

INVESTIGATING THE CONTRIBUTION OF A WORK REQUIREMENT IN
SCHEDULE-INDUCED POLYDIPSIA

Melissa Mayleen Murgittroyd Andrews

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Central Michigan University, in partial fulfillment of
the requirements for the masters degree

Thesis Committee:

Mark P. Reilly, Ph.D.

Committee Chair

Gary L. Dunbar, Ph.D.

Faculty Member

Carl M. Johnson, Ph.D.

Faculty Member

May 2, 2013

Date of Defense

Roger Coles, Ed.D.

Dean
College of Graduate Studies

June 19, 2013

Approved by the
College of Graduate Studies

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ABSTRACT

INVESTIGATING THE CONTRIBUTION OF A WORK REQUIREMENT IN SCHEDULE-INDUCED POLYDIPSIA

by Melissa Mayleen Murgittroyd Andrews

Adjunctive behavior, in which responses are induced by intermittent schedules of reinforcement, occurs with both response-independent and response-dependent food schedules, however the manner of food delivery can affect the probability of adjunctive behavior. For example, schedule-induced drinking (polydipsia) in rats has been shown to *increase* (Burks, 1970), whereas schedule-induced attack in pigeons has been shown to *decrease* (Kupfer, Allen and Malagodi, 2008) when food is delivered response independently, relative to response dependently. Two experiments using rats were conducted to assess the reliability and generality of Burks' result with schedule-induced drinking. Experiment 1 systematically replicated Burks by comparing drinking under fixed-ratio and yoked fixed-time schedules with the response lever removed during the response-independent condition. Experiment 2 compared drinking under a fixed-ratio and a yoked matched-time schedule similar to Kupfer, Allen and Malagodi's procedure. Water consumption was greater in both experiments under response-independent conditions, replicating and extending the generality of previous polydipsia research but not previous schedule-induced attack research. It is unclear why the relation between work requirement and adjunctive behavior is opposite in these different forms of adjunctive behavior.

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CHAPTER I

INTRODUCTION

Adjunctive or schedule-induced behavior is a class of behavior that is induced by intermittent schedules of reinforcement and is considered a separate class from operant and respondent behavior (Falk, 1966a). Research examining the controlling variables of adjunctive behavior is important because adjunctive behaviors are distinguished from other well-established behavioral processes. Thus far, adjunctive behavior has been demonstrated in various species and as a number of different behaviors, including drinking (or polydipsia) in rats (e.g., Falk, 1961a), attack in pigeons (e.g., Azrin, Hutchinson, & Hake, 1966), hose biting in squirrel monkeys (e.g., Hutchinson, Azrin, & Hunt, 1968), and wheel-running in rats (e.g., Levitsky & Collier, 1968).

While adjunctive behaviors can vary considerably and are found across a number of species, they all share certain general characteristics that enable them to be classified and distinguished as adjunctive. Adjunctive behaviors develop under intermittent as opposed to continuous reinforcer delivery (Falk, 1961b; Azrin, Hutchinson, & Hake, 1966); if reinforcers are delivered too frequently or not frequently enough, adjunctive behaviors will not develop. The relationship between the amount of adjunctive behavior and inter-food intervals (IFIs) is a bitonic function with high levels of adjunctive behavior occurring at intermediate IFI values, and less adjunctive behavior occurring at extreme values. When adjunctive behavior develops at these intermediate values it is considered to be excessive in nature, often unnecessary or even harmful to the organism; yet these behaviors are undertaken anyway. Adjunctive behaviors are temporally organized and tend to occur immediately following a reinforcer (Falk, 1961b; Hutchinson, Azrin, & Hunt, 1968). They have also been shown to be reinforcing in their own right; subjects will work for the opportunity to engage in adjunctive behavior (Falk, 1966a).

Finally, a response-reinforcer contingency is not necessary to produce adjunctive behavior, although it may affect the amount of behavior emitted (Cherek, Thompson, & Heistad, 1973). These general characteristics shared among adjunctive behaviors suggest that experimental results from one type of adjunctive behavior should generalize to other types of adjunctive behavior.

The present study focused on schedule-induced polydipsia (SIP), which was the first adjunctive behavior studied. John Falk initially reported SIP in rats in 1961 and used it as a model of psychogenic polydipsia in people, which refers to long-lasting and high rates of fluid ingestion. Falk's study included fourteen rats lever pressing on a variable-interval (VI) 1-min schedule of food reinforcement. Eventually these rats drank approximately 0.5 ml of water after each pellet and averaged 92.5 ml of water consumption over a 3-hr session, over 3 times more water than during a 24 hour non-experimental period.

The excessive nature of this drinking led Woods and colleagues (1993) to look into how well SIP models obsessive compulsive disorder (OCD). Not only does SIP have face validity (looks similar to OCD) with its repetitive and unnecessary behavior, but it also has predictive validity in regards to how SIP rats and OCD patients react to pharmacological treatments (Albelda & Joel, 2012). van Kuyck and colleagues (2008) also showed a similarity in the brain regions associated with SIP and OCD. The nucleus accumbens, the bed nucleus of the stria terminalis and the mediodorsal thalamic nucleus have all been implicated in compulsive behaviors and when stimulated at specific frequencies, resulted in decreases in SIP. Mittleman and colleagues (1988) also showed correlations between drinking levels in SIP and plasma corticosterone levels, modeling the effect of hypothalamic-pituitary-adrenal alterations that occur in OCD patients. Besides its use as an animal model of OCD, SIP is commonly studied in order

to see how environmental manipulations, such as schedule of food delivery, affect adjunctive behavior in general.

SIP has been shown to develop under different types of schedules of reinforcement including interval (King & Schaeffer, 1973), ratio (Burks, 1970), time (Wayner & Greenberg, 1973), and even second-order schedules (Rosenblith, 1970). Falk (1961b) stated that as long as the IFI is approximately 30 s or greater, SIP will typically develop regardless of the schedule type. Time-based schedules such as fixed-interval (FI) and variable-interval (VI) schedules are often used in SIP research because they enable greater control over the IFI. Fixed-ratio (FR) schedules have also been used to induce SIP; however, because the reinforcement rate is determined by the response rate of the subject, the IFI cannot be as precisely controlled as FI and VI schedules. SIP can also be induced by fixed-time (FT) schedules in which food is delivered independently of behavior.

Furthermore, multiple schedules can be used within a single experiment to compare schedule-induced differences in adjunctive responding. Previous research has compared response-independent FT schedules to response-dependent FR schedules to see how a response-requirement affected SIP and found a greater amount of drinking under FT conditions (Burks, 1970; Schaffer, Diehl, & Salzberg, 1966; Schaffer & Salzberg, 1967). While IFIs in an FR schedule cannot be precisely controlled by the experimenter, the amount of effort (i.e., number of lever responses per pellet) can be via manipulation of the ratio requirement. Therefore, FT and FR schedules both allow for exact control over the amount of work necessary to earn food, making the comparison between free food and various efforts to earn food easier.

Schaffer and Salzberg (1967) compared mean water intake and number of lever presses under an FR 50 and an FT 45-s schedule of food delivery. Rats were placed on an FT 45-s

schedule with the lever available. After 47 sessions all rats were moved to an FR 50 for another 26 sessions. The amount of water consumed was greater in the FT than the FR condition for the majority of the rats. Thus, SIP occurred at a higher level when the rats did not have to work for food. However, these results may not be solely attributable to the difference in work requirement. Although exact IFI lengths were not reported, 50 lever presses will not be completed in exactly 45 s every time, making it apparent that the IFIs between the FR 50 and FT 45-s conditions were not equal. Moreover, IFIs in the FR session were dependent upon the rat's behavior and therefore varied in length whereas IFIs in the FT condition were always 45 s and ended in food delivery regardless of behavior. Due to the degree of influence that the intermittency of food delivery has on adjunctive behavior, these procedural characteristics make it difficult to conclude that the lack of a work requirement was the exclusive controlling variable.

Burks (1970) compared SIP across FR and FT schedules using a within-subject yoking procedure that better equated the IFIs between the two conditions. Rats were trained to lever press for food pellets up to an FR 20 with continuous access to a water bottle. Following the FR condition, rats were moved to a yoked FT condition in which the FT interval length was the average IFI of the previous FR condition. Each rat's average IFI was calculated by dividing time spent within the FR condition by the number of pellets earned. This yoking procedure ensured that food was delivered at approximately the same average rate within the FR and FT conditions. After drinking stabilized within the FT condition, rats were moved on to the next FR condition. In total, three FR conditions (FR 20, FR 40, and FR 80) were implemented with each FR condition immediately followed by a yoked FT condition.

As in the Schaeffer and Salzberg (1967) study, drinking—as measured by grams consumed—during the FT condition generally exceeded drinking during the FR condition,

indicating that a response-reinforcer contingency did affect the amount of water consumed. The lever was left available during the FT condition and the option to lever press, even though unnecessary for food delivery, may have influenced the amount of drinking in both of these studies. Indeed, Burks' (1970) cumulative records revealed that lever pressing continued during small IFIs and, to a lesser extent, during larger IFIs.

It is important to understand if the presence or absence of a work requirement was the primary variable responsible for differences in drinking, as another aspect of the schedule change (i.e., moving from variable to fixed IFIs) may have influenced the results obtained. During an FR schedule each reinforcer is delivered based upon the behavior of the subject, creating variability in IFI lengths. FT schedules deliver food after the same amount of time, every time, creating a fixed pattern with no variability. The temporal variability of these food deliveries may have influenced the amount of water consumed in both Schaeffer and Salzberg's (1967) study and Burks' (1970) study.

King and Schaeffer (1973) manipulated the variability of IFI lengths by comparing SIP under a VI 60-s schedule to an FI 60-s schedule, keeping the average rate of food delivery similar. Under fixed intervals, water consumption increased faster within the first 5 sessions, but beyond the sixth session and throughout the remainder of the experiment variable intervals maintained the highest levels of water consumption. SIP developed and maintained at different levels under each schedule, suggesting that the variability of the IFIs does play a role in the amount of adjunctive behavior induced and that the effect may be dependent on how long the behavior has been developed. King and Schaeffer's results contradict previous research (Burks, 1970; Schaeffer & Salzberg, 1967), where more drinking was found in the condition with fixed rather than variable IFIs.

Burks presumed that rats consumed more water during the FT conditions because the removal of the lever-pressing contingency created more time to drink. Indeed, there was less lever pressing during the FT conditions. It is reasonable to assume that the time originally allocated to lever pressing was re-allocated to drinking. Due to the number of changes that took place between the FT and FR conditions, it is unknown whether extra time was the only contributing variable to the greater drinking.

Kupfer, Allen and Malagodi (2008) examined another form of adjunctive behavior, schedule-induced attack, in pigeons. A target pigeon was restrained and wore protective gear while the subject pigeon would attack it following food deliveries. Attack probability was compared across a response-dependent and a response-independent schedule. Pigeons were trained to key peck in the presence of a house light for access to grain on increasing FR values without the target pigeon present. Final FR values were chosen to equate IFIs across pigeons, and once these values were attained target pigeons were re-introduced to the chambers. Once key pecking stabilized, the key was covered by a metal plate and pigeons were moved to a response-independent matched-time (MT) condition. A within-subject yoking procedure was used in which daily IFIs were recorded from the previous 20 FR sessions in the order in which they were experienced. During the 20 yoked MT sessions, food was delivered according to the exact sequence of intervals that occurred during each consecutive FR session. These 20 MT sessions were repeated in succession until stability of attack was attained. The key was then uncovered and pigeons were reversed to the original FR schedule. To prevent food delivery following an attack, a change-over delay (COD) was in place during all conditions; if attack occurred within 5 s of food delivery, food delivery was delayed until at least 5 s with no attack had elapsed. Under these circumstances schedule-induced attack was less under the response-independent than the

response-dependent schedule similar to previous schedule-induced attack research (see Flory & Everist, 1977), but the opposite relation that Burks (1970) found in SIP.

Specifying the nature of the discrepant results between SIP and schedule-induced attack studies is essential for understanding the principles underlying adjunctive behavior. Differences between the SIP research and the schedule-induced attack research may play some role in the different results found. First, there are species differences: SIP research employs rats whereas attack research employs pigeons. Second, the type of the adjunctive behavior differs. Third, each of the studies used FRs for the response-dependent condition but the response-independent schedules were constructed differently; Burks calculated an average IFI for the FT condition with fixed IFIs whereas Kupfer, Allen and Malagodi used a yoked MT procedure with variable IFIs. Fourth, Kupfer, Allen and Malagodi employed a COD so that food was not delivered within 5 s of an attack whereas Burks' study had no COD and rats were able to drink just prior to food deliveries.

Why does SIP research show more adjunctive behavior during response-independent schedules than response-dependent schedules when schedule-induced attack research shows less? SIP and schedule-induced attack look very different, yet both are classified as adjunctive behaviors and should therefore adhere to the same laws governing adjunctive behaviors. Such results suggest that there may be different mechanisms underlying each type of adjunctive behavior.

Due to the discrepancies found between results of prior SIP and schedule-induced attack research, the purpose of the current study was to increase the reliability of increased drinking during response-independent schedules by using procedures controlling possible confounding variables. Previous SIP research had the lever available during the response-independent

condition and the effect of this availability on the amount of water consumed is not yet known. Therefore, Experiment 1 was conducted to see how the availability of a lever during a response-independent condition affected the amount of SIP when compared to a response-dependent condition where lever pressing was required for food. Variability in IFIs across response-independent and response-dependent conditions has not yet been controlled for in an SIP study. Thus, Experiment 2 also compared SIP across a response-independent and response-dependent condition but controlled IFI variability across conditions by using a more exact yoking procedure.

CHAPTER II

EXPERIMENT 1 METHOD

Subjects

Four male Sprague-Dawley rats (Charles-River, Portage, MI) 9 months of age and maintained at 85% free feeding weight served as subjects. They were housed individually in polycarbonate tubs with free access to water and post-session supplemental feedings were given in order to maintain experimental weight. The colony room was on a reversed 12 hour light-dark cycle with lights on and off at 2000 and 0800 respectively. Sessions were conducted ~5 days a week at approximately the same time every day during the dark part of the cycle. All rats had equal experimental histories of lever pressing with delays for grain/sucrose pellets.

Apparatus

Sessions took place in four equally equipped Coulbourn operant-conditioning chambers (Coulbourn Instruments, Whitehall, PA) measuring 29 cm high \times 25 cm wide \times 29 cm deep with aluminum paneled front and back walls, plexiglass side walls and ceiling, and wire grid flooring. Located on the front wall was a recessed food tray positioned 2.5 cm above the floor, measuring 3 cm wide \times 4 cm tall \times 3 cm deep, and centered 11 cm in from each side. The food tray delivered 45-mg Bio-Serve® Dustless Precision Pellets (Bio-serv, Frenchtown, NJ, Product # F0021). Located 4.5 cm to the right of the food tray was the water bottle. The water bottle was placed in a recess measuring 1.5 cm up from the wire grid floor and 3 cm wide \times 4 cm tall \times 2.5 cm deep. Within the recess were two sensor beam rods 2 cm from the bottom of the recess, 1.4 cm deep, and measuring approximately 0.8 cm in length. These rods were located at the very tip of the water bottle spout when the water bottle was present and each time the beam was broken a

response was recorded. Located on the back wall was a house light 27 cm from the floor, 12.5 cm in from each side, and protruding 2 cm into the chamber. Each operant-conditioning chamber was housed in a sound-attenuating chamber to control for extraneous light and noise. Each sound attenuating chamber was equipped with a video camera to allow for observation during sessions.

Procedure

Rats were trained to lever press under an FR 1 in the presence of the house light and with free access to a water bottle which remained present throughout the experiment. Grams consumed (calculated by using pre- and post-session weights of the water bottle) and the number of licks measured by photo beam breaks served as dependent measures. The response requirement for the FR schedule was gradually increased to FR 30 for SD347, FR 50 for SD348 and SD350, and FR 90 for SD349. The ratio values were increased until a rat's lever response rate plateaued, allowing for a large work requirement and a large contrast to free food delivery without ratio strain. These schedules remained in effect until lever response rates and drinking stabilized for each individual rat, as judged by visual inspection of the graphed data. Table 1 shows the order of conditions and the number of sessions in each condition for each rat. Polydipsia was considered developed when there was a noticeable increase of within session water consumption and when licks primarily followed pellet deliveries. Each session lasted until 30 pellets were delivered or until one hour had elapsed.

After a rat reached stability, the lever was removed from the chamber and food was delivered according to an FT schedule in which the FT length was the average IFI from the previous 10 FR sessions. The average IFI was calculated by dividing the total time spent in the

last 10 sessions by the number of pellets earned within that time. SD349 did not develop polydipsia after 31 sessions on the FR schedule and was moved on to the FT condition.

Within the FT condition, grams consumed and number of licks were the only measurements taken. Once these measurements stabilized for each rat, the lever was returned to the chamber and the rat was reversed back to its original FR condition. Once stable, another FT condition was instated using an average IFI from the last 10 sessions of the most recent FR condition to create the new FT length. During the second FT condition, the lever remained in the chamber. The experiment ended when responses stabilized within the last FT condition.

Because number of pellets earned in a session could vary, drinking is presented as amount consumed in grams per pellet, photo beam breaks are presented as number of beam breaks per pellet, and lever pressing is presented as lever presses per minute. These calculations normalize the data and facilitate comparisons across conditions and rats. The data from the last five sessions, representing the steady state performance of each condition, are presented.

CHAPTER III

EXPERIMENT 1 RESULTS

The number of sessions within each condition varied based on each rat's performance (see Table 1). There were individual differences in the rate of SIP acquisition and maintenance, with SD347 developing polydipsia the quickest and SD348 maintaining the highest level of drinking. SD349 never developed polydipsia in the FR condition, but water consumption began to increase within the first three sessions of the FT condition. SD349 was removed from the study early due to health issues and only experienced 5 days on the last condition of the study.

Table 1. Order of conditions and the number of sessions under each condition for each rat in Experiment 1.

Rat	Schedule	Sessions
SD347	FR 30	68
	FT 33.8" No lever	32
	FR 30	28
	FT 43.7" Lever	23
SD348	FR 50	57
	FT 39.6" No Lever	29
	FR 50	30
	FT 41.5" Lever	45
SD349	FR 90	31
	FT 150.6" No lever	38
	FR 90	24
	FT 216.0" Lever	5
SD350	FR 50	52
	FT 35.0" No lever	34
	FR 50	30
	FT 42.0" Lever	45

Figure 1 shows the average lever response rates across conditions. Lever response rates during the first FR condition ranged between 30 and 90 lever presses per minute and decreased slightly during the second FR condition (ranging from 20 to 75 lever presses per minute). Average lever response rates during the second FT condition varied among rats with a range of 0 to 50 lever presses per minute, and were always lower than lever response rates during FR conditions. Rats SD347 and SD350 maintained minimal lever pressing during the second FT condition with lever response rates decreasing by 94.57% and 99.95% (respectively) from lever response rates during the second FR condition. SD348 and SD349 decreased in lever response rates by only 42.04% and 51.92% (respectively) from the second FR condition lever response rates to the second FT condition lever response rates (SD349's lever response rate was declining upon his removal from the study).

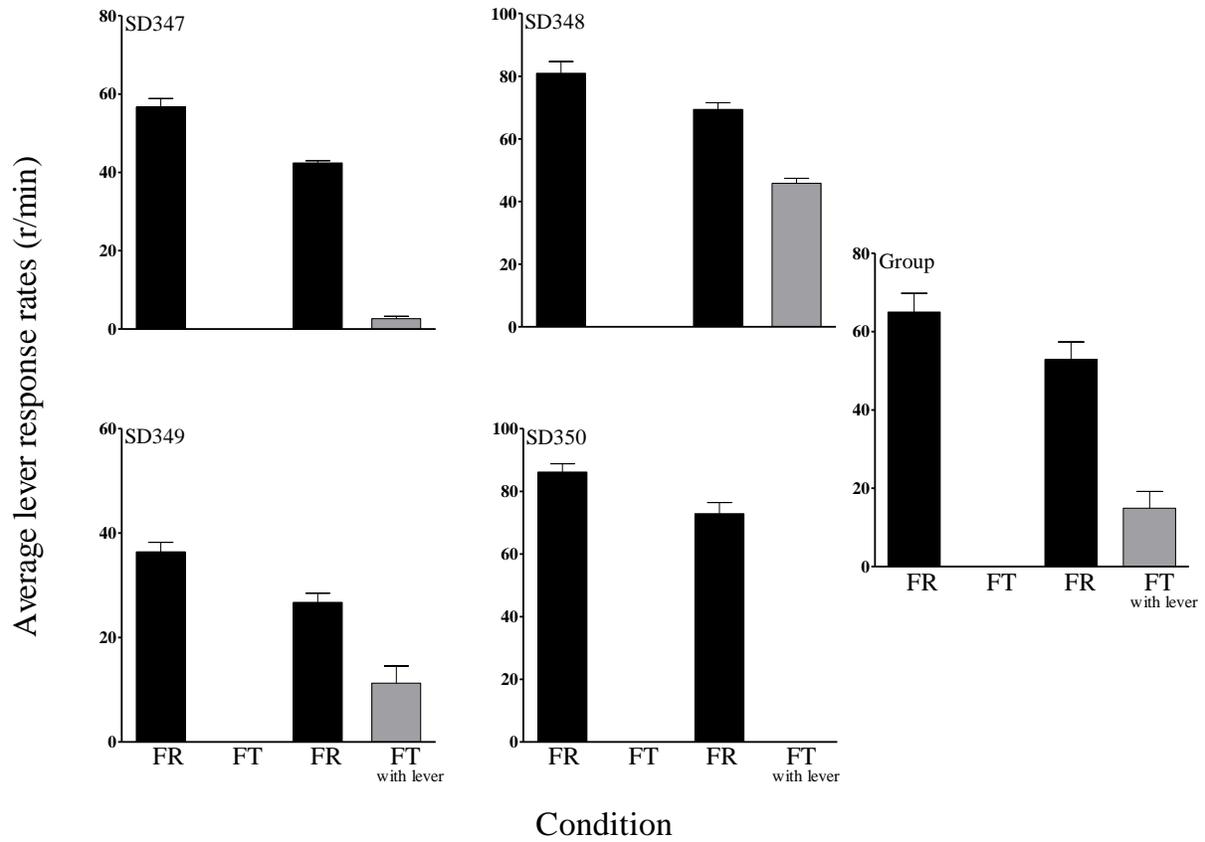


Figure 1. Lever response rates averaged over the last 5 sessions of each condition for each rat and as a group. FR=Fixed Ratio, FT=Fixed Time.

Figure 2 shows the amount of water consumed in grams per pellet across conditions. Differences in water consumption between rats and conditions are notable. All four rats had greater water consumption during the first FT condition as compared to the first FR condition, and during the second FT condition as compared to the second FR condition. Individual average increases in water consumed from the first FR to the first FT ranged from 0.15 g to 0.76 g per pellet. Individual average increases in water consumed from the second FR to the second FT ranged from 0.01 g to 0.46 g per pellet. As a group, the average increase in water consumed from the first FR condition to the first FT condition was 0.42 g per pellet and the average water consumed from the second FR condition to the second FT condition was 0.28 g per pellet.

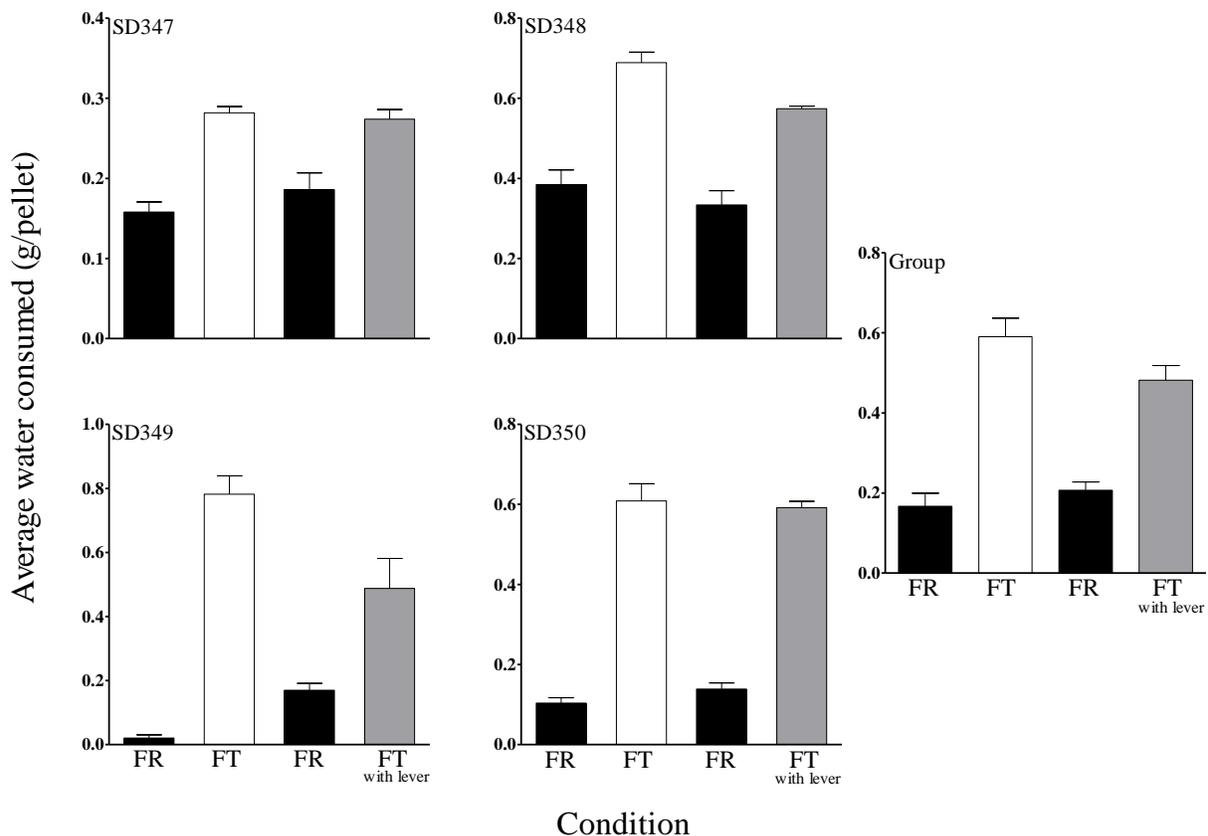


Figure 2. Amount of water consumed (g) per pellet averaged over the last 5 sessions of each condition for each rat and as a group. FR=Fixed Ratio, FT=Fixed Time.

Figure 3 shows the number of photo beam breaks per pellet across conditions. As would be expected, the number of photo beam breaks fluctuated across conditions in accordance with water consumption in Figure 2. All rats exhibited more photo beam breaks within FT conditions as compared to respective FR conditions. The individual average increases in the number of photo beam breaks from the first FR to the first FT condition ranged from 28 to 132 beam breaks per pellet. Individual average increases in the number of photo beam breaks from the second FR to the second FT ranged from 12 to 148 beam breaks per pellet. As a group, the average increase in the number of photo beam breaks per pellet was 150 from the first FR condition to the first FT condition and 79 from the second FR condition to the second FT condition.

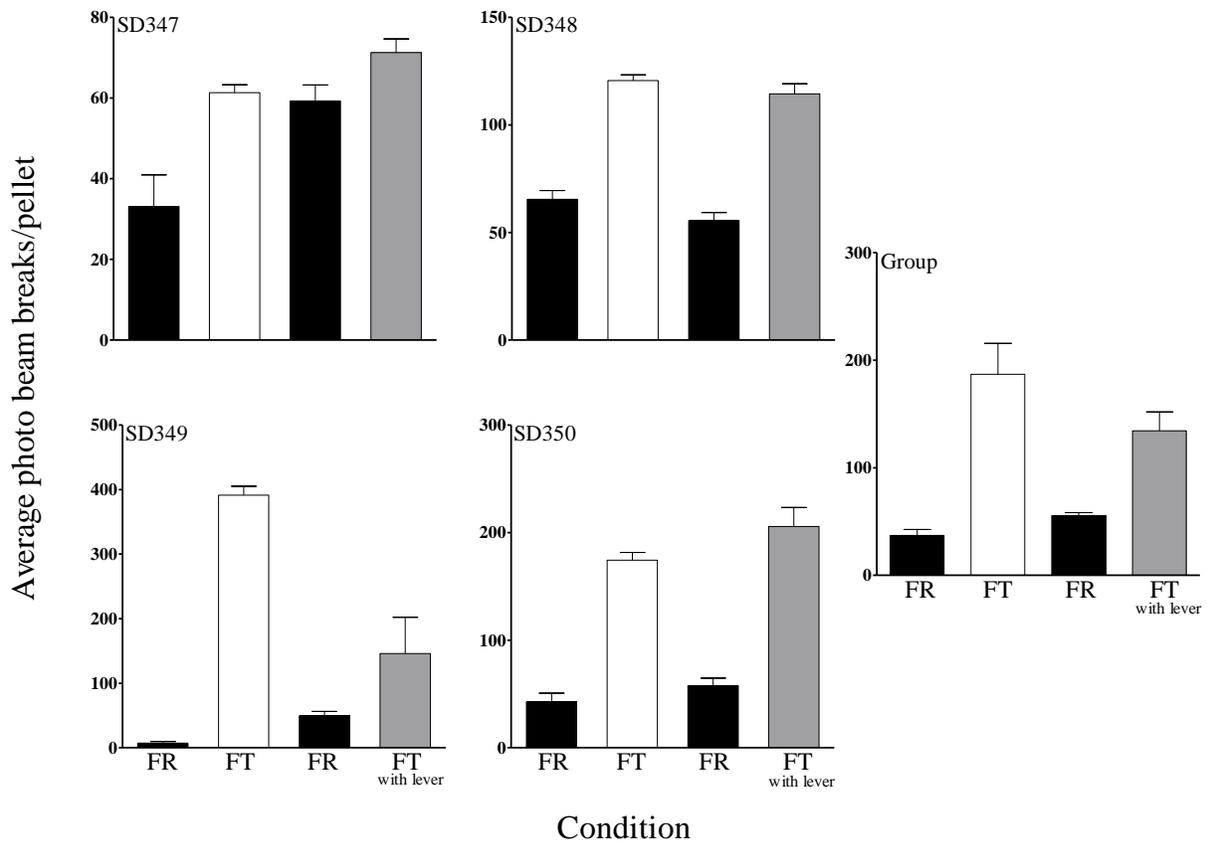


Figure 3. Number of photo beam breaks per pellet averaged over the last 5 sessions of each condition for each rat and as a group. FR=Fixed Ratio, FT=Fixed Time.

In order to find any relationships between the adjunctive drinking and lever pressing, correlations were conducted comparing grams consumed per pellet to lever response rates. All sessions in a condition were used to run these correlations. Table 2 reports under which conditions relationships were found to be significant. Correlations were conducted on the first FR condition, second FR condition, both FR conditions combined, and the FT condition in which the lever was available. The relationships show a negative correlation between lever response rates and water consumed; as water consumption increased, lever pressing decreased.

Table 2. Correlations by condition between lever response rate and water consumed per pellet for each rat.

Rat	Condition	Pearson R	
SD347	First FR	0.11	
	Reversal FR	0.28	
	Both FRs	-0.19	
	FT	-0.51	*
SD348	First FR	-0.16	
	Reversal FR	-0.81	***
	Both FRs	-0.47	***
	FT	-0.41	**
SD349	First FR	-0.04	
	Reversal FR	-0.14	
	Both FRs	-0.48	***
	FT	-0.42	
SD350	First FR	-0.67	***
	Reversal FR	-0.58	**
	Both FRs	-0.66	***
	FT	-0.78	***

* $p < .05$, ** $p < .01$, *** $p < .001$

CHAPTER IV

EXPERIMENT 1 DISCUSSION AND EXPERIMENT 2 INTRODUCTION

The purpose of Experiment 1 was to see how the availability of a lever during a response-independent condition would affect polydipsic drinking when compared to a response-dependent condition during which food delivery was contingent upon lever pressing. Water consumption was greater in response-independent conditions regardless of the lever being available. There was, however, more drinking during the first FT condition without the lever than in the second FT condition with the lever. Lever response rates decreased only slightly from the first FR to the second FR condition and were greatly attenuated during the second FT condition.

The results of Experiment 1 replicated and expanded previous research by demonstrating greater SIP during response-independent food delivery relative to response-dependent food delivery conditions regardless of the presence or absence of a lever (e.g. Burks, 1970). Water consumed from the first FT condition to the second FT condition was similar for both SD347 and SD350, and decreased for both SD348 and SD349. SD348 and SD349 also showed the highest rates of lever pressing within the second FT condition relative to other rats, indicating that time may have been spent lever pressing rather than drinking for these two rats. Comparisons between the two FT conditions should be taken with caution since all rats experienced food deliveries spaced farther apart (i.e., the IFI was longer) during the second FT condition: SD347's average IFI increased by 3.9 s, SD348's increased by 1.9 s, SD349's increased by 65.4 s and SD350's increased by 7 s. Therefore, any differences that were found between the two FT conditions could be due to more than just the presence or absence of a lever (i.e., IFI length).

The lack of development of SIP in SD349 during the initial response-dependent condition was unexpected. This rat nearly had to be removed from the study (adjunctive behavior cannot

be compared between conditions if it does not develop) but once moved to the FT condition, SD349 began drinking. It is possible that other behaviors may have competed with acquisition of SIP.

Although the results of Experiment 1 replicate prior SIP research, they contradict previous schedule-induced attack research wherein schedule-induced attack in pigeons is reduced during a response-independent schedule. These opposing results may be due to a number of variables including species differences, differences in the kind of adjunctive behavior, or how the schedules were arranged. Experiment 2 was undertaken to determine whether the yoking procedure contributed to the discrepant results. Previous studies examining SIP have used within-subject yoked FT schedules with a fixed IFI during the response-independent condition, whereas the IFI in the response-dependent condition was always variable since FR completion was response-dependent (e.g., Burks, 1970). In contrast, Kupfer, Allen and Malagodi (2008) used a within-subject yoked MT procedure which kept the variability of IFIs equivalent across the response-independent and response-dependent conditions. The same within-subject yoked MT procedure was employed in Experiment 2, in addition to replicating other procedural variables such as how training was conducted and the use of a COD, to enable a more accurate comparison to the results found by Kupfer, Allen and Malagodi.

CHAPTER V

EXPERIMENT 2 METHODS

Subjects

Eight male Sprague-Dawley rats (Charles-River, Portage, MI) 7 months of age and maintained at 85% free feeding weight served as subjects. They were housed in individual polycarbonate tubs with free access to water and were provided supplemental feedings after experimental sessions in order to maintain experimental weight. The colony room was on a reversed 12 hour light-dark cycle with lights on and off at 2000 and 0800, respectively. Sessions were conducted ~ 7 days a week at approximately the same time every day during the dark part of the cycle. All rats all had similar histories of being trained by students in an introductory behavior analysis class to lever press for liquid-sucrose reinforcers.

Apparatus

The same equipment from Experiment 1 was used.

Procedure

Rats were trained to lever press under an FR 1 in the presence of the house light and the response requirement was eventually increased to FR 15 for BA1216, FR 35 for BA1221, FR 48 for BA1218 and BA1220, FR 50 for BA1219 and BA1222, FR 70 for BA1217 and FR 110 for BA1215. These ratios were chosen so that all rats had similar IFIs. Each ratio tended to generate an average session IFI of around 30 s or longer for each rat while maintaining stable response rates. When the terminal FR value was attained, the experiment began.

Bottles were placed in the chambers and lever pressing continued with water freely available. The FR condition continued until there were 15 consecutive sessions with no trends in lever response rates or amount of water consumed for individual rats, as based on visual inspection of the graphed data. Once stable, the lever was removed from the chamber and the MT condition began. BA1215 and BA1221 did not develop polydipsia under the FR schedule and were moved on to the MT condition after completing at least 30 FR sessions. For the MT condition, daily IFIs were recorded from the previous 5 FR sessions in the order in which they were experienced. During the within-subject yoked MT sessions, food was delivered according to the exact sequence of intervals that occurred during each FR session. These 5 MT sessions were randomly chosen with replacement and repeated until 15 sessions devoid of trends in water consumption occurred. The lever was then reintroduced to the chamber and the original FR schedule was re-instated for the final condition. BA1222 never developed polydipsia under any of the conditions and was therefore removed from the study.

During all conditions of the experiment a COD of 5 s was employed to ensure that pellets were never delivered within 5 s of drinking. This COD reduces the likelihood of accidental reinforcement. Sessions ended after 30 pellets were delivered or 30 min had elapsed. The data from the last five sessions representing the steady state performance of each condition were presented.

CHAPTER VI

EXPERIMENT 2 RESULTS

Table 3 reports the number of sessions per condition for each rat, as well as the average IFI for the last 5 sessions of each condition. Rats BA1217 and BA1218 developed SIP within 10 sessions of the FR condition while BA1215 and BA1221 never developed SIP under the FR condition (they eventually became polydipsic during the MT condition).

Figure 4 shows the amount of water consumed in grams per pellet across conditions. All seven rats consumed more during the MT condition than during the FR condition. The average increase in water consumption from the FR to the MT condition ranged from 0.11 g to 0.47 g per pellet. As a group, the average increase in water consumption from the FR condition to the MT condition was 0.24 g per pellet.

Figure 5 depicts the number of photo beam breaks per pellet across conditions. The number of photo beam breaks fluctuated across conditions similarly to water consumption. All rats exhibited a higher number of photo beam breaks within the MT conditions compared to the initial FR condition. The average increase in the number of photo beam breaks from the FR to the MT condition ranged from 14 to 51 beam breaks per pellet. As a group, the average increase in the number of photo beam breaks per pellet was 32 from the FR condition to the MT condition.

Table 3. *Order of conditions, number of sessions and average IFIs under each condition for each rat in Experiment 2.*

Rat	Schedule		Sessions	5 day average IFI in sec	± SD
BA1215	FR 110		32	30.44	1.07
	MT	No lever	54	31.83	3.53
	FR 110		36	29.91	1.82
BA1216	FR 15		53	48.34	8.80
	MT	No lever	49	43.74	8.74
	FR 15		26	68.21	0.75
BA1217	FR 70		35	40.21	3.01
	MT	No lever	18	39.85	2.40
	FR 70		23	44.53	0.89
BA1218	FR 48		35	43.88	5.06
	MT	No lever	111	45.78	4.52
	FR 48		32	47.05	4.96
BA1219	FR 50		49	47.85	3.34
	MT	No lever	52	48.24	3.00
	FR 50		24	71.95	6.95
BA1220	FR 48		23	50.82	4.69
	MT	No lever	49	50.87	4.58
	FR 48		34	55.66	9.45
BA1221	FR 35		32	34.07	1.85
	MT	No lever	40	35.27	1.62
	FR 35		68	49.33	3.39

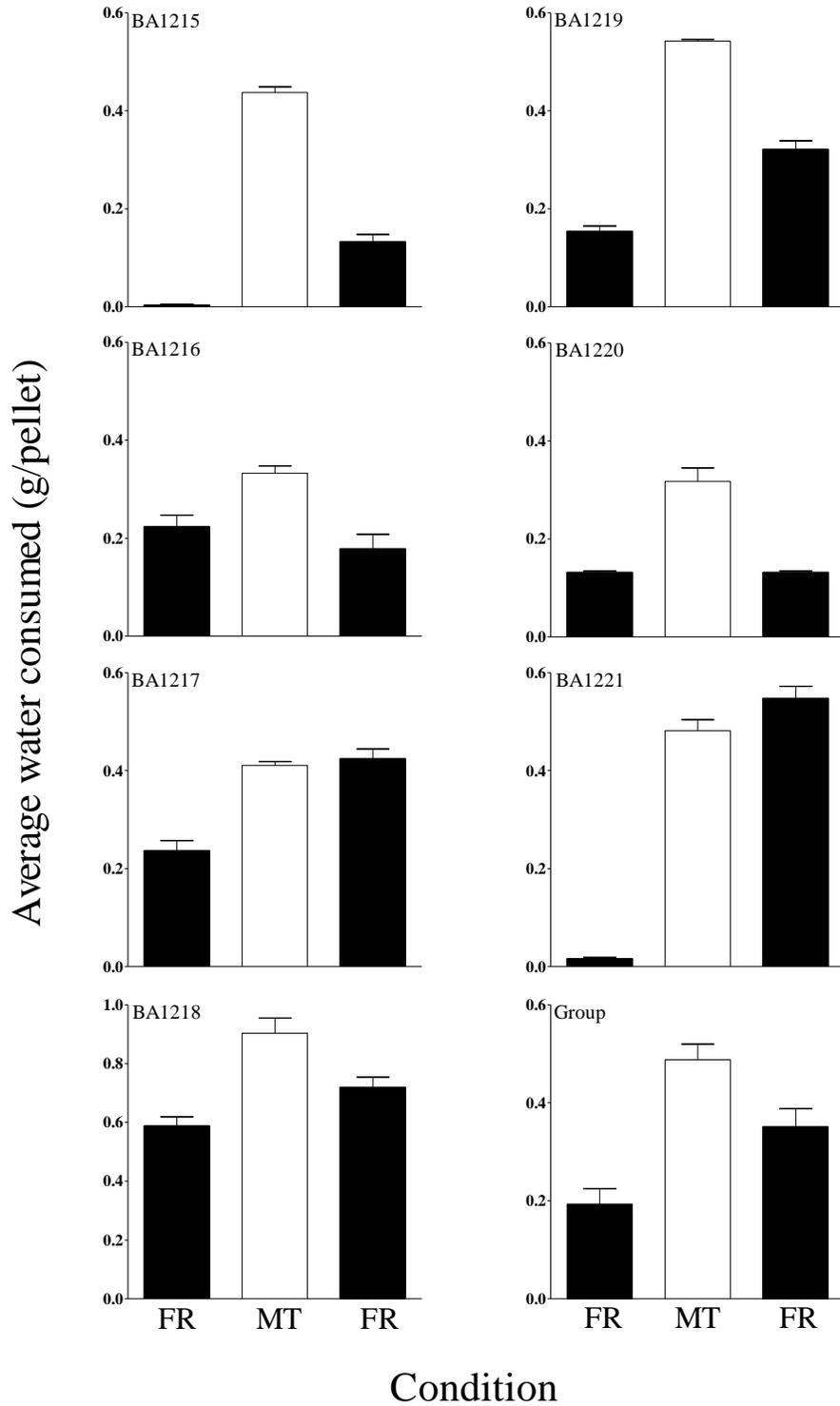


Figure 4. Amount of water consumed (g) per pellet averaged over the last 5 sessions of each condition for each rat and as a group. FR=Fixed Ratio, MT=Matched Time.

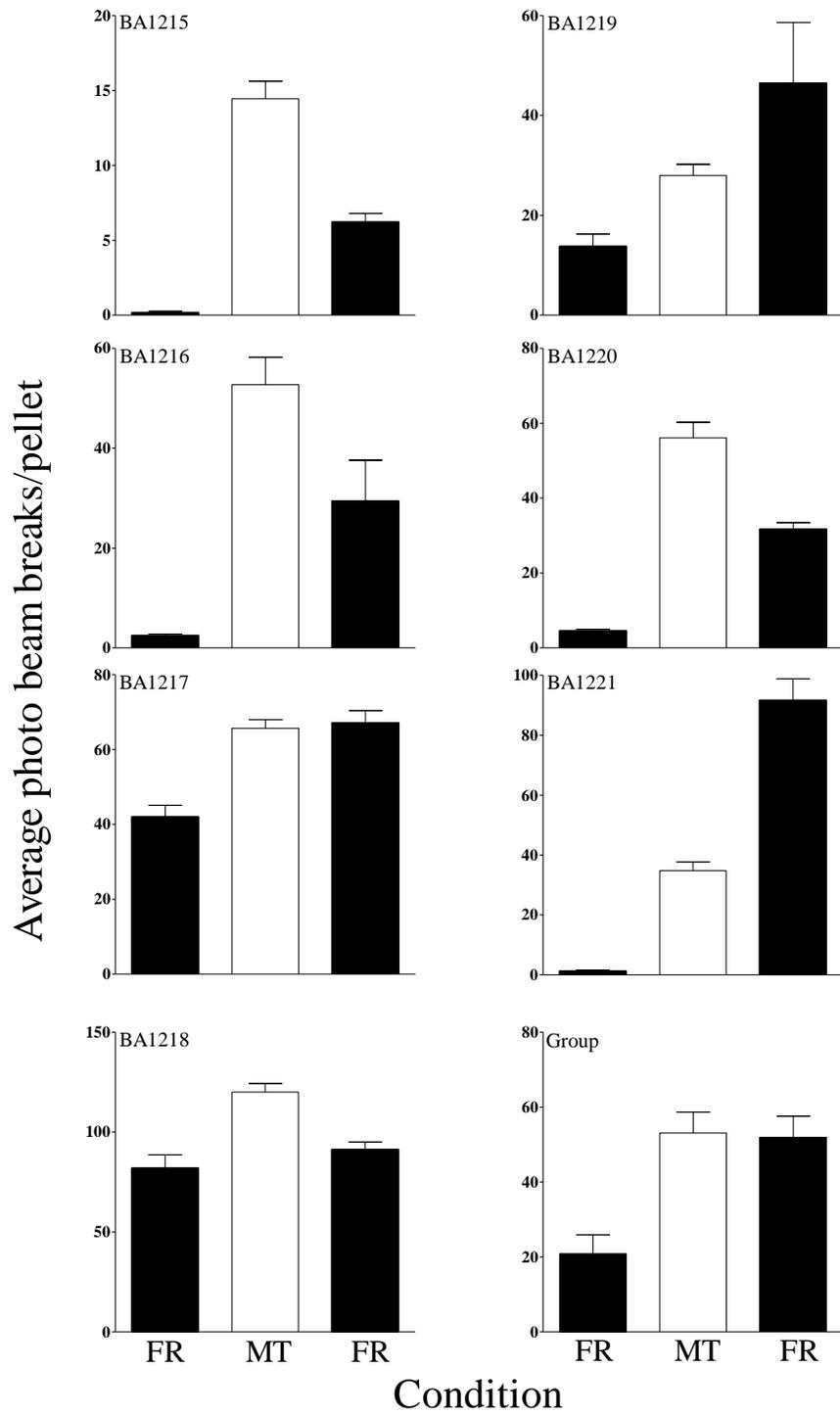


Figure 5. Number of photo beam breaks per pellet averaged over the last 5 sessions of each condition for each rat and as a group. FR=Fixed Ratio, MT=Matched Time.

Figure 6 illustrates average lever response rates across conditions. Average lever response rates for the first FR condition ranged between 20 and 240 responses per minute and during the second FR condition ranged between 10 to 245 lever presses per minute. Average lever response rates are not reported for the MT condition because the lever was not present.

To see how the operant (i.e., lever pressing) and adjunctive (i.e., drinking) behaviors may have interacted; correlational analyses were conducted using all sessions within FR conditions. Table 4 reports relationships between lever response rates and water consumed in grams per pellet during all sessions of the first FR condition, the second FR condition, and both FR conditions combined. There were negative correlations found between lever pressing and water consumption (and a single positive correlation for BA1221) as in Experiment 1; as water consumption increased, lever pressing decreased.

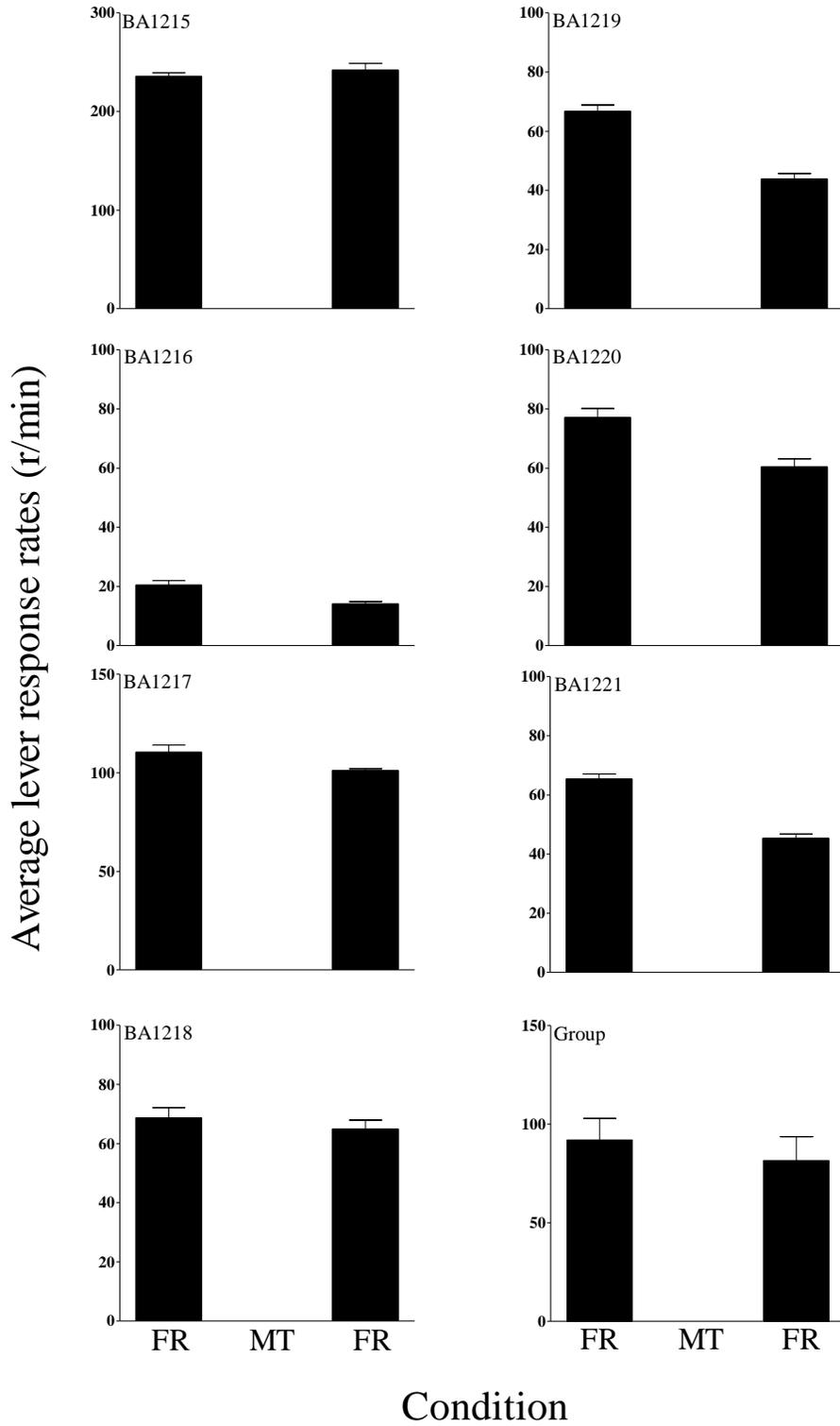


Figure 6. *Lever response rates averaged over the last 5 sessions of each condition for each rat and as a group. FR=Fixed Ratio, MT=Matched Time.*

Table 4. *Correlations by condition between lever response rate and water consumed per pellet for each rat.*

Rat	Condition	Pearson R	
BA1215	First FR	-0.23	
	Reversal FR	-0.30	
	Both FRs	-0.50	***
BA1216	First FR	-0.26	
	Reversal FR	-0.44	**
	Both FRs	-0.57	**
BA1217	First FR	-0.53	**
	Reversal FR	-0.30	
	Both FRs	-0.65	***
BA1218	First FR	-0.69	***
	Reversal FR	-0.38	*
	Both FRs	-0.78	***
BA1219	First FR	-0.55	***
	Reversal FR	-0.80	***
	Both FRs	-0.79	***
BA1220	First FR	-0.46	**
	Reversal FR	-0.59	**
	Both FRs	-0.53	***
BA1221	First FR	-0.10	
	Reversal FR	0.33	**
	Both FRs	-0.53	***

* $p < .05$, ** $p < .01$, *** $p < .001$

CHAPTER VII

EXPERIMENT 2 DISCUSSION

The purpose of Experiment 2 was to determine the extent to which procedural differences, such as using a more accurate yoking procedure or implementing a COD, may have contributed to the contrasting results between SIP and schedule-induced attack when response-independent and response-dependent food delivery conditions were compared. Experiment 2 used procedures similar to Kupfer, Allen and Malagodi (2008) such as their yoking procedure which was conducted by recording the sequence of IFIs within sessions from the FR condition and using these sequences to deliver pellets freely during the MT condition. Food in the MT condition was therefore delivered at the same intervals as in the FR condition. Despite equating previous procedural differences, SIP was greater in all rats in the MT condition compared to the FR condition; drinking increased when no work was required to earn food.

Some rats failed to develop SIP during one or more conditions. For instance, BA1222 never developed SIP under the response-dependent or the response-independent condition. BA1215 and BA1221 did not develop SIP within the response-dependent condition, but did develop SIP under the response-independent condition. Lever pressing for these rats may have competed with acquisition of SIP, as indicated by the correlational data presented.

The results of Experiment 2 replicate past SIP research by showing more drinking during a response-independent as compared to a response-dependent condition. The number of replications showing this same effect continues to grow, each replication using different, and often more accurate, procedures. Schaeffer and Salzburg (1967) showed greater drinking in an FT 45-s schedule than in an FR50 schedule with no COD and no way to control for IFI length or variability between the response-dependent and the response-independent conditions. Burk's

(1970) compared drinking across FRs and yoked FTs and also found greater drinking in the response-independent condition. Burk's controlled for length of IFIs, but still had no control for the variability in IFI length between the two conditions. Experiment 2 controlled for length and variability of IFIs across conditions and still revealed greater drinking in the response-independent condition, showing this effect to be very robust.

CHAPTER VIII

GENERAL DISCUSSION

Experiment 1 and Experiment 2 were both conducted to examine the reliability of the finding that SIP is greater during response-independent, as compared to response-dependent, schedules of food delivery. Experiment 1 was conducted to see how the availability of a lever during response-independent food deliveries affected the amount of SIP when compared to response-dependent food deliveries where lever pressing was required to earn food pellets. SIP was greater during response-independent (FT) food deliveries, regardless of whether a lever was present. During the FT condition with the lever available, lever response rates decreased relative to FR conditions yet the continued responding evidenced by some rats may have contributed to the lower levels of SIP as compared to the previous no-lever FT condition. There was a negative relationship between lever response rates and grams of water consumed per pellet. Experiment 2 was conducted to compare SIP across response-dependent and response-independent food deliveries while controlling variability of IFIs between the two conditions using procedures similar to Kupfer, Allen and Malagodi (2008). The MT condition produced more SIP than the FR condition, a finding opposite of that demonstrated in schedule-induced attack research conducted by Kupfer, Allen and Malagodi. Again, a negative relationship was revealed between lever response rates and amount of water consumed.

Both experiments showed greater water consumption during response-independent food deliveries, decreases in lever response rates during the second FR conditions (except for BA1215 who had an increase in lever response rate) and significant negative correlations between lever response rates and water consumed (except for BA1221 who revealed a positive relationship in one condition). A difference in results between the two experiments occurred during the second

FR condition: two rats (BA1217 and BA1221) from Experiment 2 consumed more water during their second FR condition compared to the first FR condition, whereas all rats in Experiment 1 consumed approximately the same amount in both FR conditions.

Within both of the studies, large differences were shown in the acquisition and maintenance of SIP between subjects. The average amount of water consumed varied among the subjects ranging from no drinking taking place to up to 0.90 g consumed per pellet. Lopez-Grancha and colleagues (2008) found that administration of *d*-amphetamine or cocaine dose dependently reduced SIP differently in rats consuming large amounts of water compared to those consuming small amounts of water. These results suggest that dopaminergic differences may affect the amount of drinking that occurs during SIP. Pellon and colleagues (2011) support dopamine's role in SIP by showing that SIP correlates positively with D2 receptor binding and correlates negatively with D1 receptor binding in areas of the brain such as the nucleus accumbens, medial prefrontal cortex, amygdala, and the ventral tegmental area. Moreno and colleagues (2012) suggest serotonin also plays a role when they found that rats consuming large amounts of water in SIP also exhibit higher serotonin activity in the amygdala. It is possible that neuroanatomical differences may influence the acquisition and maintenance of SIP and future research should look into this possibility further.

The results of Experiment 1 and Experiment 2 were similar despite several procedural differences. In Experiment 1 an FT schedule was used during the response-independent condition, whereas in Experiment 2 an MT schedule was used to arrange the response-independent delivery of food. A yoking procedure was employed in both response-independent schedules; in the FT condition, the yoking procedure equated the overall food delivery rate to the FR condition and in the MT condition the yoking procedure ensured that food was delivered at

the exact intervals that it was delivered in the initial FR condition. The availability of the lever during the response-independent condition also varied between Experiment 1 and Experiment 2: two response-independent conditions were conducted in Experiment 1, one with the lever present and one with the lever absent, whereas only a single response-independent condition was conducted in Experiment 2 and the lever was absent during this condition. Lever training differed between the two experiments with the water bottle present during training in Experiment 1 whereas the water bottle was absent during training in Experiment 2. Despite these differences in procedure, both experiments had similar findings.

The results from both experiments are also consistent with prior SIP research (Burks, 1970; Schaffer, Diehl, & Salzberg, 1966; Schaffer & Salzberg, 1967), which demonstrates greater adjunctive drinking when work is not required to earn food. These two experiments combined, in addition to the published literature, provide strong evidence that the delivery of free food as compared to earned food produces a greater amount of SIP. The reliability with which this effect is produced makes it hard to understand why schedule-induced attack shows the opposite results under the same manipulations, particularly in light of the attempts to keep Experiment 2 as similar to Kupfer, Allen and Malagodi (2008) as possible.

There remained some differences between Experiment 2 and Kupfer, Allen and Malagodi's (2008) experiment that may have inadvertently contributed to the discrepant results. When comparing most studies examining the effect of a work requirement on SIP and schedule-induced attack, the species of the subjects (i.e., rats versus pigeons), the operant response required during the response-dependent condition (i.e., lever pressing versus key pecking), and the type of food delivered (i.e., food pellets versus timed access to grain) typically differ. Also, the nature of the relationship between the operant response required to earn food and the

adjunctive behavior differs; key pecking is more akin to attack than lever pressing is to drinking water.

The type of adjunctive behavior is also different; although it is most common that SIP is studied in rats while schedule-induced attack is studied in pigeons, there are instances in which this is not the case. Dale (1979) has shown SIP in pigeons, and Huston and DeSisto (1971) studied interspecies schedule-induced attack in rats between response-independent and response-dependent schedules. Huston and DeSisto found more schedule-induced attack when work was required for food, fitting nicely with previous schedule-induced attack research. These studies are atypical compared to most adjunctive behavior research, but may be a good direction for future research to tease apart if it may be species or the type of adjunctive behavior causing differences in results obtained. The discrepancies between SIP and schedule-induced attack leave questions to be answered regarding the generality of controlling factors across different types of adjunctive behaviors, although Experiment 1 and Experiment 2 were able to add to the list of variables that affect SIP in the same way.

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