Mixed Fixed-Ratio Schedules II:

The Effect of a Stimulus Change on Primes in the Large Ratio

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ABSTRACT

In mixed schedules which consist of large and small fixed-ratio components, a phenomenon known as priming occurs. Priming is evident when a run of responses followed by a pause occurs at the beginning of the large fixed ratio. The length of this run approximated the number of responses in the small ratio. The present study compared priming under a mixed fixed-ratio 10 fixed-ratio 100 schedule in which a change in key color was programmed in the large ratio with priming under the same mixed schedule without the stimulus change. In Experiment I, priming developed much slower and the number of responses in a prime was more variable in the mixed schedule without the stimulus change than the mixed schedule with a stimulus change following the first ten responses in the large ratio. In Experiment II, two factors were examined: (1) the role played by the presence of the food-reinforced fixed-ratio 10 component and (2) the location of the stimulus change in the large fixed-ratio component. Priming occurred only when the food-reinforced fixed-ratio 10 component was present. The location of the stimulus change determined the distribution of the number of responses in a priming run which suggests that the control exerted by the stimulus change could be transferred to stimuli along the response dimension.

RESUMEN

En los programas mixtos o mezclados, que consisten en componentes de razón fija grandes y pequeños, se presenta un fenómeno conocido como preparación. La prepara-

ción es evidente cuando se presenta una carrera de respuestas seguida por una pausa al comienzo de la razón fija grande. La longitud de esta carrera se aproxima al número de respuestas en la razón pequeña. El presente estudio comparó la preparación bajo un programa mixto razón fija 10, razón fija 100 en el que se programó un cambio de color en la llave en la razón grande con preparación bajo el mismo programa mixto sin el cambio de estímulo. En el Experimento I, la preparación se desarrolló más lentamente y el número de respuestas en una preparación era más variable en el programa mixto sin el cambio de estímulo que en el programa mixto con un cambio de estímulo que seguía a las primeras diez respuestas en la razón mayor. En el Experimento II, se examinaron dos factores:

1. *El papel desempeñado por la presencia del componente de razón fija 10 reforzado con comida y,*
2. *La ubicación del cambio de estímulo en el componente de razón fija grande. La preparación ocurrió sólo cuando estaba presente el componente de razón fija 10 reforzado con comida. La ubicación del cambio de estímulo determinó la distribución del número de respuestas en una carrera de preparación, lo que sugiere que el control ejercido por el cambio de estímulo puede transferirse a los estímulos a lo largo de la dimensión de respuesta.*

Ferster and Skinner (1957) were the first to note that priming runs occurred in mixed (mix) schedules consisting of one large fixed-ratio component (e.g., FR 190) and one small fixed-ratio component (e.g., FR 30). These priming runs occurred at the beginning of the large FR and consisted of a run of responses approximately the same length as the small ratio followed by a pause. Since then, little additional work has occurred with primes, although several other investigators (Bullock, 1960; Dews, 1958; Weissman, 1960) have noted their occurrence in mixed schedules. Recently, several studies have presented quantitative evidence of changes in the frequency of primes as a fuction of the frequency of the small component (Alferink and Crossman, 1975; Crossman and Silverman, 1973).

One possible reason for this scarcity of work on primes is the inability to control a prime precisely. Ferster and Skinner (1957) suggested that the length of a priming run corresponds ". . .roughly to the size of the smaller ratio" (p. 580). Thus, attempts to study priming have been restricted to definitions which allow an investigator to determine the frequency of priming by examining cumulative records. For example, Crossman and Silverman (1973) and Alferink and Crossman (1975) studied priming in mixed FR 100 FR 10 schedules with a prime defined as a run of from ten to twenty responses at the beginning of a ratio in the former study and from nine to eighteen in the latter. In addition, both studies required this run of responses to be followed by a pause of at least nine seconds. However, these definitions of primes imply considerable variability.

Several studies have attempted to make definitions of the priming run more explicit by using a response on a separate operandum to terminate the run. Using a fixed consecutive number (FCN), or counting schedule, Mechner (1958a, 1958b) required a minimum number of consecutive res-

ponses on lever A before a response on lever B was reinforced. Although the lever B response made the definition of run termination more explicit, it did not eliminate the variable lengths of the response sequences on lever A.

The priming run in a mixed FR schedule has been described as responding which produces a stimulus condition that signals non-reinforcement for the shorter component and hence, the aminal pauses (Alferink and Crossman, 1975). Earlier studies have suggested that exteroceptive stimulus changes produce better control over responding than do response-produced stimuli. Thus, Ferster and Skinner (1957) reduced the number of non-reinforced responses in a fixed-interval (FI) schedule by providing the subject with an exteroceptive stimulus correlated with the passage of time in the interval (added clodk), Lydersen and Perkins (1974) obtained greater accuracy in a discrimination paradigm with exteroceptive stimuli than with response-produced stimuli and Laties (1972) reduced the variability in the lengths of response runs in an FCN procedure by providing a stimulus change following completion of the response requirement. These studies suggest that providing an exteroceptive stimulus change in the larger component of mixed FR FR schedule following the completion of the response requirement of the smaller component would probably reduce the variability in the length of the prime.

EXPERIMENT I

The purpose of this experiment was to compare the development of priming under a standard mix FR 10 FR 100 schedule with that under a mix FR 10 chain FR 10 FR 90 schedule. The latter schedule is referred to as "mix" since the same key color is present in the food-reinforced FR 10 and in the FR 10 component of the chain. It was expected that changing the key color after the tenth response in the chain would affect both the rapidity with which primes begin to appear in the chain, as well as the number of responses in a priming run.

Method

Subjects

Four White King pigeons maintained at approximately eighty percent of their free-feeding weight served. Two subjects (K-9 and K-12) were previously trained on a fixed-ratio 100 schedule, while the other two subjects (K-11 and K-53) had no previous history with ratio schedules. The age and sex of each pigeon was undetermined.

Apparatus

Two identical three-key pigeon chambers were used (Lehigh Valley). The inside dimensions of the chambers were 53 X 47 X 59 cm. Reinfor-

cement consisted of 3-sec access to an illuminated hopper containing Purina Pigeon Chow. The center response key, located 10.5 cm above this food hopper, was transilluminated by a red light during each session, except during reinforcement. The remaining two keys were not used and remained dark. The chamber was illuminated during experimental sessions by two 7.5 W bulbs located near the top of the front panel on which the response keys were mounted. The experiment was controlled and data were recorded by electro-mechanical equipmen housed in an adjacent room. Primes were recorded by an on-line, PDP-8 digital computer (Digital Equipment Corporation).

Procedure

Birds K-9 and K-12 were already trained to respond on an FR 100 schedule, and following exposure to a chained (*chain*) FR FR schedule (see Experiment II), were placed on a *mix* FR 10 FR 100 schedule. The key remained red during both FR 10 and FR 100. Birds K-11 and K-53 were trained to respond on an FR 100 schedule by gradually increasing the response requirement. Following this training, K-11 and K-53 were placed on a *mix* FR 10 *chain* FR 10 FR 90 schedule. The key was red during FR 10 and green during FR 90; thus, a stimulus change was provided after ten responses in the component requiring 100 responses. The probability of the food-reinforced FR 10 occurring in the standard mixed schedule or in the mixed chain schedule was fixed at approximately 0.25 and was determined by a pseudorandom sequence which specified that no more than three consecutive FR 10s could occur. Daily sesion length was fixed at 60 reinforcements or 2 hours, whichever occurred first.

A prime was defined as a run of from 8-40 responses followed by a pause of at least 5 sec. A frequency distribution of the number of responses in a priming run was obtained for each sesion. Each schedule remained in effect for a minimum of 18 sessions and until the behavior stabilized (or a maximum of 40 sessions). The behavior was considered stable when the mode of the frequency distribution of priming run lengths for one block of three sessions was identical to the mode of the following three-session block.

Results

Figure 1 shows the percentage of FR 100s (or *chain* FR 10 FR 90s) containing a prime for each session. On the *mix* FR 10 FR 100 schedule (birds K-9 and K-12), primes were infrequent in the first 8-14 sessions and then gradually increased to approximately 85-95 percent. On the *mix* FR 10 *chain* FR 10 FR 90 schedule (birds K-11 and K-53), priming rapidly increased to approximately one hundred percent for both birds.

While the data in Figure 1 provide an account of increases in priming over sessions, no information is provided about the changes in run length
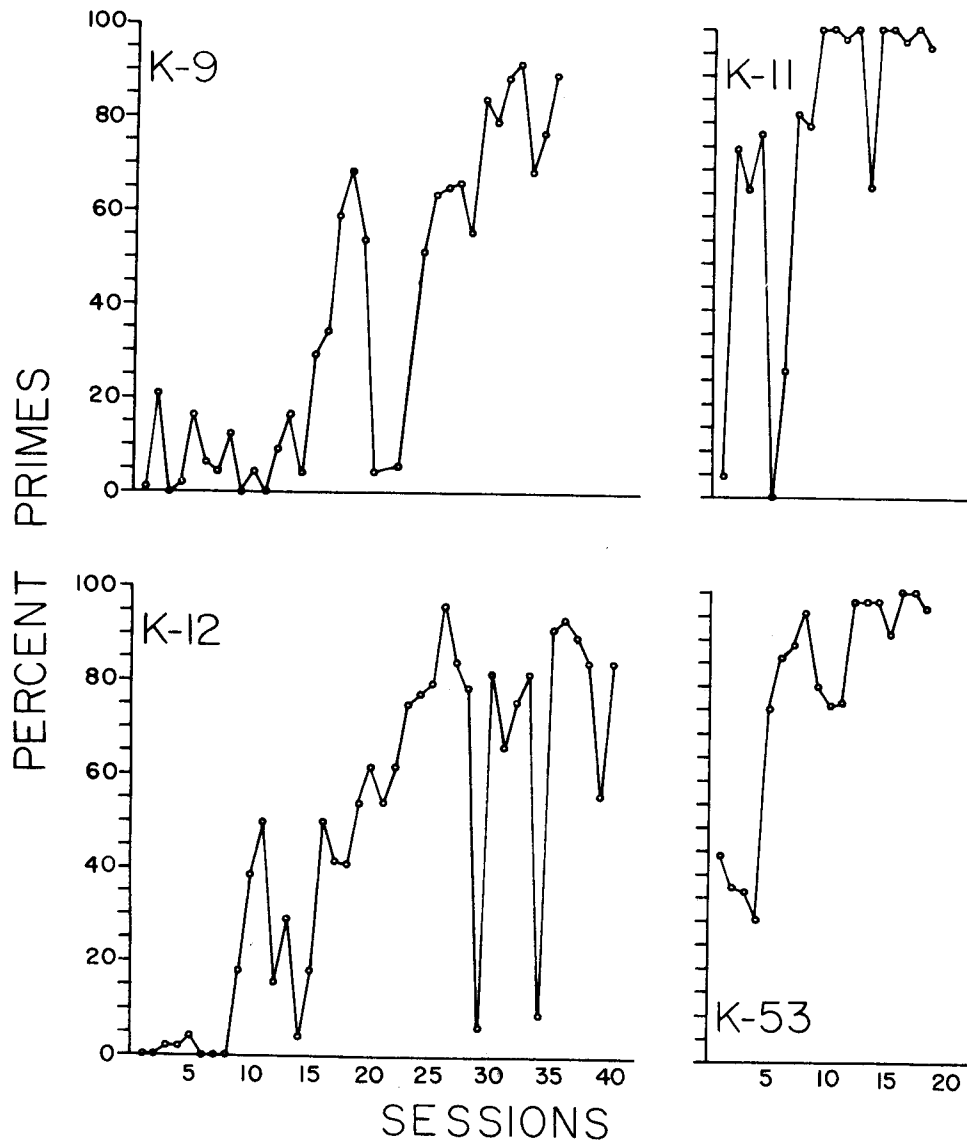
Figure 1. Percent of FR 100s (or *chain* FR 10 FR 90s) containing primes for each session. Birds K-9 and K-12 were on a mixed FR 10 FR 100 schedule and birds K-11 and K-53 on a mixed FR 10 chained FR 10 FR 90 schedule.

which accompanied this increased priming. This additional information is provided in Figure 2 in which the frequency distribution of the number of responses in a prime is shown for every fourth session. In the initial sessions on the *mix* FR 10 FR 100 schedule (K-9 and K-12), the number of responses in a priming run varied unsystematically without the formation of a definite mode. As priming increased in frequency, a mode which more closely approximated ten responses occurred. The modal frequency for K-9 and K-12 in the last six sessions occurred at 14-16 responses, but considerable variability in priming run length was evident.
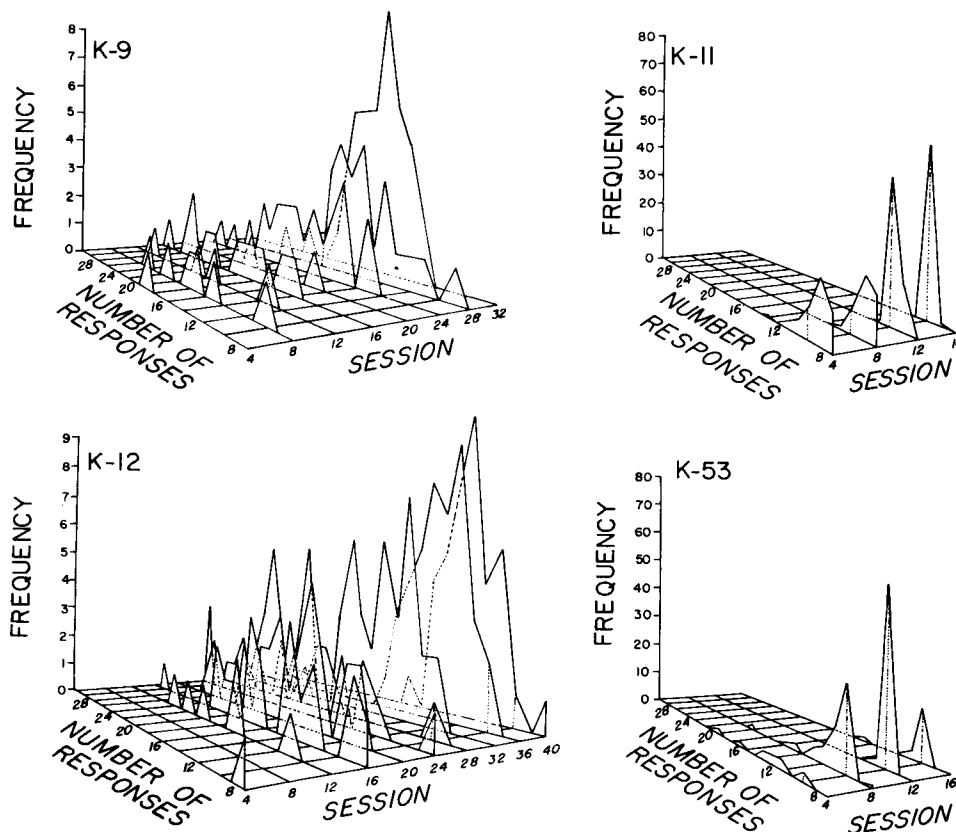

Figure 2. The frequency distribution of the number of responses in a priming run for every fourth session. Birds K-9 and K-12 were on a mixed FR 10 FR 100 schedule and birds K-11 and K-53 were on a mixed FR 10 chained FR 10 FR 90 schedule. Dashed lines indicate priming runs consisting of ten responses. Note the difference in the frequency ordinate for the mixed FR 10 FR 100 schedule (birds K-9 and K-12) and the mixed FR 10 chained FR 10 FR 90 schedule (birds K-11 and K-53).

The development of primes was more rapid in the *mix* FR 10 *chain* FR 10 FR 90 schedule. While primes were variable in length in the initial sessions, a mode of ten responses developed and was consistently maintained. In the final sessions, primes which did not consist of ten responses were infrequent.

EXPERIMENT II

Experiment I demostrated that priming developed more rapidly under the *mix* FR 10 *chain* FR 10 FR 90 schedule than under the standard *mix* FR 10 FR 100 schedule. Moreover, a modal priming run length which was relatively invariant was established early in the mixed chain procedure.

Throughout the first experiment, the location of the stimulus change in the *chain* component was fixed on the basis of the size of the smaller food-reinforced schedule, i.e. FR 10. The purpose of the second experiment was to determine whether manipulating the location of the stimulus change in the *chain* component would affect the distribution of responses comprising a prime, and also to determine whether priming occurs in a *chain* FR 10 FR 90 schedule.

Method

Subjects

Pigeons K-9 and K-12 served.

Apparatus

The apparatus was the same as in Experiment I.

Procedure

Both K-9 and K-12 were initially exposed to a *chain* FR 10 FR 90 schedule following training on an FR 100 schedule. The key was red during FR 10 and green during FR 90. Since the food-reinforced FR 10 did not occur, any primes would be a function of the stimulus change alone. After the behavior stabilized, the schedule was changed to *mix* FR 10 FR 100 (see Experiment I). Thus, the small FR was added and the green key color was removed. Primes which occurred in this condition provided a baseline of priming controlled by the small FR.

Subsequeñtly the stimulus change (a change from a red to a green key color) was added to the FR 100 making the large component in the mixed schedule into a chained schedule. This stimulus change occurred after either 10, 20, or 30 responses in the chained schedule (see Table 1). Conditions were changed when the behavior stabilized or a maximum of forty sessions

ocurred. The stability criteria and all other conditions, remained the same as in Experiment I.

TABLE 1. *A summary of the experimental conditions for Experiment II and the number of sessions each remained in effect.*

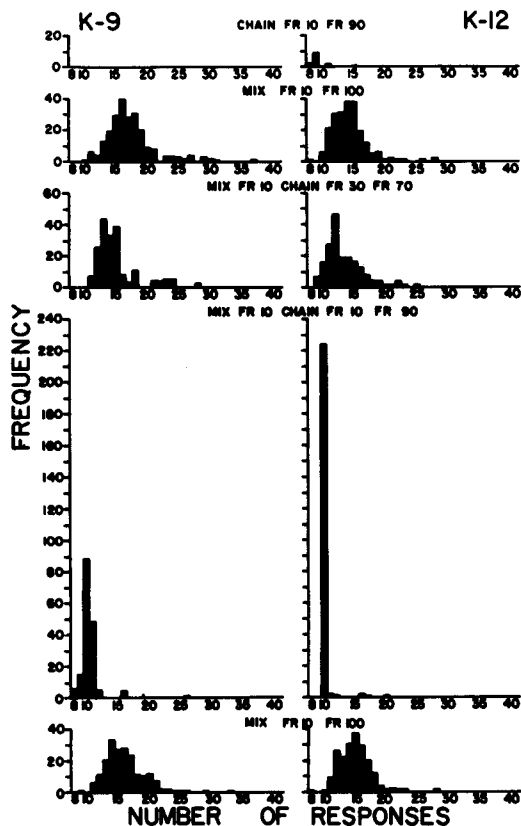|	Number of Sessions	
Condition	K-9	K-12
Chain FR 10 FR 90	20	15
Mix FR 10 FR 100	36	40
Mix FR 10 *Chain* FR 20 FR 80	5	6
Mix FR 10 *Chain* FR 30 FR 70	12	7
Mix FR 10 *Chain* FR 10 FR 90	9	6
Mix FR 10 FR 100	12	11

Figure 3. Frequency distributions of the number of responses in a priming run from the last six sessions for each condition.

Results

In Figure 3, frequency distributions of the number of responses in a prime are shown for each condition. The *chain* FR 10 FR 90 schedule produced few primes. On the *mix* FR 10 FR 100 schedule, primes were frequent and generally consisted of approximately 15 responses for both subjects.

On the *mix* FR 10 *chain* FR 20 FR 80 schedule (not shown in Figure 3), primes tended to occur most frequently after runs of twenty responses although other priming run lengths were frequent. The occurrence of these primes may have resulted from a failure to discriminate between runs of then responses and runs of twenty responses. Therefore, although the stability criterion had not been reached, the difference between these runs was enlarged and the schedule was changed to *mix* FR 10 *chain* FR 30 FR 70. Under this schedule, primes always preceded the occurrence of the stimulus change. Also, the entire distribution shows a slight shift to the left, particularly for bird K-9, when compared to the *mix* FR 10 FR 100 distributions.

On the *mix* FR 10 *chain* FR 10 FR 90 schedule, primes generally consisted of ten responses. In addition, much less variability in the number of responses in a prime was evident for this schedule as opposed to the other mixed schedules. Each of the last six session modes for K-12 and five out of the last six session modes for K-9 occurred at primes consisting of ten responses. On the other mixed schedules (excluding the *mix* FR 10 *chain* FR 20 FR 80 schedule), individual session modes did not necessarily correspond with the overall mode for the block of six sessions.

DISCUSSION

In a standard mixed schedule, e.g., mix FR 10 FR 100, the number of responses in a prime is a product of response-produced stimuli since the animal does not receive exteroceptive feedback after emitting 10 responses in the FR 100 component. As a result, the length of the priming run varied considerably as shown in the present experiment, and the appearance of primes in the FR 100 components developed slowly. In contrast, if the animal was provided with an exteroceptive stimulus after emitting 10 responses in the FR 100 component, primes developed rapidly and consisted almost exclusively of runs of ten responses.

The variability in prime run lenght under the *mix* FR 10 FR 100 schedule in the present experiment agree with results previously obtained using observing response techniques (Hendry, 1969). In Hendry's study, responses on an observing key changed the schedule on the food key from a *mix* FR 20 FR 100 to a *mult* FR 20 FR 100. Generally, the animal would make an observing response before responding on the food key. However, sometimes an abserving response was not emitted at the beginning of a ratio; instead, it occurred after approximately thirty responses in the FR 100.

While the observing procedure is not directly comparable to the procedure used in the present study, the modal run length under the observing procedure was roughly proportional to the modes at 15 responses which occurred on the *mix* FR 10 FR 100 schedule in the present study.

Comparisons between the affects of exteroceptive stimuli with response-produced stimuli have been made in several previous studies. Lyderson and Perkins (1974) showed that a discrimination between two different FR schedules developed more rapidly and with greater accuracy with exteroceptive rather than response-produced stimuli.

In the present study, "accuracy" was also better with an exteroceptive stimulus than without one in that the large ratio contained a larger percentage of primes with the exteroceptive stimulus. Likewise, primes developed more rapidly with the exteroceptive stimulus than when only response-produced stimuli were available. In addition, the run-length distributions on which the discrimination between ratios was presumably based in the Lyderson and Perkins experiment were less variable with the exteroceptive stimulus than without it.

These results thus confirm those of Laties (1972) who found that a stimulus change following the completion of the response requeriment reduced the variability in run lengths in an FCN schedule. The present study also showed that an even greater reduction in variability could be obtained in mixed FR schedules than was obtained by Laties in an FCN schedule.

Since the first experiment generated findings which integrated well with the results from several different procedures as just discussed, the second experiment explored several of the variables thought to be responsible for the highly stereotyped pattern of priming under the *mix* FR 10 *chain* FR 10 FR 90 schedule. When the birds were placed on a simple *chain* FR 10 FR 90, there was very seldom an instance where a pause developed following the FR 10 component. This, of course, implicates the necessity of the food-reinforced FR 10 component in the mixed schedule if priming is to appear. The absence of a pause following the stimulus change in *chain* FR FR schedule has been reported previously (Crossman, 1969; Jwaideh, 1973; Sheldon, 1971).

Given that the necessity of the food-reinforced FR 10 schedule together with a stimulus change following ten responses in the chain had been shown, the next question was how priming would be affected by changing the locus of the stimulus change within the chain. It might be expected, for example, that with the stimulus change following thirty responses in the chain, i.e., *mix* FR 10 *chain* FR 30 FR 70, the priming run length would increase to thirty. However, the typical run length in most primes was thirteen rather than thirty responses when the stimulus change occurred after thirty responses. This suggests that the exteroceptive stimulus did not determine prime run length as it did in the *mix* FR 10 *chain* FR 10 FR 90 schedule. In other words, it now appears that there must be a closer correspondence between the size of the small food-reinforced FR schedule

and the size of the first component in the chain. There was, in the present study, an opportunity to examine priming with the *mix* FR 10 *chain* FR 20 FR 80 schedule. Although this procedure was not run to complete stability, the fact that primes consisting of twenty responses increased in frequency suggests that the exteroceptive stimulus change exerted more control under this schedule, than under the *mix* FR 10 *chain* FR 30 FR 70 schedule where primes of thirty responses seldom, if ever, occurred.

Relevant to the remarks made earlier in conjunction with the various possible sources of stimulus control in the mixed schedule, it now seems reasonable to conclude that when the sizes of the small food-reinforced FR schedule and the first link of the chain are widely discrepant, priming run length falls under the control of response produced stimuli, as in standard mixed schedules. However, as the differences in the size of these two variables is reduced, control by the exteroceptive stimulus change predominates. The precise point at which control transfers from one source of stimuli to the other cannot be determined from the present data, but future manipulations within the paradigm outlined in Experiment II would seem to offer promising direction.

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