particular operant must contact the extinction contingencies for extinction to be in effect is consistent with any existing theoretical accounts of extinction phenomena. A number of authors have proposed that particular operants must contact the extinction contingencies for their probability of occurrence to be reduced under particular stimulus conditions (e.g., Estes, 1955; Schoenfeld, 1968; Skinner, 1950). Thus the central assumption of the Prevention of Extinction Hypothesis is not without foundation.

It was found in Experiment 4 that the occurrence of Behaviour 1 during the training of Behaviour 2 was a function of the schedule of reinforcement of Behaviour 2. The degree of resurgence on the other hand, was an inverse function of the schedule of reinforcement of Behaviour 2. Consistent with the Prevention of Extinction Hypothesis, the degree of resurgence was also an inverse function of the occurrence of Behaviour 1 during the training of Behaviour 2 (though the data were variable). The occurrence of Behaviour 1 during the training of Behaviour 2 was only indirectly manipulated by the schedule of reinforcement for Behaviour 2.

The above discussion of the degree of extinction suggests that this is not sufficient for the Prevention of Extinction Hypothesis to be supported. Specifically, the number of occurrences of Behaviour 1 during the training of Behaviour 2 which would have been reinforced under the schedule previously in effect for Behaviour 1 needed to be directly manipulated. As for Experiment 3, then, the degree of extinction of Behaviour 1 was not directly manipulated. Thus the results of Experiment 4 also cannot be taken as a direct test of the Prevention of Extinction Hypothesis. Given this, it appeared that the distribution of the total occurrence of Behaviour 1 over the training and extinction of Behaviour 2 was well described by an analysis assuming the Prevention of Extinction Hypothesis. It is important to note that the hypothesis does not state why the prevention of extinction might be a function of the schedule of reinforcement of Behaviour 2. Other descriptions are required for this relation and some will be proposed later.

There was no effect of length of training of the second behaviour upon the degree of resurgence found in Experiment 5. In that study, the length of training was manipulated by the number of reinforcers delivered for Behaviour 2 on an FR 1 schedule. As with the results of Experiment 1, then, it cannot be said that an effect might not occur under different circumstances, for instance, with length of

training being manipulated under a RR schedule. Given this, the results of Experiment 5 taken with those of Experiment 1 suggest that neither the reinforcement nor the extinction of Behaviour 2 has any effect upon the degree of occurrence of the first behaviour. Instead, as suggested by the results of Experiments 3 and 4, the reinforcement of the second behaviour determines where in time the extinction of the first behaviour will occur. All the evidence here is consistent with the Prevention of Extinction Hypothesis but cannot be used to support this hypothesis directly. A specific test of the Prevention of Extinction Hypothesis must directly manipulate the contact of Behaviour 1 with the extinction contingencies.

It was noted in the introduction of Experiment 5 that J. A. Mulick (personal communication, 6 July, 1999) suggests that the distribution of the occurrence of the first behaviour over time during the training of the second behaviour could reduce the total occurrence of the first behaviour. It was suggested that this was an addition to the Prevention of Extinction Hypothesis rather than being contradictory to it. The discussion of the degree of extinction above suggests another interpretation. If a VI or RI schedule was used to train the first behaviour then contact with the extinction contingency would depend somewhat upon the time at which responses occurred relative to that under which responses were previously reinforced. Thus responses occurring close in time to each other are less likely to contact extinction contingencies than those whose occurrence is separated by a period of time. In other words, the distributed occurrence of the first behaviour during the training of the second behaviour would include a greater proportion of responses that contribute to the degree of extinction than the massed occurrence of the first behaviour during the training of the second behaviour. As such the Prevention of Extinction Hypothesis might be taken to predict an effect similar to that suggested independently by J. A. Mulick (personal communication, 6 July, 1999). This has implications for behaviour change in applied settings which will be discussed later.

If the Prevention of Extinction Hypothesis is found to be correct, then resurgence, as it has been defined here, will cease to be a separate phenomenon, and will instead become behaviour under extinction. The problem will then become one of determining the variables that prevent a behaviour from contacting the extinction contingencies. Because the Prevention of Extinction Hypothesis

makes no explicit statement about these variables, other theories are necessary for this. Some possibilities will be outlined below. Before this, however, some rival hypotheses that do not assume that resurgence is the result of the prevention of extinction will be considered.

Resurgence as Spontaneous Recovery

It has long been known that when the rate of occurrence of a behaviour has been reduced by extinction, a period of rest from the stimuli alone often results in a later rate increase, termed “spontaneous recovery” (Kimble, 1961). If the rate of occurrence of Behaviour 1 has been reduced by extinction prior to the extinction of Behaviour 2 then any increase in Behaviour 1 rate at the start of Behaviour 2 extinction might be termed spontaneous recovery if it does not depend upon Behaviour 2 for any control. If, however, the rate of occurrence of Behaviour 1 has not been reduced by extinction prior to the cessation of reinforcer delivery for Behaviour 2 then any reoccurrence of Behaviour 1 in extinction may not be termed spontaneous recovery. Experiment 2, 3, and 5 all showed reoccurrence of Behaviour 1 when there had been no prior extinction of Behaviour 1. Such reoccurrence may not be described as spontaneous recovery.

Part of the argument above rests on the meaning of the term “extinction”. The term extinction has commonly been used to describe both the procedure of reinforcer cessation and the reduction in behaviour after the cessation of reinforcer delivery (Mackintosh, 1974). In addition, Hearst (1988) noted that the term has been used to describe an underlying process. While these usages are somewhat confusing (Hearst, 1988) they are perhaps acceptable as long as the only variable which has been changed is reinforcer cessation. This is because the reduction in behaviour in extinction would be a function of the extinction procedure, so the procedure, behaviour, and process might be considered crudely synonymous. In terms of the Prevention of Extinction Hypothesis, if reinforcer cessation is the only variable manipulated then behaviours should occur and contact the extinction contingencies.

Extinction, however, has also been used to describe procedures other than just reinforcer cessation (e.g., DRA), which result in a reduction in responding (e.g., Delamater, 1996). Viewed in this way, the phases of Behaviour 2 training in the present experiments might be described as extinction procedures because the

occurrence of the first behaviour was reduced. Defining extinction in this way would mean that what has been termed resurgence here always occurred after Behaviour 1 extinction. Thus the “resurgence” in the present studies could be termed spontaneous recovery. Using the term extinction to refer to any reduction in behaviour under any procedure may not, however, be very useful. Allowing the behaviour generated by different procedures to be subsumed under the same term runs the risk of including behaviours under the control of different variables. Nevertheless, such a definition of extinction may allow the resurgence here to be termed spontaneous recovery.

Another essential part of the definition of spontaneous recovery, however, is rest. This means that a period of absence from the stimulus conditions intervenes between the extinction and recovery of the response, and is considered to be responsible for the recovery observed. It would seem unlikely that the differential recovery observed in Experiments 3 and 4 was the result of periods between sessions, as this time was reasonably constant. This would also suggest that the present results cannot be described as spontaneous recovery. In any event, spontaneous recovery denotes a phenomenon, it does not state why that phenomenon occurs.

Resurgence as Response Variability

A number of studies suggest that behaviour becomes more variable when reinforcer delivery ceases (Antonitus, 1951; Eckerman & Lanson, 1969; Margulies, 1961; Millenson & Hurwitz, 1961; Millenson et al., 1961; Morgan & Lee, 1996; Notterman & Mintz, 1965; Stebbins & Lanson, 1962; Stokes, 1995). From this it can be argued that the changes in response probability termed resurgence might merely be measured instances of variability in extinction in an impoverished environment.

Against this view of resurgence, Epstein (1983) compared the occurrence of a previously reinforced behaviour with the occurrence of a behaviour that had not been previously reinforced. The occurrence of this latter behaviour estimates the occurrence of previously unreinforced behaviour. Epstein (1983) argued that because the previously reinforced behaviour occurred more often, the re-occurrence of this behaviour could not be considered to be solely the result of responding becoming more variable in extinction. The topography of behaviour was counterbalanced across subjects suggesting that occurrence in extinction was

not a function of operant rate.

The comparison used by Epstein (1983), however, could potentially be confounded by experimental history. For instance, it might be the case that differential reinforcement took place during the reinforcement of Behaviour 1. This would occur if the behaviour that was not previously reinforced occurred at some point during the training of the reinforced behaviour. In addition, there is potential for differential reinforcement when shaping behaviour by successive approximations. Such differential reinforcement may have resulted in less of the unreinforced behaviour in extinction. If this was the case then Epstein's (1983) comparison would be flawed.

From the present results another analysis is possible. If resurgence was merely measured instances of variability in extinction it would not be expected that the degree of resurgence would differ with the amount of extinction of Behaviour 2 held constant. Because Experiments 3 and 4 showed that the degree of resurgence could be manipulated with the amount of Behaviour 2 extinction constant it would appear that resurgence cannot solely be described as a product of variability in extinction.

Instead, the present results suggest that some of what has been termed variability in extinction may, in fact, be the occurrence of previously reinforced behaviour. Further investigations into this possibility are required because, as noted by Sidman (1960), variability itself must be accounted for rather than being regarded as intrinsic to behaviour. Such research would require precise definition and measurement of behaviour so that what was reinforced can be separated from what was not reinforced. One method of measuring behaviour uses computers and video cameras to locate a part of an organism in three dimensional space (e.g., Eldridge et al., 1988). This method may be useful as it allows for behaviour to occur and be recorded without the constraints on variability or of measuring variability that physical operanda may impose.

Resurgence as Described by the GML

Thus far, the concepts of extinction-induced resurgence, spontaneous recovery, and variability in extinction do not add to an understanding of the present results. The data here are consistent with the Prevention of Extinction Hypothesis. However, this hypothesis does not state why the schedule of reinforcement for Behaviour 2 should determine the occurrence of Behaviour 1

during the training of Behaviour 2. It has previously been noted that the GML describes the distribution of behaviour over two alternatives as a function of the relative rate of reinforcement for those alternatives, normally in the steady state. In studying resurgence, the point at which reinforcement for Behaviour 2 begins is the same point at which reinforcement for Behaviour 1 ceases. In other words, resurgence might be described as transition behaviour. Davison and Hunter (1979) proposed that the distribution of behaviour over two concurrent schedules during the transition from one relative reinforcement rate to another was a joint function of the current reinforcement ratio and the past reinforcement ratios. Behaviour allocation in session n is a function of the reinforcement ratio in session n , session $n-1$, and $n-2$ etc as shown below with the free parameters used in Equation 1.

$$\log\left(\frac{B1(n)}{B2(n)}\right) = a \log\left(\frac{r1(n)}{r2(n)}\right) \bullet b \log\left(\frac{r1(n-1)}{r2(n-1)}\right) \bullet c \log\left(\frac{r1(n-2)}{r2(n-2)}\right) \dots + \log k \quad (5)$$

Davison and Hunter (1979) noted that this model could not account for schedule changes involving extinction because the reinforcement ratios would approach infinity. They proposed instead that the behaviour ratio from the last session ($n-1$) could be used to summarise the effect of the past reinforcer ratios as this behaviour ratio would be less likely to approach infinity (Davison & Hunter, 1979).

In Experiment 4, however, only one behaviour was reinforced at a time and the transition, within each component, was between two simple schedules. As a result of this there were no reinforcer ratios or behaviour ratios for the behaviour in transition so the model proposed by Davison and Hunter (1979) cannot be strictly applied. It is possible, however, that the allocation of behaviour in the transition between simple schedules may also be a function of past and current reinforcer rate, as suggested for concurrent schedules by Davison and Hunter (1979). If so, then the occurrence of a first-trained behaviour during the training of a second behaviour should be a function of the ratio of the past rate of reinforcement for the first-trained behaviour and the current rate of reinforcement for the second-trained behaviour.

In this way we can derive two assumptions that help describe some of the

“resurgence” phenomena in terms similar to that of the GML. First, from Davison and Hunter (1979), that the occurrence of Behaviour 1 during the reinforcement of Behaviour 2 is a function of both the past rate of reinforcement of Behaviour 1 and the current rate of reinforcement of Behaviour 2. Second, from the Prevention of Extinction Hypothesis, that the occurrence of Behaviour 1 during the extinction of Behaviour 2 is an inverse function of the degree of occurrence of Behaviour 1 during the training of Behaviour 2. If these two assumptions are correct then the ratio of the occurrence of Behaviour 1 during Behaviour 2 training to the occurrence of Behaviour 1 during Behaviour 2 extinction (resurgence) should match the ratio of Behaviour 1 obtained reinforcer rate to Behaviour 2 obtained reinforcer rate. That is:

$$\log\left(\frac{B1t}{B1e}\right) = a \log\left(\frac{r1}{r2}\right) + \log k \quad (6)$$

where $B1$ refers to the occurrence of Behaviour 1, t the training of Behaviour 2, e the extinction of Behaviour 2, $r1$ to the rate of reinforcement of Behaviour 1 when it was reinforced, $r2$ to the rate of reinforcement for Behaviour 2 when it was reinforced, and the parameters a and k are those of Equation 1. If this model is correct then the phenomenon being termed “resurgence” can be described by a variation of the Generalised Matching Law. Currently, however, this Matching Law model describing “resurgence” has not been tested as relative rate of reinforcement has not been manipulated. The data from Experiment 4 showing an effect of rate of reinforcement is consistent with a GML model though.

If it were found that this model was applicable then there would be some implications for the study of behaviour. Because the term “resurgence” would no longer be required there would be a gain in conceptual economy. In addition, the large body of research on choice (see Davison & McCarthy, 1988, for a review) might be applied to resurgence, giving a better understanding of the variables that might affect resurgence.

Resurgence as Described by Behavioural Momentum

In Experiment 4 it was found that the extinction data for the second behaviours could also be described by Behavioural Momentum theory. That is, the resistance ratio for the second behaviours in extinction was related to the

contingency ratio within a condition. It is also possible that the resistance ratio was related to the contingency ratio at another point in the experimental procedure where the second behaviours were disrupted. It will be remembered that the second behaviours were trained under their respective stimuli (Phase 3) and that the stimuli previously associated with the first behaviours were then presented in the multiple schedule (Phase 4). The reinstatement of the stimuli associated with the first behaviours might thus be viewed as a disrupter intervening during the reinforcement of the second behaviours. According to Nevin (1992), the resistance ratio of the two second behaviours would be a function of the contingency ratio in this case, as shown in Equation 4. In other words, there would be greater disruption of the second behaviour with the leaner schedule and so more of the first behaviour might occur there. The results of Experiment 4 are consistent with this model. If the Prevention of Extinction Hypothesis is correct then the different degrees of occurrence of the first behaviours during the training of the second behaviours would result in different degrees of resurgence.

Alternatively, it might be the case that it is the different resistance of the first and second behaviours that are relevant to the occurrence of the first behaviour when the second behaviour is reinforced in the multiple schedule. Equation 4 could also be applied in this case and would likewise predict that more first behaviour would occur under the leaner second behaviour schedule. Both of these predictions from Behavioural Momentum apply only to the present data. They cannot account for the data of Leitenberg et al. (1975) because in that study there was no preliminary training of the second behaviour for a disruptor to intervene between. Because of the potential confounds in that study, however, changes in the degree of resurgence there cannot be attributed to the rate of Behaviour 2 reinforcement. Thus a Behavioural Momentum model cannot be ruled out even considering the data of Leitenberg et al. (1975). What is required is an unconfounded demonstration that rate of reinforcement of Behaviour 2 determines the degree of resurgence.

The above discussion of a Behavioural Momentum account of the present results assumed, as did the discussion of the GML account, that the Prevention of Extinction Hypothesis was correct. It was assumed here that the task was to provide a description that encompassed the effect of the rate of reinforcer delivery for the second behaviour upon the degree of prior extinction of the first behaviour

and hence the degree of its resurgence. However, a Behavioural Momentum model can also be proposed that does not require the Prevention of Extinction Hypothesis.

Nevin (1993) discusses the predictions of a Behavioural Momentum model for the elimination of a problem behaviour by DRA and DRO procedures. These procedures are quite similar to the present paradigm. Central to Nevin's (1993) argument is that response rate is determined by response-food (operant) contingencies and resistance to change is determined by colour-food (Pavlovian) contingencies (Nevin et al., 1990). In the current procedure, when two second behaviours are reinforced at different rates in a multiple schedule, Nevin et al. (1993) predict that the rate of the first behaviour should be lowest in the component with the richer rate of reinforcement. This is presumably because behaviour at this point is a function of the response-food contingency for the first behaviour relative to that of the second behaviour and this is low when the rate of reinforcement for the second behaviour is high. This is essentially the relation described in the GML analysis above to account for the occurrence of the first behaviour during the training of the second behaviour. Although the data from Experiment 4 are consistent with such an account, as previously mentioned they cannot provide conclusive support for an account of this nature.

When reinforcer delivery ceases for the second behaviour Nevin et al. (1993) would predict that the resistance to change of the first behaviour would be highest in the component with the richer rate of reinforcement. If the rates of the first behaviours during their training were similar then resistance to change might also be seen in the number of behaviours occurring in extinction. The degree of resurgence should be highest in the component with the richer rate of reinforcement, as found in Experiment 4. This is because behaviour in extinction is assumed to be a function of colour-food contingencies and these contingencies will be highest in the component with the highest rate of second behaviour reinforcement (Nevin, 1993). According to this model, the degree of resurgence is not a product of the degree of prior extinction. Instead, it is a product of the rate of reinforcer delivery under each stimulus condition. Whether or not this is in fact the case cannot be determined from the present data.

It is worth noting, however, that there is a prediction that follows from assuming that the degree of occurrence Behaviour 1 is a function of the Pavlovian

contingences. This is that the training of a second behaviour will affect the degree of occurrence of the first behaviour if the Pavlovian contingencies are different for the first and second behaviours. In Condition 3 of Experiment 5, two first behaviours were trained, in a multiple schedule, under RI 45-s schedules. Then a second behaviour was trained under a FR 1 schedule in one component and the other component stimuli were not presented (and hence a second behaviour was not trained for this component). If the occurrence of the first behaviour is a function of the Pavlovian contingences, then more first behaviour should occur when the second behaviour was trained than when it was not trained. This is because the Pavlovian contingences should be stronger under FR 1 than they would be under RI 45-s. This was not observed in the results of Experiment 5. Thus there are some data here which are contrary to this model based on Nevin's (1993) suggestions. There may be other interpretations of Behavioural Momentum possible which might account for all of the data here but they are not obvious.

A Discussion of Resurgence in Terms of Operant Class Membership

One question for consideration is whether Behaviour 1 and Behaviour 2 are members of different (but related) operant classes or whether they might be better considered as simply differing topographical forms within one operant class. In a discussion of the usage of the term operant, Catania (1973) suggests that an operant relation is shown when changes in the probability of occurrence of a response are correlated with changes in the stimuli that follow occurrences of this response. The term contingency is used to describe the relation between response properties and the production of stimuli. The term operant class describes the behaviour generated by the contingencies, with respect to those contingencies (Catania, 1973). "Thus, when an operant relation has been demonstrated, it is appropriate to say that contingencies have generated an operant class." (Catania, 1973, p. 32). It is important to note that these terms do not merely describe the occurrence of behaviour, but also its occurrence as a function of an environmental variable. There is an additional point which is also evident in the original usage of the terms operant and operant class by B. F. Skinner.

An operant is a class, of which a response is an instance or member. The

usage is seldom respected. Strictly speaking, it is always instances which are counted in determining frequency, and from that frequency the probability of a *response* inferred. The probability is frequently taken, however, as the measure of the strength of an *operant*. Strength of a response has no meaning except as a property of an instance, such as its force or speed. It is always a response upon which a given reinforcement is contingent, but it is contingent upon properties which define membership in an operant. Thus a set of contingencies defines an operant. (Skinner, 1969, p.131).

The unit of predictive science is, therefore, not a response but a class of responses. The word “operant” will be used to describe this class. The term emphasizes the fact that the behavior *operates* on the environment to generate consequences. The consequences define the properties with respect to which responses are called similar. ...The operant is defined by the property upon which reinforcement is contingent – the height to which the head must be raised. (Skinner, 1953, p. 65-66).

It can be seen, in both Skinner’s and Catania’s view, that the properties upon which reinforcement is contingent define and generate an operant class. It is of interest whether the results of the present studies can be described in these terms.

The results showed increases and decreases in the probability of occurrence of the first and second behaviours (rate) with changes in contingences (reinforcement and extinction). The terms operant relation and operant class therefore seem applicable. The contingencies, including the physical properties of the response upon which reinforcer delivery was contingent, differed between the first and second behaviours. The contingencies also differed because Behaviour 1 and Behaviour 2 were generally reinforced on different schedules. In addition, different contingencies were in effect for the first and second behaviours at different times. As contingencies define an operant and the contingencies were different, it might be said that there were two operant relations and hence two operant classes: one class for Behaviour 1 and one class for Behaviour 2. The results of the present experiments might then be interpreted as informing on the

variables that control the occurrence of members of different operant classes. The results of the present studies can be described using the terms operant relation and operant class in their conventional usage. However, whether two behaviours should be described as members of different operant classes because of the fact that reinforcers were contingent on different physical properties, at different times, and under different schedules, needs to be discussed.

Catania (1973) noted that an operant class may be used to describe those responses which had properties that could fulfil the contingency (descriptive operant class) and those that were modified by the contingency (functional operant class). The following examples will assume, for simplicity, that the responses which occurred were all functional operants. That is to say an operant relation was demonstrated in all cases.

Operation of a key may activate a single microswitch, which in turn, results in delivery of wheat (reinforcement). In this case, the operant class would be all the responses which had activated the microswitch, for instance pecking with a closed beak, pecking with an open beak, pecking on a particular angle, scratching with a foot and many other variants. There is thus scope for considerable topographic variation within an operant class that is defined by the simple contingency of “if microswitch depression then reinforcement”. The possibility for topographic variation can be made even more obvious if we connect a further 9 keys, at different places in the operant chamber, to the same microswitch. Because the contingency is the same for responses that activate any key (responses to any of these keys activates the same microswitch, resulting in reinforcer delivery) any of these responses which occurred would, by definition, be part of the same operant class. In addition, the membership of responses in an operant class is not dependant upon their activation of the same microswitch. If each key had its own microswitch, but if reinforcer delivery followed any microswitch depression, then the contingency would be “if microswitch depression 1 or microswitch depression 2 or microswitch depression 3...then reinforcement”. Because of this, any of the responses which activated any of the 10 keys would be a member of the operant class defined by these specific contingencies.

The same logic applies to the case where microswitches are embedded in different operanda, for instance behind a key or in a door-push operandum. If the

contingency was “if microswitch in key depressed or microswitch in door-push depressed then reinforcement” the responses that fulfilled this contingency (key pecks and door pushes of some description) would be members of the same operant class. Moreover, transducers different from a microswitch might be used without resulting in different operant classes. For instance, if the contingency is “if infrared beam break or if microswitch depression then reinforcement” then, as with the above examples, any response which fulfilled the criteria defined in the contingency might be a member of the same operant class. The point of all these examples is that the topographic differences between the first and second behaviours here do not necessarily mean that they are members of two different operant classes. Another way of viewing the contingency (or contingencies) present in the chamber might be “if door push or left-key peck then reinforcer”. Physical properties alone do not define the operant class because the contingency allows for either topographical behaviour to be reinforced.

The conventional view of the present procedure might still suggest that the first and second behaviours should be considered to be members of different operant classes because of the times the two behaviours were reinforced. As a result of the contingency for door pushing being in effect at a different time to that for key pecking, there were two contingencies. A “if door push then reinforcement, if left-key peck then no reinforcement (extinction)” contingency during Behaviour 1 training and a “if left-key peck then reinforcement, if door push then no reinforcement (extinction)” contingency during Behaviour 2 training. Thus Behaviour 1 and Behaviour 2 would be considered members of two different operant classes. The results of the present experiments clearly showed that Behaviour 1 and Behaviour 2 were well maintained in their appropriate training phases so it might be assumed that they were members of different operant classes. Maintenance of the behaviours, however, can only indicate that the first part of each contingency has been contacted, which is “if door push then reinforcement” during Behaviour 1 training and “if left-key peck then reinforcement” during Behaviour 2 training. It does not necessarily follow that unreinforced responses have occurred in either phase. The extinction contingencies may or may not have been contacted in either case where behaviour was maintained.

If unreinforced occurrences are eliminated entirely (so that the extinction

contingencies are not contacted) then the contingency contacted is actually “if door push then reinforcement *or* if left-key peck then reinforcement”. It might be argued that *or* is misused here because of the different periods of time in which reinforcement was contingent upon the two different topographies. However, in most experimental manipulations (such as the theoretical 10 key examples used above) responses cannot occur at the same time but the contingent relation between responses and reinforcement are taken as necessarily defining the operant class. Allowing *or* to be used in this way, with no unreinforced occurrences of behaviour, there is one contingency contacted and thus door pushes and left-key pecks would be defined as members of the same operant class. Consistent with this possibility, the results of the present experiments suggest that the degree of resurgence of the first behaviour was influenced by the degree of contact with the extinction contingency in effect during the training of the second behaviour. It would appear that different contingencies being in effect at different points of time does not necessarily create different operant classes, but rather these differences must be contacted for different operant classes to be established.

The first and second behaviours might still be considered to be members of different operant classes because of differences in the reinforcement schedules used for these behaviours. For instance, Behaviour 1 responding generated by an RI 45-s schedule would be a different operant class from Behaviour 2 responding generated by a FR 1 schedule (i.e., Experiment 3), because the property that reinforcement is contingent upon is different in the two cases. There would be thus two different contingencies. During Behaviour 1 training the contingency might be described as “if Behaviour 1 after an interval averaging 45 s then reinforcement, if Behaviour 2 then no reinforcement (extinction contingency)”. During Behaviour 2 training the contingency might be described as “if Behaviour 2 then reinforcement, if Behaviour 1 then no reinforcement (extinction contingency)”. However, the argument outlined above, that two different contingencies only create different operant classes if they are contacted, can also be used in this case. For instance, if Behaviour 1 never occurs during the training of Behaviour 2 then the extinction contingency for Behaviour 1 responding under the RI 45-s schedule is never contacted. The contingency contacted in this experiment would be described as “if Behaviour 1 occurs after an interval averaging 45 s then reinforcement *or* if Behaviour 2 occurs then reinforcement”.

Because there is one contingency, Behaviour 1 and Behaviour 2 might be considered to be members of the same operant class.

The results of the present experiments suggest that the degree of resurgence is influenced by the degree to which the extinction contingency is contacted, which could be said to be the degree to which there are two different contingencies. With this view then, the two behaviours are members of one operant class unless the extinction contingences were contacted. Furthermore, the environmental controlling variables here, previous extinction of Behaviour 1 and rate of reinforcement for Behaviour 2, might be interpreted as two values of the very variable that defines the operant relation. That is to say that changing the stimuli that followed the occurrence of behaviour (reinforcement and extinction) changed the probability of behaviour (degree of resurgence). It seems plausible then that the present results bear upon the distribution of topographically different members of the same operant class.

It would appear that the first and second behaviours might be viewed as members of the same operant class or of different operant classes. In any event, the results of the present studies inform on the distribution of operant behaviour as a function of environmental variables. It might be argued that the operant class discussion above is one of definition and has no practical significance. The question of whether the two behaviours were members of the same or different operant classes is important, however, because of the implications for the prediction of dynamic behaviour.

In the present studies there was only one behaviour which was available to reoccur. Guerin (1994) noted that there are currently no strong predictions about reoccurrence if there were two previously reinforced behaviours that could reoccur. The present results suggest that the previously reinforced behaviour that had been exposed to extinction the least, prior to the extinction of the recently reinforced behaviour, would reoccur the most, all things being equal. But what would happen if this previously reinforced behaviour had been reinforced by a different reinforcer from that used with the other previously reinforced behaviour and with the recently reinforced behaviour? As the reinforcers differed between the previously reinforced behaviour (with the least prior extinction) and the recently reinforced behaviour they should be members of different operant classes. If the two behaviours in the present experiments are viewed as members of

different operant classes then the present results make one prediction. The previously reinforced behaviour that had been least exposed to extinction prior to the extinction of the recently reinforced behaviour would reoccur the most, regardless of reinforcer. If the two behaviours in the present experiments had been controlled by the same reinforcer and therefore could possibly be viewed as members of the same operant class then another prediction can be made. The previously reinforced behaviour that had the same reinforcer as the recently reinforced behaviour, which in this hypothetical case was the one that had been exposed to extinction the most, would reoccur most.

The above discussion suggests a new resurgence experiment that could be performed with hens that are both food and dust-bathing deprived. Two first behaviours would be trained in a multiple schedule as in Experiment 3 and 4 (head bobbing under red, door pushing under green) but using dust-bathing as a reinforcer. Then two second behaviours would be trained using wheat as a reinforcer as in Experiment 3 (right-key pecking under red, left-key pecking under green), and finally reinforcer delivery would cease. This final phase would consist of the two stimulus conditions (red and green) in effect consecutively but separated by a period of dust-bathing. Under the first stimulus condition (i.e., red), extinction would be in effect for both the first and second trained behaviours because subjects are both food and dust-bathing deprived. Because of this resurgence should occur. Then the subjects would have free access to dust-bathing, until dust-bathing ceases to occur, and then the second stimulus condition (i.e., green) would be in effect. At this point, dust-bathing should no longer function as a reinforcer. Thus extinction would not be in effect for the first behaviour but would still be in effect for the second behaviour. If resurgence occurs across different operant classes then a similar degree of resurgence would occur in this condition (green) to that which occurred in the other condition (red). If resurgence only occurs within the same operant class then little resurgence should occur under green in comparison to that which occurred under red. This experiment would need to be more complicated to rule out confounds such as order effects in extinction. However, it should serve to illustrate that operant class membership and its relation to resurgence is empirically testable.

Implications

The present studies were conducted, using hens, in a highly controlled laboratory environment. It is possible that the present findings may not replicate in different species or under different environmental conditions. Even given this possibility, there are still a number of implications possible from the findings of the present experiments. Only further research will show whether these inferences are warranted.

Usage of the Term Resurgence

This thesis operationally defined resurgence as the occurrence of previously reinforced behaviour during the extinction of a recently reinforced behaviour. The results were largely consistent with the view that resurgence is the occurrence of Behaviour 1 in extinction displaced in time by the training of Behaviour 2. If this is, in fact, the case, then the term “resurgence” would seem to be unnecessary as it is merely another name for behaviour occurring in extinction. One of the theoretical approaches outlined above may provide a conceptually economic description of the phenomenon. Resurgence, then, may not be a basic phenomenon; it may instead be reducible to other principles (e.g., matching). Until there is further evidence that resurgence is only the deferred extinction of Behaviour 1, however, the term resurgence is still useful in an operational sense.

The phenomenon of resurgence has been used to help account for other phenomena, most commonly problem solving (e.g., Epstein, 1987; Epstein, 1991; Epstein, et al., 1984; Nakajima & Sato, 1993). The present results show that resurgence varies as a function of variables. Any account of a phenomenon, such as problem solving, in which resurgence is instrumental needs to understand the variables that determine resurgence. Take, for instance, the case where both pushing a box and standing on a box are required to solve a problem (i.e., for reinforcement). Pushing a box and standing on a box are trained consecutively and then reinforcer delivery ceases. Pushing the box may resurge and this, in combination with the occurrence of standing on the box, solves the problem (achieves reinforcement). The present results suggest that the resurgence of box pushing is not automatic, it may or may not occur. If pushing the box occurred frequently during the training of standing on the box, and so contacted extinction, then resurgence of box pushing may not occur. If so, the problem would not be

solved. If pushing the box did not occur during the training of standing on the box, and so did not contact extinction, then resurgence of box pushing may occur and the problem might be solved. Ideally, the observation that previously reinforced behaviour occurs when reinforcer delivery ceases for another behaviour should be described in terms of the variables responsible for this occurrence. At the very least, the variables that might affect resurgence need to be appreciated when resurgence is used to account for other phenomenon.

Resurgence Applied to Humans

As noted in the General Introduction it is not known whether the reoccurrence of previous behaviour seen in the human studies was resurgence as studied here (the occurrence of previously reinforced behaviour during the extinction of recently reinforced behaviour) or a different phenomenon. This is because it is difficult to establish whether the consequences delivered were reinforcers and thus whether extinction had been in effect in the human studies. The present findings can only be generalised to human studies when it is clear reinforcement occurred in the latter. However, the present results might be used to make some predictions about human behaviour where reinforcer manipulation can be controlled, such as when DRA is used.

As noted in the General Introduction some early work on the phenomena we have termed resurgence investigated the effectiveness of a procedure termed DRA (Enkema et al., 1972; Leitenberg et al., 1970; Leitenberg et al., 1975). In this procedure an alternative behaviour (Behaviour 2) is reinforced to reduce the occurrence of a problem behaviour (Behaviour 1). Like these earlier studies, the present results suggest that a DRA procedure will be effective in avoiding the occurrence of a problem behaviour (Behaviour 1). In addition, the procedure will reduce the probability of the problem behaviour (Behaviour 1) more rapidly if the rate of reinforcer delivery for the alternative behaviour (Behaviour 2) is rich (Experiment 4). This will be effective only as long as reinforcement for the new behaviour is continued, however. The results suggest that problem behaviour will reoccur if reinforcer delivery ceases for the alternative behaviour. Here, the extent of problem behaviour reoccurrence was reduced by exposure to extinction contingencies in Experiment 3. Experiment 4 showed that there might be greater reoccurrence of the problem behaviour when the rate of alternative reinforcement

was rich. The length of training of the alternative behaviour should make no difference to the occurrence of the problem behaviour as shown in Experiment 5. The present results are a reminder that maintenance of behaviour change is something that has to be explicitly programmed and which requires further research.

It was noted above that J. A. Mulick (personal communication, 6 July, 1999) suggested that the distributed occurrence of Behaviour 1 during the training of Behaviour 2 might reduce the occurrence of Behaviour 1. It has been suggested here that this is consistent with the Prevention of Extinction Hypothesis when the previous schedule of reinforcement for the first behaviour had a time criterion, such as a RI or VI schedule. This is because only those responses previously reinforced under the time criterion are assumed to contact extinction and so change the rate at which the first behaviour occurs. Those Behaviour 1 responses which occur during extinction but which were not reinforced under the first behaviour schedule are assumed not to contribute to contacting extinction. This possibility is worthy of future research because it suggests one way in which the occurrence of a problem behaviour, both during the training of an alternative behaviour and during the extinction of an alternative behaviour, might be reduced. Specifically it suggests that the problem behaviour should not be completely eliminated during the training of the alternative behaviour but neither is it necessary to allow it to occur continuously. Rather the optimal strategy might be to distribute the occurrence of the problem behaviour throughout the training of the alternative behaviour.

Conclusion

We now know that resurgence in hens is not induced by the extinction of Behaviour 2 nor is the degree of resurgence altered by the length of training of Behaviour 2. Instead, the degree of resurgence is an inverse function of the amount of previous extinction of Behaviour 1 and is also a function of the schedule of reinforcement of Behaviour 2. In combination, these results suggest that rather than resurgence being a basic phenomenon, resurgent behaviours are similar to other occurrences of behaviour and differ only in the point in time at which they occur. Resurgence can be best described by models of behaviour derived from the GML or Behavioural Momentum without using the term

“resurgence”. Not only is this conceptually economic, but it suggests that there is great potential for environmental control over the occurrence of previously reinforced behaviours during the extinction of a recently reinforced behaviour.

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26 0 0 187 0 18 13 8 360 4 1 2 5	26 0 2 29 0 0 0 0 360 2 1 6 6	26 0 0 0 0 0 0 0 0 360 4 1 6 7
26 0 8 0 0 18 12 8 24 1 1 5 5	26 0 0 0 6 0 0 0 360 3 2 6 6	26 0 1 1 0 0 0 0 0 360 1 1 6 7
26 8 0 0 0 18 14 8 22 2 2 5 5	26 0 1 8 0 0 0 0 360 4 1 6 6	26 0 0 0 0 0 0 0 0 360 2 2 6 7
26 0 8 0 0 18 13 8 20 3 1 5 5	26 0 5 107 0 0 0 0 360 1 1 6 6	26 0 0 0 0 0 0 0 0 360 3 1 6 7
26 8 0 0 0 18 14 8 21 4 2 5 5	26 1 0 0 0 1 0 0 0 360 2 2 6 6	26 1 0 0 0 0 0 0 0 360 4 2 6 7
26 0 0 224 0 0 0 0 360 1 1 6 5	26 0 0 3 0 0 0 0 360 3 1 6 6	26 1 0 0 0 0 0 0 0 360 1 2 6 7
26 7 0 0 0 160 0 0 0 360 2 2 6 5	26 1 0 0 0 0 0 0 0 360 4 2 6 6	26 0 0 4 0 0 0 0 0 360 2 1 6 7
26 0 0 183 0 0 0 0 360 3 1 6 5	26 1 0 0 8 0 0 0 360 1 2 6 6	26 1 0 0 0 0 0 0 0 360 3 2 6 7
26 0 0 0 127 0 0 0 0 360 4 2 6 5	26 0 2 10 0 0 0 0 360 2 1 6 6	26 0 2 0 0 0 0 0 0 360 4 1 6 7
26 8 0 0 18 0 0 0 0 360 1 2 6 5	26 0 0 0 0 0 0 0 360 3 2 6 6	26 2 0 0 0 0 0 0 0 360 1 1 6 7
26 0 8 45 0 0 0 0 360 2 1 6 5	26 0 0 5 0 0 0 0 360 4 1 6 6	26 2 0 0 0 0 0 0 0 360 2 2 6 7
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26 0 6 22 0 0 0 0 360 1 1 6 5	26 0 0 2 0 0 0 0 360 3 1 6 6	26 1 0 0 0 0 0 0 0 360 1 2 6 7
26 4 0 0 11 0 0 0 0 360 2 2 6 5	26 1 0 0 0 0 0 0 360 4 2 6 6	26 0 0 0 0 0 0 0 0 360 2 1 6 7
26 0 0 4 0 0 0 0 360 3 1 6 5	26 0 0 0 26 0 0 0 360 1 2 6 6	26 0 0 0 0 0 0 0 0 360 3 2 6 7
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26 2 0 0 10 0 0 0 0 360 1 2 6 5	26 1 0 0 0 0 0 0 360 3 2 6 6	26 0 1 57 0 0 0 0 360 1 1 6 7
26 0 2 38 0 0 0 0 360 2 1 6 5	26 0 0 0 0 0 0 0 360 4 1 6 6	26 0 0 0 2 0 0 0 360 2 2 6 7
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26 0 0 2 0 0 0 0 360 4 1 6 5	26 1 0 0 2 0 0 0 360 2 2 6 6	26 1 0 0 0 0 0 0 0 360 4 2 6 7
26 0 7 83 0 0 0 0 360 1 1 6 5	26 0 0 0 0 0 0 0 360 3 1 6 6	26 0 0 0 0 0 0 0 0 360 1 2 6 7
26 0 0 0 9 0 0 0 0 360 2 2 6 5	26 0 0 0 0 0 0 0 360 4 2 6 6	26 0 0 0 0 0 0 0 0 360 2 1 6 7
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26 1 0 0 2 0 0 0 0 360 4 2 6 5	26 0 1 1 0 0 0 0 360 2 1 6 6	26 0 0 0 0 0 0 0 0 360 4 1 6 7
26 1 0 0 8 0 0 0 0 360 1 2 6 5	26 0 0 0 0 0 0 0 360 3 2 6 6	26 0 4 206 0 13 9 6 360 1 1 2 8
26 0 1 4 0 0 0 0 360 2 1 6 5	26 0 0 2 0 0 0 0 360 4 1 6 6	26 0 0 0 69 15 8 5 360 2 2 2 8
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26 0 2 0 0 0 0 0 0 360 4 1 6 5	26 1 0 0 0 0 0 0 360 2 2 6 6	26 0 0 111 26 14 9 360 4 2 2 8
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26 1 0 0 2 0 0 0 0 360 2 2 6 5	26 1 0 0 0 0 0 0 360 4 2 6 6	26 0 1 249 0 15 11 7 360 2 1 2 8
26 0 0 0 0 0 0 0 0 360 3 1 6 5	26 1 0 0 8 0 0 0 360 1 2 6 6	26 0 0 1 126 23 13 8 360 3 2 2 8
26 1 0 0 0 0 0 0 0 360 4 2 6 5	26 0 2 0 0 0 0 0 360 2 1 6 6	26 0 0 237 0 18 13 8 360 4 1 2 8
26 1 0 0 1 0 0 0 0 360 1 2 6 5	26 1 0 0 0 0 0 0 360 3 2 6 6	26 0 2 223 0 18 12 8 360 1 1 2 8
26 0 1 0 0 0 0 0 0 360 2 1 6 5	26 0 2 0 0 0 0 0 360 4 1 6 6	26 0 0 262 0 11 8 5 360 2 1 2 8
26 0 0 0 0 0 0 0 0 360 3 2 6 5	26 0 1 313 0 9 6 4 360 1 1 2 7	26 0 0 0 123 29 16 10 360 3 2 2 8
26 0 1 0 0 0 0 0 0 360 4 1 6 5	26 0 0 0 153 23 13 8 360 2 2 2 7	26 0 0 0 130 35 20 12 360 4 2 2 8
26 0 1 0 0 0 0 0 0 360 1 1 6 5	26 0 0 242 0 20 14 9 360 3 1 2 7	26 3 0 0 79 12 6 4 360 1 2 2 8
26 1 0 0 1 0 0 0 0 360 2 2 6 5	26 0 0 0 155 20 12 7 360 4 2 2 7	26 0 0 0 120 26 14 9 360 2 2 2 8
26 0 1 0 0 0 0 0 0 360 3 1 6 5	26 2 0 0 157 15 8 5 360 1 2 2 7	26 0 1 249 0 9 6 4 360 3 1 2 8
26 1 0 0 0 0 0 0 0 360 4 2 6 5	26 0 0 289 0 18 12 8 360 2 1 2 7	26 0 0 233 0 13 9 6 360 4 1 2 8
26 1 0 0 2 0 0 0 0 360 1 2 6 5	26 0 0 0 153 20 11 7 360 3 2 2 7	26 4 0 0 108 20 11 7 360 1 2 2 8
26 0 1 0 0 0 0 0 0 360 2 1 6 5	26 0 0 291 0 13 9 6 360 4 1 2 7	26 0 1 248 0 13 10 6 360 2 1 2 8
26 0 0 0 0 0 0 0 0 360 3 2 6 5	26 0 1 238 0 26 19 12 360 1 1 2 7	26 0 0 245 0 18 13 8 360 3 1 2 8
26 0 0 0 0 0 0 0 0 360 4 1 6 5	26 0 0 274 0 13 10 6 360 2 1 2 7	26 0 0 172 17 10 6 360 4 2 2 8
26 0 2 246 0 11 8 5 360 1 1 2 6	26 0 0 0 143 9 5 3 360 3 2 2 7	26 3 0 0 101 15 8 5 360 1 2 2 8
26 1 0 0 152 15 7 5 360 2 2 2 6	26 0 0 0 148 26 14 9 360 4 2 2 7	26 0 0 142 23 14 8 360 2 2 2 8
26 0 0 250 0 18 13 8 360 3 1 2 6	26 0 0 0 98 26 14 9 360 1 2 2 7	26 0 0 232 0 13 9 6 360 3 1 2 8
26 0 0 162 20 12 7 360 4 2 2 6	26 0 0 0 145 32 17 11 360 2 2 2 7	26 0 0 280 0 11 8 5 360 4 1 2 8
26 6 0 0 90 17 10 6 360 1 2 2 6	26 0 0 225 0 9 6 4 360 3 1 2 7	26 0 1 166 0 31 22 14 360 1 1 2 8
26 0 0 167 0 13 9 6 360 2 1 2 6	26 0 0 0 33 23 15 360 4 1 2 7	26 1 0 0 142 29 17 10 360 2 2 2 8
26 0 0 147 32 18 11 360 3 2 2 6	26 2 0 0 141 23 12 8 360 1 2 2 7	26 0 0 257 0 7 5 3 360 3 1 2 8
26 0 0 181 0 13 9 6 360 4 1 2 6	26 0 0 310 0 18 13 8 360 2 1 2 7	26 0 0 0 157 20 12 7 360 4 2 2 8
26 0 0 132 0 15 11 7 360 1 1 2 6	26 0 0 320 0 13 9 6 360 3 1 2 7	26 1 0 0 122 15 9 5 360 1 2 2 8
26 0 0 202 0 18 12 8 360 2 1 2 6	26 0 0 139 17 9 6 360 4 2 2 7	26 0 0 219 0 18 12 8 360 2 1 2 8
26 0 0 130 26 14 9 360 3 2 2 6	26 1 0 0 140 23 13 8 360 1 2 2 7	26 0 0 135 20 11 7 360 3 2 2 8
26 0 0 166 17 9 6 360 4 2 2 6	26 0 0 161 26 14 9 360 2 2 2 7	26 0 0 213 0 13 9 6 360 4 1 2 8
26 1 0 0 85 23 12 8 360 1 2 2 6	26 0 0 291 0 15 11 7 360 3 1 2 7	26 0 4 202 0 11 8 5 360 1 1 2 8
26 0 0 116 17 10 6 360 2 2 2 6	26 0 0 241 0 22 16 10 360 4 1 2 7	26 0 0 265 0 20 14 9 360 2 1 2 8
26 0 0 174 0 22 16 10 360 3 1 2 6	26 0 2 247 0 15 11 7 360 1 1 2 7	26 0 0 134 17 9 6 360 3 2 2 8
26 0 0 197 0 9 6 4 360 4 1 2 6	26 0 0 168 23 11 8 360 2 2 2 7	26 0 0 143 35 19 12 360 4 2 2 8
26 0 0 81 26 0 9 360 1 2 2 6	26 0 0 293 0 11 8 5 360 3 1 2 7	26 0 0 79 23 13 8 360 1 2 2 8
26 0 1 191 0 9 0 4 360 2 1 2 6	26 0 0 160 32 16 11 360 4 2 2 7	26 0 0 163 15 8 5 360 2 2 2 8
26 0 0 231 0 13 0 6 360 3 1 2 6	26 1 0 0 137 20 10 7 360 1 2 2 7	26 0 0 228 0 15 11 7 360 3 1 2 8
26 0 0 129 20 0 7 360 4 2 2 6	26 0 0 288 0 13 9 6 360 2 1 2 7	26 0 0 165 0 0 0 360 4 2 2 8
26 3 0 0 113 20 10 7 360 1 2 2 6	26 0 0 171 9 5 3 360 3 2 2 7	26 0 0 119 26 15 9 360 1 2 2 8
26 0 0 111 35 17 12 360 2 2 2 6	26 0 0 213 0 20 14 9 360 4 1 2 7	26 0 0 169 29 17 10 360 2 2 2 8
26 0 0 231 0 18 12 8 360 3 1 2 6	26 1 0 320 0 11 8 5 360 1 1 2 7	26 0 0 240 0 15 11 7 360 3 1 2 8
26 0 0 242 0 20 14 9 360 4 1 2 6	26 0 0 310 0 18 13 8 360 2 1 2 7	26 0 0 228 0 20 14 9 360 4 1 2 8
26 0 4 197 0 15 11 7 360 1 1 2 6	26 0 0 144 17 10 6 360 3 2 2 7	26 1 0 217 0 11 8 5 360 1 1 2 8
26 0 0 95 41 21 14 360 2 2 2 6	26 0 0 135 23 13 8 360 4 2 2 7	26 0 0 111 9 5 3 360 2 2 2 8
26 0 0 207 0 13 9 6 360 3 1 2 6	26 0 0 111 29 15 10 360 1 2 2 7	26 0 0 221 0 22 15 10 360 3 1 2 8
26 0 0 162 12 6 4 360 4 2 2 6	26 0 0 154 32 15 11 360 2 2 2 7	26 0 0 132 38 22 13 360 4 2 2 8
26 0 0 104 20 11 7 360 1 2 2 6	26 0 0 253 0 15 11 7 360 3 1 2 7	26 0 0 98 0 0 0 360 1 2 3 8
26 0 0 269 0 4 3 2 360 2 1 2 6	26 0 0 248 0 15 10 7 360 4 1 2 7	26 0 0 156 0 20 14 9 360 2 1 2 8
26 0 0 137 23 13 8 360 3 2 2 6	26 1 0 0 91 32 16 11 360 1 2 2 7	26 0 0 143 0 0 0 360 3 2 3 8
26 0 0 205 0 18 12 8 360 4 1 2 6	26 0 0 269 0 33 23 15 360 2 1 2 7	26 0 0 227 0 20 14 9 360 4 1 2 8
26 0 2 240 0 18 12 8 360 1 1 2 6	26 0 0 150 23 11 8 360 3 2 2 7	26 0 8 0 0 18 12 8 19 1 1 5 8
26 0 0 251 0 15 11 7 360 2 1 2 6	26 0 0 121 29 15 10 360 4 2 2 7	26 8 0 0 0 18 13 8 17 2 2 5 8
26 0 0 133 17 10 6 360 3 2 2 6	26 0 1 262 0 18 12 8 360 1 1 2 7	26 8 0 0 0 18 12 8 18 3 1 5 8
26 0 0 158 23 13 8 360 4 2 2 6	26 0 0 279 0 22 16 10 360 2 1 2 7	26 8 0 0 0 18 13 8 19 4 2 5 8
26 2 0 0 107 29 15 10 360 1 2 2 6	26 0 0 157 0 0 0 360 3 2 3 7	26 0 1 159 0 0 0 0 360 1 1 6 8
26 0 0 150 15 8 5 360 2 2 2 6	26 0 0 252 0 13 9 6 360 4 1 2 7	26 8 0 0 29 0 0 0 360 2 2 6 8
26 0 0 193 0 15 11 7 360 3 1 2 6	26 0 8 0 0 18 13 8 16 1 1 5 7	26 0 3 12 0 0 0 0 360 3 1 6 8
26 0 1 240 0 11 8 5 360 4 1 2 6	26 8 0 0 0 18 14 8 14 2 2 5 7	26 1 0 0 0 0 0 0 0 360 4 2 6 8
26 3 0 0 147 12 7 4 360 1 2 2 6	26 0 8 0 0 18 13 8 16 3 1 5 7	26 6 0 0 0 18 0 0 0 360 1 2 6 8
26 0 0 213 0 22 16 10 360 2 1 2 6	26 8 0 0 0 18 14 8 19 4 2 5 7	26 0 9 17 0 0 0 0 360 2 1 6 8
26 0 0 184 15 8 5 360 3 2 2 6	26 2 0 369 0 0 0 0 360 1 1 6 7	26 0 0 0 0 0 0 0 0 360 3 2 6 8
26 0 0 156 26 15 9 360 4 2 2 6	26 3 0 0 81 0 0 0 360 2 2 6 7	26 0 0 0 0 0 0 0 0 360 4 1 6 8
26 0 0 132 29 16 10 360 1 1 2 6	26 0 3 109 0 0 0 360 3 1 6 7	26 0 2 81 0 0 0 0 360 1 1 6 8

26 1 0 0 2 0 0 0 360 2 2 6 8
26 0 0 0 0 0 0 0 360 3 1 6 8
26 0 0 0 0 0 0 0 360 4 2 6 8
26 1 0 0 55 0 0 0 360 1 2 6 8
26 0 1 10 0 0 0 0 360 2 1 6 8
26 1 0 0 0 0 0 0 360 3 2 6 8
26 0 0 1 0 0 0 0 360 4 1 6 8
26 0 5 0 0 0 0 0 360 1 1 6 8
26 0 0 0 0 0 0 0 360 2 2 6 8
26 0 0 0 0 0 0 0 360 3 1 6 8
26 0 0 0 0 0 0 0 360 4 2 6 8
26 1 0 0 0 0 0 0 360 1 2 6 8
26 0 1 0 0 0 0 0 360 2 1 6 8
26 0 0 0 0 0 0 0 360 3 2 6 8
26 0 0 0 0 0 0 0 360 4 1 6 8
26 0 1 0 0 0 0 0 360 1 1 6 8
26 0 0 0 0 0 0 0 360 2 2 6 8
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26 0 0 0 0 0 0 0 360 3 2 6 8
26 0 0 0 0 0 0 0 360 4 1 6 8
26 0 0 0 84 29 16 10 360 1 2 2 9
26 0 0 271 0 11 8 5 360 2 1 2 9
26 0 0 0 135 26 14 9 360 3 2 2 9
26 0 0 275 0 20 14 9 360 4 1 2 9
26 0 2 185 0 13 10 6 360 1 1 2 9
26 0 0 0 123 12 6 4 360 2 2 2 9
26 0 0 255 0 9 6 4 360 3 1 2 9
26 0 0 0 131 29 15 10 360 4 2 2 9
26 0 0 0 61 15 8 5 360 1 2 2 9
26 0 0 0 126 23 12 8 360 2 2 2 9
26 0 0 199 0 29 20 13 360 3 1 2 9
26 0 0 245 0 15 11 7 360 4 1 2 9
26 0 1 237 0 18 13 8 360 1 1 2 9
26 0 0 308 0 18 13 8 360 2 1 2 9
26 0 0 0 122 35 19 12 360 3 2 2 9
26 0 0 0 138 15 8 5 360 4 2 2 9
26 4 0 0 97 29 15 10 360 1 2 2 9
26 0 0 0 152 17 9 6 360 2 2 2 9
26 0 0 221 0 24 18 11 360 3 1 2 9
26 0 0 226 0 22 16 10 360 4 1 2 9
26 1 0 0 86 17 9 6 360 1 2 2 9
26 0 0 210 0 13 10 6 360 2 1 2 9
26 0 0 244 0 18 12 8 360 3 1 2 9
26 0 0 0 132 20 11 7 360 4 2 2 9
26 0 2 228 0 24 17 11 360 1 1 2 9
26 0 0 0 134 17 9 6 360 2 2 2 9
26 0 0 250 0 20 14 9 360 3 1 2 9
26 0 0 0 134 17 10 6 360 4 2 2 9
26 0 0 0 80 44 25 15 360 1 2 2 9
26 0 0 257 0 15 11 7 360 2 1 2 9
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26 0 0 215 0 15 11 7 360 4 1 2 9
26 0 1 184 0 15 11 7 360 1 1 2 9
26 0 0 245 0 13 9 6 360 2 1 2 9
26 0 0 0 104 17 10 6 360 3 2 2 9
26 0 0 0 123 32 19 11 360 4 2 2 9
26 5 0 0 141 17 9 6 360 1 2 2 9
26 0 0 221 0 20 14 9 360 2 1 2 9
26 0 0 0 110 20 11 7 360 3 2 2 9
26 0 0 0 113 23 13 8 360 4 2 2 9
26 0 0 0 113 23 14 8 360 1 2 2 9
26 0 0 0 146 32 20 11 360 2 2 2 9
26 0 0 241 0 31 22 14 360 3 1 2 9
26 0 0 229 0 15 11 7 360 4 1 2 9
26 0 1 244 0 20 14 9 360 1 1 2 9
26 0 0 303 0 9 6 4 360 2 1 2 9
26 0 0 0 69 0 0 0 180 3 2 3 9
26 0 0 250 0 11 8 5 360 4 1 2 9
26 0 8 0 0 18 12 8 17 1 1 5 9
26 8 0 0 0 18 14 8 27 2 2 5 9
26 0 8 0 0 18 11 8 31 3 1 5 9
26 8 0 0 0 18 14 8 27 4 2 5 9
26 0 10 128 0 0 0 0 360 1 1 6 9
26 2 0 0 0 59 0 0 0 360 2 2 6 9
26 0 0 4 0 0 0 0 360 3 1 6 9
26 0 0 0 0 0 0 0 360 4 2 6 9
26 2 0 0 0 54 0 0 0 360 1 2 6 9
26 0 4 56 0 0 0 0 360 2 1 6 9
26 1 0 0 0 6 0 0 0 360 3 2 6 9
26 0 0 0 0 0 0 0 360 4 1 6 9
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26 1 0 0 0 5 0 0 0 360 2 2 6 9
26 0 0 0 0 0 0 0 360 3 1 6 9
26 2 0 0 0 0 0 0 0 360 4 2 6 9
26 1 0 0 8 0 0 0 0 360 1 2 6 9
26 0 1 0 0 0 0 0 360 2 1 6 9
26 0 0 0 0 0 0 0 360 3 2 6 9
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26 0 0 0 7 0 0 0 360 2 2 6 9
26 0 0 0 0 0 0 0 360 3 1 6 9

26 0 0 0 0 0 0 0 360 4 2 6 9
26 3 0 0 0 0 0 0 360 1 2 6 9
26 0 1 0 0 0 0 0 360 2 1 6 9
26 0 0 0 0 0 0 0 360 3 2 6 9
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26 0 0 0 0 0 0 0 360 4 1 6 9
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26 0 0 285 0 13 9 6 360 2 1 2 10
26 0 0 0 102 15 9 5 360 3 2 2 10
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26 0 0 0 137 20 12 7 360 4 2 2 10
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26 2 0 0 84 0 0 0 360 2 2 6 10
26 0 0 113 0 0 0 0 360 3 1 6 10
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26 0 0 15 0 0 0 360 2 1 6 10
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26 1 0 0 2 0 0 0 360 1 2 6 10

26 0 0 0 0 0 0 0 360 2 1 6 10
26 1 0 0 0 0 0 0 360 3 2 6 10
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26 0 0 0 0 0 0 0 360 3 1 6 10
26 0 0 0 0 0 0 0 360 4 2 6 10
26 1 0 0 4 0 0 0 360 1 2 6 10
26 0 0 3 0 0 0 0 360 2 1 6 10
26 0 0 0 0 0 0 0 360 3 2 6 10
26 0 0 0 0 0 0 0 360 4 1 6 10

Appendix C

Appendix C shows the data from Phases 2, 4, and 5 of Experiment 4 for all subjects and conditions. Response rate per session was calculated by dividing the total responses during the occurrences of a component by the total occurrence time of this component in each session exclusive of magazine-operation time.

Abbreviation													Explanation																									
H													Hen number																									
L													Left-key pecks																									
R													Right-key pecks																									
B													Head bobs																									
D													Door pushes																									
O													Magazine-operation time (s)																									
A													Magazine-access time (s)																									
F													Magazine operations																									
T													Time (s, excluding magazine-operation time)																									
N													Component number, four components per session																									
S													Stimulus condition, 1 = Red 2 = Green																									
P													Phase																									
C													Condition number																									
H	L	R	B	D	O	A	F	T	N	S	P	C	81	0	0	0	0	0	0	0	600	4	2	5	1	81	293	0	0	0	19	14	8	291	4	2	4	2
81	0	4	19	1	19	10	7	183	1	1	2	1	81	6	0	0	1	0	0	0	600	1	2	5	1	81	473	0	0	0	17	12	7	600	1	2	4	2
81	0	0	5	23	21	8	7	144	2	2	2	1	81	0	34	0	0	0	0	0	600	2	1	5	1	81	0	418	0	0	19	13	8	476	2	1	4	2
81	0	0	33	2	19	11	7	118	3	1	2	1	81	0	0	0	1	0	0	0	600	3	2	5	1	81	266	0	0	0	19	14	8	238	3	2	4	2
81	0	0	12	51	21	8	7	277	4	2	2	1	81	0	0	0	0	0	0	0	600	4	1	5	1	81	0	542	0	0	19	13	8	517	4	1	4	2
81	0	0	0	18	21	10	7	65	1	2	2	1	81	0	6	5	0	0	0	0	600	1	1	5	1	81	0	275	0	0	0	0	0	600	1	1	5	2
81	0	0	9	2	19	13	7	110	2	1	2	1	81	6	0	0	0	0	0	0	600	2	2	5	1	81	568	0	0	0	0	0	0	600	2	2	5	2
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81	0	0	50	0	19	12	7	196	4	1	2	1	81	0	0	0	0	0	0	0	600	4	2	5	1	81	580	0	0	0	0	0	0	600	4	2	5	2
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26 8 0 0 0 20 16 8 9 3 2 4 2	26 0 0 224 0 14 9 7 360 3 1 2 3	26 0 2 0 0 0 0 0 360 3 1 5 3
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