THE ROLE OF SIGNAL FUNCTIONS IN TWO-AND-THREE LINK CHAIN AND TANDEM SCHEDULES OF REINFORCEMENT WITH EQUAL INTER-FOOD INTERVAL

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ABSTRACT

THE ROLE OF SIGNAL FUNCTIONS IN TWO-AND-THREE LINK CHAIN AND TANDEM SCHEDULES OF REINFORCEMENT WITH EQUAL INTER-FOOD INTERVAL

by James W. Becker

It is well established that previously neutral stimuli may function as conditioned reinforcers following a history where those stimuli consistently predict upcoming food. However, Gollub (1958) showed that stimuli in multi-link chain schedules with long inter-reinforcer intervals can have rate-attenuating effects on behavior when compared to tandem control conditions without such stimuli. This effect is measured both by response rate and by post-reinforcement pauses. It is unknown whether the behavior-attenuating effects of signals is due solely to the inter-food interval because this variable was always confounded with the number of links and consequently the stimuli presented. The proposed study addressed this issue by comparing lever pressing by rats under two-and three-link fixed-interval chain and tandem schedules when the inter-food interval was held constant. Responding within each link was compared using a mixed-groups design. Each rat experienced two conditions where temporal proximity to the upcoming reinforcer was either intermittently signaled (chain) or unsignaled (tandem). Consistent with the literature, post-reinforcement pauses were longer during the chain compared to the tandem schedule. Moreover, the 3-link schedule produced longer pauses during the chain compared to the 2-link schedule. This result was expected; because the initial-link stimulus associated with the longer schedule, (i.e. more links) was more temporally removed from food compared to the initial-link stimulus associated with the shorter schedules

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CHAPTER I

INTRODUCTION

Human actions often involve extended sequences of behavior that eventually lead to a terminal reinforcer. These sequences are considered a behavioral chain whereby a set of responses have to be emitted in a specific order. Reynolds (1968) provided a good example of going out to eat as a behavioral chain. The initiation of that chain might be calling a friend and inviting them out to dinner. The sequence of behaviors that follow would be many: walking to the car, driving to the restaurant, being seated, ordering the food, and finally consuming the meal. Each step in the chain is necessary for the next; for example, we would not order food without a waiter present nor would we enter a car before opening the door.

An important feature of such behavioral chains is that each response changes the environment in some unique way (i.e., produces a stimulus change). A traditional analysis of stimuli in behavioral chains posits two functional roles of the stimuli: reinforcing and discriminative. Stimuli in chains serve a reinforcing function when they increase the probability of behavior that produced those stimuli. Such stimuli can also serve a discriminative function when they increase the potential for subsequent behavior (i.e., next step in the chain). Signaling a waiter, for example, results in the waiter coming to the table (thus reinforcing the signaling) and increases the probability that the food order will be placed.

In laboratory settings, chain schedules are used to study extended sequences of behavior, often involving non-human animals. A chain schedule is a compound schedule in which reinforcers are produced by successive completion of two or more schedules of reinforcement, each operating in the presence of a different stimulus (Catania 2013, pg. 217). Each schedule of reinforcement within a chain schedule are accompanied by a unique stimulus is defined as a link, which is a single component of the chain. Although chain schedules and behavioral chains are similar, there is a difference. Because chain schedules of reinforcement are programmed in laboratory settings, they allow for control of the inter-reinforcer interval (IRI) and the number of links. The IRI is defined as the time between reinforcer presentations. The number of links refers to the number of schedules needed to be completed before a reinforcer is produced. In chain schedules, short or long IRIs and the number of links can be programmed based upon the experimental question.

To determine how signals in chain schedules affect behavior, a baseline needs to be established in a condition that does not have different stimuli in the links. Tandem schedules serve this function because they are identical compound schedules to the chain, but unlike chain schedules, all links operate under the presence of a single stimulus (Catania, 2013 pg. 217). Therefore, any changes in behavior resulting from a tandem and chain schedule transition can be attributed directly to the addition or removal of the stimuli.

This thesis describes a new experiment that evaluated whether the inter-food interval or the number of links controls behavior during chain schedules with long IRI's. In order to facilitate an understanding of chain schedules, a brief overview of the literature related to chain schedules is provided. Articles related to conditioned reinforcement and stimulus control are discussed as these are necessary for understanding chain schedule behavior, but an in-depth review of these two areas is outside the scope of the current review (see Kelleher, & Gollub, 1962; Williams, 1994; Shahan, 2010; and Dinsmoor, 1995 for a more detailed review of this literature.

Prior to behavioral chains first being investigated in the laboratory, they were conceptualized as eating reflexes (Mangus, 1924 as cited by Skinner 1938), and later studied as conditioned reflexes by Pavlov (1927). However, in 1938 Skinner first studied behavioral chains in a laboratory setting using operant conditioning. He indicated that behaviors could produce a consequence that would set the occasion for an additional response to occur which was necessary to produce reinforcement. Using this framework, Ferster and Skinner (1957) created chain schedules of reinforcement, which arranged contingencies whereby the first behavior produces a stimulus, and in the presence of that stimulus, an additional behavior produces reinforcement. Within chain schedules, two of the most common classifications of behavioral chains are heterogeneous and homogeneous. A heterogeneous chain is when the topography of the response differs within the sequence (as in the dinner example). Homogeneous chains in which the topography of the response in the sequence is identical have been studied more extensively in laboratory settings (Skinner, 1938; Ferster & Skinner, 1957; Keller & Fry, 1962). Based upon this early research, it was generally assumed that stimuli in chain schedules *always* functioned as discriminative stimuli and conditioned reinforcers. In 1958, that assumption was challenged by the dissertation of Lewis R. Gollub.

Gollub (1958) investigated the effects of multi-link (involving more than two link) chain schedules with long inter-reinforcement intervals (IRI). Pigeons had to complete a series of five fixed-interval (FI) 1-min schedules for food to be delivered. The first key peck after 1 min moved to the next FI schedule; the first key peck after the following 1 min moved to the next link, and so on. This progressed until the fifth or terminal link was reached. In the terminal link, the first key peck after 1 minute produced 4.5-s access to grain. In the tandem-schedule condition, a single stimulus (white light) was present throughout each of the five links. In the chain-schedule condition, each link was associated with a different colored key light, so a key peck that fulfilled the schedule requirement and initiated the next link was accompanied with a stimulus change. Key pecking was disrupted and actually ceased for some pigeons in the initial link of the chain schedule upon transition from the tandem to the chain condition. Overall, the general rate of key pecking decreased across sessions in the chain-schedule condition but not in the tandem-schedule condition. Post-reinforcement pauses (PRPs) increased for all subjects during the chain condition compared to the tandem condition, and this increase occurred mainly in the presence of the initial-link stimulus. Gollub (1958) conducted additional tandem and chain comparisons with two-and three-link schedules with FI values of 30 s and 1.5 minutes. Interestingly, during the two-link FI 30-s chain schedule increased key pecking in the initial link, suggests that the stimulus paired with food functioned as a condition reinforcer. Wallace (1982) however, failed to replicate this result in a systematic replication of Gollub's two-link chain schedule using three different FI values (8, 32, and 120 seconds). Moreover, with all of Gollub's subsequent chain schedules (3 and 4 link), evidence for conditioned reinforcement (i.e., higher rates of response in the chain schedule) was not observed.

In 1973, Jwaideh also compared behavior under multi-link tandem and chain schedules. However, she used fixed ratio rather than fixed interval schedules and investigated schedules with different number of links while equating the ratio requirement. Across conditions of the experiment, pigeon's key pecked under both three-and five-link tandem and chain FR schedules (e.g., FR 20, FR 20, FR 20 and FR 12, FR 12, FR 12, FR 12, FR 12). To progress through the links, a fixed number of responses were required. Food was presented only after completing the ratio requirement in the terminal link. Consistent with Gollub, the PRP durations were generally longer during the chain condition, except at the smallest FR value, and run rates were lower under the chain schedule than the tandem but only at the largest FR value. Moreover, PRP duration was longer under the five-link than the three-link chain schedule.

The results from Gollub and Jwaideh are fascinating and counterintuitive because the stimuli during the extended chain schedules failed to generate higher response rates relative to the tandem schedule. This contrasted with earlier findings—and the general consensus—that stimuli during chain schedules function as conditioned reinforcers. Gollub (1958) interpreted his results based on the establishment of stimuli as conditioned reinforcers. The stimulus present during the tandem schedule was continuously illuminated throughout the interval and was temporally contiguous with food. The stimuli, especially, in the early links of the chain schedule were temporally removed from food. Therefore, from that perspective, the stimuli in the tandem schedule were more likely to function as conditioned reinforcers and maintain responding throughout the tandem interval. However, in the chain schedule, only the terminal stimulus was directly correlated with food. It was the failure of the initial and middle-link stimuli to develop as conditioned reinforcers that Gollub posited as the reason responding was not maintained during the five-link schedule. Jwaideh's argument, on the other hand, was somewhat different and focused on the nature of antecedent control. During the chain schedule a "least favorable" relationship develops with the initial link stimulus: Because food never occurs in the presence of this stimulus, it comes to function as an ess-delta (S^{Δ}), and so decreases the probability of a response.

In conjunction with Gollub and Jawaideh revealing that stimuli in chain schedules may, not always, function as conditioned reinforcers; Fantino (1969b) hypothesized that if two chain schedules with equal inter-reinforcer intervals were segmented differently and tested for preference that preference should develop for the schedule with the least amount of links. To investigate this question, Duncan and Fantino (1972) used a concurrent chain schedule to examine preference. In Experiment 1, pigeons responded on two concurrently available keys with identical initial link variable-interval (VI) 60-s schedules. Each key provided access to a different terminal link, in this case, either an un-segmented FI 30 s or a 2-link chain schedule of FI 15 s FI 15 s. Results revealed that preference developed for the un-segmented schedule. This is believed to have occurred because the stimulus in the un-segmented schedule was functioning as a conditioned reinforcer, whereas in the two-link schedule there is an additional stimulus presentation prior to the food-paired stimulus. Similar, to Jwaideh's interpretation, food is never available in the presence of the first link stimulus, so it functions as an S^{Δ} for responding and, as a result, shifts preference to the un-segmented schedule. In Experiment 2, the choices in the terminal links were between a two-link chain schedule (FI 60 s FI 60 s) and a three-link chain schedule of (FI 40 s, FI 40 s FI 40 s). Preference developed for the key paired with the two-link schedule. Because there is an additional stimulus presentation in the three-link chain schedule, and food is never available in the presence of either stimulus they both function as S^{Δ} for responding and shift preferences towards the two-link.

Although Gollub's demonstration of signals not maintaining behavior under a five-link chain schedules was in contrast with the earlier perspective, the number of links during the chain schedule was confounded with the IRI. When Gollub compared the two-and five-link schedules he did not compensate for the increase in the IRI that resulted from increasing the number of links. This leads to an issue in interpretation, insofar as, it is unclear which variable (number of links or inter-food interval) contributed to the reduction in responding. By holding the IRI constant and then directly comparing a two-and three-link chain schedule, we can further elucidate which characteristic of the schedule (i.e., number of links or inter-food interval) is the controlling variable.

The present study was designed to evaluate whether the inter-food interval or number of links controls behavior during chain schedules with long IRI's. Two groups of rat's lever pressed on either a two- or three-link schedule with equal-value initial links, with the presence and absence of signals being investigated across conditions. Both tandem and chain schedules had identical inter-food interval of 180 seconds regardless of the number of links. The three-link schedule was comprised of three FI 60-s schedules in each link (e.g. FI 60 s, FI 60 s, FI 60 s). The 2-link schedule was comprised of an FI 60 s in the first link and an FI 120 s in the second link (e.g. FI 60 s, FI 120 s). The predicted outcome of this experiment was first, that tandem schedules will maintain higher rates of behavior and shorter pauses (PRPs) then chain schedules. Secondly, the three-link chain schedule will maintain longer pauses (PRP) and lower response rates than the two-link chain schedule. This prediction was based upon results obtained by Gollub's research on multi-link schedules, and through the literature as what properties stimuli are most likely to acquire during extended chain schedules. If, on the other hand, the IRI duration is what matters most as opposed to number of links, then both two-and three-link chain schedules should show no differences in behavior.

CHAPTER II

METHOD

Subjects

Eight male Sprague-Dawley rats were used for this experiment (approx. 1 yr.). Rats were maintained at 85% free feeding weight (FFW). Rats came from the behavioral analysis lab class with experience lever pressing for food under simple schedules of reinforcement. Subjects were individually housed and placed on a reverse day/night cycle, 12-hour day: 12 hours' night (lights on at 8:00 pm). Experimental sessions were conducted five days per week at approximately the same time of day and during the night cycle.

Apparatus

Sessions were conducted in four standard Med-Associates (Georgia, VT) rat operant chambers measuring 29 cm long by 23 cm wide, and 21 cm tall. Left and right response levers were mounted on the front panel 6 cm from the grid floor and between these levers was an opening for a pellet dispenser that delivered 45 mg sucrose pellets (Bio-Serv) into a food hopper located in the center of the front panel 2 cm above the floor, 5 cm wide by 4 cm tall. Left and right stimulus lights were mounted 7 cm above the levers, and a tone generator with speaker was mounted on the upper right corner of the rear wall of all chambers. Finally, a house light (28v) with a shielded bulb was mounted in the middle of the rear wall, 17 cm above the grid floor.

Procedure

Because all rats had previously been trained to lever press, they were placed under fixed-interval (FI) 180-s schedule of reinforcement, during which reinforcement was delivered upon the first lever press after 180 s had elapsed.

Rats were randomly assigned to either the three-link or a two-link group, with 4 rats in each group. Both of these conditions always totaled the minimum IRI of 180 s and remained consistent throughout the study. The three-link schedule comprised three FI 60-s schedules in each link (e.g. FI 60 s, FI 60 s, FI 60 s). The two-link schedule comprised an FI 60 s in the first link and an FI 120 s in the second link (e.g. FI 60 s, FI 120 s). Once the rats demonstrated reliable lever pressing, determined through visual inspection of the data, a tandem schedule was implemented for a minimum of 20 sessions. Under this schedule arrangement, the requirement for each link had to be satisfied to proceed to the next link. Completion of the terminal link produced a food pellet. The three-link FI schedules required the rats to lever press once after 60 s to advance to the subsequent links and ultimately produce food. The two-link FI schedule required the rats to lever press once after 60 s to advance to the next link then lever press after 120 s to produce food. During the tandem schedules, the house light was the only illumination and it remained on throughout the session.

A minimum of 20 sessions was conducted before a condition change occurred. When the 20th session was reached, the data were analyzed for trends. When there were no trends in responding or pauses the tandem schedule was replaced with a chain schedule. If trends were present, the tandem schedule continued until stability was reached.

In the chain schedule, signals were presented through the stimulus light above the left lever. Each link was represented by a unique stimulus (solid, .06 s on/off, .22 s on/off) and two link (solid, .22 s on/off). Completion of a link schedule requirement advanced the schedule to the next link, which was accompanied by a stimulus change.

This study utilized a between group comparisons design with a reversal. The tandem schedule was in effect for minimum of 20 sessions. Once the criterion was met, rats were subjected to their respective chain schedule for a minimum of 20 sessions. Finally, rats were returned to their respective tandem schedules for 20 sessions.

Data Analysis

The primary data of interest was pausing. Pauses were separated into two categories, link pauses and PRP. A link pause occurs after completing the previous link, but before starting the next (i.e., after link 1, but before link 2 and after link 2, but before link 3). Average pausing constitute the time that the rat was not engaged in the target behavior (lever pressing) and was not experiencing a link 1 or link 2 pause. Run rates also were analyzed; they were calculated by dividing the total number of responses by the total session time minus the total PRPs. Run rates were analyzed during each link and for the entire session. Data from the last 10 sessions, representing steady state, are presented.

CHAPTER III

RESULTS

The number of sessions varied within each condition based upon the rat's performance (see Table 1). There were individual differences with average number of reinforcers earned, and the largest reduction is most noticeable in the 3-link group (BA1412, 13, 19, 28).

Table 1. *Number of sessions and reinforcers earned under each condition for each rat.*

Subject	Condition	# of Sessions	Reinforcers Earned: Mean	Reinforcers Earned: SD
BA1418	Tandem	24	15.9	1.36
	Chain	84	11.9	2.77
	Tandem	20	14.2	1.67
BA1420	Tandem	13	13.9	1.75
	Chain	23	12.4	1.64
	Tandem	30	13.7	1.43
BA1423	Tandem	13	16.7	1.09
	Chain	22	13.4	1.81
	Tandem	28	15.4	1.23
BA1438	Tandem	43	13.9	1.52
	Chain	55	7.6	3.39
	Tandem	22	8.9	3.36
BA1412	Tandem	21	14.4	1.77
	Chain	40	7.9	3.62
	Tandem	49	8.0	2.74
BA1413	Tandem	35	14.1	1.59
	Chain	31	9.9	1.67
	Tandem	40	12.3	1.99
BA1419	Tandem	27	15.4	1.31
	Chain	64	11.5	2.48
	Tandem	47	14.3	1.54
BA1428	Tandem	50	11.0	2.80
	Chain	35	7.6	3.38
	Tandem	47	7.1	2.03

Figure 1a shows the average post-reinforcement pause across conditions for both groups. Average pause duration for group 1 (2-link) during the tandem condition ranged from 50 to 100 seconds and increased during the chain condition, ranging from 130 to 500 seconds. Average pause duration for group 2 (3-link) ranged from 80 to 120 seconds during the tandem and increased in 3 of 4 rats (230 to 400 seconds) during the chain.

Figure 1b shows the average PRP across conditions for each subject. In the 2-link following the reversal, 2 of the 4 subjects returned to previous levels with BA1420 and BA1423 stabilizing at 126 and 80 seconds (respectively) and the 3-link, 3 of the 4 rats returned to levels similar to baseline with BA1412 failure to return skewing the group average.

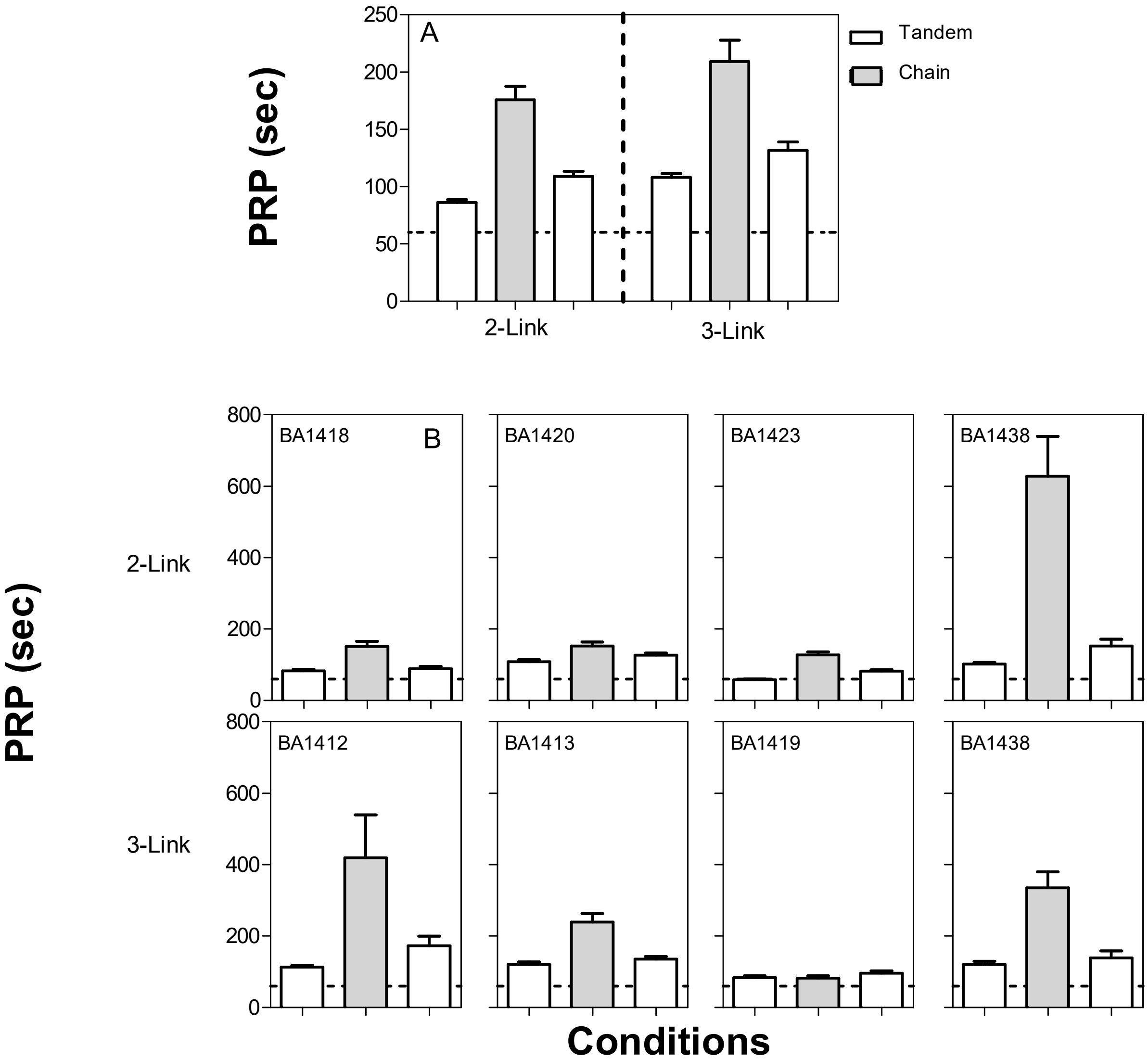


Figure 1. *A. (top graph) Post-reinforcement pausing (+SEM) over last 10 sessions across each condition for each group. B. (bottom graphs) Post-reinforcement pausing (+SEM) over last 10 sessions across each condition for subject in each schedule.*

Figure 2a shows the proportions of post-reinforcement pauses that were longer than the programmed link duration per group. Calculating run rate requires the number of responses divided by the link time minus the PRP; therefore, any PRP that went beyond the link duration would set-up a zero value in the denominator failing to calculate. As a result, initial link run rate was not a valid measure. Proportion of PRP longer than link duration provides a better analysis of run rate data. Between 2-link and 3-link proportions differences are visible between the tandem schedules (60% and 75%), but during the chain proportions were at similar level (65%) respectively.

Figure 2b shows the proportions of PRP longer than the link duration per subject. In the 2-link group 3 of the 4 subjects had tandem levels greater than 60% (BA1423 45%) with that increasing during the chain for 3 of the 4 (BA1438 reduced from 65% to 50%). The 3-link group had all subjects above 60% during the tandem and 2 of the 4 subjects maintained or increased during the chain (BA1412 and BA1419 decreased from 80% and 65% to 60% and 50%).

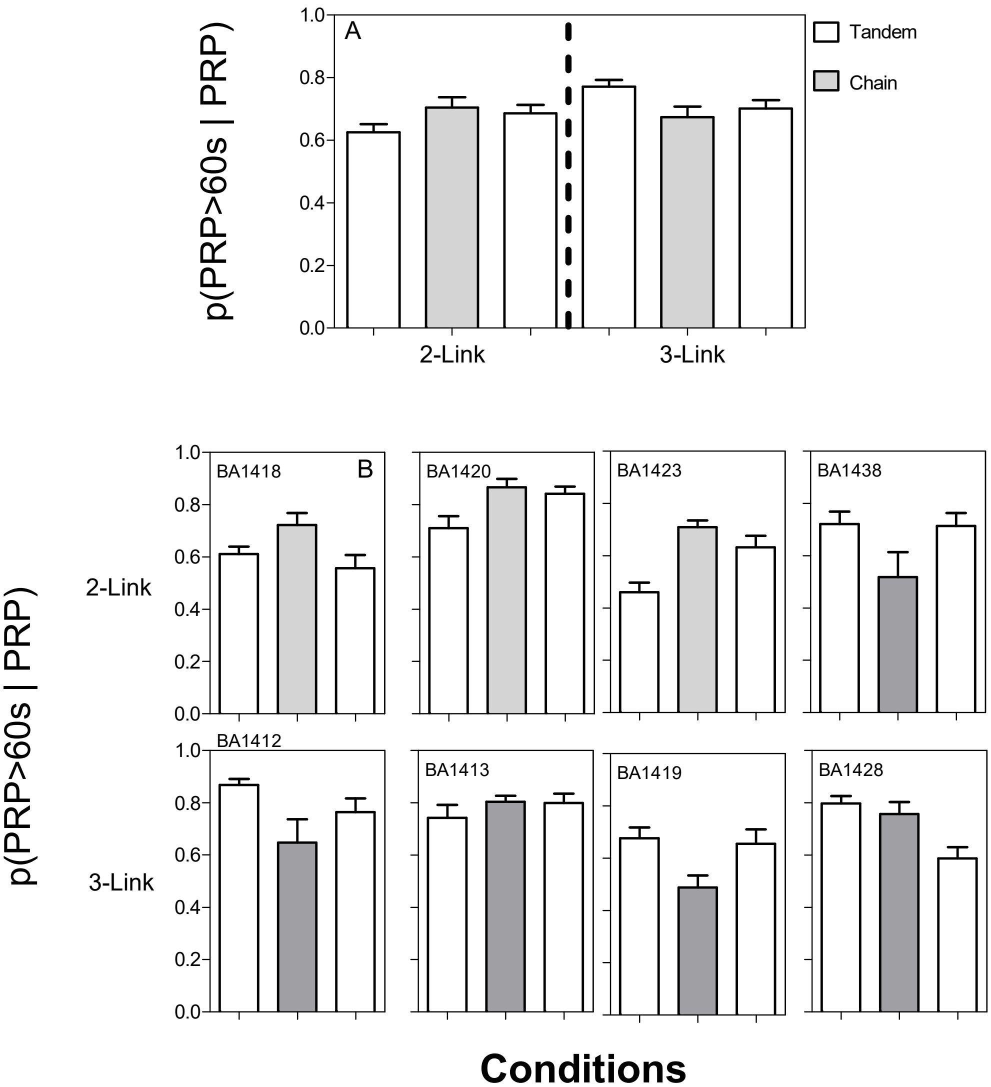


Figure 2. *A. (top graph) Proportions of PRP longer than initial link duration (+SEM) over last 10 sessions across each condition for each group. B. (bottom graphs) Proportions of PRP longer than initial link duration (+SEM) over last 10 sessions across each condition for subject in each schedule.*

Figure 3a shows average link 2 pause for both groups. The 2-link group pauses held at 20 seconds during the tandem schedule, during the chain and reversal the 2-link maintained stability with similar levels to baseline. The 3-link group held around 20 seconds in the tandem condition and increased to 40 seconds (respectively) during the chain, during the reversal pausing did not return to baseline, but held at levels similar to the chain.

Figure 3b shows average link 2 pause for subjects in both groups. In the 2-link group, BA1418 and BA1438 are most noticeable as 1418 had the largest increased in pausing during the chain. 1438 decreased in pausing during the chain (19 seconds) but during the reversal increased to 40 seconds stabilizing above baseline. In the 3-link group, BA1412 and BA1428 paused longer than the link duration during the chain, during the reversal 3 of the 4 rats returned to pausing below the programmed duration with the exception of BA1428, causing an increase in the average.

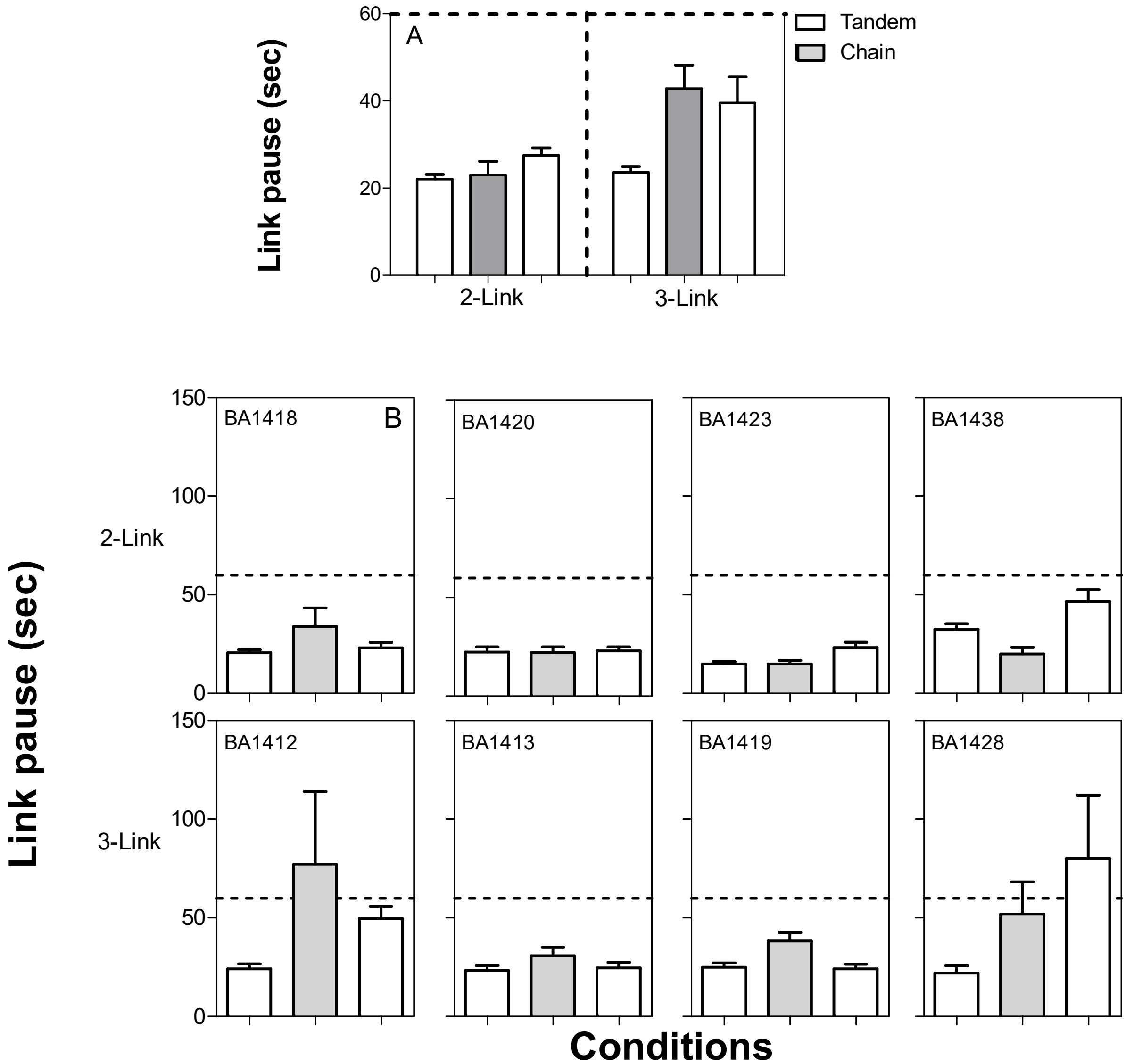


Figure 3. *A. (top graph) Link 2 pause (+SEM) over last 10 sessions across each condition for each group. Dashed line denotes programmed link duration. B. (bottom graphs) Link 2 pause (+SEM) over last 10 sessions across each condition for subject in each schedule.*

Figure 4a shows the proportions of link 2 pauses that were longer than the programmed link duration per group. In all conditions, the 2-link group had 10% or less of pauses go beyond the programmed duration. The 3-link group proportions were at 10% for the tandem schedule and increased to 20% during the chain, with proportions maintaining similar for 2 of the 4 subjects during the reversal.

Figure 4b shows the proportions of link 2 pauses longer than the link duration per subject. In the 2-link group, 2 of the 4 subjects had no pausing longer than the programmed duration during the chain. In the 3-link group 3 of the 4 subjects had proportions above the link duration in both tandem and chain conditions. Conclusion from this figure, with relatively lower number of trials that exceed 60-s pausing justifies further analysis of running rate.

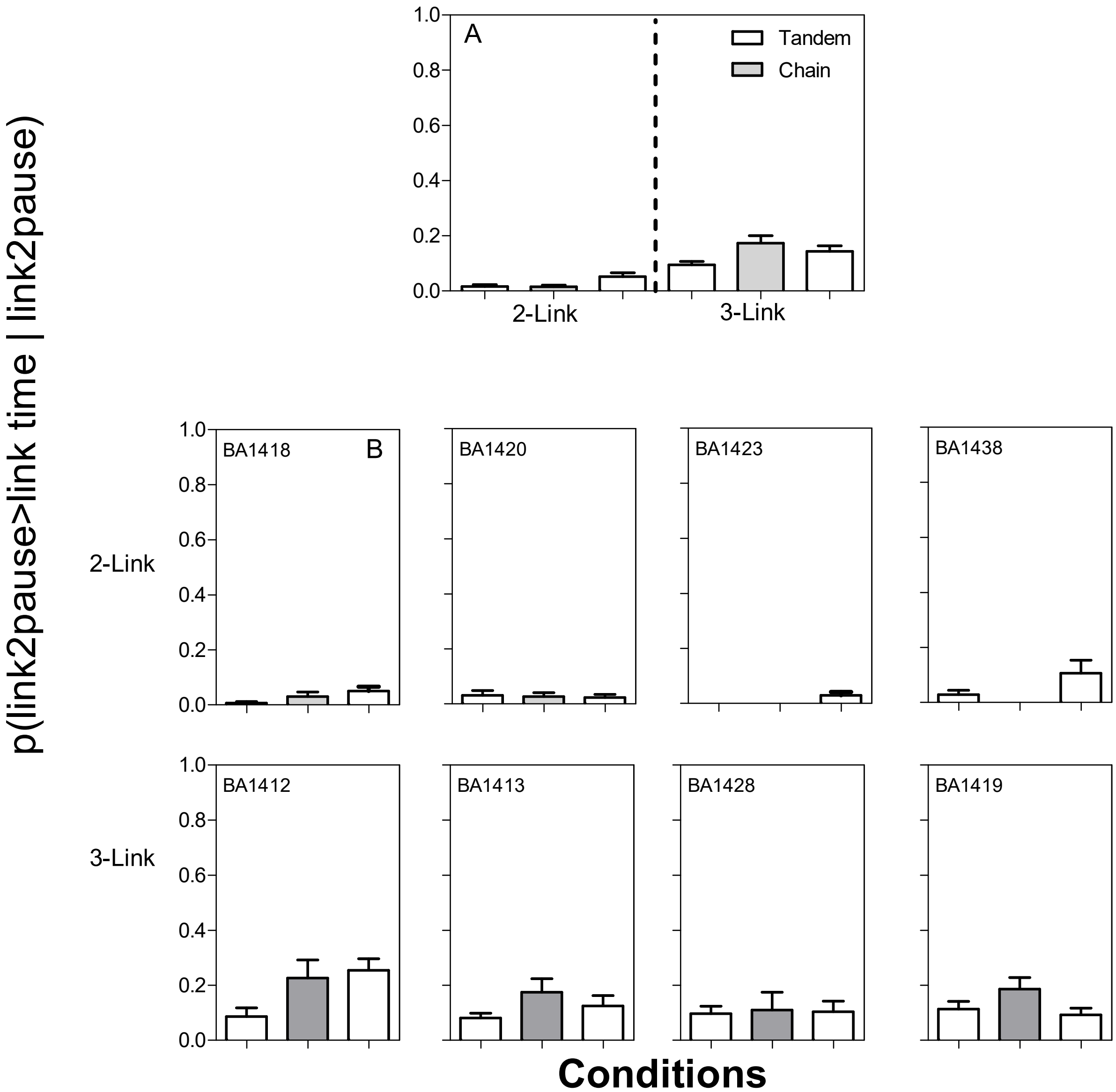


Figure 4. *A. (top graph) Proportion of Link 2 pause (+SEM) longer than link duration over last 10 sessions across conditions for each group. B. (bottom graphs) Proportion of Link 2 pause (+SEM) longer than link duration over last 10 sessions across conditions for each subject in each schedule.*

Figure 5a shows the average link 2 run rate across conditions for both groups. In the 2-link group, there was no difference in run rate across all conditions. Run rates in the 3-link group were approximately 10 responses per minute during the tandem condition and decreased during the chain to 8 responses per minute respectively.

Figure 5b shows the average link 2 run rate across conditions per subject with no visible differences between the conditions. For the 3-link group all subjects demonstrated a reduction in responding when transitioning from the tandem condition to the chain, with only BA1419 and 1428 returning to similar baseline levels during the reversal.

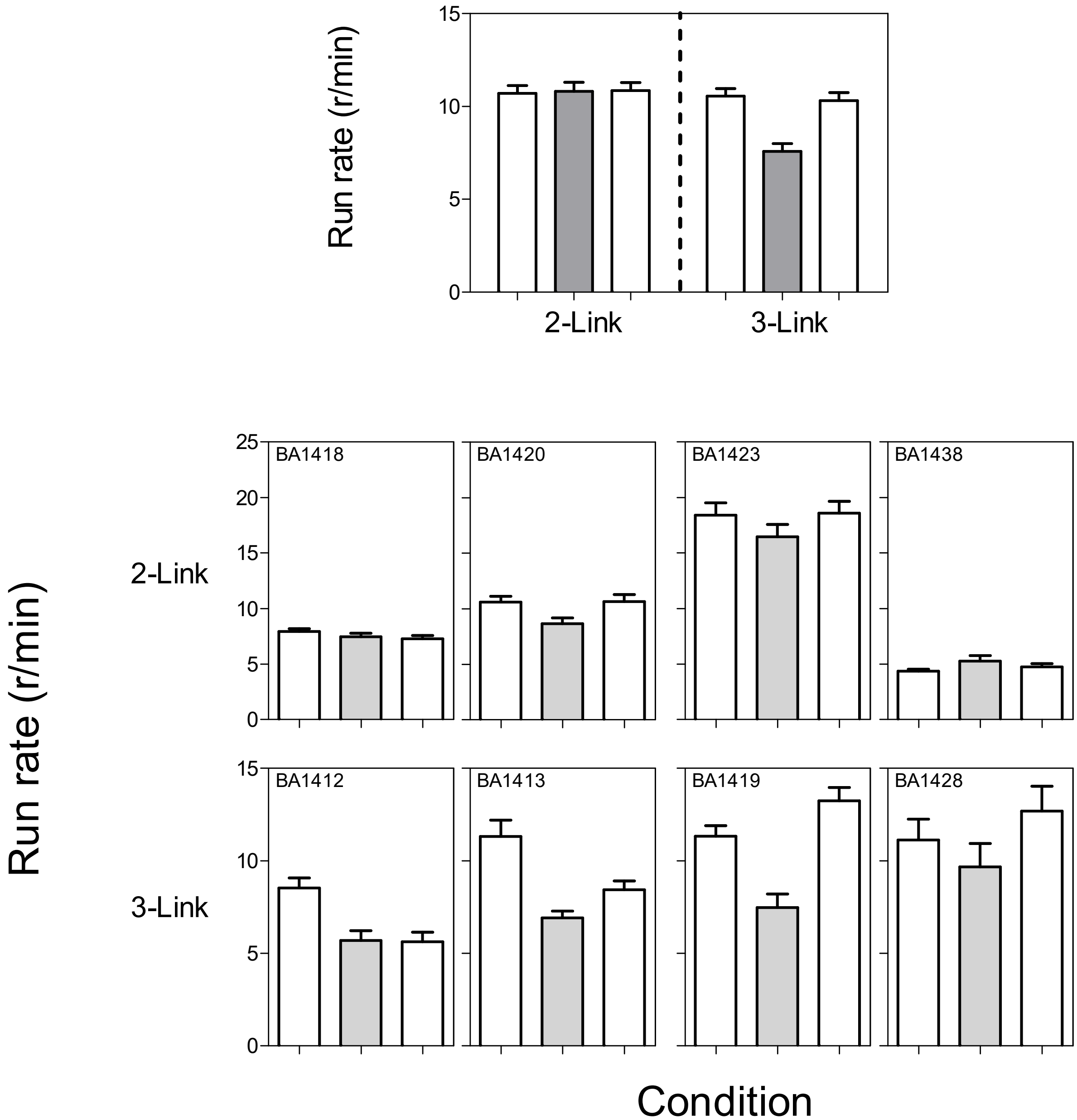


Figure 5. *A. (top graph) Second link Run rate (+SEM) over last 10 sessions across conditions for each group. B. (bottom graphs) Second link run rate (+SEM) over last 10 sessions across conditions for each subject in each schedule.*

Figure 6a shows the proportions of link 3 pauses that were longer than the programmed link duration for the 3-link group. During all conditions, less than 10% of pauses exceeded the programmed duration. Figure 6b shows those proportions for each subject; with 3 of the 4 subjects having some pauses extend beyond the link duration in all conditions, (BA1428 showed no pause longer that 60-s during the reversal). As previously, because of the relatively low number of trials that exceed 60-s pausing this justifies further analysis of run rate.

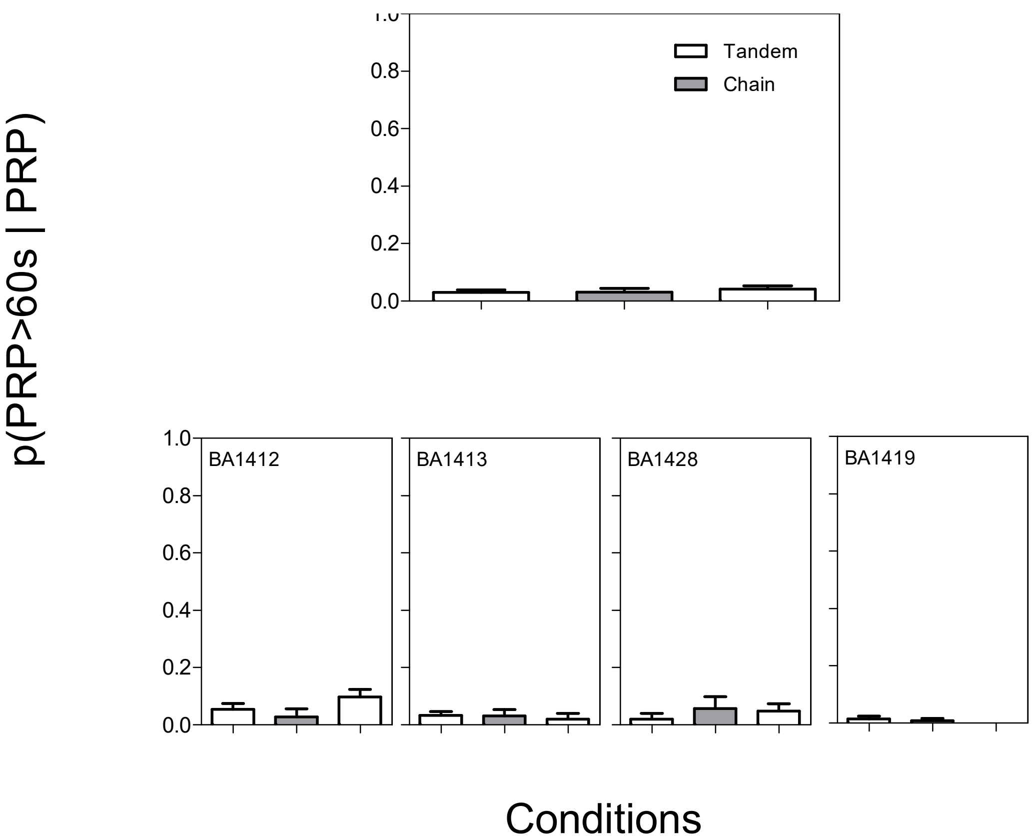
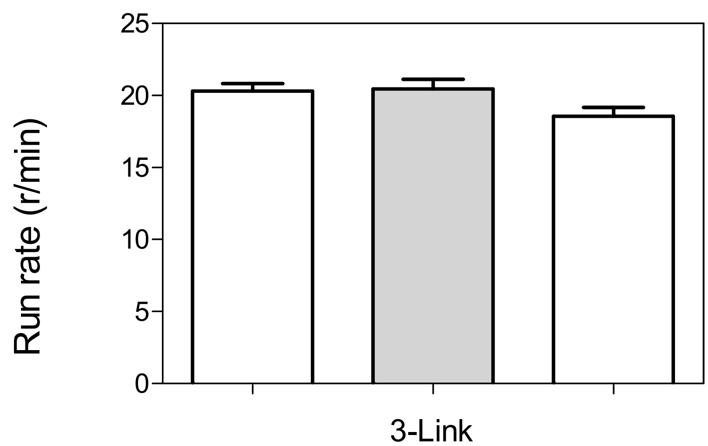


Figure 6. *A. (top graph) Proportion of Link 3 pause (+SEM) longer than link duration over last 10 sessions across conditions for3-link group. B. (bottom graphs) Proportion of Link 3 pause (+SEM) longer than link duration over last 10 sessions across conditions for each subject*

Figure 7a shows the average link 3 run rate across conditions for the 3-link group. Run rates held at approximately 20 responses per minute during all conditions. Figure 7b shows the average link 3 run rates for each subject. BA1412 and 1413 showed a decrease in responding from tandem to chain, and BA1419 and 1428 had a slight increase in responding when moving from the tandem condition to the chain.



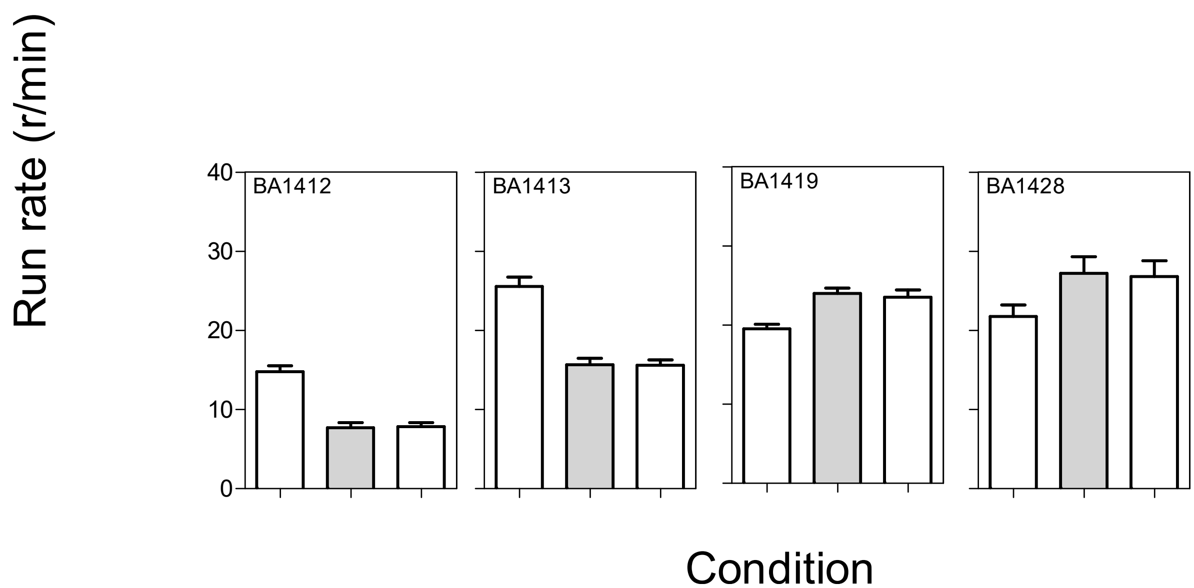


Figure 7. *A. (top graph) Third link Run rate (+SEM) over last 10 sessions across conditions for3-link group. B. (bottom graphs) Third link run rate (+SEM) over last 10 sessions across conditions for each subject.*

Figure 8 A and B depicts run rates across the initial, middle, and terminal link for both the 2-and-3 link groups as a function of time. As with calculating initial link run rate, a similar problem occurs with this analysis. As lever pressing decreases, the post-reinforcement pause supersedes the scheduled FI value and creates a flooring effect that compresses the initial link graph. This analysis is best for interpretation of running rates during the middle and terminal links of both schedules. In both groups, subjects responded at a higher rate during the tandem condition compared to the chain. Notably in the 2-link group, BA1418 and BA1438 responses in the chain condition increased above the tandem during the terminal link, suggesting that the stimulus paired with the terminal link was functioning as a discriminative stimulus. Furthermore, this was also evident in the 3-link group, subject BA1419 and BA1428 also presented higher responses in the chain condition during the terminal link; moreover, the acquisition of the discriminative function was faster compared to the 2-link group with BA1419 demonstrating discrimination within two sessions and BA1428 within four.

A mixed ANOVA with 2-and-3 link groups (between-subject) and conditions (within-subject) was conducted, $F\ (2,12) = 4.88$, $p=.056$. The mixed analysis showed no statistical significances between the two groups or within the tandem and chain comparison.

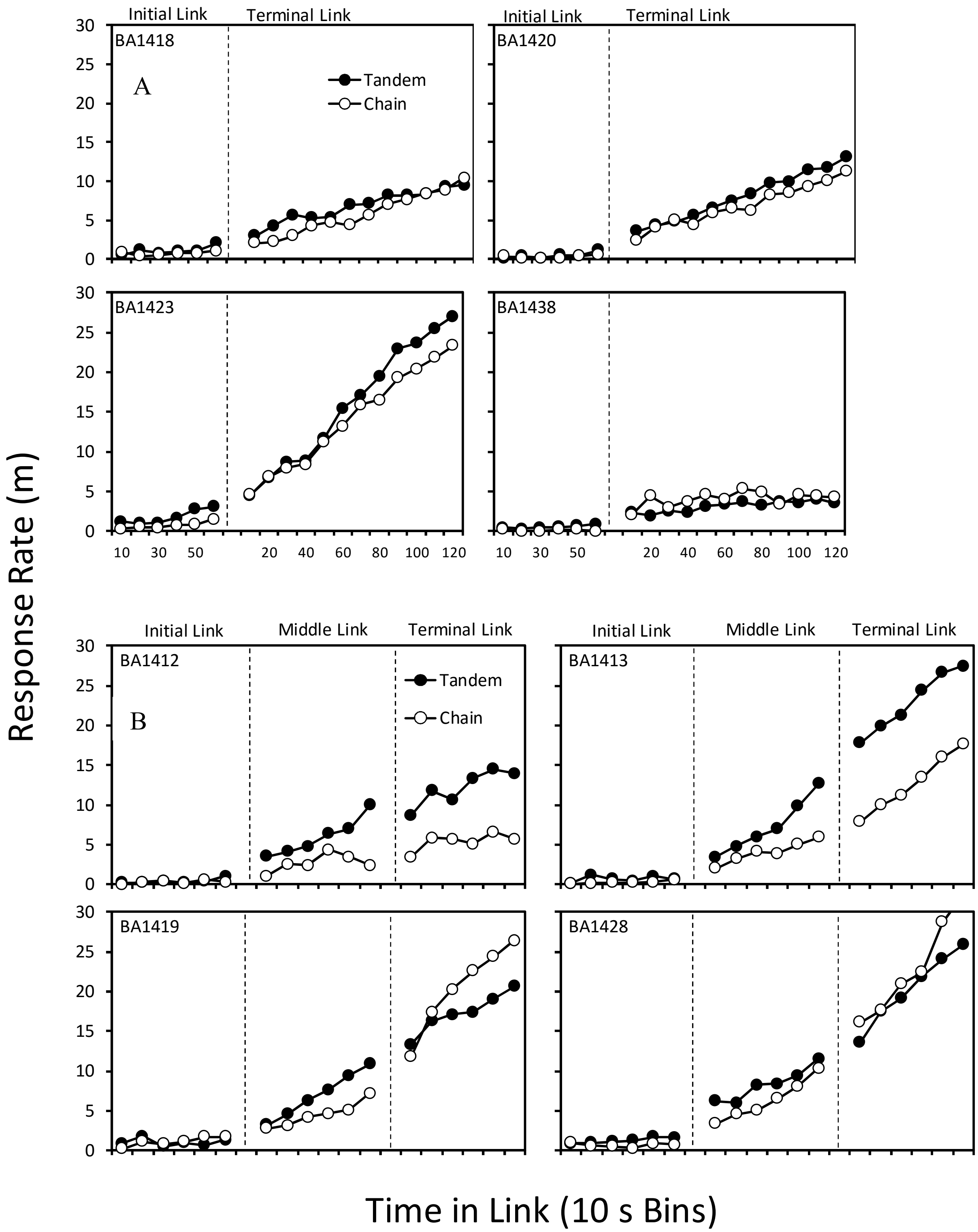


Figure 8. *A. (top graphs) Run rate in 10 session bins across all links (initial, terminal) as a function of time for each subject of 2-link group. B. (bottom graphs) Run rate in 10 session bins across all links (initial, middle, and terminal) as a function of time for each subject of 3-link group.*

CHAPTER IV

DISCUSSION

This experiment was conducted to evaluate whether the inter-food interval or number of links controls behavior during chain schedules with long IRI's. We hypothesized two outcomes for this experiment, first that tandem schedules will maintain higher rates of lever pressing and shorter pauses (PRPs) compared to a chain schedule. Secondly, the three-link chain schedule will maintain longer pauses (PRP) and lower response rates than the two-link chain schedule.

Overall, the tandem schedule yielded less pausing and maintained higher lever pressing compared to the chain schedules, which agrees with previous research (Ferster & Skinner, 1957; Kelleher & Fry1962; Jwaideh, 1973). In addition, during the chain condition, the 3-link group demonstrated larger post-reinforcement pausing compared to the 2-link group.

Run rates appeared to be a less sensitive measure for this manipulation when viewed as aggregates; however, when analyzing responding across each link and through each condition (Figure 5), it can be seen that behavior follows a similar trajectory to a scallop pattern, which is typically seen in FI schedules. Two subjects from each group revealed data that suggests the stimulus in the terminal link was functioning as a discriminative stimulus, as responding in the chain schedule was higher compared to the tandem. The three-link schedule run rates during the tandem were similar to the 2-link and during the chain schedule demonstrated response patterns similar to Gollub's findings.

Conditioned reinforcement in the two-link schedule was not replicated as demonstrate by Gollub. This could have resulted from limiting the number of sessions to approximately 20 compared to Gollub's approximate 120 sessions. Gollub described a transition that the organism should go through with three different phases, the second being discrimination and the third being conditioned reinforcement. Gollub's pigeons showed conditioned reinforcement after five sessions, where the rats did not. As demonstrated in Figure 5 two subjects were in what could be described as Gollub's "second phase" as the data suggests the terminal stimulus was functioning as a discriminative stimulus, if the subjects would have continued with more session's conditioned reinforcement could have developed.

Prior to conditioned reinforcement occurring in the two-link and three-link chain schedule, the signal in the initial link functions to signal the relative temporal distance to food and reduces responding in the initial link. This is most apparent in the 3-link schedule because the first two signals have never been paired with food, the initial link stimulus is signaling that no food is available and that another stimulus will occur next that also signals no food availability.

This study has two main limitations; first, during the tandem condition only the house light provided illumination, Gollub used a white key light during his tandem condition, which also functioned as the terminal link stimulus in the chain schedule increasing the number of pairings between stimulus and food. Secondly, flashing lights were used as signals for each link, which differs from the colored key lights Gollub used. Although it has been demonstrated that rats can come under stimulus control of flashing lights (D'Amato, 1961); Fox, Smethells, and Reilly (2013) showed that to get stimulus control with flashing lights a significant number of sessions (+100) were required. Even though two subjects indicated that the terminal signal had discriminative properties, having more sessions congruent to Gollub (approx. 120 compared to 20 per condition) in conjunction with using flash rate may have provided more robust effects of discrimination or conditioned reinforcement for all subjects.

This was a novel approach in using flashing lights as signals within a tandem/chain procedure, and as such, more research is necessary to continue to understand the function of the signals during these schedules. Moreover, the IRI did not influence behavior with this manipulation; however, it cannot be dismissed as factor that can control behavior during chain schedules and warrants further study.

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