

Running Head: BETTA SPLENDENS ON FIXED-RATIO WITH MIRROR  
PRESENTATION REINFORCEMENT

Fixed-Ratio Performance of  
Siamese Fighting Fish (Betta splendens)  
with Mirror Presentation as the Reinforcer

by Dorothy Chitty

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**Fixed-Ratio Performance of Siamese Fighting Fish (Betta splendens)  
with Mirror Presentation as the Reinforcer**

**BY**

**Dorothy Chitty**

**A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University  
of Manitoba in partial fulfillment of the requirements of the degree**

**of**

**DOCTOR OF PHILOSOPHY**

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**Abstract**

Fixed-ratio (FR) schedule effects on the responding of four Betta splendens, including the postreinforcement pause (PRP) and the partial-reinforcement-extinction effect (PREE) were examined with mirror presentation as the reinforcer. A computer-tracking system provided a continuous record of the three-dimensional location of the fish within the aquarium. The distance of location for responding in relation to the location of the mirror reinforcer was manipulated to determine its effect on responding across incremental FR schedules. Results of fish reinforced for swimming into a far location showed a small but consistent increase in responding to ratio increases, and increased resistance to extinction to higher ratios. Results of fish reinforced for swimming into the near location were suggestive of increased responding with ratio increases and provided preliminary evidence of a PREE. There were indications that other variables need to be brought under control when a mirror reinforcer is used with Betta splendens. Increase in activity elicited by the mirror reinforcer appeared to have obscured the effect of the ratio change for fish reinforced for swimming into the near location. Results found for fish reinforced for swimming into a near location were consistent with previous FR research with this species when a mirror reinforcer was used. Results found for fish reinforced for swimming into a far location were consistent with previous FR research when a food reinforcer was used. The increased resistance to extinction found with the far location appeared to be the result of delay in reinforcement caused by swimming the longer distance to the reinforcer location. Overall, these results indicate that past research on schedules of reinforcement with food appear to generalize to mirror presentation reinforcers when procedural parameters are manipulated to bring about schedule control with Betta splendens.

Fixed-Ratio Performance of Siamese Fighting Fish (Betta splendens)  
with Mirror Presentation as the Reinforcer

The generality of research on schedules of reinforcement has been questioned because of the limited number of species studied and because of its reliance on food and water as reinforcers (Hogan & Roper, 1978; Shettleworth, 1972). Hogan, Kleist, and Hutchings (1970) found that Siamese fighting fish (Betta splendens) behave like other species on fixed ratio (FR) schedules when food is used as the reinforcer, whereas they behave differently when a reinforcer that elicits aggressive-display behaviour is used (i.e., mirror presentation). Findings such as these have been cited as evidence that there are limits to the generality of the effects of reinforcement including limits on learning across species and reinforcer types (Hogan & Roper, 1978; Shettleworth, 1972).

The failure to replicate an effect predicted by the principles of reinforcement with an aggressive-display eliciting reinforcer for the Betta splendens species casts doubt on those principles. The principles of reinforcement are assumed to predict behaviour for any event that meets the criteria of a reinforcer (O'Donohue & Krasner, 1988). Assuming that the finding of a counter instance refutes a scientific theory (Kourany, 1998), then the principles of reinforcement have been shown to be false (i.e., nongeneral) by Hogan et al.'s research.

However, Sidman (1960) argues that a failure to replicate may be an instance of incomplete understanding of the controlling variables rather than a

nongeneral theory. Trying to get a better understanding of the controlling variables, he claims, is the only adequate way to evaluate generality. He states that most experimenters are cautious about claiming that an effect is “real” and that the same caution should be held when an effect failed to occur. This latter argument has been supported in the philosophy of science (Kourany, 1998; O’Donohue & Krasner, 1988). As well, Shettleworth’s (1972) review of the research on reinforcement stressed that there is a need for more systematic research on unconventional reinforcers (i.e., other than food and water) and their effects on a species before concluding that new principles need to be derived. Thus, gaining a better understanding of findings such as Hogan et al.’s in the study of Betta splendens seems to be a necessary part of the ongoing evaluation of the generality of reinforcement effects.

Betta splendens (Bettas) are a domesticated fish known for their aggressive display. The males of this species engage in aggressive display in the presence of another male, a model or film of another male, or a mirror. Components of the aggressive display include: extending the gill covers forward; releasing the branchiostegal membrane to hang just below the gills; and spreading the dorsal, caudal, and ventral fins (Simpson, 1968). Studies of the learned behaviours of Bettas have included those of habituation (Baenninger, 1966), classical conditioning (Thompson, 1969), and operant conditioning (Goldstein, 1967; Thompson, 1963; Thompson & Sturm, 1965).

In the context of operant conditioning, the behaviour of male Bettas has been studied under fixed-ratio (FR) schedules of reinforcement. These are

schedules in which every  $n$ th response is followed by a reinforcer (Ferster & Skinner, 1957). Thompson (1969) was the first to demonstrate that these fish could maintain responding on FR schedules though he found that the maximum ratio was quite low relative to that for other species.

In Hogan , Kleist, and Hutchings' (1970) study, male Betta splendens were reinforced for swimming through a tunnel on schedules of FR 1 through to FR 6. In the first experiment of the study of these fish, the operant behaviour of swimming through the tunnel was followed immediately by a 20-s mirror presentation. In a second experiment with a new group of fish, swimming through the tunnel was followed immediately by the delivery of food. During 12-hour sessions, Hogan et al. measured the mean frequency of responding per schedule from all eight fish. The means remained constant as the ratio increased for the group of fish with mirror-presentation reinforcement; whereas, the means increased as the ratio increased for the group of fish with food reinforcement.

These results found for the food reinforcer were in line with what Hogan et al. expected based on what they describe as “typical” findings with other species; whereas the results found for the mirror presentation were not what they expected because they were different from the findings with other species. They concluded that the mirror-presentation reinforcer and the food reinforcer “may depend on different mechanisms for their effects” (p. 356). They did not define or expand on this idea of different mechanisms.

Hogan et al.'s findings for the effects of an aggressive-display eliciting reinforcer on responding are supported by results of Turnbough and Lloyd

(1973). They exposed Bettas to FR 1, FR 2, and return to FR 1 as a part of a longer sequence of reinforcement schedules. The operant response of swimming into the upper or lower portion of an E-shaped chamber was reinforced with a 10-s film segment of a red male Betta. The median number of responses per session showed no consistent change as the ratio size changed. This study was limited in the ratio values examined; however, their results were similar Hogan et al.'s study when an aggressive-display eliciting reinforcer was used.

At least three issues arise when considering Hogan et al.'s findings in terms of generality of past research on the effects of reinforcement on responding. The first issue involves generalization across species. Most research on schedules of reinforcement have been conducted on pigeons and rats (Shettleworth, 1972). Studying effects that are relatively consistent for rats and pigeons is recommended before attempting to replicate with a new species (Madden, Chase & Joyce, 1998; Sidman, 1960). As will be argued later, Hogan et al. did not study an effect that has been consistently replicated with rats and pigeons.

The second issue arising from Hogan et al.'s study concerns the generality of different types of reinforcement effects. Hogan et al. examined a specific schedule effect: the increase in overall response as FR schedules increase. The change in overall response is only one of several parameters that can indicate a reinforcement effect. It would be interesting to know if other effects found with increasing the values of FR schedules for other species occur for Betta splendens, such as the lengthening of the post-reinforcement pause

(PRP), changes in patterns of with-in session responding, and the partial-reinforcement-extinction effect (PREE).

The third issue is the generality of reinforcer types. Hogan et al. found between-subject differences in responding across reinforcer types for Betta splendens. They conclude that the different effect of mirror presentation as compared to food as the reinforcer suggests a different mechanism. This implies that there are unique effects of this type of reinforcer with this species. Sidman (1960) however, argues that we should determine whether there is a need for better experimental control before interpreting findings of differences as having theoretical significance. Sidman (1960) defined experimental control as “the investigator’s ability to manipulate an individual subject’s behaviour in a precise and reliable fashion” (p. 342). Thus, different parameters of this reinforcer need to be examined to determine if these fish can be brought under the control of the FR schedule (i.e., schedule control) using mirror presentations as the reinforcer before assuming its effects are unique.

### **Across-Species Comparison**

Hogan et al. discussed their findings with Betta splendens in comparison with “typical” findings for other species. Madden, Chase, and Joyce (1998), in their discussion of across-species comparison of human operant behaviour, object to the term “typical” as a reference to the behaviour of other species. They find this term does not accurately reflect research findings on schedules of reinforcement as the findings are not always consistent within subjects or between subjects, let alone between species.

Hogan et al. studied the effect of FR size on overall response rate with Bettas. Research with other species (i.e., rats and pigeons) has produced inconsistent findings on the relationship of overall response rate to ratio size (Crossman, Bonem & Phelps, 1987). Overall response rate refers to the average number of responses per unit of time for one session (Ferster & Skinner, 1957). When FR size increases, researchers have found that overall response rate either increases (Boren, 1961), shows no consistent effect (Felton & Lyon, 1966; Powell, 1968), or increases and then decreases beyond a certain ratio (Barofsky & Hurwitz, 1968; Crossman et al., 1987). Thus, the effect of FR schedules on overall responding may not be a valid criterion of interspecies generality.

Few studies of the effect of FR schedules on overall response rate have been conducted on fish. One study by Rozin and Mayer (1964) indicated that goldfish, reinforced with food, do increase overall response rate as the ratio is increased. Hogan et al. (1970) were able to experimentally control the overall responding of Bettas to FR schedules with food but not with mirror presentations as the reinforcer.

Considering the sparse literature on the effect of FR schedules on the performance of fish, it seems appropriate that the analysis of FR schedules be further extended to the species of Betta splendens. However, the general inconsistency of the FR schedule effect on overall responding in pigeons and rats suggests that we need to look at other reinforcement effects when carrying out across-species comparisons.

### **Other FR Schedule Effects**

The only schedule effect, other than that of the change in overall response rate to ratio changes, demonstrated with Betta splendens involves the differential-reinforcement-of-other-behaviour (DRO) schedule. Turnbough and Lloyd (1973) used a DRO procedure with Bettas for the operant of swimming into a chamber. They defined the DRO schedule as the presentation of a reinforcer after a fixed period of time elapsed since the last response. (Procedurally, though, it appears that they provided reinforcement after a fixed period of either no responding or since the last response; from their results, it can be seen that the number of reinforcements obtained was higher than the number of responses.) They exposed male Bettas in a within-subjects design to conditions of FR 1, FR 2, DRO (100 s) and extinction using an aggressive-display eliciting reinforcer (i.e., a film of a male Betta). Similar to Hogan et al.'s results (1970), they found no consistent change in responding when comparing FR 1 and FR 2 conditions. However, they were able to demonstrate a consistent finding across all fish of a decrease in responding under the DRO schedule. They conclude from their results that they were able to demonstrate a schedule effect of reinforcement with DRO that had not been possible with FR using an aggressive-display-eliciting reinforcer. They suggest that it was possible to demonstrate the control of the contingencies using the DRO schedule because it eliminates the possibility of a response being paired with the reinforcer (and therefore eliminates the general activity elicited by the reinforcing stimulus); and at the same time the frequency of reinforcement per session can be held constant with prior experimental conditions.

Lattal and Metzger (1994) were also able to demonstrate control of responding with a DRO procedure using male Bettas when the reinforcer was an aggressive-display eliciting reinforcer (i.e., mirror presentations). Their procedure for DRO, which differed from Turnbough and Lloyd (1973), was to provide reinforcement for every response but after a delay. Using a between-subjects design, fish were exposed either to an FR 1 condition or to a tandem FR 1-DRO schedule of two different delay conditions (10 s or 25 s). They found that responding was highest in the FR 1 condition followed by the tandem FR 1-DRO 10s delay condition whereas there was no consistent change in responding for the 25s delay condition relative to baseline levels. This demonstrated control for both the FR 1 and the tandem FR 1-DRO 10-s conditions.

Further, they exposed a third group to a variable-time (VT) 147-s schedule, then to a tandem FR 1-DRO 10-s schedule, and finally to a second VT 147-s schedule. The VT schedule involved response-independent mirror presentations at the group mean rate of reinforcement found with fish exposed to the 10-s delay. Overall, they found more consistent changes in responding when reinforcement was dependent on responding (FR and/or DRO schedules) regardless of the delay than when reinforcement was independent of responding (VT schedule). Comparing the response-dependent conditions, they found that responding was more frequent when the delay was shorter (i.e., responding was greater for no delay than for the 10-s delay, and greater for the 10-s than for the 25-s delay).

This evidence of experimental control found with the DRO schedule for Bettas suggests that other schedule effects may be possible. A schedule effect that occurs for other species in response to FR schedules involves the post-reinforcement pause (PRP). A PRP is a period of no responding that occurs after the delivery of the reinforcer. The duration of the PRP has been found to increase as the ratio size was increased for rats and pigeons reinforced with food (Felton & Lyon, 1966; Ferster & Skinner, 1957; Powell, 1968). Thus, the PRP of Bettas should be studied as to whether it varies with the FR requirement, as it does with rats and pigeons.

There have been instances of FR research in species, other than rats and pigeons, where no change in overall response rate was found as the ratio was changed but changes did occur with the PRP. Roper (1973) found with mice that there was no change in overall responding as the FR size increased when nesting material was used as the reinforcer. However, he found that the PRPs increased in duration as the ratio was increased. Hogan et al. (1970) and Turnbough and Lloyd (1973) did not measure the PRP of the Bettas in their studies. It seems logical to examine the PRP to see if the effect that occurred for mice can occur for Bettas, since the Bettas also showed no change in overall rate of responding as the ratio was increased in previous research. Thus, the effect of change in FR size on the PRP needs to be determined before it can be concluded that FR schedules do not control responding in Bettas.

An interesting schedule effect found with rats and pigeons is the resistance of responding to extinction after intermittent reinforcement schedules.

It takes longer for responding to be extinguished after intermittent than after continuous reinforcement schedules (CRF) (Boren, 1961). This partial-reinforcement-extinction effect (PREE) can be interpreted as a demonstration of experimental control of intermittent reinforcement schedules over responding. The PREE has been demonstrated with a variety of species (Table 1) including rats (Boren, 1961; Perkins and Cacioppo, 1950) bees (Grossmann, 1973) and different species of fish (Goldstein & Hall, 1990; Gonzalez, Eskin & Bitterman, 1962, 1963; Gonzalez & Bitterman, 1967).

Although the PREE has been demonstrated in other species of fish conditioned with food, such as the Archer fish, Toxotes jaculator (Goldstein & Hall, 1990), African mouth breeder, Tilapia macrocephala (Gonzalez et al., 1962), and the Goldfish, Carassius auratus (Wertheim & Singer, 1964), it has not been tested in Bettas. Extinction, however, has been demonstrated with Bettas: after conditioning on a CRF schedule, responding decreased when it was no longer followed by the reinforcer (Goldstein, 1967; Hogan et al., 1970; Hogan, 1967). Thus, one means of determining experimental control of the Betta to intermittent schedules is to demonstrate a PREE after conditioning on an FR schedule.

Table 1

Past research on the Partial-reinforcement-extinction effect (PREE) with different species, schedules, and procedures when food was the reinforcer.

Researcher	Species	Schedule type	Response measured	Procedure			
				Discrete trials	Free operant	Between-subject	Within-subject
Boren (1961)	Rats	FR	Mean overall response rate of group		X		X
Perkins & Cacioppo (1950)	Rats	100% vs.50%	Mean overall of group	X			X
Grossmann (1973)	Bees	FR	Overall		X	X	
Goldstein & Hall (1990)	Archer Fish	VR	Overall		X		X
Gonzalez, Eskin & Bitterman (1962)	African Mouth-breeder fish	Expt 1: VI, FI & CRF	Overall		X	X	
		Expt 2: 100% vs 50%	Overall	X		X	
Gonzalez, Eskin, & Bitterman (1963) Expt. 2	African Mouth-breeder fish	Extended	Latency of response	X		X	
Gonzalez & Bitterman (1967) Expt 1	Goldfish	100% or 50%, FR 1 or 5	Overall	X		X	
Wertheim & Singer (1964)	Goldfish	CRF, VI	Overall		X	X	

Note: **100 %** refers to each trial having the potential for correct responding to be reinforced; **50%** refers to each trial having only half of the overall # of trials having the potential for correct responding to be reinforced. **Extended** refers to progressively longer runs of unreinforced trials.

The PREE also can be examined from the differences in within-session patterns of responding during extinction after CRF as compared to after FR schedules, which has been studied in pigeons. Responding during the extinction phase, after conditioning on a CRF schedule, begins at a higher rate than the terminal rate of the conditioning phase, and then continues but alternates between high and low rates. Responding during the extinction phase after an FR schedule begins with a high rate of responding and alternates with periods of no responding; the periods of no responding become longer and longer as the session progresses (Ferster & Skinner, 1957).

This is not a well-studied effect with species other than pigeons. However, an examination of within-session patterns of responding in conjunction with across-session patterns with Bettas during extinction allows a further comparison with the pigeon, a well-studied species under conditions of reinforcement schedules (Ferster & Skinner, 1957).

To further our understanding of Bettas and their response to FR schedules, it would seem appropriate to examine a number of FR schedule effects as well as the effect of FR schedule changes on overall response rate. As indicated, these other schedule effects would be seen by noting whether changes in the PRP occur as the ratio increases, and by noting whether there is a PREE, and finally by measuring both overall response rate and within-session patterns of responding during the extinction phases. The PREE makes a broad discrimination between the effects of intermittent (FR) and continuous reinforcement (CRF) schedules on responding. Measuring the PRP and overall

response rate, on the other hand, allows for the finer discrimination of the effects of making changes within the intermittent schedule type (i.e., increasing the FR value).

### **The Effect of the Type of Reinforcer**

The apparent lack of experimental control of the responding of Bettas with FR schedule of the mirror presentation could result from the use of a nonfood reinforcer. The reinforcers typically used in research on schedules of reinforcement are food and water (Ferster & Skinner, 1957; Hogan & Roper, 1978). Stimuli that have been used to elicit aggressive display in Bettas (another male Betta, a model of a male Betta, and mirror presentations) have been shown to be reinforcers: responding on CRF schedules increased from baseline levels when followed by these stimuli and thus, it can be concluded that they are positive reinforcers for Bettas (Bols & Hogan, 1979; Goldstein, 1967).

Hogan et al. (1970) compared two types of reinforcers, mirror presentations and food, and the effect of fixed-ratio schedules on the swimming of Bettas through a short tunnel. They were able to obtain experimental control over the overall responding of Bettas to FR schedules with food (i.e., mean overall responding increased as the FR schedule increased), but not with mirror presentations (i.e., mean overall responding remained constant as the ratio size increased).

Hogan et al. (1970) hypothesized from these results that, for Bettas, display-eliciting reinforcers operate on a different motivational system than that of food reinforcers. The proposition was that different patterns of responding are

representative of a different underlying mechanism (Shettleworth, 1972) likely due to the “nature” of the reinforcer (Hogan et al., 1970). They found across-species generality when food was used as the reinforcer, so the different pattern of responding to changes in FR schedules when mirror presentations were used was suggested to indicate at least two different motivational systems for this species. In effect, Hogan et al. appear to be suggesting that there are different principles for nonfood reinforcers than for food reinforcers.

This argument assumes that food consistently affects responding; however, qualitative and quantitative differences within this reinforcer category have been found (Hogan & Roper, 1978). There is research to suggest that a number of variables impact on the effectiveness of food as a reinforcer such as level of deprivation, food type and food quantity (Hogan & Roper, 1978).

For example, Ashe and Chiszar (1976) studied qualitative changes in food reinforcement with sunfish (Lepomis gibbosus). Previous research had found no change in responding of sunfish to changes in quantity of food which was different than results found for other species. This led Ashe and Chiszar to compare two different kinds of food rather than quantity. They found that sunfish responded more quickly in a discrete trial procedure for mealworms than for food pellets. Thus, they were able to bring about a change of responding when a parameter they called “quality” of food reinforcement was varied.

Their research suggests that there may be numerous parameters of any type of reinforcer that need to be examined before concluding theoretical differences across species based on their response to a type of reinforcer. Thus,

another question regarding the Betta is whether parameters of an aggressive-display eliciting reinforcer can be manipulated to bring about FR schedule effects.

Some research has been conducted on specific parameters of aggressive-display eliciting reinforcers to determine their effect on the operant behaviour of male Bettas maintained by CRF but not by FR schedules. Thompson (1963) examined the reinforcing effects of three visual stimuli capable of eliciting aggressive display in Bettas. When responding was compared across CRF schedule sessions, the highest rates of responding were maintained by mirror presentations, intermediate rates by a moving model of a displaying male Betta, and low rates by the same model in a stationary position.

Thompson and Sturm (1965) compared the effect of different coloured models of male Bettas on responding of male Bettas on CRF schedules. They found that a Betta was most likely to respond at the highest rate to models most dissimilar to its own colouring. These findings of the effect of dissimilar coloured models bringing about greater responding appear to contradict Thompson's earlier finding (1963) that mirror presentations maintain the highest responding (i.e., the mirror image would be the same colour as the fish). However, they attributed the greater response rate maintained by the mirror presentations as being due to the complexity of the mirror image versus that of the models. Thus, it would seem wise at this stage in the study of Betta performance on FR schedules with aggressive-display eliciting reinforcers, to use the stimulus that maintains the highest responding, the mirror presentations.

Hogan et al. (1970) investigated the effects of varying the duration of mirror presentation. Bettas on CRF schedules were exposed to mirror reinforcement durations of 5 s, 10 s, and 40 s. There were no systematic changes in responding across these conditions. Overall, the implications of the research on aggressive-display eliciting reinforcers are that mirror presentations maintain more responding than models; and that changes in the duration of mirror presentation have no effect on responding.

Thus, it would seem appropriate in the evaluation of the generality of aggressive-display eliciting reinforcers, to continue research using the stronger stimulus of mirror presentations. Further, even though duration does not appear to be an important variable, in attempting to better understand Hogan et al.'s (1970) findings of this type of reinforcer on FR responding, it seems appropriate to use 20-s mirror presentations as they did.

Parameters of an unconventional reinforcer have been manipulated to obtain experimental control. Roper (1973) observed that mice responded at an overall lower rate when responding was reinforced with nesting material than would be expected if responding had been reinforced with food. He suggested that if the initial overall response rate could be increased, the FR performance normally found with food might be found with nest material. He proposed that by moving the operandum closer to the reinforcer dispenser, a higher rate of responding might occur, making it possible to study FR performance under these conditions.

Roper (1975) in Experiment 1 positioned the operandum 3.5 cm from the reinforcer dispenser in contrast to the 6-cm position used in the 1973 study. With this closer positioning of the operandum relative to the reinforcer dispenser, Roper found that not only did the overall response rate increase relative to results he had found previously (Roper, 1973) but also an increase in response rate occurred as the FR size was increased.

To verify that it was the distance between operandum and reinforcer dispenser that controlled the rate of responding, Roper (1975) in Experiment 2 compared the two operanda locations using a within-subject design. Roper tested the mice under four conditions: the key (operandum) was located at a distance of 3.5 cm (similar to Experiment 1) or 6 cm (similar to the 1973 study) from the reinforcer dispenser with noncontingent reinforcement or a CRF schedule for delivery of nest material; thus, each mouse was tested under contingent and noncontingent conditions for each key location. When reinforcement was noncontingent, responding was low for both operanda. However, when reinforcement was contingent, responding occurred at a higher rate for the 3.5-cm than for the 6-cm operandum. Roper concluded that operant-reinforcer distance is a critical variable when nesting material is used as the reinforcer.

In Experiment 3 (Roper, 1975) the operant-reinforcer distance was manipulated using food as the reinforcer. Changes in operant-reinforcer distance had no effect on FR performance when food deprivation was high; the response rate of the mice increased as the ratio increased regardless of operandum location. Changes in operant-reinforcer dispenser distance were more evident

when deprivation was low. The overall response rate of the mice increased as the ratio increased when the operandum was located 3.5 cm from the dispenser.

Overall response rate was slightly less when the operandum was located 6 cm from the dispenser but there was still an increase in responding as the ratio increased (though, not enough to maintain the rate of reinforcement received on the previous ratio). An even more substantial decline in overall response rate occurred when the operandum was 8.5 cm from the reinforcer dispenser than for the 6-cm operandum location. The overall response rate did not increase as the ratio increased when the 8.5-cm operandum was used.

The results of Experiment 3 indicate that the location of the operandum relative to the reinforcer dispenser affects performance on FR schedules for food reinforcement when deprivation is low. Thus, the effect on responding found with nest-building material when the relative distance between operandum and reinforcer dispenser is manipulated only occurs for a food reinforcer when food deprivation is low.

Hogan et al.'s (1970) results are similar to those of Roper (1973) in that responding was lower to the unconventional reinforcer than to food (i.e., Bettas responded at a lower rate when mirror presentations were the reinforcer than when food was the reinforcer). Roper's research suggests that a close location of operandum to the location of the mirror presentations could result not only in an increase in overall rate of responding but also in changes in the overall response rate of the Betta when FR size is increased. Thus, the manipulation of the

distance of operandum relative to mirror presentations may result in experimental control of the behaviour of Bettas under FR schedule conditions.

Unlike Hogan et al.'s (1970) conclusions about mirror presentations being different in "nature", Roper (1975) claimed to have demonstrated, with the three experiments of his study, that the unconventional reinforcer of nest building is not qualitatively different than food. Rather that nest-building material is a weak reinforcer, since the effects on responding of mice for food at low deprivation levels are similar to the effects of nest-building material. However, a more conservative conclusion is that both food at low deprivation levels and nest-building material are similar in that they require further procedural manipulations to demonstrate control over behaviour than needs to occur for food at high deprivation levels. Thus, it is not a question of a continuum of reinforcer strength but of procedural control. This conclusion has more scientific relevance, as it requires the experimenter to determine what methods were required to bring about schedule control rather than to speculate on the inherent qualities of a reinforcer.

The present study was designed to answer two outstanding issues raised about FR schedule effects on the responding of Bettas as a result of the research by Hogan et al. (1970). The first issue is that the effects of changes in FR size on overall response rate were inconsistent across species; and thus, examining only this effect on the responding of Bettas is inconclusive in refuting the generality of the principles of reinforcement. Other FR schedule effects need to be studied using aggressive-display eliciting reinforcement with Betta splendens because

these effects have been found to be more consistent across species. In the present study the PRP was measured as well as the overall response rate across increasing FR schedules of reinforcement. The PREE was also examined by comparing responding during extinction after a CRF schedule to responding during extinction after an FR 6 schedule.

The second issue is that of obtaining experimental control by varying a specific parameter of the procedure using the unconventional reinforcer of mirror presentation. Following Roper's research cited above, the effect of varying the parameter of distance between the location of the response and the reinforcer was investigated. The present experiment was intended to augment current research on unconventional reinforcers and their effects on a species by extending the analysis of the FR schedule of reinforcement with Betta splendens with an aggressive-display-eliciting reinforcer. In a broader aim, the purpose of this experiment was to further explore reinforcement effects to obtain a more complete understanding of the controlling variables and to evaluate the generality of the principles of reinforcement.

## **Method**

### **Subjects**

Four experimentally naive male Betta splendens 4 to 5 cm in length, and dark in colour (blue and red hues) were obtained from a local pet store. Each fish was selected based on whether it engaged in aggressive display when in the presence of a mirror. The fish were housed individually in a row of 5-L tanks (home tank). Solid barriers, the length of the long tank wall, were positioned

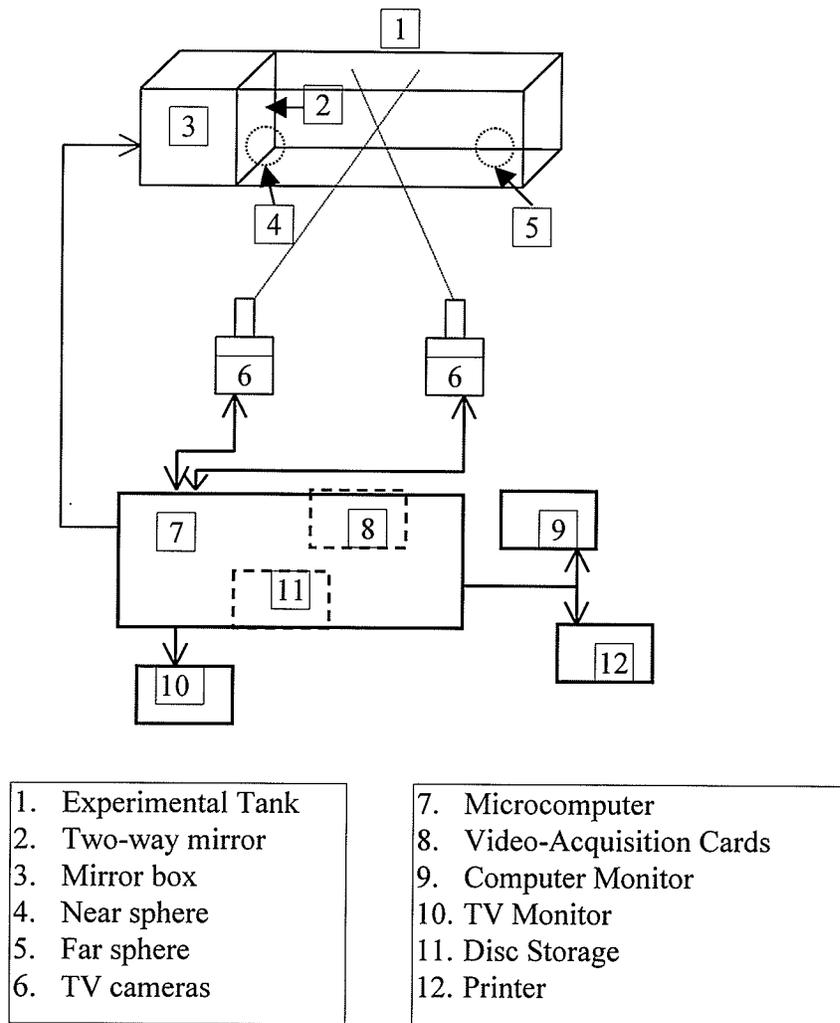
between each home tank to visually isolate the fish from each other; the front and back walls were not covered. Each home tank contained brownish-red gravel on the bottom, plants in small clay pots, and aged tap water (i.e., water drawn from the tap and left in a large container for at least 48 hrs) maintained at a temperature of  $26.7 \pm 1$  °C. The water for each home tank was filtered daily for at least 30 minutes while the fish was absent (i.e., during the experimental session). Each fish was fed freeze-dried red grubs or fish-food flakes (the amount the fish could eat within 5 min) in its home tank once a day at least one hour after an experimental session. The room in which these home tanks were housed was on a cycle of 12 hrs of light followed by 12 hrs of dark.

### **Apparatus**

Fish were transported from a home tank to an experimental tank in a transparent, Plexiglas box (11 x 11 x 11 cm) with an open side on the top. Sessions occurred in an experimental tank (61.2 x 27.3 x 26 cm) filled with aged tap water and covered with a glass sheet to maintain a temperature of  $26.7 \pm 1$  °C. The walls of the experimental tank were transparent. To maintain clean and clear conditions, water was filtered each day outside of experimental sessions and, as well, one third of the water was replaced twice a week. The pH level was tested once every 2 weeks for the first three-month period of the experiment and was found to be in the acceptable pH range of 5.0 to 9.0 (Rnic, 1975). Outside of experimental sessions, a heater maintained the water temperature at  $26.7 \pm 1$  °C which is the temperature at which the Betta is most likely to engage in aggressive display to an aggressive-display eliciting stimulus (Hess, 1952 as cited in

Simpson, 1968). During experimental sessions the heater and thermometer (positioned on the short wall across from where the mirror box was positioned – see Figure 1) were removed from the experimental tank to prevent interference with the computer-tracking system described below. The heater and thermometer were replaced between sessions to maintain the water temperature. The temperature was checked before and after each experimental session. Temperatures taken after an experimental session remained within  $26.7 \pm 1$  °C even though the heater was not available during the session.

Two Panasonic WV-BL200 video cameras were positioned 184 cm from the closer of the two experimental tank longer glass walls. The focal point of the cameras was positioned beyond the tank (i.e., the other side of the tank in relation to the cameras) to give accurate three-dimensional tracking. The cameras were mounted 29.5 cm apart and were angled towards each other at 13.1 degrees relative to their mounting bar, simulating binocular vision (Besko, 1995). They were connected to two video acquisition (VA) cards installed in a 386, 33 MHz IBM compatible personal computer with 4 MB of RAM, a 40-MB hard disk, a VGA card and a monitor. See Figure 1 for a schematic diagram of the setup.



**Figure 1.** Experimental tank, two-way mirror apparatus, and components of the computer-tracking system.

This tracking system recorded the three-dimensional position (i.e., the x, y, and z coordinates) of the darkest object in the experimental tank every 1/10th of a second. Specifically, the system tracked the center of the highest dark row consisting of at least 3 pixels in the image of each camera. Surfaces around the experimental tank were covered with white materials to eliminate any dark areas, other than the fish, that the cameras might record: The surface of the table supporting the experimental tank and the wall behind were covered in white felt material; the camera side of the table from the surface to the floor was covered by a white Bristol-board (81 x 102 cm); a second white Bristol board stood in front of the experimental tank with a cut-out (26 x 56 cm) uncovering the long wall of the tank. This Bristol board hid the wall of a two-way mirror box and other possible shadows from behind the tank. A visual display computer program was used prior to each session to detect any dark spots in the tank or surrounding area that might interfere with the tracking of the fish.

The operant response was determined by the detection of the tracking system of the fish within a 7.5-cm diameter virtual sphere; the operant response was considered completed when the fish was not detected by the tracking system within the 7.5-cm in diameter virtual sphere. The sphere was called a virtual sphere because its location in the experimental tank was programmed into the computer but was not visible to the fish.

A two-way mirror provided the reinforcer: it was situated flush against the left sidewall of the tank and was attached to a white box with a 40-watt light bulb inside (see Figure 1). The mirror was in this position throughout the

experiment including the preliminary, baseline, and extinction sessions (see Design section). The mirror consisted of reflective glass that reflected an image (i.e., mirror presentation) only when the light in the box was off. The light bulb was connected to the computer and was programmed to go on or off as the experimental procedure required. The mirror box was located on one of the sidewalls of the experimental tank to ensure no interference with the tracking system. If the mirror had been placed in the middle of the back wall, for instance, the cameras would have detected the outline of the box as a dark area and would not have tracked the fish.

### **Procedure**

#### **Measures**

The operant response was to swim into a location, determined by the tracking system, which had no obvious visible antecedent stimuli (i.e., the virtual sphere). The fish had to leave and re-enter the sphere area before a new response was recorded. The system had to detect the fish outside of the sphere before a new response could be detected. There was no explicit feedback for the operant response with the exception of the onset of the reinforcing consequence. The diameter of the sphere was 7.5 cm, which was similar to that of the circular rings used with Bettas in the research of Goldstein (1967) and of Hogan (1967).

There was likely variability in the part of the fish's body detected by the tracking system for both entering and exiting the sphere. The tracking system detects the highest dark spot in the tank (see technical explanation under Apparatus). If the fish was swimming below the sphere, the ventral fin may be

detected first by the computer as an entry; if the fish was swimming above the sphere, the caudal fin may be detected first and so on. The amount of variability in detection that is possible depends on the length (4 to 5 cm), width (approximately 1 cm), and height (approximately 4 to 5 cm when ventral and caudal fins are both extended) of the fish. Thus, the topography of the fish swimming into or out of the sphere could vary within these detection parameters.

Throughout the study, the tracking-system recorded: (a) time of each response; (b) swimming locations (30 points per second averaged in blocks of 3 giving 10 data points per second) to be later plotted in a trajectory; (c) distance in cm of the fish from the center of the virtual sphere 10 times per second [which was derived from (b)]; (d) time of the reinforcer presentation; and (e) time of loss of tracking (i.e., when the fish was not in view of both cameras).

Cumulative records of the last three sessions for each reinforcement schedule phase were examined for a break-run pattern (i.e., a period of no responding immediately after reinforcement, followed by a high rate of responding until reinforcement occurred) that is typical of other species on FR schedules (Ferster & Skinner, 1957). The cumulative records exclude the time reinforcement was available.

To investigate the postreinforcement pause (PRP) within each schedule for each fish, the time period that occurred from termination of reinforcement presentation to the first response after reinforcement was recorded. The PRP durations for the last three sessions were examined as they had met criteria for stability. This avoided the transition state of responding (i.e., learning) where

responding may still be under the control of the previous schedule (Sidman, 1960), and would show durations that were likely under the control of the new schedule. Percentage distributions of PRP durations were determined for each schedule for each fish as follows: The durations of the PRPs for the last three sessions of each schedule were categorized into 10-s blocks. The first 10-s block included times from greater than 0 to 10 s. The second block included times from greater than 10 s to 20 s and was labelled 20 s, and so on. The percentage of PRPs that fell within each 10-s block was calculated for each schedule because the number of PRPs varied with the schedule (e.g., CRF had a higher number of PRPs than the FR 6) and with the location of the experimental sphere (i.e., the fish had a higher overall rate of responding on the near sphere than on the far sphere).

Swimming trajectories of the PRP were also plotted for the last three sessions of each phase for each fish. Measuring the operant response and PRP is typical in the study of FR performance (Ferster & Skinner, 1957; Felton & Lyon, 1966). The measures involving the swimming topography are quantitative measures that require the tracking system and are not typical of past research on schedules of reinforcement.

### Design

When a fish was to be tested, it was captured in its home tank by placing the open side of the Plexiglas box at a right angle to the surface of the water located near where the fish was swimming. A downward pressure was placed on the box forcing water into the box along with the fish. The fish and water were

then carried in this box from the home tank to the experimental tank. This procedure was used for transporting the fish to and from the experimental tank. The fish was released into approximately a center location of the experimental tank. There was no habituation period. The session began approximately 5s after the fish was released.

Each fish was tested separately in the experimental tank, once per day, at approximately the same time each day, six days per week. The order of testing remained the same across days and each fish was numbered according to its placement in the order. Each session ran for 30 minutes excluding the total reinforcer time (20 s for each mirror presentation) with a total session time limit of one hour. Thus, sessions could range from 30 minutes to one hour. Table 2 shows the sequence of phases for each fish.

Prior to testing, at least three Preliminary daily sessions of 30 min each were carried out to determine the swimming topography of each fish within the experimental tank. A fish was released into the experimental tank to be tracked by the system with no further procedures until recaptured after the 30 minutes. The swimming trajectories of the fish in the tank for the entire session were plotted. The criterion for choosing a sphere location was for the fish to have swum into a location infrequently but with a greater-than-zero probability within each session. Locations of the spheres were chosen that appeared to be less dense in terms of the plotted trajectories (x, y, z coordinates) for all preliminary sessions using visual inspection. Designating the sphere coordinates and counting sphere hits tested the choice of the location. Baseline was considered

Table 2

Outline of the Experimental Design including the Location of the Experimental

Sphere Relative to the Mirror Wall for each Fish.

Schedule Sequence	Number of sessions for each fish and response criteria to change to the next phase								Experimental sphere	
	Fish 1		Fish 2		Fish 3		Fish 4		Near	Far
Preliminary	3 sessions	>0 & ≤30 responses	11	>0 & ≤30	3	>0 & ≤30	5	>0 & ≤30	All fish	All fish
Baseline	12	Last 3 data points within 5%	4	No upward trend	12	No upward trend	12	No upward trend	All	All
CRF (#1)	8	5%	21	>20 sessions and no apparent conditioning	7	5%	6	5%	Fish 1, 3	Fish 2, 4
Extinction (#1)	14	5%	26	5%	21	5%	22	>20 sessions -no trend	1, 3	2, 4
CRF (#2)	5	5%	19	>10 sessions -no trend in last sessions	10	5%	5	5%	Fish 1, 2	Fish 3, 4
FR 2	13	5%	20	> 10 sessions -no trend	7	5%	20	5%	1, 2	3, 4
FR 3	13	>10 sessions & no trend	11	> 10 sessions -no trend	6	5%	10	5%	1, 2	3, 4
FR 4	22	>10 sessions & no trend	6	5%	13	> 10 sessions -no trend	6	5%	1, 2	3, 4
FR 6	11	5%	4	> 10 sessions -no trend	30	> 10 sessions -no trend	6	5%	1, 2	3, 4
Extinction (#2)	14	Same # of sessions as Ext (#1)	22	> 20 sessions -no trend	21	>20 sessions -no trend	22	>20 sessions -no trend	1, 2	3, 4
FR 6	--	--	4	*3 data pts in upward trend	--	--	--	--	Fish 2	none

\*Note: The expected direction of the trend is opposite to that of the previous phase (i.e., extinction).

to have started when the location was specified and shown to meet criteria (Table 2). The purpose of this procedure was to choose an existing behaviour that had the potential to increase with the experimental manipulations.

Two sphere locations were chosen for each fish: one sphere was located close to the two-way mirror (near sphere); the other sphere was located far from the mirror (far sphere). See Table 3 for the x, y, and z coordinates for the center of each selected sphere. The center coordinates in mm for the near sphere and for the far sphere were the same for Fish 3 and 4 and slightly different for both Fish 1 and 2. For one session during the FR 6 phase for Fish 2, the z coordinate was designated incorrectly; this lowered the sphere by 2.5 cm. The distance of the center of the spheres relative to the closest point on the mirror wall (i.e., the tank wall next to the mirror) was the same for each fish with the exception of Fish 1. For Fish1, the center of the near sphere and the far sphere were both slightly farther from the mirror wall than for the other fish.

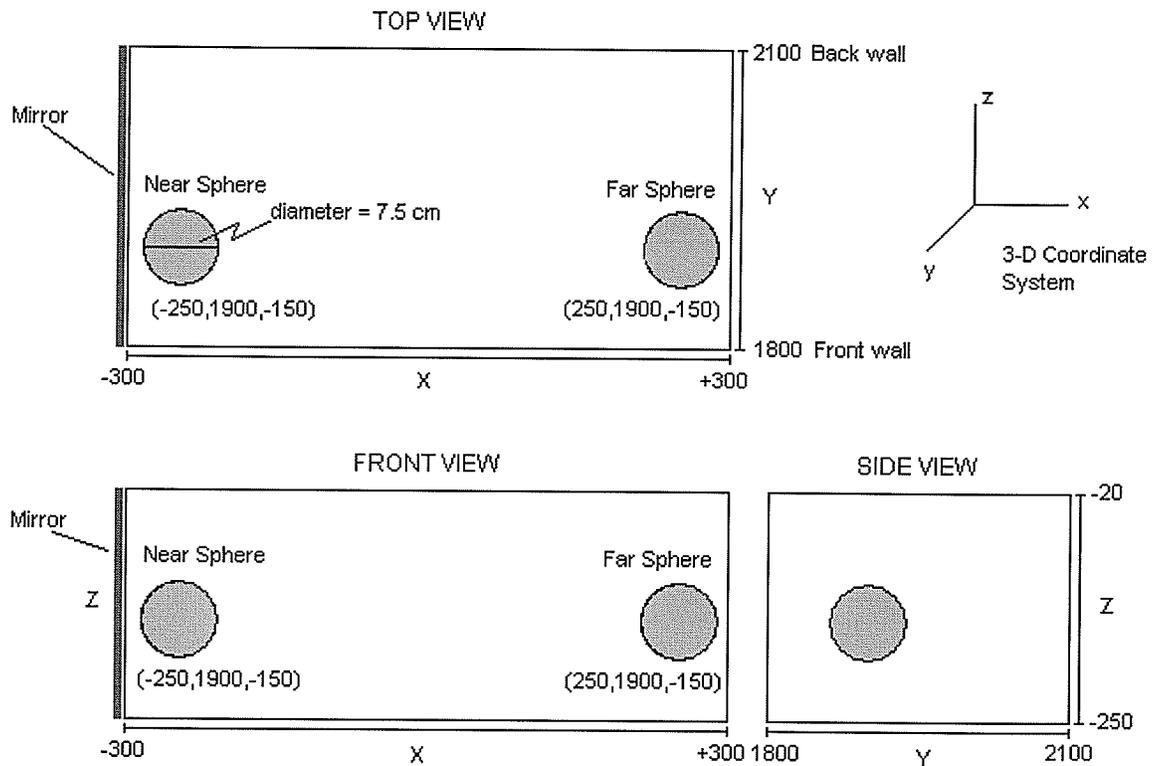
Table 3

Center coordinates, based on the tracking system, for the two virtual spheres for each fish with locations near and far from the mirror wall.

Fish	Center coordinates (x, y, z) in mm and the distance in cm along the x-axis of the center to the closest point on the mirror wall for each sphere:			
	Near Sphere		Far Sphere	
	Center (mm)	Distance (cm)	Center (mm)	Distance (cm)
Fish 1	x = -225 y = 1850 z = -125	7.5	x = 225 y = 1900 z = -125	52.5
Fish 2	-250 1860 -125	5.0	250 1860 -125	(FR 6 one data point: 250 1860 -150) 50.5
Fish 3	-250 1900 -150	5.0	250 1900 -150	50.5
Fish 4	-250 1900 -150	5.0	250 1900 -150	50.5

See Figure 2 for a representative diagram of sphere locations in relation to the experimental tank walls. The x coordinates begin at the middle of the tank where the two camera images meet at the same point; this point was labelled  $x = 0$ . Distance from this point across the long wall of the aquarium was measured in millimeters; the distance going to the right was labelled with positive values and distance going to the left was labelled with negative values. The y coordinates are measurements in mm from the camera lens through the front wall to the back of the aquarium. The z coordinates are measurements in mm from the point where the two camera images meet ( $z = 0$ ); points down toward the bottom of the aquarium from that value were labelled with negative values and points up toward the top of the aquarium from that value were labelled with positive values. The coordinates of the spheres used with Fish 3 and 4 were given as an example in this diagram.

Once the sphere locations were established during the preliminary sessions, the Baseline phase was introduced (Table 2). Each phase in the experiment (not including the preliminary phase) was introduced for a fish after it had achieved stable overall responding in the previous phase or after 10 sessions if there was no obvious trend in the last 3 sessions. For all experimental phases except for the extinction phase, stability was defined as the overall response rate of the last three sessions not varying by more than 5%, or as no trend in the data being apparent to visual inspection. Stability for extinction phases was defined as the overall response rate having decreased to approximately baseline level determined by visual inspection or 20 consecutive



**Figure 2.** A representative diagram of near and far locations (mm) of the virtual spheres within the experimental tank using the coordinates of the spheres for Fish 3 and 4 as an example. The top view is looking down into the tank (x, y coordinates), the front view is looking through the front wall of the tank (x, z coordinates), and the side view is looking through the sidewall of the tank (y, z coordinates).

sessions and no obvious trend in the last three sessions.

During the Baseline phase the operant level of responding for each fish was measured for two responses: swimming into the near and into the far spheres (as defined above). Mirror presentation did not occur for this condition. In the next phase, each fish was put on a continuous reinforcement schedule (CRF #1) for swimming into one of its two spheres. For two fish (Fish 1 and Fish 3) swimming into the near sphere was reinforced. This location was designed to be analogous to the typical experimental conditions of rats and pigeons with the operant response occurring close to the location of the reinforcer. For the two other fish (Fish 2 and Fish 4) swimming into the far sphere was reinforced. The sphere to which responding did not result in mirror presentation was designated as a "control" sphere. It served as a control for responding to the other sphere and provided a baseline for the two fish that were conditioned to this new location in the second experimental phase. In particular, responding due simply to increased activity elicited by the mirror (Goldstein, 1967) should have been recorded on the control sphere; whereas responding due to the contingencies of reinforcement should have been recorded only on the other sphere (designated as the "experimental sphere").

When a fish achieved stable responding during CRF, the first extinction phase (Extinction #1) was introduced: mirror presentations no longer occurred for responding to either sphere. When stability had been achieved, another CRF phase (CRF #2) was introduced.

A purpose of the second CRF phase was to confirm that Bettas could learn to swim into a location that is not associated with a discriminative stimulus. This was done by demonstrating with two of the fish that responding on a location could be extinguished and then re-established, and by demonstrating with the remaining two fish that responding could be conditioned on two different locations. One fish (Fish 1) previously conditioned to a near sphere, and another fish (Fish 4), previously conditioned to a far sphere, were reconditioned to the same sphere. The remaining two fish (Fish 2 and 3) were conditioned to what were previously their respective control spheres (this meant that Fish 2 once conditioned to respond on a far sphere, was conditioned to swim into a near sphere; and Fish 3 previously conditioned to respond on a near sphere, was conditioned to a far sphere).

When stable responding on the second CRF schedule occurred for a fish, the schedule was changed to an FR 2. The following phases of the experiment subsequently changed the size of the ratio to an FR 3, an FR 4, and then to an FR 6 after stability was achieved on each schedule phase. Bettas have developed ratio strain after FR 4 (Thompson, 1969) or FR 6 (Hogan et al., 1970). Ratio strain was defined procedurally in this study as the fish failing to obtain more than three reinforcements in each of two consecutive sessions (Roper, 1973); the responding of the fish in this study never met this criterion for ratio strain.

When a fish achieved stability on the FR 6, the second extinction phase (Extinction #2) occurred for that fish: responding on either sphere did not result in mirror presentations. This phase was continued until stability occurred. This

second extinction phase was compared to the first extinction phase for the two fish conditioned to respond on only one sphere location to determine whether the PREE occurred. One potential problem with comparing extinction rates of responding in a within-subject single-organism design, is that the PREE is reduced on successive extinction phases that are alternated with reconditioning (Sidman, 1960). However, the PREE is not typically eliminated after only one extinction and reconditioning (Perkins & Cacioppo, 1950).

A growth on the right side of Fish 2's torso just behind the pectoral fin was first noted on the ninth day of the second CRF. Although increasing in size throughout the study, this growth had no obvious effect on the fish's behavior. To ensure that the decrease in responding during the second extinction phase for Fish 2 was due to learning and not to effects caused by the growth, a second introduction of the FR 6 schedule followed the second extinction phase. This re-introduction served to further confirm that swimming into the near sphere was an operant response for Fish 2.

## **Results**

### **Swimming into a Virtual Sphere as an Operant Response**

Figure 3 shows the overall response rate (i.e., number of responses per minute for a session) for Fish 1, 2, 3 and 4 respectively across all conditions on the experimental sphere and for selected sessions on the control sphere. When the location of the experimental sphere was near the mirror wall (i.e., near sphere), the location of the control sphere was far from the mirror wall (i.e., far sphere), and vice versa. Only selected sessions are shown for the control sphere because

of a computer program error that led to an inaccurate record of responses into the control sphere. Though it was possible to recalculate the number of control sphere responses from the database, the process was time consuming and did not reveal any substantive differences from the original calculations (i.e., there were no differences in trend and the data points were within the general range of the original calculations). Thus, only the numbers of control response accurate for sessions prior to a change in conditioning phase or at the beginning of an extinction phase were calculated and shown in Figure 3.

As noted in the method section, there was no feedback for responding in the virtual sphere with the exception of the last response, which was followed by the mirror presentation. It was observed that during the higher schedules, fish not facing the mirror wall when the light bulb was first turned off (i.e., at the onset of mirror presentation) would pause, and slowly turn toward the mirror wall. When these fish were not facing the mirror wall, they were on occasion observed to begin displaying (i.e., fin extensions) prior to turning towards the mirror wall. The mirror presentation was accompanied by a decrease in illumination as the light bulb in the mirror box turned off. It seems likely that the decrease in illumination had become a discriminative stimulus associated with the mirror presentation.

#### Responding on the Experimental Sphere.

The results as shown in Figure 3 indicate that swimming into a virtual sphere was an operant response in that this response increased during the CRF phase when followed by the mirror presentation consequence for each fish and

decreased when not followed by the consequence during the extinction phases. The exception to this is responding on the far sphere location for Fish 2. As shown in the top left graph of Figure 3, the overall response rate for Fish 1 increased relative to baseline during the first CRF phase and subsequently decreased during the first extinction phase when the experimental sphere was in the near location. This was followed by an increase in response rate during the second CRF phase and responding was maintained through to the FR 6 phase. As shown in the top right graph of Figure 3, the overall response rate for Fish 2 did not change substantially during the first CRF phase relative to baseline when the experimental sphere was in the far location; though there was an increasing trend across the CRF phase. When the experimental sphere was in the near location, however, there was an increase in responding relative to the baseline during the second CRF phase, which was maintained through to the FR 6 phase. Responding then decreased for this fish during the second extinction phase (i.e., extinction of near-sphere responding after FR 6) and increased again with the re-introduction of a second FR 6 phase.

As shown in the bottom left graph of Figure 3, the overall response rate for Fish 3 increased relative to baseline during the first CRF phase and decreased during the first extinction phase when the experimental sphere was in the near location. Then, when the experimental sphere was switched to the far location, overall response rate on this sphere for Fish 3 increased relative to the baseline of this sphere during the second CRF. It continued to increase through to the FR 6 phase, and decreased during the extinction phase. As shown in the bottom right

graph of Figure 3, the overall response rate for Fish 4, with the experimental sphere only in the far location, increased relative to baseline during the first CRF phase and decreased during the first extinction phase. This was followed by an increased response rate during the second CRF that continued to increase through to the FR 6 phase.

### Responding on the Control Sphere.

Swimming into the control sphere was recorded during at least the last three sessions of each reinforcement phase. This sphere was included in the design to monitor the potential increase in activity elicited by the mirror presentations during reinforcement phases. Overall, it was found that responding on the control sphere occurred when it was in the near location whereas little to no responding on the control sphere occurred when it was in the far location. As shown in the top left graph of Figure 3, there was little to no responding on the control sphere, which was in the far location, for Fish 1 for each of the reinforcement phases. As shown in the top right graph of Figure 3, there were similar results for Fish 2; with little to no responding on the control sphere when it was in the far location during the second CRF phase up to and including the first FR 6 phase.

As shown in Figure 3 during the first CRF phase, swimming into the control sphere, which was in the far location, for Fish 3 occurred at a low rate. As well, when the first and second CRF phases are compared for Fish 3, the overall response rate on the control sphere was at a lower rate when at a far location (i.e., during the first CRF phase) than when at a near location (i.e., during the second

CRF phase). During higher FR phases, swimming into the near (control) sphere for Fish 3 tended to be at or near the baseline level with the exception of one session during each of the FR 3 and the FR 6 phases where responding on the control sphere was at a slightly higher rate relative to baseline. For both Fish 2 and Fish 3, there was less responding on the far (control) sphere during reinforcement of responding on the near sphere than during the baseline and extinction phases.

As shown in Figure 3, there was a higher rate of responding on the control sphere in the near location than on the experimental sphere in the far location during the first CRF phase for Fish 4. The rates of responding on both spheres were similar during the second CRF phase. As the ratio increased, the overall response rate on the near (control) sphere was at a lower rate than it had been during the second CRF phase. When each phase from CRF #2 to FR 6 is compared, there was generally a higher overall response rate on the control (near) spheres for Fish 3 and 4 than on the control (far) spheres for Fish 1 and 2.

Fish 3 was reinforced for swimming into the near sphere during the first CRF phase, and then was reinforced for swimming into the far sphere during the second CRF phase and subsequent FR phases (with swimming into the near sphere as the control sphere). As shown in Figure 3, Fish 3 showed a slight increase in swimming into the near sphere on the second and third session of the extinction #2 phase as compared to responding during the initial baseline and during the FR 6 phase. Thus for Fish 3, the previously learned behavior of swimming into the near sphere increased during the initial sessions during

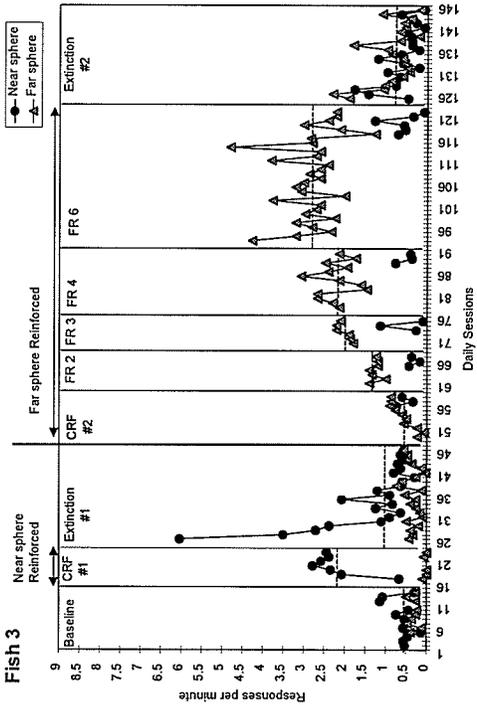
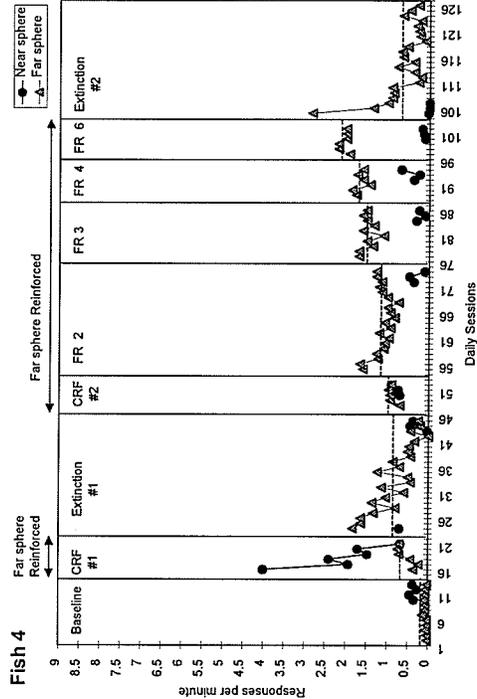
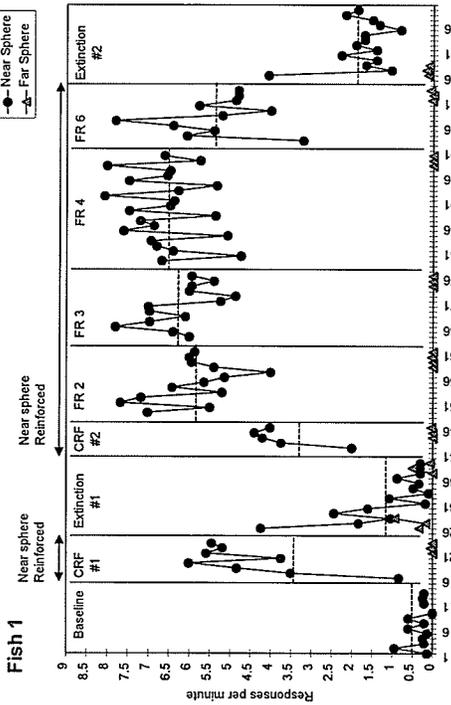
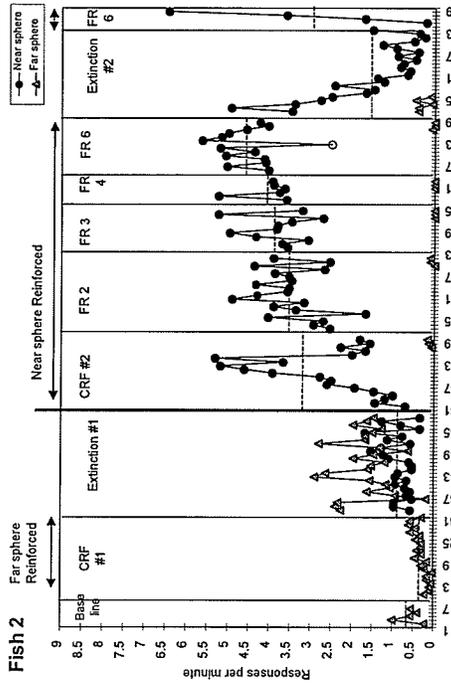


Figure 3. Overall response rate of swimming into the experimental and control spheres for each fish. The dotted line across each phase is the mean response rate on the experimental sphere. Fish 1 was reinforced for swimming into the near sphere only. Fish 2 was reinforced for swimming into the far sphere on the first CRF schedule and then reinforced for swimming into the near sphere on the second CRF and subsequent FR schedules. The open circle data point for responding to the near sphere in the FR 6 phase indicates an error in positioning the sphere in a slightly different location. Fish 3 was reinforced for swimming into the near sphere on the first CRF schedule and then reinforced for swimming into the far sphere on the second CRF and subsequent FR schedules. Fish 4 was reinforced for swimming into the far sphere only.

extinction of swimming into the far sphere.

Responding on the Near and Far Spheres during CRF.

Figure 4 compares overall response rates on a CRF schedule for each location of the experimental sphere across and within subjects. Responding was higher for fish when reinforced for swimming into the near sphere than when reinforced for swimming into the far sphere. This difference was clearly evident when results were compared across subjects as well as within subjects (i.e., across conditions for the fish reinforced for responding on both near and far sphere locations). The overall response rate was higher for Fish 1 and 2 on the near sphere than for Fish 3 and 4 on the far sphere. It is possible to compare within-subject responding for each of these sphere locations for Fish 2 and 3. The results for both fish showed a higher overall response rate on the near sphere than on the far sphere. The overall response rate for Fish 2 on the far sphere, although followed by the consequence, did not exceed the baseline levels of responding. However, the baseline rates had a range that included response rates found for both Fish 3 and 4 when conditioned to the far sphere. Fish 2, then, came into contact with the mirror presentations at a similar rate to Fish 3 and 4, but overall response rate did not increase above baseline levels as it did for the near sphere.

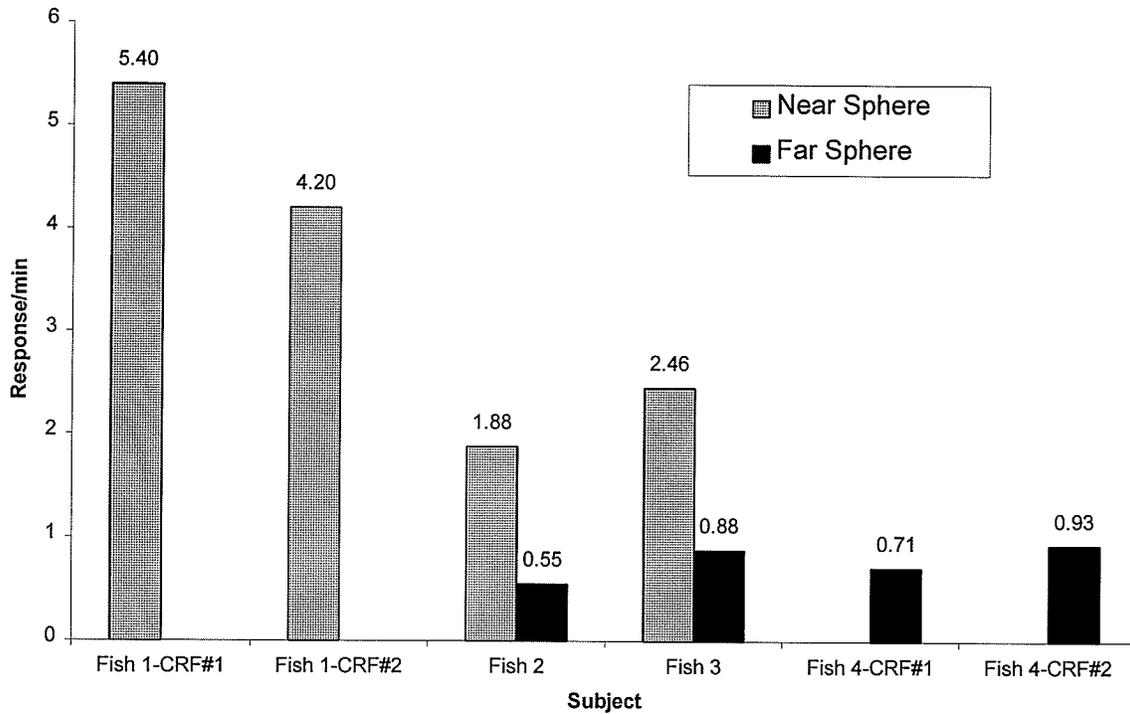


Figure 4. Mean overall response rate from the last three sessions of each fish on CRF schedules for responding on near and far experimental spheres. (Note that the far-sphere data for Fish 2 is presented even though it did not respond above its baseline level on this sphere.)

### **FR Schedule Effects**

#### **FR Schedule Effect on Overall Response Rate**

As shown in Figure 3, there were generally small increases in overall response rate as the schedule increased for all fish. The mean overall response rate is shown by the dotted line across phases for each fish. (Note that the means of the initial three phases of baseline, CRF #1, and extinction #1 for Fish 2 and 3 were for a different experimental sphere than for the subsequent phases). The general increase in means for all fish must be viewed with caution considering the extent of overlapping data points across phases. This occurred more so in the results of Fish 1 and 2 than in those of Fish 3 and 4. As well, the overall rate of responding was generally higher for Fish 1 and 2 (responding on the near sphere was reinforced) than for Fish 3 and 4 (responding on the far sphere was reinforced). However, there was consistency across fish in that the means generally increased as the ratio was increased.

Results for Fish 1 show variable overall response rates with small increments evident when looking at the means across FR phases. The exception to this is the FR 6 phase where the mean dropped below that of the FR 2 phase but was still higher than the means for both CRF phases. There was a large and immediate increase in responding, relative to the previous CRF phase, on the introduction of the FR 2 schedule that was generally maintained. The subsequent FR phases had small immediate increases in rate with the exception of the FR 6 phase where there was an immediate decrease in rate.

Results for Fish 2 for each FR phase show rates that, although generally higher than those during the last five sessions of the second CRF phase, tend to overlap with other phases. There was little apparent change in response rate for Fish 2 on the introduction of each FR schedule with the exception of an immediate increase in overall response rate on the introduction of the FR 2 schedule relative to the last 5 data points of the preceding CRF phase. However, the means show a consistent but small increase for each phase from CRF #2 through to the FR 6. For one session during the FR 4 phase, the coordinates of the near sphere were incorrect which resulted in a close-by but different location. This session is indicated in the graph by an open circle; responding dropped dramatically for that session but resumed for the following session when the coordinates were corrected.

For Fish 3, overall response rate increased with each ratio increment. For the FR 4 and FR6 phases, responding was more variable (i.e., more overlapping and a wider range of data points) than for the lower ratios. There was an immediate increase in responding on the introduction of each schedule with the exception of FR 4.

For Fish 4, there were small increases in overall response rate from the second CRF phase to the FR 6 phase. When adjacent phases are looked at, there are overlapping data points; however, there were no overlapping data points between the second CRF phase and the FR 3 phase, and between the FR 4 and the FR 6 phases. Interestingly, these are ratio increases of 2 responses, although this was only directly implemented from the FR 4 to the FR 6 phase. There was

an immediate but small increase in responding with the introduction of each FR phase followed by a slight decrease in responding during the FR 2, FR 3 and FR 4 phases; whereas the increased level was maintained during the second CRF and FR 6 phases.

In sum, all fish showed some evidence of increase in overall response rate as the ratio size was increased. For Fish 1 and 2, overall response rate was generally higher but more variable than for Fish 3 and 4. Despite the location at which responding was reinforced, there was a tendency for small increases in the mean overall response rate across phases as the size of the ratio was increased for all fish.

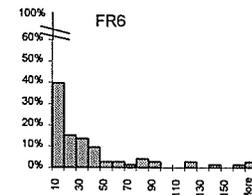
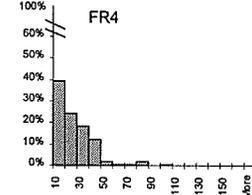
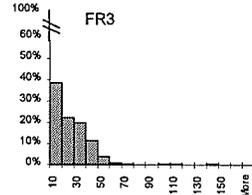
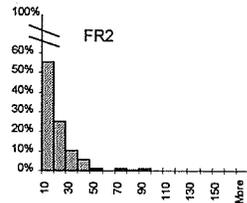
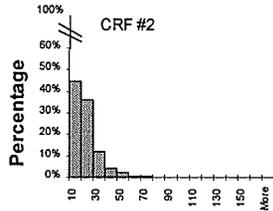
### Postreinforcement Pause on FR schedules

#### **PRP percentage distributions.**

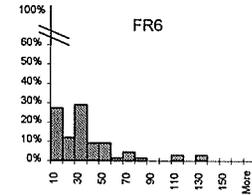
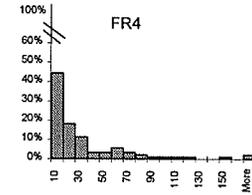
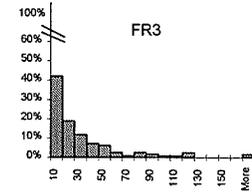
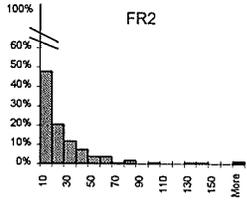
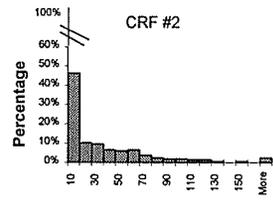
The PRP percentage distributions for each fish on each schedule are shown in Figure 5. For Fish 1, the highest percentage of PRPs across all schedules fell within the first 10 s. However, there was a difference between the CRF and the FR 6 schedules with longer PRPs occurring during the FR 6 schedule. For Fish 2, the highest percentage of PRPs across all schedules except one fell within the first 10 s. The exception was the FR 6 schedule where the highest percentage fell within the 30-s block (i.e., >20 s to 30 s); though, the second highest percentage of PRPs during the FR 6 schedule was within the first 10 s.

The PRPs for both Fish 3 and 4 (with responding to the far sphere reinforced) were generally longer than the PRPs for Fish 1 and 2 (with

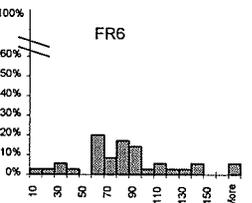
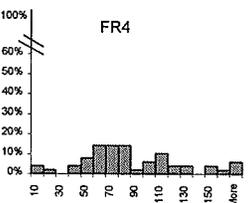
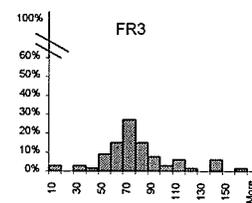
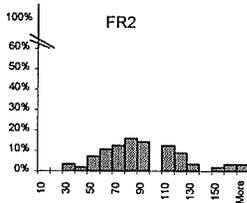
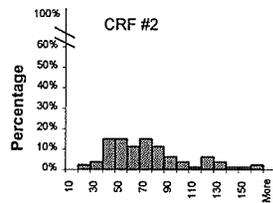
Fish 1



Fish 2



Fish 3



Fish 4

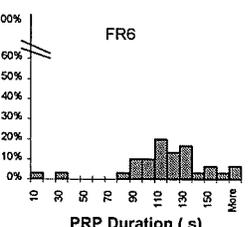
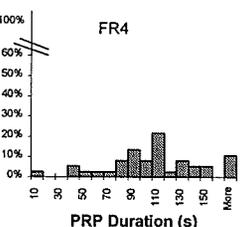
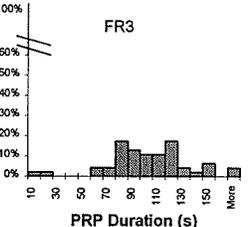
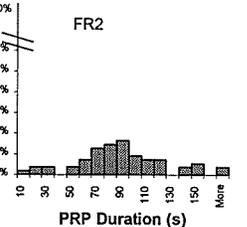
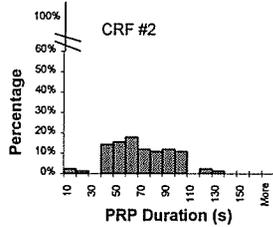


Figure 5. For Fish 1 and 2, reinforced for swimming into the near sphere, and Fish 3 and 4, reinforced for swimming into the far sphere, the above distributions are the percentage of postreinforcement pause (PRP) with durations that fell within 10 s blocks for the last three sessions of each fixed-ratio (FR) schedule.

responding to the near sphere reinforced). For Fish 3 the distribution of PRPs shifted in the direction of longer PRPs from the CRF to the FR 2 schedule. For this fish there appeared to have been a general shift back to shorter PRPs during the FR 3 schedule, with a definite peak in the distribution at slightly greater than 25 percent of the pauses being within the 70-s block (i.e., >60 s to 70 s). In comparison, during the CRF schedule, the highest percentage of PRPs in the distribution was 15 percent for each of the 40-s, 50-s, and 70-s blocks. Thus, the shift in the distribution for the FR 3 of Fish 3 was to a greater percentage of longer PRPs with respect to the CRF, and a shift to shorter PRPs with respect to the FR 2. Further, for Fish 3 there were distribution shifts to longer PRPs as the ratio increased from FR 3 to FR 4 and then, to FR 6. For Fish 4 there was a general shift to longer PRPs for each increase in the ratio from CRF to FR 6 schedules.

Overall, for Fish 1 and 2, the highest percent of PRPs within each distribution generally remained unchanged though there was a slight trend to increase (most evident during the FR 6 phase) as the ratio increased. In contrast, for Fish 3 and 4, there was a general shift in the highest percent of PRPs in the direction of longer PRPs as the ratio increased.

### **Median PRP.**

There was a general tendency for the median of the PRPs to increase as the ratio was increased as can be seen in Figure 6. For Fish 1 and 2, this increase is clear when one only looks at CRF, FR 3, and FR 6 phases. This apparent trend is broken by the decrease in median PRP duration of the FR 2 phase for both fish

Bettas on Fixed-Ratio 56

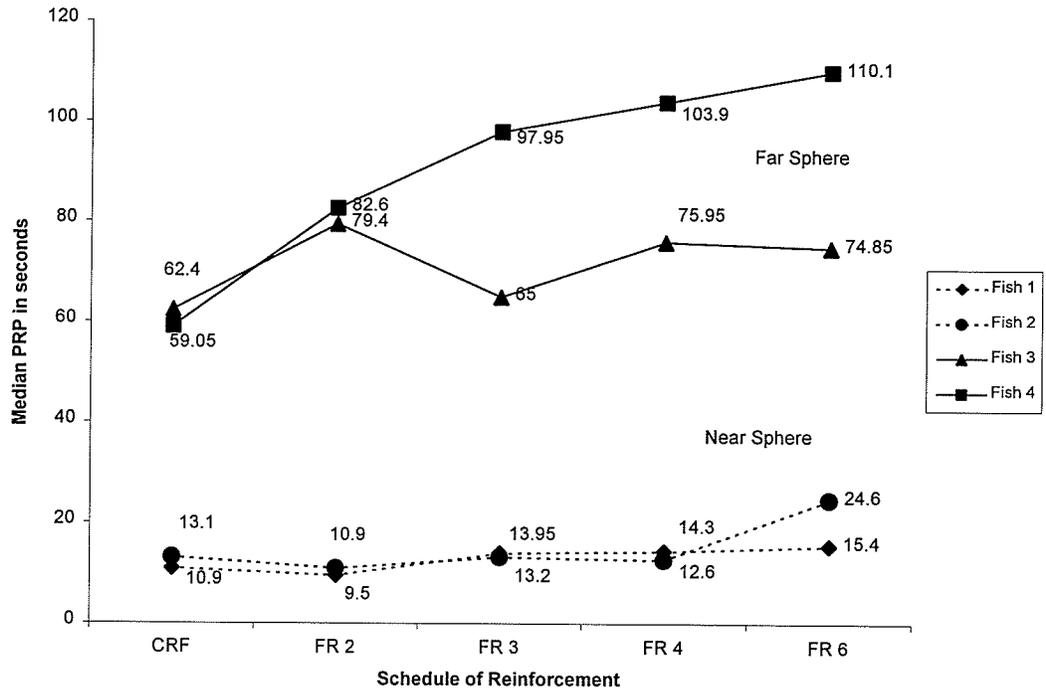


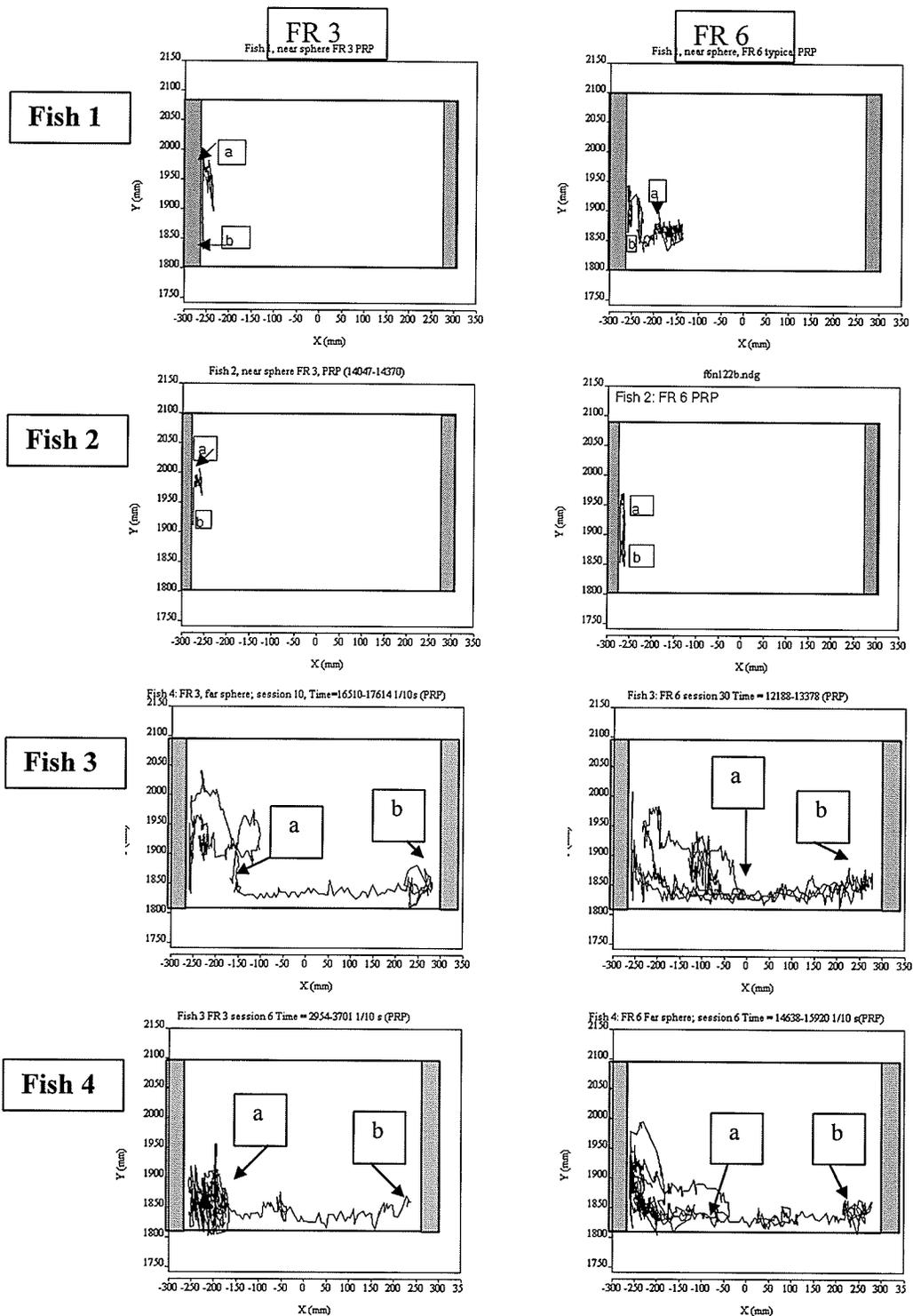
Figure 6. Comparison of median PRP in seconds on the experimental sphere across sequential fixed-ratio phases for each fish.

and the FR 4 phase for Fish 2. For Fish 3, there is a difference between the median of the CRF and any one of the FR phases; however, across the FR phases the median duration does not change in a consistent direction. For Fish 4, there is a consistent increase in median PRP duration as the ratio increases. When these medians are considered along with results from the distributions of PRP durations (Figure 5), it seems that there is evidence of increasing PRP durations across all fish as the ratio was increased.

**Swimming trajectories of fish within the experimental tank during PRP.**

To further explore the behavior of the fish during the PRPs, three-dimensional swimming trajectories (x, y, and z coordinates over time) were examined for selected PRPs for the last three sessions of each schedule to determine the general swimming locations and patterns of the fish within the experimental tank. PRPs were selected based on graphs plotting swimming location relative to the experimental sphere (i.e., distance from sphere) across time. Swimming trajectories during PRPs were then examined for both similar and different distances from the sphere.

Figure 7 shows swimming trajectories during representative PRPs on FR 3 and FR 6 sessions for each fish. These swimming trajectories are line plots of the x, y coordinates over time with the z coordinate suppressed. They give a view as if one were looking down from the top or up from the bottom of the experimental fish tank. In these graphs, the Y-axis denotes the location of the



**Figure 7.** Representative swimming trajectories (x and y coordinates with z suppressed) of each fish during a postreinforcement pause (PRP) for an FR 3 and an FR 6 session. The rectangle within each graph denotes the location of the experimental tank walls. The view is from the top of the tank with the line of the Y-axis being the location of the mirror wall. Shaded areas indicate regions in the tank that could not be tracked. “a” indicates the location of the fish just after the termination of the reinforcer, and “b” indicates the location of the fish just prior to the first response.

wall of the tank that was adjacent to the mirror, and a parallel solid line at approximately  $X = 300$  denotes the location of the opposite sidewall of the tank. Parallel to the  $X$  axis, at  $Y = 1800$  mm, a solid line denotes the location of the front, long wall of the tank (i.e., the wall closest to the cameras), while another parallel solid line at just below  $Y = 2100$  mm denotes the location of the back, long wall. The shaded areas indicate that loss of tracking by the computer occurred in these areas near the sidewalls. No notable differences were found across schedules and thus, FR 3 and FR 6 were chosen and represent all FR phases.

It is evident in each of the graphs in Figure 7 that each fish tended to swim close to the mirror wall during most of the PRP. Each fish started the PRP (i.e., see the area indicated by the "a" box in each graph) by swimming from its location in the tank when the reinforcer terminated to the mirror wall. It continued swimming near the mirror wall until finally swimming to the experimental sphere. The PRP ended when the fish swam into the experimental sphere, which was the first operant response for the ratio (i.e., see the area indicated by the "b" box in each graph).

Examining locations of fish at the beginning of a PRP (i.e., immediately after the reinforcer was terminated; see "a" box in each swimming trajectory) indicates that for fish for which responding at a far sphere was being reinforced, the fish were located at a farther distance from the mirror wall than for fish where responding at a near sphere was being reinforced. This suggests that during the reinforcement period those fish for which swimming into the far sphere was

reinforced engaged in swimming that led to locations farther from the mirror wall than occurred for those fish for which swimming into the near sphere was reinforced. In other words, the location of reinforced responding seemed to have affected the swimming topography immediately after the reinforcement period.

### **Cumulative record patterns of responding and PRP.**

Figure 8 presents representative cumulative records for Fish 1 and 2 on FR 2 and FR 6 on the near sphere, and for Fish 3 and 4 on FR 2, 3, 4, and 6 on the far sphere. During the FR 2 session Fish 1 and 2 generally had short periods of no responding after reinforcement (PRP) followed by responding. The findings for FR 3, FR 4 and FR 6 sessions with these fish were similar enough that only cumulative records for an FR 6 session are shown. For Fish 1 and Fish 2, the PRPs on higher ratios became more variable in duration with more pauses that were long in duration after reinforcement than occurred during the FR 2 sessions. Also, pausing between responses (i.e., during the run) was more evident in the sessions with higher ratios than during the FR 2 sessions.

The cumulative records of Fish 3 show a more consistent break-run pattern during FR 2 and FR 3 sessions than were shown in the records of Fish 1 and 2. This pattern for Fish 3 was generally evident for the FR 4 session; however, occasional pausing between responses (i.e., during the run) occurred. Pausing between responses became more frequent during the FR 6 session. This change in break-run pattern for FR 4 and FR 6 is suggestive of ratio strain for these schedules (Sidman, 1960). The cumulative records of Fish 4 show a break-

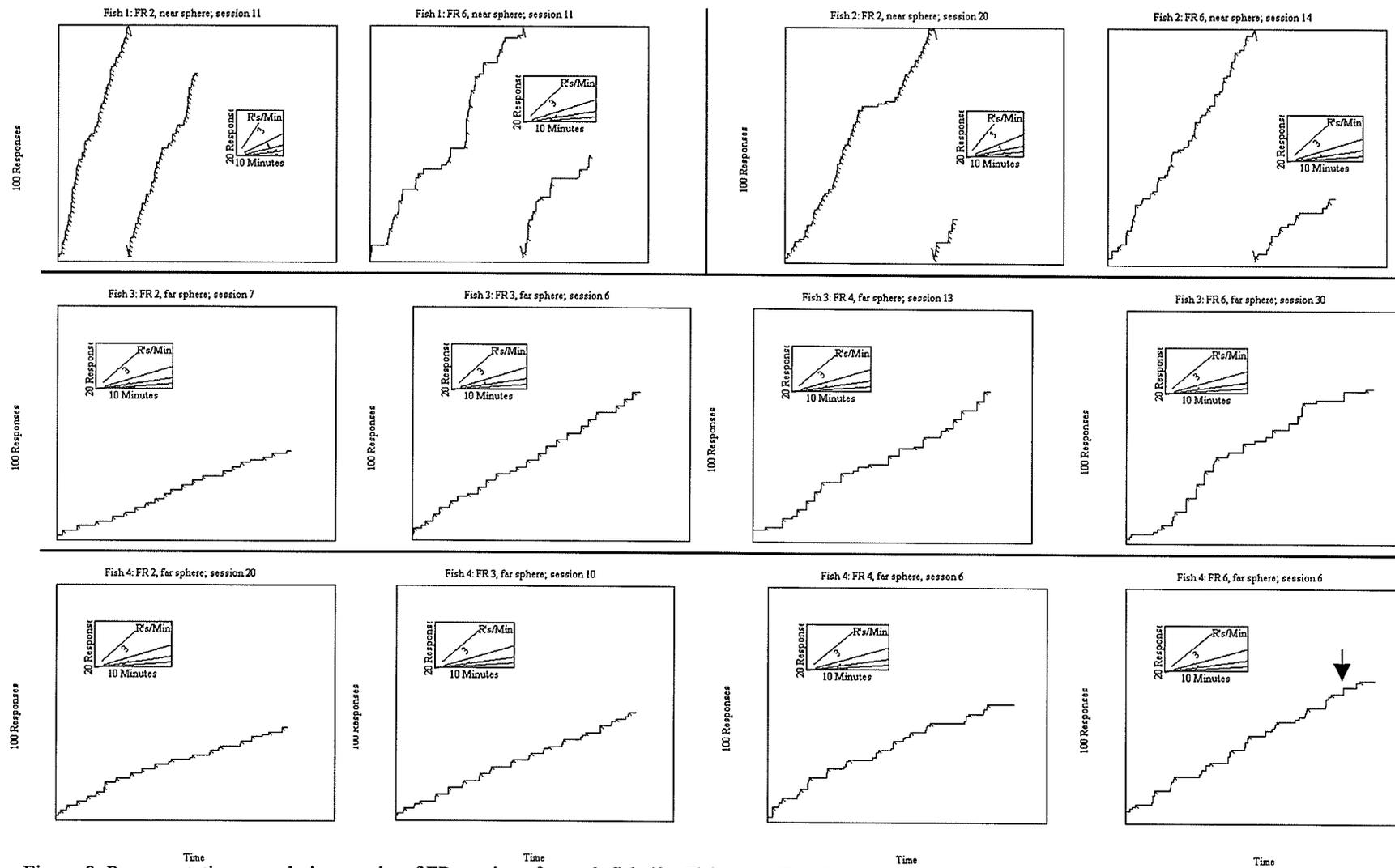


Figure 8. Representative cumulative graphs of FR sessions for each fish (for Fish 1 and Fish 2 the FR 6 session is representative of the lower ratios not shown). Fish 1 and Fish 2 were reinforced for swimming into the near sphere. Fish 3 and Fish 4 were reinforced for swimming into the far sphere. The arrow in FR 6 graph for Fish 4 indicates a long pause.

run pattern for each FR schedule. There was a long pause between responses during the run on one occasion at the end of the FR 6 session shown in the figure. However, all other runs for Fish 4 during this session had inter-response times that were shorter than the PRPs.

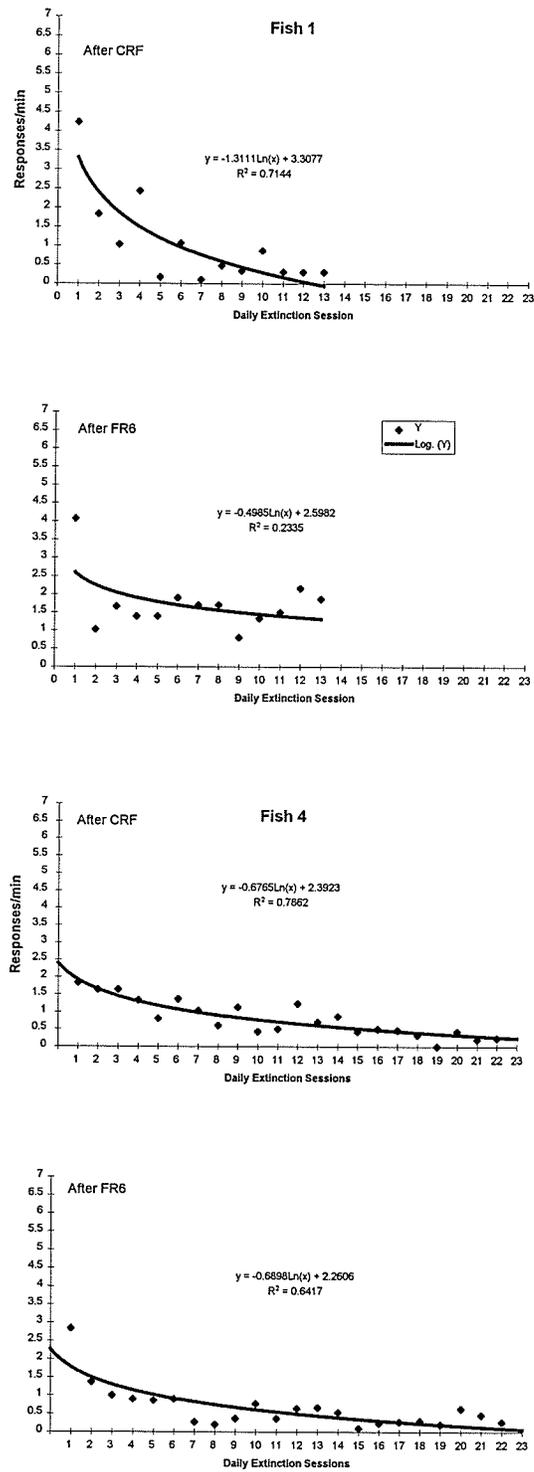
### Partial-reinforcement-extinction effect

#### **Overall response rate and Partial-reinforcement-extinction effect.**

The Partial-reinforcement-extinction effect (PREE) was examined with Fish 1 and Fish 4, these being the only fish that received extinction after CRF and FR 6 schedules for responding at the same location (Figure 9).

For Fish1 (near sphere) the line of best fit for the extinction #1 phase appears to have a steeper slope than that for the extinction #2 phase. This is confirmed by logarithmic equations for the lines. For the extinction #1 phase the equation for the line is  $y = -1.3111\text{Ln}(x) + 3.30777$ ; and for the extinction #2 phase, it is  $y = -0.4985\text{Ln}(x) + 2.5982$ . Thus, the slope for the extinction #1 phase is steeper than the slope for the extinction #2 phase, which indicates a PREE.

When comparing the two graphs of overall response rates for Fish 4 (far sphere) during extinction, there was little difference between the decrease in overall rate of responding after the first CRF phase (extinction #1) and after the FR 6 phase (extinction #2). The lines of best fit confirm this. The equation of the logarithmic line for extinction #1 is  $y = -0.6765\text{Ln}(x) + 2.3923$  and for extinction



**Figure 9.** Plots of overall response rate per session during extinction of swimming into the near sphere after CRF phase (extinction #1 phase) and after FR 6 phase (extinction #2 phase) for Fish 1 and 4. The exponential decay curves are the lines of best fit, determined by the method of least squares.

#2, it is  $y = -0.6898\ln(x) + 2.2606$ . Thus, the slopes for both extinction phases are similar. The slopes of both Fish 4's extinction phases are more similar to that of Fish 1's extinction phase after the FR 6 than after the CRF phase.

Responding was initially at different levels during extinction depending on the location of the sphere the fish was conditioned to swim to. As shown earlier, responding during conditioning for the two spheres was different (i.e., responding into the near sphere was higher than into the far sphere during conditioning as was shown in Figure 4). To make comparisons of response rate during extinction across fish and across sphere locations, each extinction session was examined as a proportion of the response rate that occurred during the last conditioning session. This means of measuring PREE ensures that comparisons can be made when there are differing initial levels of responding (Nevin, 1988).

Using this method to compare extinction results of Fish 1 and 4, Figure 10 shows that the most persistent responding occurred for Fish 4 after the CRF schedule; relative to responding during the CRF conditioning phase, responding during extinction was higher for this Fish than after the FR 6 schedule and higher than responding by Fish 1 after either schedule. Responding of Fish 4 after both CRF and FR 6 schedules was maintained longer than responding of Fish 1 after the CRF schedule. The results of Fish 1 during extinction after the CRF schedule met the criteria of the last three data points not varying more than 5% to end the extinction phase. This criteria was not met for extinction after FR 6 but the phase was discontinued. Responding of Fish 1 after the FR 6 was maintained for 14 sessions with no large changes in level after about the second session and was

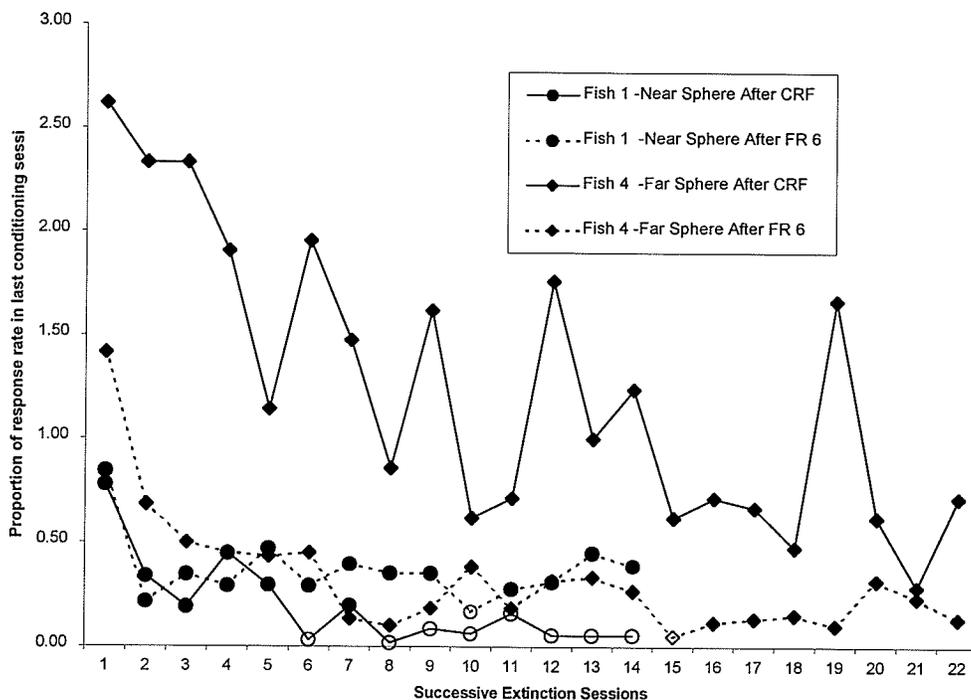
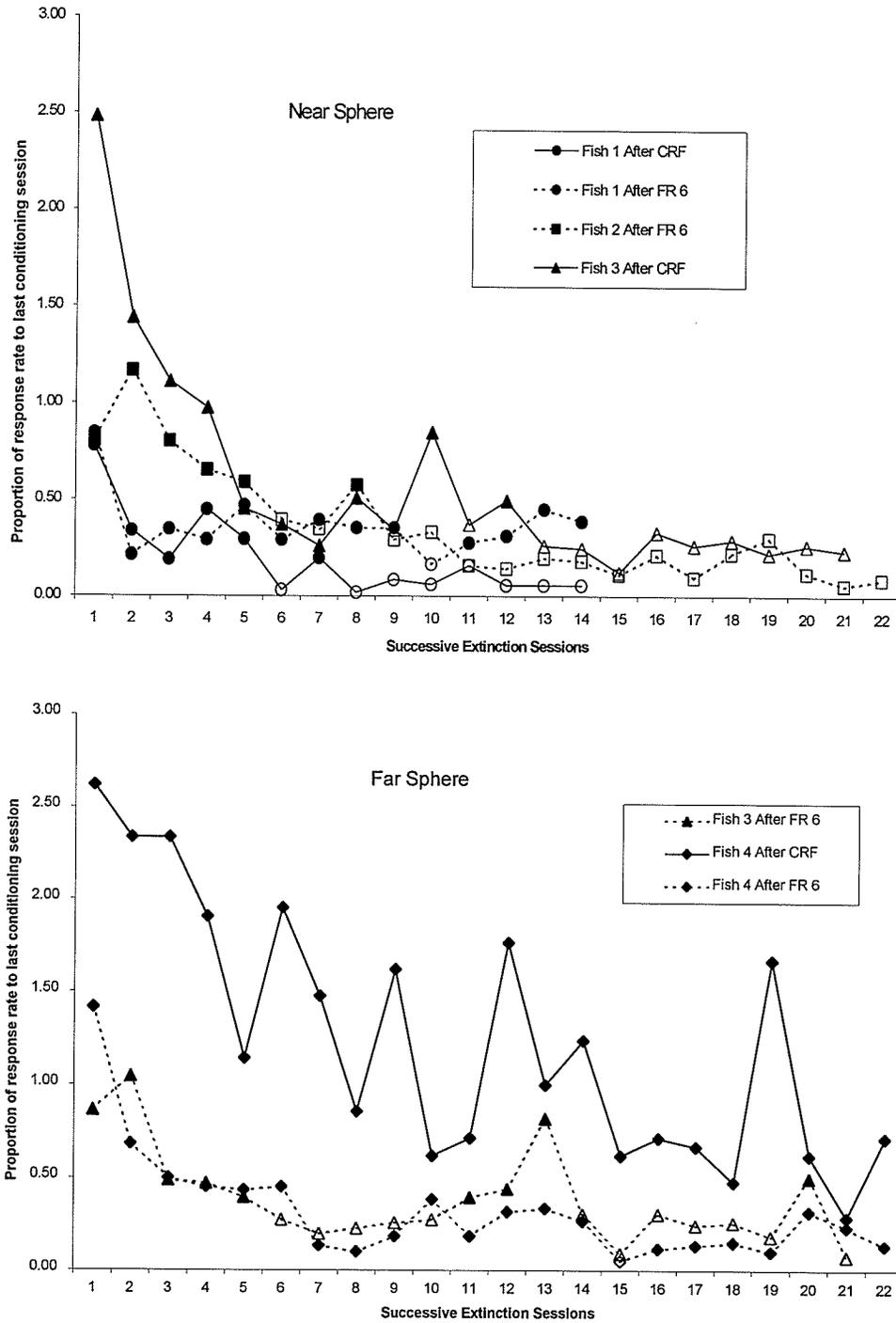


Figure 10. Comparison of extinction results after CRF (smooth line) and FR 6 (dotted line) schedules for Fish 1 conditioned to swim into the near sphere and for Fish 4 conditioned to swim into the far sphere. Data points that are not solid colour fall within baseline-operand levels. Proportion of response rate for each extinction session relative to the last conditioning session allows comparison of the two sphere locations that had such large differences in response rates during the conditioning phases.

similar after the third session to that of Fish 4 during extinction after the FR 6 schedule. Thus, it is likely that the responding of Fish 1 would have been maintained past the 14<sup>th</sup> session and at least as long as that of Fish 4. The extinction of responding of Fish 1 when proportions are examined continued to show that more responding occurred after the FR 6 than the CRF schedule.

In Figure 11, extinction results, again in proportion to the response rate in the last conditioning session, were looked at for each sphere location. Responding on the near sphere was reinforced for Fish 1, 2 and 3. The results for these three fish are shown in the top graph. It can be seen that responding above baseline levels for fish reinforced for swimming into the near sphere were reached and maintained within the 6th to the 12th session. The exception to this was the responding of Fish 1 during extinction after FR 6 schedule. Responding on the far sphere was reinforced for Fish 3 and 4. The results for these two fish are shown in the bottom graph. Responding was maintained above baseline levels for Fish 4 for 22 sessions with the exception of session 15 for the extinction phase after the FR 6 schedule. Fish 3 was still responding above baseline levels by session 20; however, there were successive sessions where responding went below baseline levels (sessions 6 to 10, and 15 to 19). Comparing the two graphs, responding continued above baseline levels in later sessions for fish reinforced for swimming into the far sphere more than for fish reinforced for swimming into the near sphere. The exception being the unknown but suggestive trend for Fish 1 to maintain responding into the near sphere after 14 sessions of CRF schedule.



**Figure 11.** Comparison of extinction results for 3 Bettas conditioned to swim into the near sphere and for 2 Bettas conditioned to swim into the far sphere relative to the mirror wall. Extinction sessions occurred after CRF (smooth line) or after FR 6 (dotted line) schedules. Data points that are not solid colour fall within baseline-operant levels. Proportion of response rate for each extinction session relative to the last conditioning session allows comparison of the two sphere locations that had such large differences in response rates during the conditioning phases.

In sum, Fish 1's results show a faster rate of extinction after the first CRF phase than after the FR 6 phase, which is suggestive of a PREE. The least persistent responding of the four fish during extinction occurred for Fish 1 after the CRF schedule. Fish 4's results showed the greatest persistence in responding of the four fish after the first CRF phase. Fish 4 maintained responding after the FR 6 schedule for as many sessions though at lower response rate in proportion to the conditioning phase than after the CRF schedule. Responding for fish reinforced for swimming into the far sphere persisted above baseline levels for more sessions than for fish reinforced for swimming into the near sphere. The exception to this was the suggestive trend of Fish 1's responding into the near sphere being maintained during extinction after the FR 6 schedule.

**Within session patterns of responding during extinction.**

Figure 12 shows cumulative records of Fish 1 and 4 for the last CRF session and for sessions at the beginning of each extinction phase. For Fish 1, comparing the last session of the CRF phase to the first session of extinction #1, the slope of the cumulative record for the extinction #1 session is much steeper than the slope for the CRF session. This is especially evident in the first 10 minutes of the session. Fish 1, then, had a higher response rate during extinction than the terminal rate of the last session of the CRF phase (as was also found when comparing the overall response rate of these two phases). During the extinction #1 session, there were periods of high responding and low responding but in no detectable pattern. As the session continued there were increasing periods of no responding. During the extinction #2 session, Fish 1 had a slightly

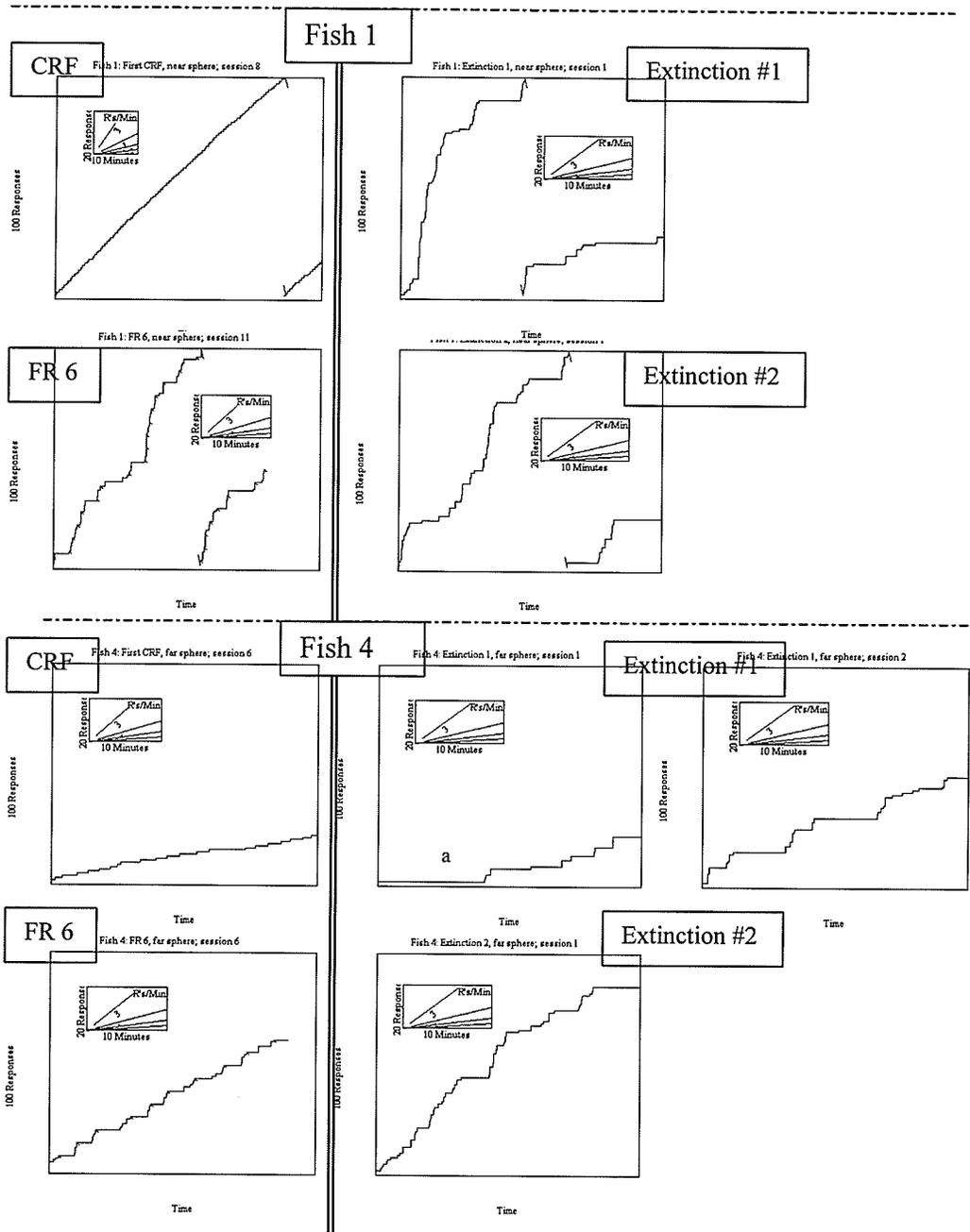


Figure 12. Cumulative records of Fish 1 and Fish 4 for the last session of the first CRF phase, the first session of the extinction #1 phase, the last session of the FR 6 phase, and the first session of the extinction #2 phase. Note that for Fish 4 the second session of extinction #1 phase is shown because of the unusual beginning of the previous session (i.e., see “a” of session 1, extinction #1).

slower rate of responding than it had during the last FR 6 session. There were periods of no responding that became longer near the end of the extinction session than those that occurred in the FR 6 session. When comparing the within-session patterns for these two extinction sessions for Fish 1 (one from each extinction phase), the main difference was the frequency of periods of no responding especially in the first half of these sessions. During the extinction session after the CRF phase, responding remained at a high rate with little to no pausing for at least the first third of the session and then periods of no responding were interspersed with periods of responding. During the extinction session after the FR 6 phase, there was a higher frequency of pausing between responses from the onset than occurred during the extinction session after the CRF phase.

During the first 10 minutes of the extinction #1 session (see area of graph designated with an "a"), Fish 4 did not respond. The reason for this is not known. However, once responding began, it was at a higher rate than the terminal rate during the last CRF session. This rate of responding then alternated with periods of no responding. For the second extinction session after the CRF phase, Fish 4 began to respond immediately and the pattern was similar to the latter part of the first extinction session in that there were high rates of responding followed by pausing. During the latter one third of the session, there was also one period in which response rate was comparable to the terminal CRF response rate. Early during the first session for the extinction #2 phase, Fish 4 had a higher response rate than it did during the last FR 6 session. The high rate of responding alternated with low rates of responding rather than with periods of

no responding. Periods of no responding did not occur until later in the session. When comparing the within-session patterns for these extinction sessions, Fish 4's responding during the extinction sessions after the CRF phase was lower and had more pausing than in the extinction session after the FR 6 phase.

### **Discussion**

The present study demonstrated operant conditioning of swimming into a virtual sphere, unmarked by any discriminative stimuli, in Betta splendens. It extended the analysis of FR schedules across species in its examination of different FR effects on the performance of Betta splendens when an aggressive-display-eliciting reinforcer (i.e., mirror presentation) was used. It also illustrated the importance of methodological considerations by varying a parameter of this reinforcer. In doing so, possible variables that were interfering with experimental control were uncovered. We will begin by discussing the FR schedule effects on the performance of these fish and how this compares to the literature on other species, and then move on to the effect of the aggressive-display eliciting reinforcer.

#### **FR Schedule Effects**

Overall, the results did not show large, consistent effects of FR schedules on the responding of Bettas. However, there was some evidence of schedule effects depending on the location of the reinforced response relative to the location of the reinforcer. When the sphere was in the far location relative to the mirror, FR schedule effects were small but more consistent than when the sphere

was in the near location. Instead of the expected resistance occurring only during extinction after the FR schedule, there was preliminary evidence to suggest that after the CRF schedule there was resistance to extinction for responding of fish at the far sphere location relative responding of fish at the near location. When the sphere was in the near location relative to the location of the mirror, FR schedule effects were less evident though there was a general trend for an increase in averages of overall response rate and of PRP duration when the ratio was increased. As well, there was preliminary evidence to suggest a PREE (i.e., greater resistance to extinction after the FR schedule than the CRF schedule) when responding of Bettas at this near location was reinforced.

#### Across- and Within-species Comparisons

An interesting finding in this study was that Bettas learned to swim into a location with no apparent visible stimuli (i.e., the “virtual” sphere) and with no feedback outside of the mirror presentations. Other experiments on Bettas have used response locations marked by visible stimuli. Goldstein (1967), and Lattal and Metzger (1994) both used swimming into a circular ring device. Turnbough and Lloyd (1973) used swimming into a separate chamber within the tank (a photocell signalled when the fish had swum into the chamber). Hogan, Kleist and Hutchings (1970) used swimming through a tunnel (a photocell was situated near the end of the tunnel to indicate that the fish had completed the response). Bronstein (1984) used swimming past a line that was drawn on the wall perpendicular to the mirror wall. In this experiment there was also no explicit feedback for the operant response with the exception of the onset of the

reinforcing consequence. This is not unusual relative to other research with Betta splendens unless it can be argued that the visible stimuli cited in the research above provided not only antecedent but consequent stimuli.

It might be suggested, then, that the small changes in responding as the ratio size changed for the fish reinforced for swimming into the far sphere was the result of the unusual operant used in this study. However, the results for the fish reinforced for swimming into the near sphere (which had the same unusual operant but in a different location) were similar to past research with Bettas conditioned to swim into locations with visible stimuli (Hogan et. al., 1970; Turnbough & Lloyd, 1973). Thus, though the results of the fish with the operant response of swimming into the far sphere were not similar to past research on Bettas, this cannot be attributed to the unusual operant.

Evidence of change in responding with ratio change found in the current study are not consistent with other research on Bettas when an aggressive-display eliciting reinforcer was used. Changes in overall response rate of the Betta were more evident to changes in ratio size than was found in Hogan et al's (1970) research. All fish in my study showed general trends of the mean per phase of overall responding and median PRP duration increasing as the ratio increased. In Turnbough and Lloyd's (1973) research, two Bettas exposed to conditions of CRF and FR 2 had median rates of responding that did not change consistently.

In my study of the Betta, the lengthening of PRP duration with increases in ratio size was more apparent for fish reinforced for swimming to the farther response location. PRP duration had not been investigated in this species

previously but the results are consistent with research on PRP in pigeons and rats (Felton & Lyon, 1966; Ferster & Skinner, 1957; Powell, 1968). As was pointed out in the introduction, research findings of FR effects on the responding of rats and pigeons have been inconsistent for overall response rate (Crossman et al., 1987) but consistent for the PRP (Felton & Lyon, 1966; Ferster & Skinner, 1957; Powell, 1968). Thus, it is interesting that in the current study, both the overall response rate and the PRP of the Betta showed signs of changing with ratio size. Further, the change in overall response rate and PRP duration resulting from the FR schedule was in the same direction (i.e., increased) as occurred for rats and pigeons (Felton & Lyon, 1966; Powell, 1968).

The pattern of responding across sessions of Bettas in the current study is consistent with past research. Ferster and Skinner (1957) found with pigeons put on a CRF schedule that initially overall response rate increased across sessions and then it would reach a rate that was maintained for the sessions that followed. In my study, the fish reinforced for swimming into a sphere on a CRF schedule had a similar response pattern to that of Ferster and Skinner's pigeons. This was not the case for one fish (Fish 2) reinforced for swimming into the near sphere. On the CRF schedule, the across-session pattern of responding showed an initial gradual increase followed by a dramatic decrease that was maintained in the subsequent sessions. Hogan's (1967) study with Bettas on a CRF schedule for mirror reinforcement found across-session patterns similar to those found in this study for the one near-sphere fish. Thus, across-session patterns of responding on the CRF schedule for the far-sphere location are similar to research with other

species whereas across-session patterns of responding on the CRF schedule for one fish (Fish 2) are similar to other research with Bettas.

The PREE, a schedule effect that occurs with rats and pigeons (e.g., Boren, 1960), where responding is more resistant to extinction after partial rather than continuous reinforcement, was found for the one fish (Fish 1) reinforced for swimming into the near location. Similar resistance to extinction after both continuous and partial reinforcement was found for the one fish (Fish 4) reinforced for swimming into the far location on these two schedule types. This was somewhat supported by a second fish (Fish 3) conditioned to swim to the far sphere where responding did occur in later sessions; though the responding of this fish was variable and did go below baseline levels for successive sessions.

The extent of the similarity of the findings of my study with Bettas and those of other studies with different species depends on the location where responding was reinforced. The results found with other species, such as rats, are that resistance to extinction will be greater after partial reinforcement than after continuous reinforcement (e.g., Boren, 1961). This PREE was found for responding of Bettas reinforced for swimming into the near sphere. However, responding was similarly resistant to extinction after continuous as after partial reinforcement schedules for fish reinforced for swimming into the far sphere. Thus, in my study both partial reinforcement and the operant of swimming into the far sphere likewise increased resistance to extinction.

In general, then, the responding of Bettas reinforced for swimming into a virtual sphere with a mirror presentation reinforcer found in my study is more

similar to the findings on other species than has been found in past research on Bettas. The extent of this similarity of responding due to FR schedule effects depended on the location of the sphere. The similarity was more obvious for the responding of the fish reinforced for swimming into the far-sphere location than into the near-sphere location. The exception was the PREE where it was the responding of the fish reinforced for swimming into the near-sphere location during extinction, which was most similar to other species.

Considering that the location of responding appears to have contributed to obtaining some schedule control, the failure to get large FR schedule effects in my study is more suggestive of an incomplete knowledge of the controlling variables than an instance of nongenerality of the effects of reinforcement (Sidman, 1960). Thus, it is important to look at each response location separately. The following discussion delves into potential reasons for decreased schedule control related to each location.

#### Responding on the Sphere Located Relatively Near the Mirror Wall

In my study the size of the effects of an increase in ratio size on overall response rate and PRPs were dependent on the relative locations of responding and reinforcer. The first difference in responding on the near-sphere location compared to the far-sphere location was the overall response rate during the CRF schedules. Swimming into the near sphere occurred at a higher overall rate than swimming into the far sphere. Roper (1975) found similar results with mice where the closer location of operandum to reinforcer dispenser led to a higher

frequency of responding. With the closer location of the operandum, an increase in overall response rate occurred as the ratio was increased for these mice.

Considering these results, we would expect that the higher rate of responding by the Bettas on the near sphere would lead to schedule control with the changes in ratio size. Though there was a suggestion of an increase in the means of the overall response rate for these fish conditioned to swim into the near sphere, there was more variability in responding than occurred for the fish conditioned to swim into the far sphere. The greater variability of responding is an indication that there are other controlling variables than those being manipulated (Sidman, 1960).

#### **Reinforcer-elicited activity.**

One explanation for the greater variability of responding and less obvious control of the schedule over responding into the near-sphere location is that increased activity occurred in the general location of the mirror reinforcer and likely influenced responding. Goldstein (1967) demonstrated with Bettas in a yoked-control study that on CRF schedules increased activity elicited by the mirror reinforcer did account for some of the responding, though the reinforcement contingencies accounted for most of the responding.

From an examination of the results of the FR phases in the current study, there is a suggestion that the responding of the fish reinforced for swimming into the near sphere was more influenced by the increase in activity elicited by the mirror than was the responding of the far-sphere fish. For the fish reinforced for swimming into the far sphere, the rate of near-sphere swimming increased during

the conditioning to the far sphere (Figure 3). However, for fish reinforced for swimming into the near sphere, the rate of far-sphere swimming showed little to no change during conditioning to the near sphere. An increase in activity elicited by the mirror presentation reinforcer, then, appears to affect the operant response that is close in location to the mirror wall.

As well, results for the two fish (Fish 1 and 2) reinforced for swimming into the near sphere on increasing ratios showed an increasing trend in the mean overall response rate as the ratio increased. This does suggest that some control of the schedule was occurring but the variability of response rate suggests that there are confounding variables (Sidman, 1960). Thus, the increase in near-sphere swimming for fish conditioned to the near sphere was likely due to the increased activity elicited by the mirror as well as to the reinforcement contingencies.

The general swimming topography during the PRPs of each fish further support that swimming into the near sphere was more probable because of its proximity to the mirror wall as well as because of the contingencies. Each fish spent most of the PRP near the mirror wall regardless of the experimental sphere location. Thus, it is likely that an increased probability of swimming near the mirror wall because of its association with the mirror presentation may have influenced the results of the fish reinforced for swimming into the near sphere.

One method of testing the extent to which the change in activity elicited by the mirror presentations affected responding would be to place the "control" sphere and experimental sphere equal distances from the mirror wall. Knowing

from the results found in this study that the fish, once exposed to the contingencies, tend to swim in the general area near the mirror wall, one would be able to compare the responding into the unreinforced sphere to that of the reinforced sphere. Higher responding on the reinforced sphere would indicate the extent to which responding was due to the operant contingencies.

A differential reinforcement of other behaviour (DRO) procedure could be used as has been done in past research with Bettas (Lattal & Metzger, 1994; Turnbough & Lloyd, 1973). This procedure involves having the reinforcement delivered after a fixed period of time has elapsed since the last response. This ensures that a period of no responding occurs before reinforcement is delivered for the last response. This contingency of reinforcement for responding followed by a period of no responding may reduce the activity in the area of the sphere and reduce the number of responses that are not due to the contingencies.

The relationship between the type of response used as the operant response and the type of stimulus used as a reinforcer has been hypothesized as a possible determinant of whether unconditioned behavior will influence the overall response rate (Hogan & Roper, 1978; Shettleworth, 1972). With Bettas, there is a high probability that the mirror reinforcer elicited a swimming response. The swimming response is a component of the aggressive display elicited by mirror presentation (Bronstein, 1984; Simpson, 1968) and it has been demonstrated that noncontingent mirror presentations result in increased swimming through a hoop (Goldstein, 1967). In Roper's (1975) study the mice had to press a pigeon key whereas in the current study the fish had to swim into a

location. It is unknown whether nest material can elicit an increased activity in mice that would result in key pressing. However, Roper did suggest that most of the activity in the PRP occurred in the nesting box whereas the fish in my study spent most of the PRP near the mirror wall. An area of future research would be to investigate operants other than solely swimming responses for Bettas to determine if changes in the overall response rate with ratio increases depend on the type of response being conditioned when the mirror reinforcer is used. For example, pressing a physical target has been used with goldfish (Gonzalez & Bitterman, 1967).

#### **PREE on the near-sphere location.**

These results have to be considered with caution as only one fish (Fish 1) demonstrated a PREE. Results for Fish 1 on the near sphere showed a difference in the effect on responding of partial reinforcement as compared to continuous reinforcement during extinction (i.e., PREE); responding during extinction was maintained longer after an FR 6 than after a CRF schedule. Results for Fish 4 suggest that responding on the far sphere persisted after both the FR 6 and CRF schedules when compared to the responding of Fish 1. As well, when the responding of Fish 4 was considered in proportion to the level of responding during conditioning, it was apparent that responding was highest for extinction after the CRF schedule.

The suggestion that a PREE occurred for the responding of Fish 1 and that similar resistance to extinction occurred after both schedule types for Fish 4 is somewhat supported by within-session patterns of responding during

extinction for these fish. For pigeons, within-session responding during extinction after a CRF schedule typically begins with a higher rate of responding than the terminal rate of the CRF phase that then alternates with a lower rate of responding. Likewise, responding during extinction after FR schedules begins with a high rate of responding; however, this high rate of responding then alternates with periods of no responding, with these periods of no responding becoming increasingly longer (Ferster & Skinner, 1957).

Within-session responding for Fish 1 during extinction after the CRF phase for the first third of the session was similar to those of pigeons in Ferster and Skinner's (1957) research. However, for the remaining part of the session, even though the expected high and low rates of responding continued, there were increasing periods of no responding more typical of responding after an FR schedule. The within-session responding during extinction after the FR 6 phase was similar to that of pigeons in Ferster and Skinner's research.

Within-session responding during extinction for Fish 4 after CRF and after FR 6 tended to involve a high rate of responding (relative to the previous conditioning phase) alternating with periods of not responding. After the CRF phase, there was lower responding and longer pausing than responding during extinction after the FR 6 phase. The differences between the two extinction phases seem to be related most to the response rate during the conditioning phase; the general pattern is the same just at different overall response rates. The general pattern of within-session responding for both extinction periods was

similar to that of pigeons during extinction after an FR schedule in Ferster and Skinner's research.

Overall, what is interesting is that the PREE was found for the one Betta reinforced for swimming into the near sphere and yet, the effect of ratio changes during conditioning on the overall response rate and PRP duration was not as obvious. Though the evidence of a PREE is preliminary, these results do suggest that the PREE can indicate a broad discrimination between the effect of the intermittent (FR) schedule and the effect of the continuous (CRF) schedules on responding. Whereas the finer discrimination of the effect of making changes within the intermittent schedule type (i.e., increase in FR size) by measuring the PRP and overall response rate, may have been obscured, as argued earlier, by the increase in activity due to the nearby location of the mirror.

The resistance to extinction found in this study for the two different sphere locations needs to be replicated to ensure that it is not a false positive (Sidman, 1960). However, the potential of either schedule or sphere location having control over responding during extinction indicates a need for further investigation of the controlling variables for the responding of Bettas when aggressive-display eliciting stimuli are used as the reinforcer.

### Responding on the Sphere Located Relatively Far from the Mirror Wall

#### **Travel time effects.**

It might be argued that the more evident increase in overall response rate as the ratio increased was not a demonstration of increased control by the schedule but rather an artifact of FR schedules for the fish reinforced for

swimming into the far sphere. As a ratio was increased, the number of times the fish swam from the location of the reinforcer to the location of responding decreased. This left more time available for responding. For example, a fish on a CRF schedule making 10 responses travels from the reinforcer location to the sphere location 10 times; whereas, the fish on an FR 2 schedule making the same number of responses travels from the reinforcer to the sphere only 5 times. If all the time between responses on a CRF schedule were spent in travel, then when the ratio increased to a FR 2, travel time for the first response will be the same as occurs on the CRF. However, for the second response there is no need to travel (the fish is at the sphere location); thus, the time previously used for travel during the CRF for every second response, accumulates during the FR 2 session and is available for responding. Thus, the time spent in travel (i.e., travel time) decreased as the FR size was increased, and the increase in response rate may have been due to the increase in time made available for responding per response.

The issue of travel time is not unique to this study. In studies of animal learning the research apparatus tends to have one location for responding and another, usually close, location for the delivery of reinforcement. When schedules of partial reinforcement are compared, the animal spends different amounts of time going between the two locations depending on the schedule just as occurred for the fish in my study. However, in my study the distance of the operant-response location from the site of the reinforcer was manipulated, which would mean that travel time was varied across fish (i.e., those fish conditioned to swim to a near location compared to those conditioned to swim to the far

location). The effect of travel time on response rate would be more evident the greater the distance between the reinforcer and response location. The fish reinforced for swimming to the far sphere travelled a greater distance from the location of the mirror after it was presented (i.e., after reinforcement) to the location of the sphere to begin responding again than did the fish reinforced for swimming to the near sphere. Results for these far-sphere fish showed small but more obvious increases in overall response rate as the ratio increased whereas those for the near-sphere fish showed variable responding, and change in rate as the ratio increased was only evident when means were obtained. Thus, the increase in overall response rate on the far sphere as the ratio size increased could merely reflect the decrease in time spent travelling between responses (which left more time available for responding) rather than increased control to the schedule relative to the responding on the near-sphere location.

As said before, travel time decreases as the ratio increases even with the same location of responding relative to reinforcer dispenser. The PRP seems a better demonstration of FR schedule control than overall response rate because changes in PRP are not confounded by travel time. Travel time was not measured directly in this study; however, it is during the PRP that travelling the distance between the locations of reinforcer and responding occurred. The distance from the mirror to the sphere is constant and thus, the average amount of time necessary to swim the distance should be a constant. If the size of the PRPs remained the same for the FR schedules as for the CRF schedule, then it would be difficult to rule out that the decrease in travel time led to the increase in

response rate as the schedule increased. However, results of fish reinforced for swimming into the far sphere showed a greater frequency of longer PRPs for the FR schedules than for the CRF schedule (Figure 5). Thus, rather than attributing the results to a procedural artifact, we can be confident that this change in PRP duration as the ratio changed indicates that these fish were responding to changes in FR schedules.

It is likely then that some other behavior related to the specific schedule was occurring during the PRP along with travelling. From the swimming trajectories during the PRPs (Figure 8), it is evident that the fish with the far response location were engaging in swimming other than simply travelling from the mirror to the sphere. All fish, regardless of the location of the experimental sphere, swam close to the mirror wall during the PRP. Swimming close to the near sphere, for fish reinforced for swimming into that sphere, cannot be easily separated from swimming close to the mirror wall because of their adjacent locations. However, with the widely separated locations of the mirror wall and the far sphere, results of the fish reinforced for swimming into the far sphere showed that most swimming during the PRP occurred near the mirror wall. Thus, behavior other than simply travel occurred during the PRP.

Thus, to ensure that one is actually evaluating the generality of the effect of changes in ratio size on responding during conditioning, measuring the PRP rather than the overall response rate is recommended to avoid the confound of travel time. The fish in my study that showed the most obvious general increasing trends of overall response rate and PRP duration as the ratio increased,

were the fish conditioned to swim into the far sphere. Though the effect was not large, it does suggest that with a better understanding of other controlling variables that this effect may be shown to generalize to Bettas when mirror presentations are the reinforcer.

### **Resistance to extinction and delayed reinforcement.**

There was some evidence in this study that resistance to extinction was greater when the fish were reinforced for swimming into the far sphere. Responding persisted longer for the one fish (Fish 4) reinforced for swimming into the far location after both continuous and partial reinforcement schedules as compared to fish reinforced for swimming into the near location. This was somewhat supported by a second fish (Fish 3) conditioned to swim into the far sphere where responding during extinction did occur in later sessions; however, the responding of this fish was variable and did go below baseline levels for successive sessions before recovering. When fish were reinforced for swimming into the near sphere location, responding in later sessions tended to reach and remain within baseline levels. The one exception was the responding of Fish 1 during extinction after FR 6; responding had not gone below baseline levels and showed no trend to do so if subsequent sessions had been carried out. Thus, the schedule effect on responding during extinction was most obvious for the one fish conditioned solely to the near sphere location. Having the location of responding far versus near relative to the mirror wall appeared to have an effect on resistance of responding to extinction in my study.

The effect of location on responding has been found in previous research with other species (Roper, 1975). It is possible that it is the timing of the delivery of reinforcement that is the important variable. The farther location of responding relative to the mirror wall may be a method of delaying reinforcement; the fish makes a response but then has to travel to where the reinforcement is presented. Thus, travel time caused by the distance of the location of responding to the location of the reinforcer could be similar to the procedure where the delivery of reinforcement is delayed.

Studies of male Bettas, when the reinforcer was an aggressive-display eliciting reinforcer, exposed to delayed reinforcement on a CRF schedule found that less responding occurred than when exposed to a CRF with no delay (Lattal & Metzger, 1994; Turnbough & Lloyd, 1973). In my study responding measured for the far sphere location was lower than that for the near sphere location. The far-sphere location may be just a method of delaying the reinforcement.

Lattal and Metzger (1994) found that a delay of 25s did not maintain responding above baseline levels. The potential delay for the fish in my study was not measured. However, travel from the reinforcer location to the response location, as well as other swimming behaviour, occurred during the PRP. Thus, it can be assumed that actual travel time is included in the median PRP for the CRF schedule for the two fish conditioned to respond to the far sphere. Fish 3 had a median PRP duration of 62.4s and Fish 4 had a median PRP duration of 59.05 (see Figure 6). The swimming topographies of these fish during the PRP,

however, do suggest that time spent in travel was much shorter than these PRP durations.

Extinction performance after delayed reinforcement has not been studied in Bettas. Extinction performance following delayed food reinforcement for rats in runways does increase persistence under some, as yet poorly defined, conditions according to a review by Campbell and Knouse (1972). In Bettas, to test whether the resistance to extinction was due to the possible delay in reinforcement with the farther distance, one could compare responding on a far sphere location with an equivalent time delay of reinforcement on a near sphere location.

#### **Effortfulness of response.**

It could be suggested that the difference found in the present study in PRP duration for responding to the far sphere as compared to the near sphere location are differences in the effortfulness of these responses. There was a greater distance to swim from the mirror wall to begin responding on the far sphere than there was to the near sphere. Swimming a greater distance could be interpreted as taking more effort. Crossman and Serna (1982) in a study with pigeons on FR schedules varied the distance that the operant key was depressed to be considered a response; the longer the distance, the more "effort" or response force was required. They found an increase in PRP as the ratio was increased for each different response effort required. Moreover, they found that the PRPs were longer and responding was less when the response effort required was high. This is very similar to the findings of the present study where the fish

reinforced for swimming to the far sphere responded with a lower overall rate and longer PRPs than the fish reinforced for swimming into the near sphere.

However, the effortfulness in Crossman and Serna's (1982) study was for each response, whereas in my study, the effortfulness was only on the first response in the run with every succeeding response requiring as little effort as that of swimming into the near sphere. Once the fish had swum to the far location, it needed only to swim in and out of the far sphere location. Thus, it may not be effortfulness that has depressed responding for fish reinforced for swimming into the far sphere.

In rats bar pressing for food, it has been found that the more effort the task requires, the lower the responding during extinction (Mowrer & Jones, 1943). Thus, it would be assumed that if rats show less resistance to extinction with more effort then the fish swimming into the far sphere should show less resistance to extinction. However, when comparing responding of two Bettas after CRF schedules, the fish reinforced for swimming into the far sphere took more sessions to reach criterion for extinction than did the fish reinforced for swimming into the near sphere. It appears then that the procedure of increasing the distance of the location of responding relative to the location of mirror presentations established increased resistance to extinction. This is the opposite of what was expected. Thus, it is unlikely that effortfulness was a factor in explaining the lower response rate found between the fish reinforced for swimming into the far sphere and the fish reinforced for swimming into the near sphere.

**Variability of responding and ratio strain.**

Although the two fish conditioned to the far sphere did show small but reliable changes in overall responding as the ratio size increased, results for one fish (Fish 3) showed variability of responding on the higher schedules which was likely a sign of ratio strain. Ratio strain was procedurally defined in my study as the fish failing to obtain more than three reinforcements in each of two consecutive sessions (Roper, 1973). None of the fish demonstrated ratio strain using this definition. However, a more precise definition of ratio strain may be conceptualized as the organism responding to the ratio schedule similar to the way it would respond to extinction (Sidman, 1960). During extinction following FR schedules, pauses (or periods of no responding) gradually lengthen and overall response rate declines (Ferster & Skinner, 1957).

Fish 3 showed an increase in overall response rate on ratio changes from CRF up to and including FR 3, but showed more variability in the response rate across sessions and inconsistency in the pattern of pausing between responses within sessions on the FR 4 and FR 6 schedules. Fish 4 did not show these signs of ratio strain. This is typical of past research where Bettas varied in the development of ratio strain from FR 4 to FR 7 (Hogan et al., 1970; Thompson, 1969).

Compared to Fish 4, Fish 3 was exposed to one main procedural difference that may explain its different pattern of overall responding and inter-response pattern on higher schedules when reinforced for swimming into the far sphere. Fish 3 was conditioned first to swim into the near sphere before being

conditioned to swim into the far sphere whereas Fish 4 was only conditioned to swim into the far sphere. Extinction-induced resurgence occurs when a previously extinguished behavior, reinforced under the same conditions as the behavior undergoing extinction, increases in frequency (Epstein, 1985). Under conditions of extinction for responding in the second sphere location, Fish 3 initially had an increase in response rate in the first sphere location compared to the previous phase.

If the increase in responding were due to an increased activity related to the transition to extinction, it would be expected that the other fish would show increased responding on the control spheres. However, the results for Fish 1 and Fish 4 (which were only conditioned to one sphere location), showed little to no responding on the control sphere during the second extinction of the experimental sphere. As well the results for Fish 2 (which was only demonstrated to be conditioned to the near sphere), showed no responding above baseline levels to the control sphere (i.e., far sphere) during the extinction of the experimental sphere (i.e., near sphere). This does seem to suggest that Fish 3 was undergoing a different effect than merely the onset of extinction. However, it is difficult to ascertain the reason for the increase in control sphere responding for Fish 3 during the second extinction phase as responding on the first sphere during extinction of the second sphere was not maintained long enough.

Variability in overall response rate across sessions and inconsistency of inter-response patterns are an indication of the need for better experimental control (Sidman, 1960). Ratio strain in Bettas needs further study to understand

the experimental control necessary to bring about consistent responding. Thompson (1969) was able with Bettas to delay the onset of ratio strain to the increase in ratio size by pairing different colored lights with the aggressive-display eliciting reinforcer (i.e., a model of a Betta). Using second-order conditioning, he was able to increase the ratio size above FR 7 and still maintain responding. It would seem that one could reduce the variability of responding and ensure schedule control by using this second-order conditioning procedure. Thus, it would be interesting to do further research on FR effects with Bettas using this procedure.

A number of variables have been suggested so far, that could have contributed to the failure to obtain large, consistent schedule effects in my study. The potential for increased activity elicited by mirror presentations or the delay of reinforcement to obscure effects, indicates a need for further investigation before assuming that the reinforcement effects do not generalize. The evidence in my study, however, does not rule out the possibility that the principles of reinforcement need to be modified to explain responding of different species with reinforcers besides food and water, such as Bettas with mirror presentations. The following is a look at the possible uniqueness of this reinforcer with this species.

### **Schedule Control and the Unconventional Reinforcer of Mirror**

#### **Presentations**

Some evidence of control by the FR schedule on the responding of Betta splendens to increases in ratio size was obtained when an aggressive-display eliciting reinforcer was used. Past research on Bettas' FR behavior with mirror

reinforcers found results that appeared similar to those found in the current study with the fish reinforced on FR schedules to respond to a sphere near in location to the mirror wall (Hogan et al., 1970; Turnbough & Lloyd, 1973); there were no obvious changes in overall response rate when the ratio was changed. As argued earlier, the increase in activity elicited by the mirror reinforcer may mask the effect of increasing the ratio size for responding on locations near the mirror.

Past research studied operanda that were located relatively close to the reinforcer and their results are similar to that of the fish, in the current study, when responding on the near sphere was reinforced. Hogan et al.'s (1970) hoop operandum was centered on the long wall of a five-gallon tank; the long wall was 42 cm, which means that the center where the operandum was situated was 21 cm from the mirror wall. Compared to the current study their operandum was farther away from the mirror wall than the near sphere of Fish 1 and Fish 2, at 7.5 cm and 5.0 cm respectively, but closer to the mirror wall than the far sphere for Fish 3 and Fish 4 at 55 cm. Considering the similarity of Hogan's results to those of the near-sphere fish along with the relative distances of the operandum to the location of the mirror reinforcer, Hogan's results were likely due to masking of the schedule effect by increased activity elicited by the mirror.

In further support of this conclusion, topographical data from the current study show that each fish spent most of the PRP within the half of the tank nearest the mirror wall, which is within the distance Hogan et al.(1970) had placed their operandum. The center of the tank in the present study was 30.6 cm from the mirror wall. In Hogan et al.'s study the hoop was situated only 21 cm

from the mirror wall. This location of the operandum likely influenced responding on FR schedules in Hogan et al.'s study in a similar manner as occurred for the near sphere in the current study.

The influence of relative distance between response location and reinforcer is even more convincing when Turnbough and Lloyd's (1973) results are considered. The distance of the operandum from the mirror in their study was similar to that of the near sphere in the current study. They found no change in overall responding to the change in the reinforcement schedule from CRF to FR.

2. Future research is required to determine what the critical values of the "near" and "far" designations are (i.e., distance of location of responding to that of the reinforcer) that provide specific differential effects.

Roper's (1975) investigation of the parameters of the unconventional reinforcer of nest material for mice was similar to the current study for Bettas with mirror presentations. Roper also demonstrated that location of responding and reinforcer dispenser affected the likelihood of changes in responding to changes in ratio size. However, location had the opposite effect in the current study than was found in Roper's study. In the current study the far location for responding brought responding under control of the FR schedules whereas Roper found that a close location of responding brought responding under the control of the FR schedules.

Besides a difference in species and type of reinforcer, there are other differences in design between Roper's study and the current study that may explain the discrepant results. One design difference is that Roper had separate

locations for the reinforcer dispenser and the terminal reinforcer-directed activity. The mice received the paper at the reinforcer dispenser but then had to travel to shred it at the site of the nest box at the other end of the cage. In the current study there was one general location where the reinforcer was presented (i.e., mirror wall), and where the fish engaged in reinforcer-directed activity (i.e., aggressive display). It may be that it is the location of terminal reinforcer-directed activity rather than the location of the reinforcer dispenser relative to location of responding that is the important condition for demonstrating FR schedule control.

From arguments presented earlier, it is possible that activity elicited by reinforcers can influence overall rate of response and PRPs (Hogan & Roper, 1978; Shettleworth, 1972) depending on the location of responding relative to the reinforcer. When considering Roper's research, it seems likely that activity elicited by the nesting material would occur in the vicinity of the nest box where the mice were consuming the material rather than near the operandum. In that respect, Roper's research design may be similar to the present study in terms of the far location of responding relative not to the location of the reinforcer but to the location of the terminal reinforcer-directed activity. This suggests that one should consider the location of terminal reinforcer-directed activity as well as the location the reinforcer is presented/delivered, especially when comparing across different types of reinforcers.

An unconventional reinforcer may account for the differences between the current study and past research with pigeons with regard to patterns of

responding across sessions on FR schedules. When food or water is the reinforcer, pigeons tend to show an increase in overall responding to a rate that is then maintained (Ferster & Skinner, 1957). The results found for the current study are not consistent with what has been found for pigeons. On the FR schedules higher than CRF, the fish generally showed an increase followed by a decrease in responding across sessions within each FR phase. An exception to this was results found for Fish 4, which were an initial increase followed by a decrease in responding, and then some recovery (i.e., a subsequent increase in responding). Roper (1973) likewise found an initial increase followed by a decrease in responding across sessions during FR schedules with mice when nesting material was used as the reinforcer. However, he also found that for some schedules there was recovery after the decrease in responding. This suggests that the general overall response rate pattern across sessions on a given schedule for the fish in this study may be typical of certain other species (e.g., mice) when unconventional reinforcers are used.

Swimming patterns found for Bettas in the current study when compared to a study with pigeons suggest across-species differences that may be due to the unconventional reinforcer. Atkinson (1985) did a topographical analysis of pigeons responding for food on FR schedules with a computer-tracking system similar to that used in the current study. He found that pigeons tended to move away from the response location (i.e., a key on the wall) during the PRP. The experimental sphere in the “near” location in the current study is most similar to Atkinson’s research in that the location of responding and the location of

reinforcer delivery are in close proximity. Unlike the results Atkinson found for pigeons, the fish reinforced for responding to the near sphere tended to remain close to this location during the PRP. The difference in PRP behaviour between fish and pigeons suggests an across-species difference. However, the swimming topography of all the fish in the current study, regardless of the location of the sphere to which responding was reinforced, indicated that these fish spent most of the PRP near the mirror wall (i.e., the reinforcer location). This difference between the results of the fish and pigeons may be due to the reinforcer type rather than the species. This possibility for Bettas could be investigated further by an examination of the PRP behaviour in a within-species (preferably within-subjects) comparison of food and aggressive-display reinforcers.

It has been postulated that the different response patterns found with Bettas when mirror presentations are the consequence are the result of an aversive component in this reinforcer type. Bols and Hogan (1979), using a T-maze, studied Bettas' choice behaviour of swimming into either the goalbox containing food or the one containing a mirror. Although both consequences maintained swimming, percent choice and speed were higher for food than for a mirror. Other behaviours that occurred for the mirror more than for food included greater time motionless in the runway, turning away from the goalbox, and air gulping. These behaviours were suggested to be indications of avoidance of the mirror due to an aversive component in the display situation.

The fish in the current study tended to spend much of the PRP near the mirror wall, which seems to challenge the notion of an aversive component.

Baenninger (1966) also found that Bettas spend most of the time in front of the mirror, and Gerlai and Hogan (1992) found that Paradise fish (i.e., a species closely related to Bettas) spend 90% of the time near a conspecific (i.e., another type of aggressive-display stimulus).

It is possible that the aversive component suggested to have occurred for the mirror consequence in the Bols et al. (1979) study was the result of the interaction of increased activity elicited by the mirror consequence and the limited space in the goalbox. It would be interesting to compare avoidance and approach behaviour in future research by comparing swimming patterns in a free operant design while varying the amount of space available where the mirror is presented as the reinforcer.

Hogan et al. (1970) were able to get experimental control of the overall responding of Bettas to FR schedules with food (i.e., the overall response rate increased as the FR schedule increased) but not with mirror presentations. Studying effects that are relatively consistent for rats and pigeons is recommended before attempting to replicate with a new species (Madden, Chase & Joyce, 1998; Sidman, 1960). The other FR schedule effects of changes in the PRP duration and PREE measured in my study have been found to be more consistent than changes in overall response rate with rats and pigeons. However, food was used as the reinforcer in much of the past research (Hogan & Roper, 1978; Shettleworth, 1972). Thus, one of the difficulties of determining the uniqueness of the mirror presentations as a reinforcer from my study is not having a comparison of these other FR schedule effects for Bettas when food is

used as the reinforcer. Future research of Bettas on FR schedules measuring the PRP and the PREE need to be performed with food as the reinforcer to ensure a more systematic comparison with research on rats and pigeons.

What the results of the present study do seem to suggest is that experimental control can be influenced by variables that are species and reinforcer specific. To be more specific, the increase in activity that affects responding in Bettas when mirror presentations are used as the reinforcer may be unique to this species with this type of reinforcer. However, this does not necessarily mean that general principles of reinforcement cannot apply to such specific variables. My study did demonstrate that responding of these fish with this reinforcer could be somewhat controlled by having a greater distance of the response location to the reinforcer location. This greater distance, on the other hand, potentially delayed reinforcement and likely contributed to the resistance to extinction that occurred after both continuous and partial reinforcement schedules. Thus, rather than indicating a lack of generality of the principles of reinforcement, my study supports the continued investigation of those conditions where the principles do not seem to generalize (Sidman, 1960).

### **Summary and Conclusions**

My experiment investigated the FR schedule effects shown with overall response rate, the PRP, and the PREE to determine whether the operant responses of Betta splendens can be controlled with an aggressive-display reinforcer (i.e., mirror presentations). To better understand this unusual reinforcer, the distance of the response location relative to the mirror wall

location was manipulated and found to bring responding under some control. That same manipulation seems to have affected resistance to extinction so that responding at the far response location became resistant even after a continuous reinforcement schedule. Thus, there was evidence to suggest procedural manipulations could affect responding on FR schedules in the same direction other species respond but that other variables were also controlling responding.

Interestingly, the answer to the question of whether there were schedule effects, other than changes in overall response rate to increases in ratio size, was made more obvious by manipulating the distance between the reinforced response and the aggressive-display reinforcer. The small but more obvious evidence of control found for the far as compared to the near response location relative to the mirror wall indicates that parameters of the aggressive-display reinforcer can be manipulated to induce changes in response patterns as the ratio is increased for Betta splendens. One explanation of the dependence on response-relative-to-reinforcer location for these measures is that results on FR schedules found for the near-sphere location were masked by the increased activity elicited by the mirror reinforcer (the close location of the sphere to the mirror wall likely led to adventitious sphere hits).

The PREE was also found to be a possible measure of schedule control; however, the results need to be replicated. Although a PREE was found for responding previously reinforced on the near-sphere location, resistance to extinction was found for responding on the far-sphere location regardless of the schedule of reinforcement during conditioning. The delay in reinforcement for

responding on the far sphere (i.e., due to the longer distance) was suggested to have increased the resistance to extinction at that location.

To better evaluate the generality of the effects of FR schedules on the responding of Betta splendens, it would seem more appropriate to study these effects using food as the reinforcer rather than an aggressive-display eliciting reinforcer for the following reasons. First, Hogan et al. (1970) were able to obtain experimental control with the overall response rate of Bettas for food but not for mirror presentation reinforcers. Second, the other schedule effects were found with rats and pigeons with the reinforcer of food and have not been demonstrated in Bettas. Though the present study was suggestive of FR effects when mirror presentations were used with Bettas, the effects were small. Third, though the present study does raise possibilities for other controlling variables, they are not easily studied. Fourth, further FR schedule results obtained with food reinforcers for this species would give a stronger basis from which to later study the possible unique effects of an aggressive-display eliciting reinforcer (e.g., mirror presentation).

Overall, the implications of the present study are that findings of past research on schedules of reinforcement with pigeons and rats likely generalize to the unconventional reinforcer of the mirror for Bettas but that further evidence is needed to better understand the controlling variables. The results of my study suggest that Hogan et al.'s (1970) findings were likely a false negative and thus, should be viewed with the same caution that a false positive would engender (e.g., Kourany, 1998). My results suggest that procedural parameters including

those involving the reinforcers need to be investigated for their effects on behavior before developing new theories for unconventional reinforcers.

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