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An Investigation of the Behavioral Effects of Methylphenidate Hydrochloride on Schedule-Induced Polydipsia in Rats

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AN INVESTIGATION OF THE BEHAVIORAL EFFECTS OF METHYL-PHENIDATE HYDROCHLORIDE ON SCHEDULE-INDUCED POLYDIPSIA IN RATS

(TITLE)

BY

Linda Sederquist Smith

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ABSTRACT

The influence of methylphenidate hydrochloride injections on six male Charles River rats displaying schedule induced polydipsia was examined in this study. Bar pressing, licking, and water consumption were measured during a total of 63 daily one hour trials conducted with a variable interval 60-second schedule of bar pressing for pellets with water constantly available. The polydipsic response was acquired by subjects during the first 28 trials. Subjects were then divided into experimental and control groups. The experimental subjects recieved a 1 mg/kg injection of methylphenidate prior to regular trials 29-49 and extinction trials 50-63. Control subjects were injected with an equal volume of physiological saline during regular and extinction trials. It was hypothesized that methylphenidate injections would affect the bar pressing, licking, and water consumption rates of experimental subjects during the last two phases. An analysis of variance was used to compare the experimental and control groups' performances for each variable. The analyses included data for the last 14 trials of each of the three phases: acquisition, regular, and extinction sessions, or trials 15-28, 36-49, and 50-63.

Results indicated that there were no significant differences between experimental and control subjects' rates on any of the variables measured. The only significant main effects were those of the three consecutive phases of the experiment. Possible explanations for the results obtained from the experiment and indications for future research are included in a detailed discussion.

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TABLE OF CONTENTS

(Continued)

LIST OF TABLES

LIST OF FIGURES

(Continued)

CHAPTER I

INTRODUCTION

A. A Historical Background of Problem

When an organism ingests an excessive, abnormal amount of fluid, it is described as being "polydipsic" (Falk, 1961). The condition can generally be traced to either of two broad physiological sources: (a) metabolic polydipsia which occurs as the result of abnormal fluid losses, as in diabetes insipidus, or (b) regulatory polydipsia resulting from a defect in the central nervous system which stimulates neural regulation centers for thirst.

A polydipsic condition may also be produced by chemical means such as sodium depletion or the administration of diuretics, and through surgical techniques usually involving the hypothalamus or loading of the stomach with fluids.

The problems associated with the production of polydipsia have long plagued researchers concerned with investigations of renal disorders, metabolic disorders, and other functions whose study necessitated an increase in the organism's fluid intake volume. The use of punishment such as shock or other avoidance contingencies to produce an abnormally large fluid intake provided an

inadequate solution to the problem of inducing polydipsia without introducing the experimental concomitant variables associated with surgical and chemical techniques.

Research in alcoholism with animals has been especially handicapped due to the difficulty of producing high, sustained rates of drinking without resorting to the above techniques.

Falk (1961) was the first to describe voluntary abnormal drinking at a high, sustained rate in normal, unrestrained animals. Although Williams and Teitlebaum (1956) noted that the usual effect of food deprivation in rats is a considerable reduction in fluid intake, Falk observed the development of polydipsic behavior in all of 14 food deprived female rats trained to bar press for pellets on a 60 second variable interval schedule (VI-60) with water freely available 24 hours a day. In this study, records were kept of (a) the subjects' (Ss') pre-experimental, 24 hour fluid intake, (b) number of licks from the drinking spout and the amount of fluid ingested during experimental sessions of 3.17 hours each, and (c) the volume of fluid consumed in the home cage during the remaining hours between daily experimental sessions.

A peculiar behavior pattern became evident from recordings made during the experimental sessions. The delivery of each pellet was followed by a burst of pro-

longed licking at the water spout. The S then returned to bar pressing until the delivery of the next pellet, after which the pattern was repeated. Falk reported that the post-pellet drinking was prolonged to the extent that pellets which were potentially available after shorter intervals (3 to 10 seconds) in the VI-60 were delayed by the excessive drinking behavior.

The mean fluid intake during experimental sessions for all Ss averaged 3.43 times higher than the pre-experimental 24 hour intake. Falk commented that the polydipsic effect was rapidly developed and evident in the first or second VI session, and never failed to develop under the VI-60 schedule. The behavior was classified as a type of regulatory polydipsia which would be called "psychogenic" if it occurred in humans.

The effects of the VI schedule of reinforcement upon fluid intake in food deprived rats were further explored by Clark (1962) who observed that: (a) changing to a fixed ratio (FR) schedule produced normal FR rates of response with only occasional drinking and post-pellet pauses of more than five seconds, (b) substitution of a dry bottle did not immediately eliminate pausing to lick, and (c) changing the distance between bar and water tube from three inches to nine inches eliminated drinking in only one of three Ss. The data indicated that drinking was developed and maintained by adventitious reinforcement

with the proximity of the water spout and the proportion of short intervals in the schedule (less than 30 seconds) being two relevant factors in the production of polydipsia.

Another possible explanation for the polydipsic behavior observed with intermittent schedules was offered by Stein (1964), who conducted four tests designed to support either the argument for adventitious reinforcement, or the possibility that thirst was induced. According to the results, the argument for adventitious reinforcement of drinking was false due to the abrupt disappearance of polydipsia when milk was substituted for pellets. Bar press rates also dropped substantially and, although there was a gradual increase, the rate never recovered to the level maintained by pellets. Emptying of the water bottle produced an abrupt, but not immediate decline in licking during three sessions with an empty bottle, returning to normal levels when the bottle was full. Bar press rates were not affected, but a breakdown in temporal discrimination was observed. After polydipsic behavior had been firmly established, a switch to a fixed interval of three minutes (FI-180) demonstrated that in all cases drinking occurred temporally at the beginning of the interval, directly following the ingestion of a pellet. Cessation of drinking was usually followed by an FI pause in bar pressing, which supports the idea that drinking is elicited by dry food as opposed to being an adventitiously

reinforced behavior. Polydipsic behavior was also developed with an FI-180 schedule in two of three Ss after a long latency period. The study concluded that: (a) the ingestion of dry food induced thirst, (b) rats drank at the end of each meal, (c) schedules increased the number of "meals" eaten, and (d) all of the foregoing contributed to increasing the volume of fluid consumed.

Segal and Holloway (1963) in a brief study of polydipsia, reported their contention that drinking served as a mediating cue in time dependent reinforcement schedules.

Thus began the speculation and experimentation in an effort to find an explanation for the varying degrees of excessive drinking behavior observed in conjunction with intermittent schedules of reinforcement. In general, the earlier explanations of the phenomenon may be summarized as follows: (a) thirst resulting from dry food and meal size, (b) adventitious or superstitious operant behavior, and (c) timing cues associated with time dependent schedules. These basic arguments spawned a profusion of articles attempting to analyze polydipsia from a variety of approaches. The majority took issue with one or more of the arguments in an effort to discredit or prove support for a particular point of view. Others endeavored only to clarify some of the variables relevant to the production of polydipsia.

Numerous suggestions were made describing possible determinants of "psychogenic polydipsia" (Segal, 1965; Segal & Deadwyler, 1964a, b; Segal & Deadwyler, 1965; Segal & Oden, 1965; Segal, Oden & Deadwyler, 1965a, b). For example, Segal and Oden (1965) contended that there were multiple determinants which included all of the preceeding as well as "emotional pacification" and "something to do while waiting for the next reinforcement".

The type of schedule best suited to inducing an excessive drinking response was of primary interest to investigators who analyzed the data to reveal the most pertinent aspects of the schedule.

Falk (1966a) investigated the length of the interpellet interval and stated that the production of schedule-induced polydipsia (SIP) was dependent upon intervals of 30 seconds or more between reinforcements. The drinking was also found to be reinforcing to the extent that it was used on a concurrent bar-press contingency. Falk suggested that SIP was similar to the aggressive behaviors produced by Azrin (1965) in pigeons during extinction intervals. Phenomena such as schedule-induced aggression and polydipsia were termed "adjunctive behaviors".

Falk (1966b) also evaluated the effects of various FI schedules upon polydipsic water intake, concluding that polydipsic behavior was unrelated to either

adventitious reinforcement or chaining, and again attributed it to "adjunctive behavior".

With further research in the effects of schedules, Falk (1967) reported that the SIP response increased as a function of greater VI length or decreased rate of food acquisition.

Increased FR schedules were used by Schaeffer and Diehl (1966) to study the effects of meal frequency and related water intake. The results were interpreted as being consistent with Stein's argument for the thirst explanation of post pellet drinking. It was noted that drinking followed, rather than preceeded bar pressing and eating. Both the number of "meals" and the amount of fluid ingested increased as a function of greater FR requirements.

However, Schaeffer and Salzberg (1967) suggested that in some instances, SIP might be traceable to the S's inability to discriminate the experimenter-imposed schedule requirement.

Colotla, Keehn, and Gardner (1970) suggested that the unavailability of reinforcement set the occasion for drinking to begin, with stimuli associated with the reavailability of reinforcement setting the occasion for drinking to end for interpellet intervals of less than 2 or 3 minutes.

Burks, Hitzing and Schaeffer (1967) demonstrated

that polydipsia could be induced in rats under a free FI-40 reinforcement schedule using 4% sucrose pellets. The data indicated that drinking immediately followed rather than preceeded pellet delivery, suggesting that post-prandial effects may explain the phenomenon.

Again demonstrating the highly motivating effects of SIP, Roll, Schaeffer and Smith (1969) conditioned an aversion to a saccharin solution by pairing ingestion of the solution with exposure to Cobalt^{60} irradiation. Under normal conditions, such treatments produce a decrement in drinking, however, polydipsic Ss showed no decrease in schedule-induced drinking.

The intimate, complex relationships among delivery of the food pellet, drinking, the length of the inter-pellet interval and the number of food pellets dispensed or "meal size" have been scrutinized by a number of investigators with varying and occasionally contradictory results.

Stein's (1964) hypothesis that excessive drinking was due to thirst was supported by Stricker and Adair (1966) who attempted to isolate the determinants of the onset of interpellet drinking. The data indicated that a post-prandial factor such as dry mouth was probably a factor motivating the drinking response.

A slightly different view was offered by Keehn (1970) in a SIP experiment using an executive and control

subject. The hypothesis proposed that a wet mouth may have become the discriminative stimulus for bar pressing with food reinforcement, due to the fact that bar pressing with food in the mouth was frequently not reinforced. The data showed that reinforcement was usually obtained when food had been washed from the mouth.

The predictability of drink onset and duration was not found to be related to meal size (Keehn and Colotla, 1970b). Drinking was reported to have occurred at the beginning of the post-pellet interval, or at the time when food became unavailable, suggesting that it depended more on meal spacing than meal size. Further experimentation (Keehn & Colotla, 1971) indicated that SIP was "...occasioned by the absence of food (extinction induced) rather than by the first stimulus effects of eating" (p. 261). According to the data, post-pellet drink durations or quantities were not systematically affected by meal sizes of from one to nine pellets.

In contrast, Flory (1971) attempted a further investigation of Falk's hypothesis that the degree of SIP produced in rats is related to the rate of food consumption, over-all mean interpellet time, or mean pellet delivery. The validity of this "consumatory theory" was tested over a wide range of delivery rates. The study found that increasing reinforcement frequency did increase polydipsia

up to a maximum at FI-120. Also, increasing reinforcement magnitude from one to two pellets decreased polydipsia when total number of pellets for both conditions was held constant. However, when it was considered that in the second condition (two pellets) there were fewer occasions for drinking, water intake or number of licks per interval showed that the greater pellet magnitude produced as much or more drinking at FIs of 30 seconds or more.

Another possible variable adding to the above confusion was discussed by Hymowitz and Freed (1972), who analyzed the data of 16 rats previously used in SIP studies for the number of licks per quarter experimental session. The analysis indicated that there was a significant decrease in drinking as sessions progressed from the first to the last quarter of each session. This finding demonstrated that the relationship between SIP and meal size was more complex than previously estimated, and that the validity of studies assuming lick rate to be independent of session length must be questioned.

In addition, a direct relationship was found between percentage of weight loss and the degree of polydipsia which could be induced (Freed & Hymowitz, 1972). Two experiments were conducted exploring the effects of such non-schedule factors as percentage of body weight loss and magnitude of reinforcer upon the volume of water

drunk by rats during SIP. The data supported those theories which relate SIP to the aversiveness of intermittent reinforcement schedules. The data also supported Falk's (1967) finding of an increase in meal size leading to a decrease in fluid consumption.

An explanation for the complex of behaviors exhibited by the polydipsic rats described in the preceeding studies continued to elude the best efforts of researchers in the field. The excessive drinking response appeared to differ as a function of a number of factors. Specific variables appearing to have an effect upon the degree of polydipsia produced were the intermittency and frequency of the reinforcement schedule or the length of interpellet intervals, the type and size of reinforcers used, and the degree of food deprivation. Suggested explanations included thirst due to an increased number of "meals", adjunctive behavior, superstitious or adventitious reinforcement, something to do between reinforcers, and the aversiveness of the reinforcement schedule.

An interesting and possibly revealing side line to the study of SIP is that the above conditions may also produce a number of seemingly analogous, compulsive behaviors in animals which bear a startling resemblance to schedule-induced drinking.

The earliest incident was reported by Hendry and Rasche (1961) who described the apparent "air drinking"

of thirsty rats. The "drinking" was found to be rewarding and also reduced the rate of bar pressing under a VI-60 schedule of reinforcement.

Mendelson and Chillag (1970) found that rats developed post-pellet licking behaviors with an airstream on a free reinforcement schedule of 60 seconds. About twice as many licks were reported to occur in rats recieving an airstream as opposed to those given water. The data was interpreted to be in agreement with Falk's suggestion that SIP was due to the frustrating effect of presenting a food deprived rat with small bits of food.

A similar case was presented by Taylor and Lester (1969) who found that "nitrogen drinking" in rats appeared to be almost identical to SIP. In this instance, the data was interpreted as supporting the argument for adventitious reinforcement initiated by thirst.

Another schedule-induced behavior, wheel-running, was reported by Levitsky and Collier (1968). The wheel-running activity occurred in a temporal pattern analogous to the SIP response pattern, and was similarly related to the intermittency of the schedule and extinction of bar pressing.

Also, Segal (1969), using rats on a free-reinforcement schedule, found that when drinking between pellets was prevented, wheel running assumed a pattern very similar to that associated with SIP. Segal had hypo-

thesized that drinking was "something to do to pass the time while waiting for the next food pellet" (p. 141), and predicted that wheel running and drinking would be competitive behaviors. However, the prevention of licking did not generally increase the amount of running. The data did not support the "something to do" hypothesis.

An additional observation of such behaviors was made by Freed and Hymowitz (1969) who reported that rats which had developed SIP would essentially stop drinking, but continue to bar press when they could chew or manipulate cellulose materials. The data was interpreted in support of the "emotional pacification" hypothesis of Segal and Oden (1965), and the motivational property of non-reward such as that which occurs in the intermittent schedules used for inducing polydipsia.

All of the foregoing accounts of polydipsia have occurred in several strains of laboratory bred rats. However, similar SIP behavior has been demonstrated in other laboratory animals. Schuster and Woods (1966) attempted to show that SIP could be produced in the Rhesus monkey and that the drinking was a function of the number of food periods allowed over a 24 hour duration. The results indicated that SIP was produced in monkeys under conditions similar to those which produce excessive drinking in rats. A manipulation of the schedule showed that drinking occurred only immediately after food periods,

thus demonstrating that chaining was not an essential condition for the production and maintenance of SIP.

The effects of various intermittent reinforcement schedules upon the production of SIP in a pigeon were observed by Shanab and Peterson (1969). It was found that SIP could be produced in a pigeon, and additionally, that the position of the water bottle appeared to have an influence upon the degree of drinking produced as part of a behavior chain. Also, it was found that after SIP was reinstated following extinction sessions, there was a marked increase over pre-extinction levels.

Each of the preceeding studies may be categorized in a number of ways, such as in terms of goals, methods, or results. The following is an attempt to add coherency by summarizing the major conclusions, interpretations, and methods used in adding to the accumulation of information which exists concerning SIP.

One of the most obvious factors in the production of polydipsic behavior is the schedule of reinforcement imposed upon the subject. Polydipsia was not observed to occur in animals being reinforced for each response (CRF). The greatest polydipsic behavior was observed under intermittent schedules where the drinking developed very quickly in response to the variability of reinforcement. The largest increases in fluid intake occurred when intervals greater than 30 seconds and less than 240 seconds

existed between reinforcements. The behavior developed less rapidly when fixed reinforcement schedules were used, as opposed to variable reinforcement.

The relationship between the type of schedule and the degree of polydipsic response has been explored by a number of investigators. The temporal relationship between bar pressing, eating, and drinking has been examined to show whether or not the drinking appeared to be part of a behavior chain, or a superstitious behavior being reinforced by the receipt of a pellet. A number of researchers have interpreted their data as supporting the argument that drinking is an operant-superstitious behavior which is reinforced by the delivery of a food pellet (Clark, 1962; Schaeffer & Salzberg, 1967; Segal, 1965; Segal, 1969; Segal & Deadwyler, 1964a, b; Segal & Deadwyler, 1965; Segal & Oden, 1965; Segal, Oden & Deadwyler, 1965a, b; Taylor & Lester, 1969). Some of these studies also included thirst as contributing to the initial acquisition of the drinking response.

Many other authors examined their results only to find evidence conflicting with that of the above. The temporal proximity of drinking, eating, and bar pressing indicated this: although the drinking may have been related to thirst, there was no relationship between the drinking and the reciept of a pellet. Generally, manipulations of schedules indicated a break between the

drink burst and succeeding bar presses and reinforcement, thus decreasing the probability of adventitious reinforcement of drinking behavior (Burks, 1970; Falk, 1966a, b; Falk, 1967; Falk, 1969, Freed & Hymowitz, 1969; Hymowitz, Freed, & Lester, 1970; Jacquet, 1972; Keehn & Colotla, 1970; Keehn & Colotla, 1971; Mendelson & Chillag, 1970; Schaeffer & Diehl, 1966; Schuster & Woods, 1966; Stein, 1964; Stricker & Adair, 1966).

"Meal size" or the number of pellets included in each reinforcement and the spacing of meals also were examined for their influence upon drinking. Stein's (1964) argument for increased thirst due to the number of small, spaced meals provided initial evidence for a number of investigators in support of this basic hypothesis (Jacquet, 1972; Schaeffer & Diehl, 1966; Segal & Deadwyler, 1964a; Stricker & Adair, 1966; Taylor & Lester, 1969). Subsequent tests of the hypothesis that drinking was increased because of the rats' tendency to drink after each meal were not supported. The exact influence of meal size upon drinking has remained unclear (Falk, 1969; Flory, 1971).

Extinction of the polydipsic response has been used by a number of researchers (Freed, Carpenter, & Hymowitz, 1970; Freed & Lester, 1970; Hymowitz & Freed, 1968; Keehn & Colotla, 1971; Ponicki & Thompson, 1972; Segal & Deadwyler, 1965; Segal, Oden & Deadwyler, 1965a, b;

Segal & Oden, 1965; Stein, 1964) in attempting to demonstrate whether or not SIP is part of an adventitiously reinforced behavior chain. The rationale was that cessation of food delivery would terminate bar pressing and drinking, or that the unavailability of fluid would result in a disruption in the bar pressing. In most cases, the results of these studies indicated, again, that there was little or no relationship between the bar pressing and drinking responses due to the particular temporal pattern of bar pressing, eating and drinking which was observed from the data. Bar pressing was found to be directly related to pellet delivery, whereas drinking was more a function of the reinforcement schedule.

The post pellet drinking burst was closely examined by several investigators (Colotla, Keehn, & Gardner, 1970; Keehn, 1970; Keehn & Colotla, 1970a, b; Keehn & Colotla, 1971) yielding the following observations: (a) the drink duration was relatively constant with a particular reinforcement schedule, (b) duration varied more as a function of time interval than meal size, (c) the drinking was occasioned by the onset of the post-pellet interval (non-reinforcement) and was generally confined to that period. Thus, the stimuli associated with the unavailability of food, non-reinforcement, or "uncertainty" were factors maintaining the SIP response.

In addition to drinking, a number of other

behaviors have been reported which appear to be related to SIP. All were produced by intermittent schedules and showed the same distinctive temporal pattern. Included were: wheel running (Levitsky & Collier, 1968; Segal, 1969), chewing and manipulating cellulose materials (Freed & Hymowitz, 1969), nitrogen "drinking" (Taylor & Lester, 1969), and air "drinking" (Hendry & Rasche, 1961; Mendelson & Chillag, 1970).

Polydipsic behavior has also been produced in the Rhesus monkey (Schuster & Woods, 1966), and in a pigeon (Shanab & Peterson, 1969).

SIP has proved to be an excellent method for producing excessive drinking for purposes of studying the physiological and behavioral effects of alcohol (Freed, 1972; Freed, Carpenter, & Hymowitz, 1970; Freed & Lester, 1970; Holman & Myers, 1968; Lester, 1961). Palatability as a factor potentially influencing SIP was also examined (Colotla & Beaton, 1971; Keehn, Colotla, & Beaton, 1970).

B. Statement of Problem

A considerable body of research and theory has evolved concerning intermittent or partial reinforcement schedules and their inherent element of extinction. It is well known that such schedules produce greater resistance to extinction than does continuous reinforcement. In addition, it has been noted that non-reinforcement may

generate apparent emotional and motivational effects (Miller & Stevenson, 1956; Skinner, 1938). A number of investigators have related partial reinforcement and extinction to the production of "frustration" (Rohrer & Sheffield, 1949, 1950; Brown & Farber, 1951; Amsel, 1958, 1961, 1962). Other experiments have undertaken to demonstrate the aversiveness of schedules containing extinction intervals (and an inferred emotional state or frustration) by measuring aggression as a dependent variable. For example, Azrin, Hutchinson and Hake (1966), using pigeons, reported that aggression typically occurred at the point of transition from food reinforcement to extinction. The burst of aggressive behavior during this period was interpreted as an indicator of the aversiveness of the impending extinction interval. The authors commented that "many schedules of intermittent reinforcement will probably possess aversive properties since intermittency necessarily involves periods of extinction" (p. 203). Additionally, the authors stated that the aversiveness of the schedule may be determined through escape conditioning in which the animal must emit a response producing a time out from the reinforcement procedure.

One of the most prominent features of SIP is that the behavior never has occurred with continuous food reinforcement. It can be induced by a variety of intermittent schedules. Much of the research in the preceeding

section was devoted to defining limits of excessive drinking which would be evoked as a function of types of schedules and lengths of inter-pellet intervals.

The possibility that the apparent compulsive nature of the drinking was dependent upon an emotional response evoked by intermittency, was suggested as early as 1961 by Lester in a SIP study with alcohol. Lester speculated "...that the unpredictable occurrance of a food reward is an anxiety producing stress in the rat..." (p. 230).

Later, Falk (1966a) noted that any schedule containing inter-reinforcement intervals of 30 seconds or more produced a SIP response in rats. A high probability of drinking upon meal termination was found. Additionally, the motivational property of the drinking was established by the subjects' responses on a concurrent FR bar pressing contingency for drinking. Falk pointed out that just as punishment produced escape responses which would sustain concurrent FR responding (Azrin, Hake, Holz, & Hutchinson, 1965), so intermittent schedules would elicit a drinking response with motivating properties on a concurrent FR schedule. Thus, SIP was compared with the schedule-induced aggression reported by Azrin, Hutchinson, and Hake (1966).

Freed and Hymowitz (1969) reported agreement with Falk, stating that both aggression and polydipsia have

a common background of exposure to schedules of frustrative non-reward. Mendelson and Chillag (1970) also found their data consistent with Falk's suggestion that SIP was due to the frustrating effect of intermittent reinforcement.

Additional support for the relating of SIP to the length of the inter-pellet (extinction) interval was provided in a study by Keehn and Colotla (1970a). The data indicated that the absence of reinforcement after bar pressing appeared to be the stimulus for the onset of drinking. The authors suggested that the behavior might be better described as "pre-interval drinking" due to its association with the unavailability of food.

Further experimentation (Colotla, Keehn, & Gardner, 1970; Keehn, 1970; Keehn & Colotla, 1970b) led Keehn and Colotla (1971) to the conclusion that drinking varied as a function of the onset of non-reinforcement (extinction) intervals with a relative constancy for any particular reinforcement schedule. The drinking was again likened to extinction-induced aggressive behavior.

Beginning with Lester's (1961) idea that schedule-induced drinking might provide valuable insights into the nature of alcohol addiction and a non-traumatic method for its study, there has been a considerable amount of research with SIP using alcohol solutions

instead of water. The importance of emotional states in creating human alcoholism brought about further speculation concerning the possibility of extinction-induced frustration in intermittent SIP schedules. Lester used Falk's technique with a 5.6% alcohol solution and found that all subjects developed a behavior pattern resembling compulsive drinking which apparently depended upon the requirement that the subject emit an operant behavior with reinforcement being intermittent, and with a fluid being available for consumption. The SIP response for alcohol was somewhat lower than for water intake under similar conditions. Lester speculated that the unpredictability of reinforcement may have been an anxiety evoking condition producing a drive for drinking in the animal.

According to the preceeding explanation of SIP in terms of frustrative non-reward, (if the emotional state generated by intermittent reinforcement is wholly or partially responsible for the drinking), any change in the subject's organismic state which reduces the effects of intermittency should decrease the amount of fluid ingested during SIP.

It has been demonstrated that alcohol can have an attenuating effect upon experimentally induced neuroses and conflict behaviors (Conger, 1951; Freed, 1968; Masserman, 1962; Masserman, Jaques, & Nicholson, 1945;

Masserman & Yum, 1946; Smart, 1965) with a wide variety of experimental designs. Although in some instances, results have not been entirely in agreement, the variation has generally been attributed to individual subject differences in response to alcohol and situational variables, (including poor definitions of conflict).

Thus, the intriguing possibility arose that not only could schedule-induced drinking provide a clue to the etiology of human alcohol addiction and other compulsive behaviors, but it could help to clarify the role of alcohol in terms of anxiety attenuation.

Holman and Myers (1967) attempted to determine whether the behavioral situation associated with SIP could create a "drive" for alcohol. Ingestion of various water-ethanol concentrations under SIP and control conditions was compared, revealing that SIP increased mean consumption only at lower concentrations (3-7% ethanol by volume). It was suggested that the noxious taste of ethanol at concentrations above 8% caused a decrease in ingestion. Also, the caloric value of ethanol to food deprived subjects was pointed out as a variable which may have influenced the results.

A study by Freed, Carpenter and Hymowitz (1970) compared the acquisition and extinction of SIP in two groups of food deprived subjects, one recieving water and the other, a 5.6% alcohol solution. The SIP response

was developed in all subjects with a significantly greater mean consumption for the water group during acquisition. It was noted that the subjects on alcohol persisted in the typical bar pressing-eating-drinking pattern for only about the first half of the sessions. During the latter half, bar pressing continued at the same rate; however, drinking became very inconsistent. The authors suggested that this cessation of drinking may have been attributable to the attenuation of frustration by the alcohol.

The water group was shown to have ingested significantly less than the alcohol group during extinction. Although both groups extinguished bar pressing by the fourth day of extinction sessions, the alcohol group's drinking did not extinguish. It continued to be high during the 10 days of extinction sessions. The authors suggested that the alcohol subjects' failure to extinguish may have been due to the caloric replenishment provided by the alcohol.

It was apparent that the variables of taste and calories confounded research of alcohol and the emotional state associated with SIP.

A further exploration of this problem was reported by Freed and Lester (1970), who compared the polydipsic ingestion of water, alcohol solutions, and acetone solutions in food deprived subjects. The equi-

intoxicating effects of acetone and ethanol were not a factor influencing ingestion. The authors noted that the influence of the taste and odor of acetone was unknown. The data supported the hypothesis that ethanol was consumed by subjects at least in part for its caloric value rather than for its pharmacodynamic effects in a frustrative, non-reward situation.

Freed (1972) tested the effects of changing the nutritive content of food pellets on polydipsic consumption of water and an alcohol solution. The pellets used for substitution were equal in size, shape, weight, and sweetness; but the total nutritional value obtainable during experimental sessions were reduced by 25, 50, 75, or 100 percent. The results indicated that polydipsic consumption of alcohol solutions were affected by the caloric value of the alcohol, and that the polydipsic consumption of any fluid was related to the nutritional property of the reinforcer.

Because of the calories and taste involved in using alcohol or a similarly intoxicating fluid, it was impossible to assess whether anxiety or frustration attenuation was a factor influencing drinking. The question of how the pharmocodynamic action of alcohol affected SIP behavior remained confounded due to the requirement of food deprivation in producing and maintaining the response.

The influence of other drugs on polydipsic

drinking was reported by Falk (1964) in an investigation of the effects of pentobarbitol and amphetamines on water ingestion. Although amphetamines reduced home cage drinking and pentobarbitol increased it, both drugs decreased drinking under SIP conditions. Bar pressing was unaffected by cessation of drinking. (The results may be interpreted in support of the hypothesis that an emotional state produced by intermittent reinforcement was a factor in influencing SIP.)

However, Segal, Oden, and Deadwyler (1965c) in a further investigation of the effects of pentobarbitol and amphetamines on SIP response, reported that pentobarbitol did not reduce drinking to an extent which could justify the conclusion that polydipsia represented an emotional state depressible by a sedative. In addition, the authors stated that because amphetamines reduced home cage drinking, the drug was inappropriate for use in testing the hypothesis.

Other studies have confirmed the reduction of polydipsic drinking due to amphetamine administration (segal & Deadwyler, 1964b; Segal & Oden, 1968).

This study was designed to continue the investigation of drug effects on schedule-induced polydipsic drinking.

The drug used was methylphenidate hydrochloride, an anti-depressant type of compound often used to

allieviate functional behavior problems in children. It has also been found useful in treating psychoneuroses, chronic fatigue, drug-induced lethargy, narcolepsy, and apathetic or withdrawn senile behavior. Its effect becomes apparent within 10 to 15 minutes after intra-muscular injection. The most common side effects are nervousness and insomnia, with occasional reports of hypersensitivity, anorexia, nausea, dizziness, palpitations, headache, dyskinesia, drowsiness, and skin rash (Physicians' Desk Reference, 1970).

The effects of three dosages of methylphenidate on behavior in rats were examined by Bindra and Baran (1959). The dependent variable measured was "general activity" or responses such as sniffing, grooming, and lying down. Methylphenidate was shown to cause significantly increased sniffing and activity changes. Lying was significantly decreased and grooming was unaffected. The degree of effect was proportionate to dosages with marked individual differences in response to the drug.

Methylphenidate was also reported to cause an increased rate of random bar pressing before conditioning with brain stimulation (Tyce, 1968). Rates of bar pressing were also increased after conditioning with and without the reinforcing administration of brain stimulation.

Bindra and Mendelson (1963) observed that methyl-

phenidate had a positive, multiplicative, interaction effect on rats pretrained to bar press for water a low and high rates. The drug decreased the rate of response with low pretraining levels, and the rate of lever pressing in rats trained to the highest operant response levels did not change.

This study has investigated the effects of methylphenidate hydrochloride on the water ingestion, bar pressing, and licking rates of polydipsic rats.

CHAPTER II

EXPERIMENTAL PROCEDURE

A. Subjects

Six male albino Charles River rats approximately 130 days old at the beginning of the experiment were used. They were housed individually in a temperature controlled and constantly illuminated laboratory. Each rat had free access to water in its home cage at all times throughout the study. Animals were randomly assigned to experimental (a_1) and control (a_2) groups with three in each group.

B. Apparatus

The experimental space consisted of a Grason-Stadler operant conditioning chamber containing a bar press lever, pellet dispenser, and drinking tube with a water bottle suspended outside. All was contained within an isolation box with an exhaust fan in a darkened room. The drinkometer was located outside of the isolation chamber. Standard Grason-Stadler automatic programming relay apparatus, cumulative recorders, and counters were located in an adjacent room. Data records included bar presses, reinforcement intervals, pellets, and licks per session.

C. Procedure

Subjects were housed individually with food and water ad libitum for nine days. Each subject was then food deprived to 85% of its' free-feeding body weight and underwent daily magazine training sessions for a two week period. After magazine training was complete, experimental sessions were defined as one hours' duration in which approximately 60 - 45 mg. Noyes food pellets were available on a VI-60 schedule (Falk, 1967). Maintenance rations were dispensed in the home cages after experimental sessions to supplement pellets.

The experiment was divided into three consecutive B treatment levels as follows: b_1 treatment was the acquisition period in which subjects were introduced to the experimental procedure including the VI-60 bar pressing for pellets reinforcement schedule, free access to water in the previously described experimental chamber, and daily one-hour sessions. The SIP response was gradually developed over 28 sessions. Subjects were not given drug or saline injections during this treatment.

Level b_2 was identical to b_1 except that 15 minutes prior to each session, the experimental (a_1) subjects were injected intraperitoneally with 1 mg/kg methylphenidate hydrochloride and control (a_2) subjects with an equal volume (0.225 cc) physiological saline solution. Level b_2 conditions continued for a 21 day

period.

Treatment b_3 introduced extinction for bar pressing conditions. All procedures during this treatment level remained identical to those in level b_2 including drug or saline injections; however, the pellet dispenser was emptied. (This procedure was preferable to electrical disconnection due to the audible "click" emitted by the pellet dispenser which may have served as a discriminative stimulus to the subjects.) Level b_3 extinction sessions were maintained for a 14 day period.

D. Statement of Research Hypotheses

The purpose of the experiment was to investigate the effects of methylphenidate hydrochloride injections on the bar pressing, water consumption and licking rates of polydipsic rats as compared to the rates exhibited by similarly polydipsic subjects injected with physiological saline solution.

More specifically, the hypotheses were the following:

1. The experimental (a_1 group) animals will exhibit no greater significant differences in bar pressing, water consumption, and licking rates than control (a_2 group) animals in the acquisition of polydipsia (b_1) level.
2. The experimental (a_1 group) animals will

differ significantly in bar pressing, water consumption, and licking rates from those responses exhibited by the control (a_2 group) animals during the drug or saline injection (b_2) level.

3. The experimental (a_1 group) animals will exhibit significantly different rates of bar pressing, water consumption, and licking as compared to the response rates exhibited by control (a_2 group) animals during the drug or saline effect on extinction (b_3) treatment level.

E. Analysis of Results

Several experiments (Falk, 1964; Segal & Deadwyler, 1964b; Segal & Oden, 1968; Segal, Oden, & Deadwyler, 1965c) indicated that polydipsic drinking could be reduced through the administration of either pentobarbitol or amphetamines, both of which affect the central nervous system, but in opposite ways.

The drug methylphenidate differs from amphetamines in lacking andrenergic action (Miller & Uhr, 1960). It is, however, similar as a "psychic energizer" (p. 99).

On the basis of these findings, the null form of each of the above hypotheses were tested with a sep-

arate split plot factorial 2.3-14 (Kirk, 1968) analysis of variance at three time intervals which included sessions during the last 14 days of each of the three b_j treatment levels. More specifically, the data analyzed from treatment b_1 (trials 1-28) included only trials 15-28; that from b_2 (trials 29-49) included trials 36-49; and that from b_3 (trials 50-63) included trials 50-63.

The schematic layout of the SPF-2.3-14 design used in this study is presented in Figure 1. In this design the two levels of a_i correspond to the methylphenidate and saline injection groups; the three levels of b_j refer to: the acquisition of polydipsia, the effects of drug or saline injections on polydipsia, and the effects of drug or saline injections on extinction. The 14 levels of c_k correspond to the last 14 trials to occur under each level of treatment conditions b_j.

Insert Figure 1 about here

The $p < .05$ level of significance was required for the rejection of the null form of the research hypotheses.

	$b_1 \ldots b_1$	$b_2 \ldots b_2$	$b_3 \ldots b_3$
	$c_1 \ldots c_{14}$	$c_1 \ldots c_{14}$	$c_1 \ldots c_{14}$
	$s_1 \ldots s_1$	$s_1 \ldots s_1$	$s_1 \ldots s_1$
a_1	$s_2 \ldots s_2$	$s_2 \ldots s_2$	$s_2 \ldots s_2$
	$s_3 \ldots s_3$	$s_3 \ldots s_3$	$s_3 \ldots s_3$
	$s_4 \ldots s_4$	$s_4 \ldots s_4$	$s_4 \ldots s_4$
a_2	$s_5 \ldots s_5$	$s_5 \ldots s_5$	$s_5 \ldots s_5$
	$s_6 \ldots s_6$	$s_6 \ldots s_6$	$s_6 \ldots s_6$

Figure 1. Type SPF-2.3-14 Design

CHAPTER III

Results and Discussion

A. Results

The mean bar pressing rates of individual subjects for the last 14 trials (c_1-c_{14}) of each level of b_j are presented in Figure 2. It is obvious that fairly wide individual rate differences existed throughout all levels of B. All subjects' rates of bar pressing continued to increase across b_1 and b_2 treatment levels and then dropped sharply when b_3 conditions were instituted.

Insert Figure 2 about here

Figure 3 graphically illustrates the mean performances of a_i groups during the last 14 trials (c_1-c_{14}) of each b_j treatment.

Insert Figure 3 about here

Although some differences existed between groups, the SPF-2.3-14 (Kirk, 1968) analysis of variance for bar pressing found the effects of treatments a_i to be insignificant. Levels of treatment b_j, however, were

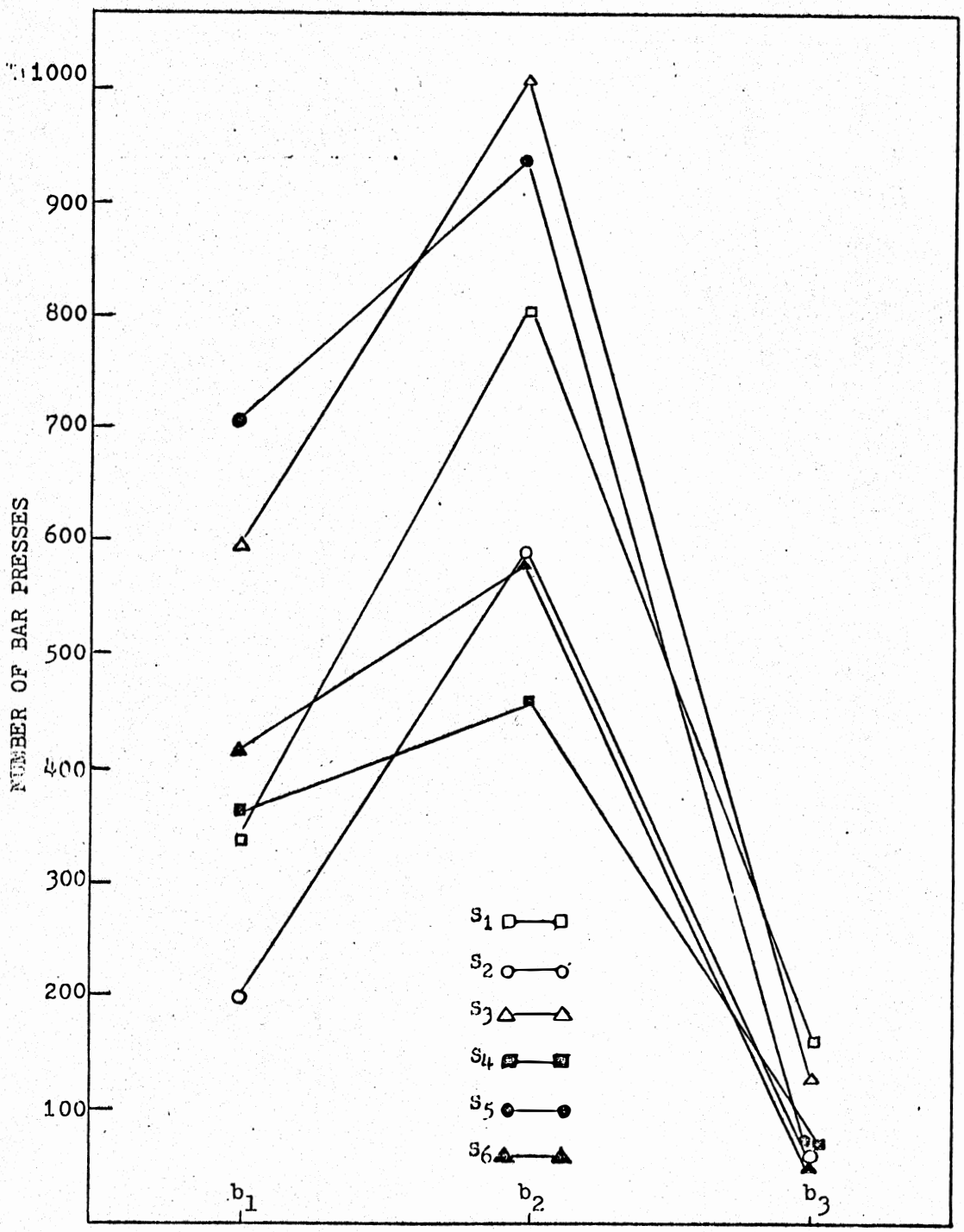

Figure 2. Mean bar pressing rates of individual subjects for the last 14 trials (c_1-c_{14}) at b_1 (acquisition), b_2 (drug), and b_3 (extinction).

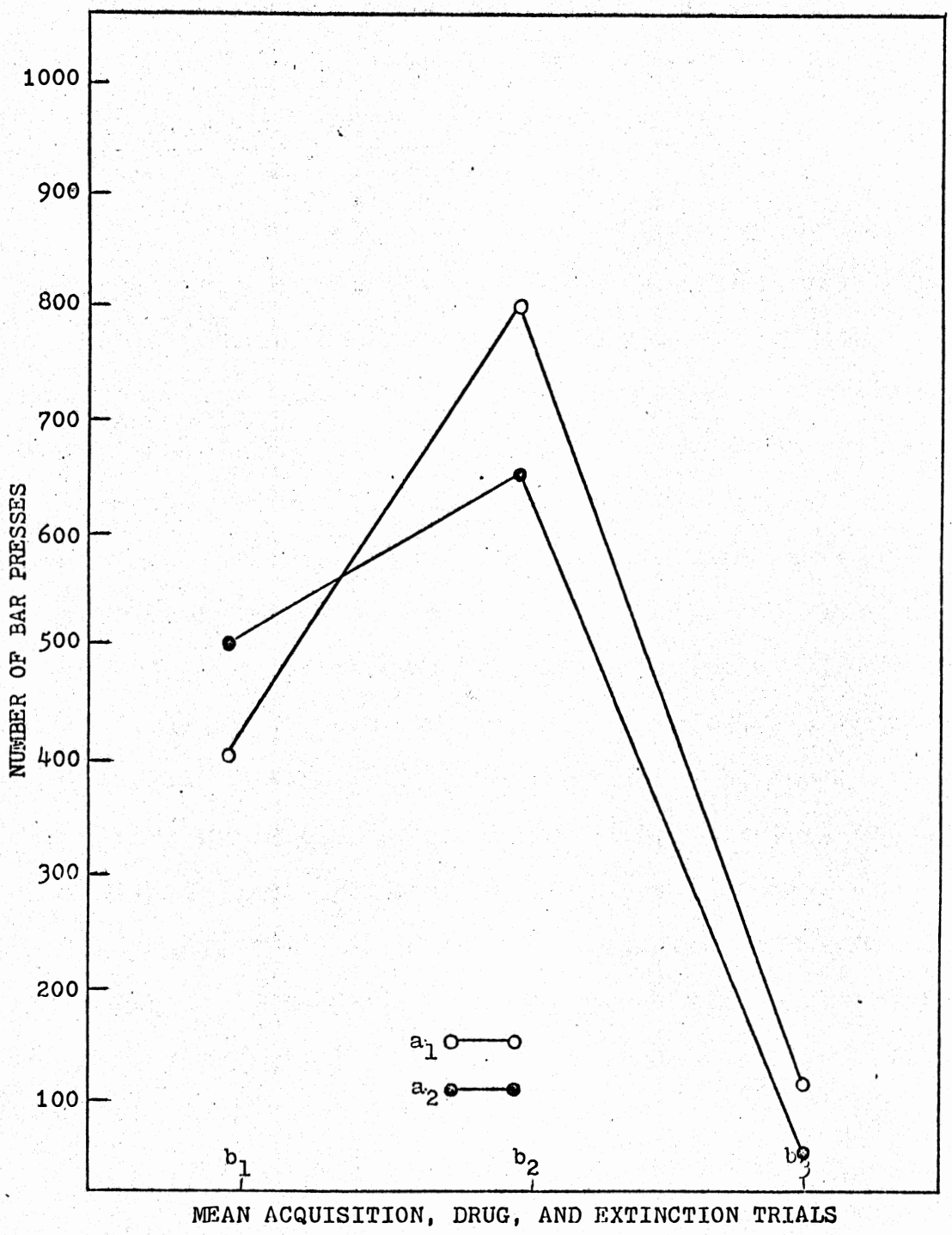

Figure 3. Mean bar pressing rates of a_1 and a_2 (experimental and control) subjects during the last 14 trials of acquisition (b_1), drug (b_2), and extinction (b_3) sessions.

significant, $p < .001$, $F = 44.5388$, $df = 2,8$. The results of this analysis are presented in Table 1.

Insert Table 1 about here

The only significant main effect of the analysis for bar pressing was that of the b_j treatment levels. From this finding it can only be concluded that subjects exhibited significantly different responses over trials 15-28, 36-49, and 50-63. A comparison of means by the Tukey method (Kirk, 1968) gave a more specific illustration of the differences among b_j treatment levels: 1) a comparison of b_2 and b_1 levels indicated that the subjects' mean bar pressing rates during trials 36-49 were significantly greater, $p < .01$, $\Psi = 5.74613$, than during trials 15-28, 2) a comparison of b_2 and b_3 level indicated that subjects' mean rates during trials 36-49 were significantly greater, $p < .01$, $\Psi = 13.30663$, than during trials 50-63, and 3) that subjects' mean rates during b_1 (trials 15-28) were significantly greater than during b_3, $p < .01$, $\Psi = 7.56021$. Degrees of freedom for all comparisons were 3,8.

The F_{max} test computed for the bar-pressing data was not significant thus indicating that the homogeneity of variance of experimental error assumption was not violated.

Table 1

Analysis of Variance Table, SPF-2.3-14.

Bar Pressing

	SOURCE	SS	df	MS	EMS	F	
1.	A	82622.88	1/4	82622.88	126	0.1018	
2.	B	17204960	2/8	8602480.	84	44.5388	*
3.	C	390104.6	13/52	30008.04	18	3.0227	**
4.	Subj w. groups	3246164.	4	811541.0	42		
5.	AB	595728.0	2/8	297864.0	42	1.5422	
6.	AC	32923.19	12/52	2532.553	9	0.2551	
7.	BC	1894103.	26/104	72850.06	6	10.3846	*
8.	B x Subj w. groups	1545164	8	193145.5	14		
9.	C x Subj w. groups	516240.8	52	9927.707	3		
10.	ABC	180180.0	26/104	6930.000	3	0.9879	
11.	BC x Subj w. groups	729583.2	104	7015.223	1		
12.	Total	21,110,204.87	187				

* $p < .001$

** $p < .005$

Figure 4 represents the mean milliliters of water ingested by each of the six subjects in each B Treatment. Again individual differences in response rate were clearly displayed.

Insert Figure 4 about here

Group means in b_j treatment levels are illustrated in Figure 5.

Insert Figure 5 about here

An SPF-2.3-14 (Kirk, 1968) analysis of variance indicated that significant differences existed only for the mean effects of b_j treatments, $p < .005$, $F = 11.2082$, $df = 2,8$. Results of the analysis are presented in Table 2.

Insert Table 2 about here

Application of a Tukey comparison of means for b_j treatments showed that significant differences existed between b_1 and b_3, $p < .01$, $\Psi = 6.13282$, and b_2 and b_3, p .05, $\Psi = 5.39362$, $df = 3,8$. No significant differences were noted between mean scores when b_1 and b_2 levels were compared.

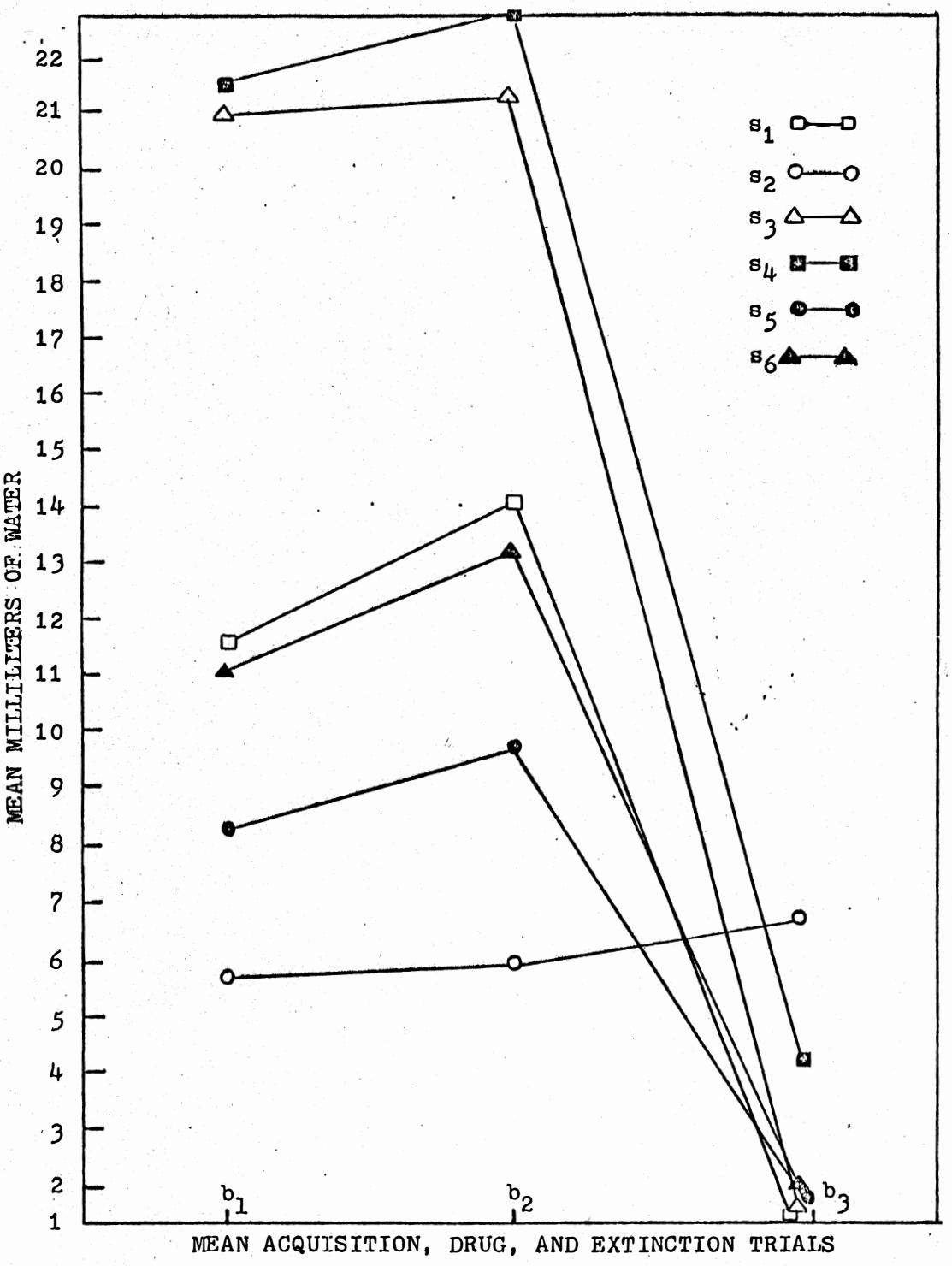

Figure 4. Mean milliliters of water consumed by individual subjects during acquisition (b_1), drug (b_2), and extinction (b_3) sessions.

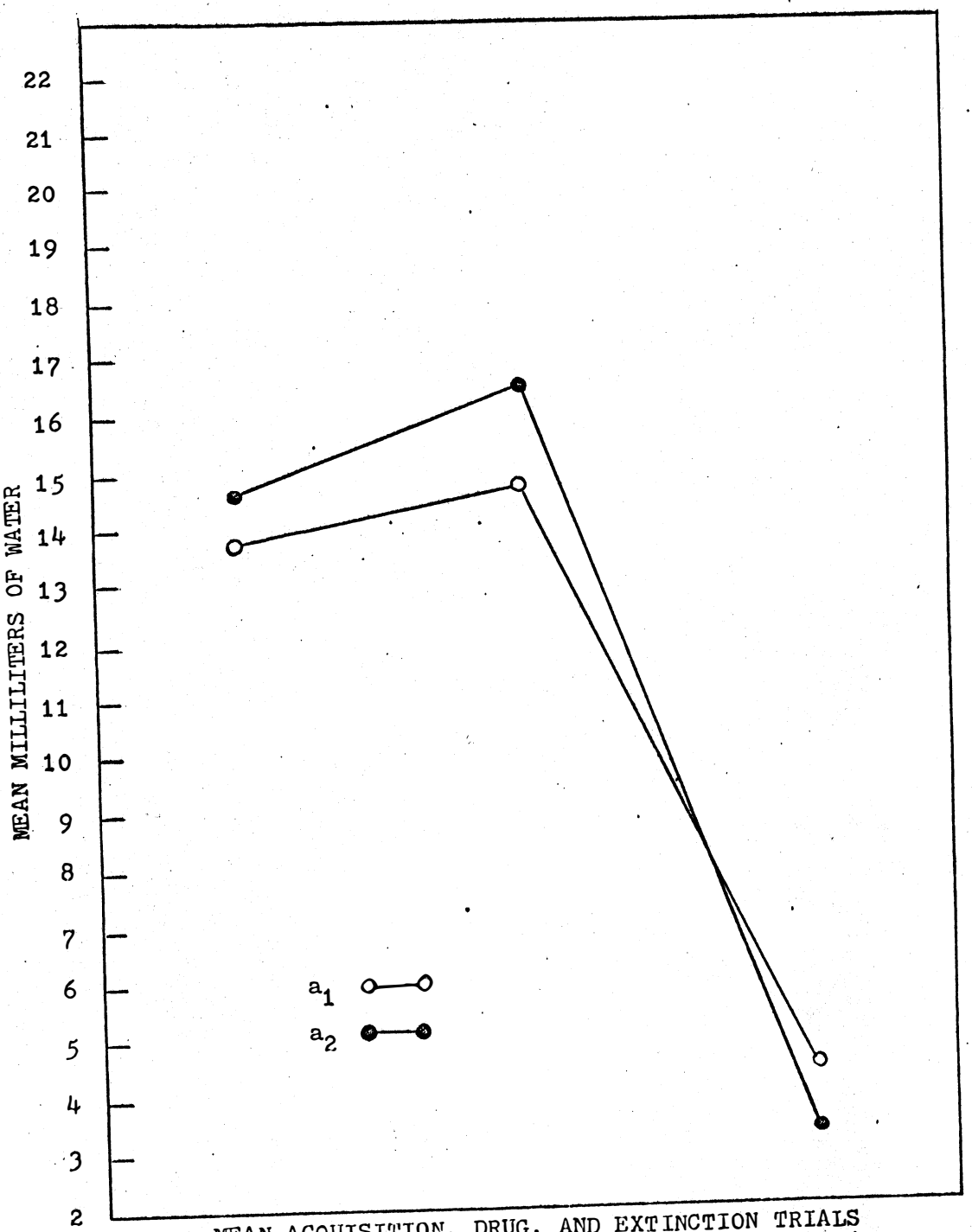

Figure 5. Mean milliliters of water consumed by a_1 (experimental) and a_2 (control) groups during acquisition (b_1), drug (b_2), and extinction (b_3) sessions.

Table 2

Analysis of Variance Table, SPF-2.3-14

Water Consumption

	Source	SS	df	MS	EMS	F	
1.	A	16.25397	1/4	16.25397	126	0.0161	
2.	B	6800.340	2/8	3400.170	84	11.2082	*
3.	C	59.88882	13/52	4.606833	18	1.0571	
4.	Subj w.groups	4027.347	4	1006.837	42		
5.	AB	88.67188	2/8	44.33594	42	0.1461	
6.	AC	37.74576	13/52	2.903520	9	0.6662	
7.	BC	85.64633	26/104	3.294089	6	0.6296	
8.	B x Subj w. groups	2426.919	8	303.3647	14		
9.	C x Subj w. groups	226.6183	52	4.358043	3		
10.	ABC	132.6448	26/104	5.101722	3	0.9750	
11.	BC x Subj w. groups	544.1609	104	5.232316	1		
12.	Total	7775.35246	187				

* $p < .005$

Calculation of an F_{max} statistic demonstrated that the assumption of homogeneity remained unviolated.

The mean number of licks recorded at b_j treatment levels for each subjects is illustrated in Figure 6.

Insert Figure 6 about here

An SPF-2.3-14 analysis of variance indicated that b_j main effects were significant, $p < .05$, $F = 5.9552$, $df = 2,8$. The results of this analysis are presented in Table 3.

Insert Table 3 about here

Figure 7 graphically represents the experimental and control group means at b_1, b_2, and b_3.

Insert Figure 7 about here

A multiple comparison of means indicated significant differences for licking rates only when b_2 and b_3 treatment levels were compared, $p < .05$, $\Psi = 4.5862$, $df = 3,8$. The F_{max} which was calculated for this set of data was insignificant for b_j treatment levels, but it did indicate that the homogeneity of error variance assumption may have been violated when subjects nested

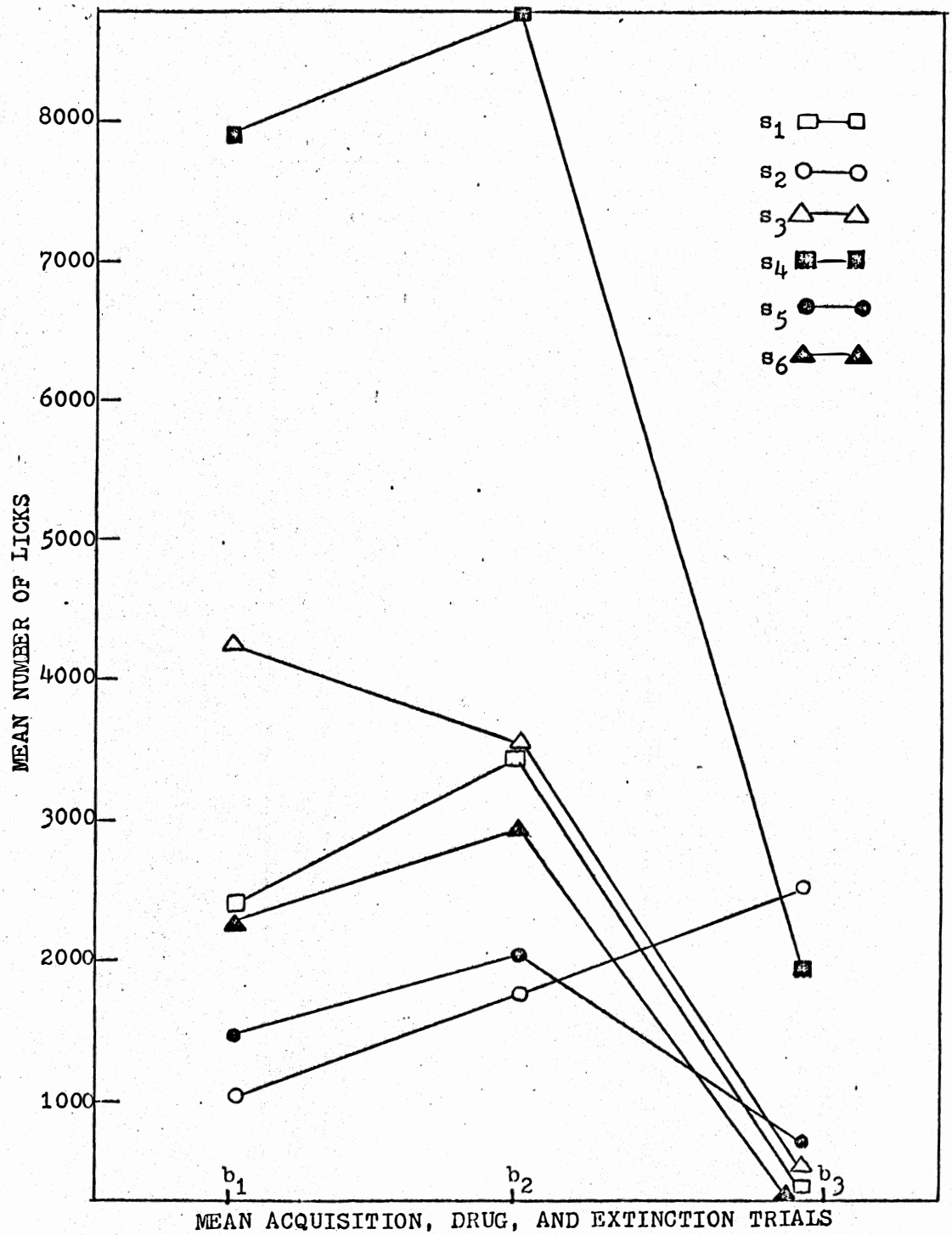

Figure 6. Mean number of licks recorded by individual subjects during acquisition (b_1), drug (b_2), and extinction (b_3) sessions.

Table 3

Analysis of Variance Table, SPF-2.3-14

Licks

	SOURCE	SS	df	MS	EMS	F
1.	A	46,954,100	1/4	46,954,100	126	0.2899
2.	B	362,500,600	2/8	181,250,300	84	5.9552 *
3.	C	9,237,757	13/52	710,597	18	1.4464
4.	Subj w. groups	647,930,900	4	161,982,700	42	
5.	AB	50,045,700	2/8	25,022,850	42	0.8222
6.	AC	4,757,955	13/52	365,997	9	0.7450
7.	BC	17,506,050	26/104	673,310	6	0.7893
8.	B x Subj w. groups	243,483,100	8	30,435,390	14	
9.	C x Subj w. groups	25,546,800	52	491,285	3	
10.	ABC	24,332,080	26/104	935,849	3	1.0971
11.	BC x Subj w. groups	88,716,960	104	853,048	1	
12.	Total	604,051,202	187			

* p .05

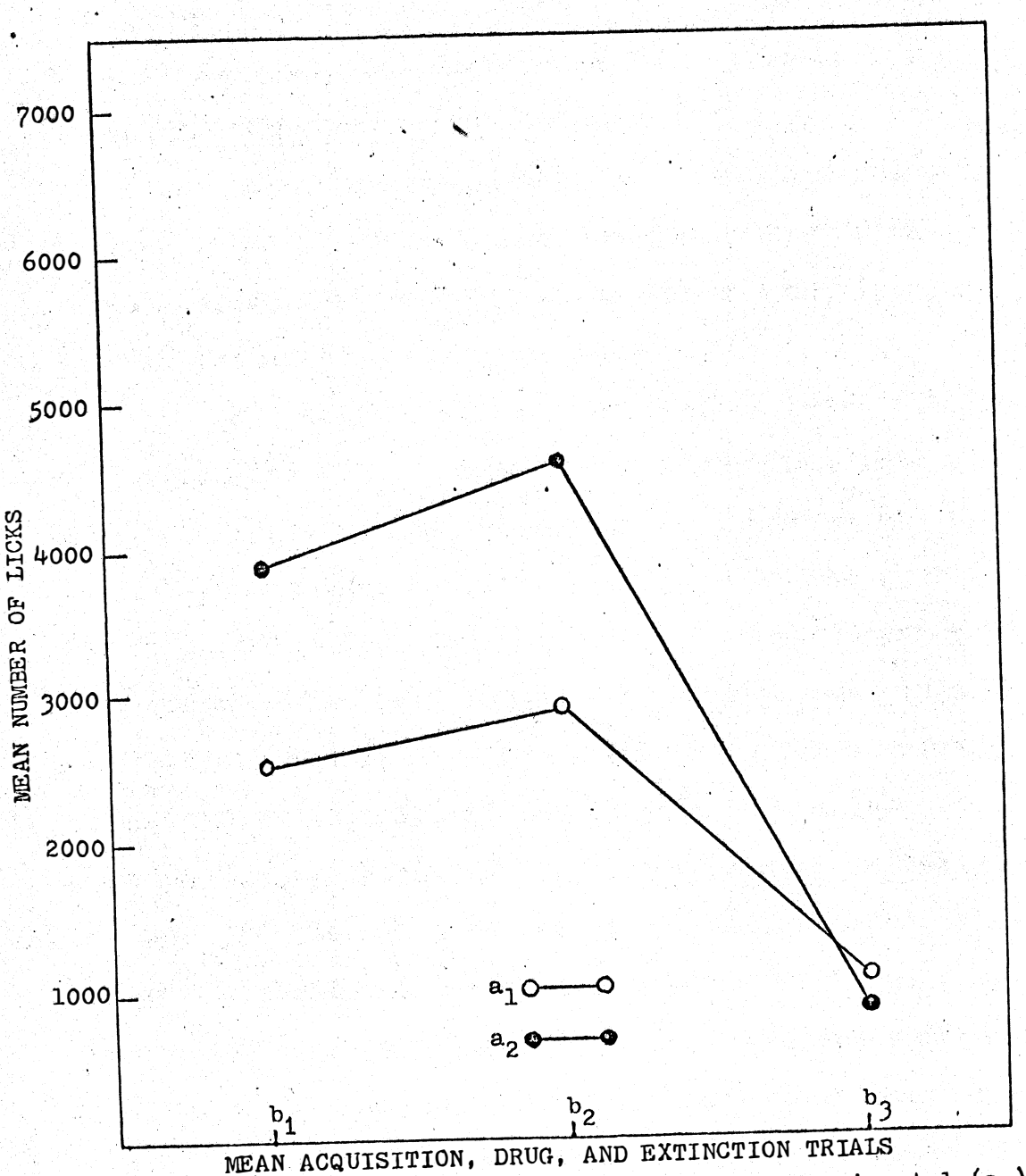

Figure 7. Mean number of licks recorded by experimental (a_1) and control (a_2) groups during acquisition (b_1), drug (b_2) and extinction (b_3) sessions.

in levels of a_1 were compared, $p<.05$. The Geisser-Greenhouse Conservative F Test (Kirk, 1968) also indicated an insignificant difference in b_j treatment levels, thus supporting the doubt cast upon the data by the F_{max}.

The only significant main effects for any of the variables at the .05 level of confidence or better were those of treatment b_j levels, or the acquisition through extinction phases of the study.

Due to the lack of significance between a_1 and a_2 levels, and for the sake of curiosity, a t-test was used to compare the adjusted mean performances of experimental and control subjects during the b_2 and b_3 levels for each of the dependent variables. These comparisons were accomplished by: 1) considering each subject's mean rate during b_1 as its baseline rate for each variable, and 2) subtracting the subject's baseline rate from its mean rate during b_2. The remainder reflected the mean increase in performance for each subject. This method decreased the variability due to individual differences and the effects of those differences upon the data to be analyzed. The same method was used to compare the mean performances of a_1 and a_2 subjects at the b_3 level: the individuals' mean rates during b_2 were subtracted from mean rates at b_3, thus yielding a score reflecting the extent of decrease in performance relative to the previous behavior of each subject.

The only significant difference revealed by the t-tests was the comparison of a_1 and a_2 subjects' mean bar presses at level b_2, $t = 4.44$, $p < .01$, $df = 4$.

Although this test cannot be considered legitimate within the design of the experiment, it does demonstrate the possibility that injections may have had an effect which was obscured by the individual differences of the subjects in this experiment.

The research hypotheses of this experiment were primarily concerned with the effects which a drug, methylphenidate hydrochloride, would have upon certain responses which were characteristic of schedule induced polydipsia. It was apparent that whatever the effects of the drug at the dosage used in this study may have been, the variables being measured were not among those to be significantly affected.

The effects of treatments b_j were predictable and expected as the result of practice and extinction. As was demonstrated by the multiple comparison of mean bar pressing rates, the responses per session significantly increased ($p < .01$) with the passage of time and with increased practice across levels b_1 and b_2.

The differences among means for bar pressing at levels of b_j are very clear. However, water consumption did not significantly increase with the passage of time when b_1 and b_2 means were compared. Signif-

icant decreases were evidenced when b_3 extinction sessions were compared with b_1 and b_2 conditions. Such a decrease is consistent with the literature which supports the association of drinking with pellet delivery.

In summary, the results of the study indicated that the use of methylphenidate had no significant effect upon the responses typically associated with schedule induced polydipsia. The effects of practice and extinction on these responses are in agreement with the foregoing survey of the literature. The absence of a decrease in drinking as a result of drug treatment could possibly be explained by the lack of andrenergic action of methylphenidate as compared to amphetamines, which have been shown to decrease drinking. A closer examination of this an other tentative explanations is presented in the section to follow.

B. Discussion

The main variable to investigated in this experiment was the influence of methylphenidate hydrochloride on the bar pressing, drinking, and licking rates of polydipsic rats before and during extinction for bar pressing. The animals were compared with a control group recieving an equal volume of physiological saline solution. The acquisition of these responses, drug influences on the responses, and drug influences on the extinction of the responses need to be examined in some detail.

The Acquisition of Polydipsia

In the present study all subjects were allowed to develop SIP prior to the introduction of injection for a period of 28 days with a one hour session per day and a VI-60 second schedule of reinforcement (Falk, 1967). It had been initially intended that all subjects should fulfill a criterion of 10% or less variability in each response rate over a period of at least seven consecutive days in order to begin the following b_j level. At no time did the measured responses vary within the 10% limits to meet this pre-determined criterion level. Figure 8 illustrates the subjects' great variability in bar pressing rates across the acquisition period, sessions 1-28.

Insert Figure 8 about here

One of the outstanding characteristics of SIP was its rapid development. Falk (1961) noted that the effect was "often fully developed" within the second of his 3.17 hour sessions. The subjects' mean water intake during sessions was 3.43 times greater than the mean pre-experimental, 24-hour consumption. Falk (1966b) and others have reported that polydipsic subjects drank one-third to one-half their body weight during experimental sessions.

On the basis of these results the subjects of this experiment (in sessions approximately one-third the length of Falk's) would have been expected to consume between 22 and 50 milliliters of water per session. However, only two of the six subjects, S_3 and S_4, approached comparable rates with means of 20.1 and 20.6 milliliters for the 28 one hour sessions. The other subjects' mean intakes during acquisition of SIP were: S_1, 10.6; S_2, 4.7; S_5, 7.4; and S_6, 10.0 milliliters. The mean consumption for all subjects was 12.2 milliliters, a rate scarcely half the predicted value for one-hour experimental sessions.

Falk (1966b) reported that session length did not appear to be a major factor in the production

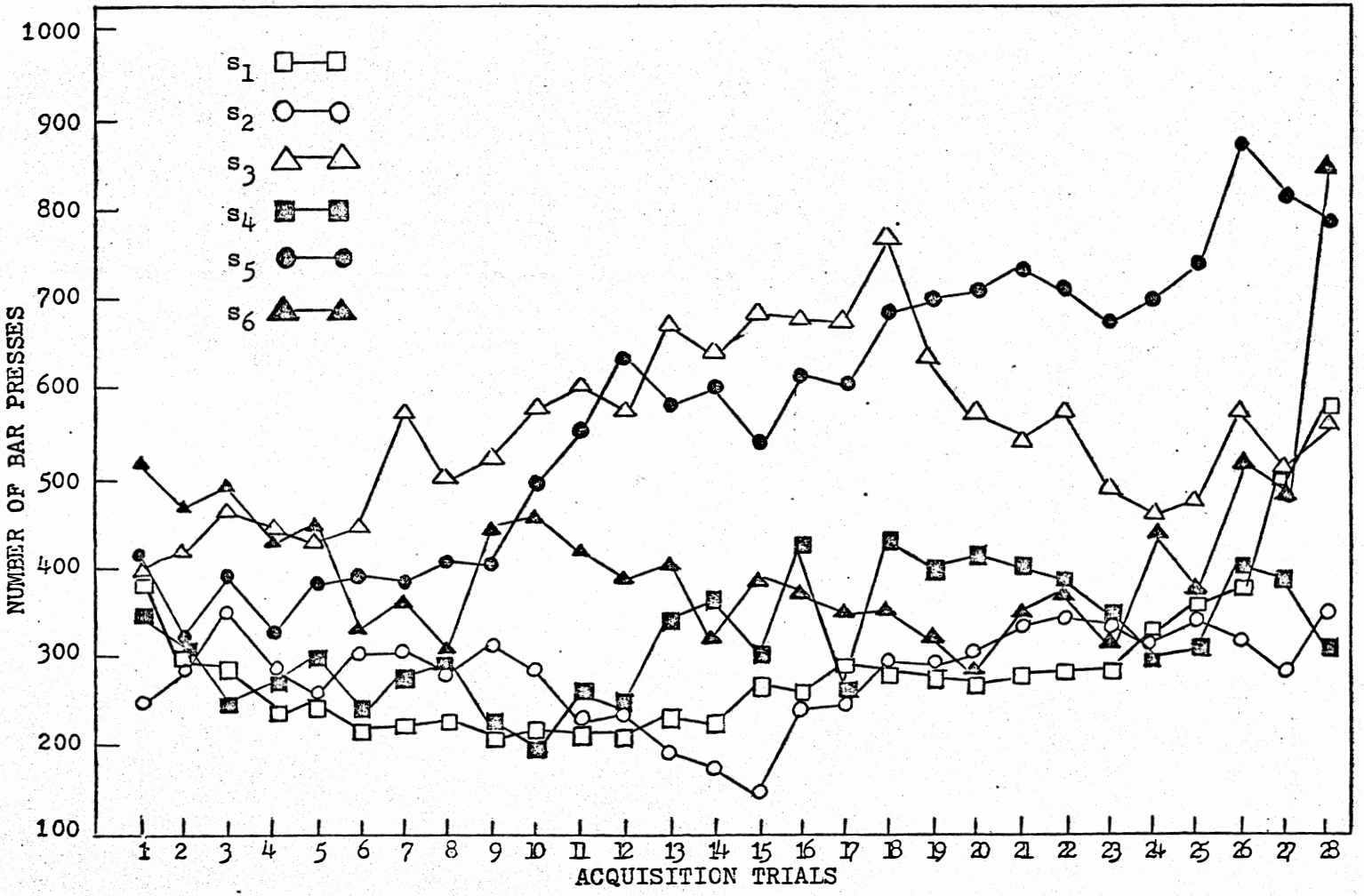

Figure 8. Individual subjects' bar pressing rates during acquisition (b_1) trials, 1-28.

of SIP, but that increased drinking occurred as a function of the inter-pellet interval length. Thus, the most likely explanation for the lower water consumption values reported in the present experiment is that too few long intervals were used in the VI-60 second schedule of reinforcement. The water consumption rates for all subjects are presented in Figure 9.

Insert Figure 9 about here

The Effects of Methylphenidate on Established SIP

As was previously stated, the subjects did not meet the pre-determined criterion of varying in response rate 10% or less over seven consecutive days. Generally, the day to day variation in responses was approximately 20% or less. After 28 acquisition sessions, it was decided by the experimenter that the response was well established and stable enough to begin the b_2 level in which subjects were randomly divided into experimental and control groups for injection purposes.

During this treatment level, increased response rates were noted for bar pressing for both the drug and control groups. The mean response rate for all subjects during b_1 acquisition was 454.6 bar presses per session as compared to 730.2 during b_2. When comparing mean group rates for b_1 and b_2 responding: the drug group

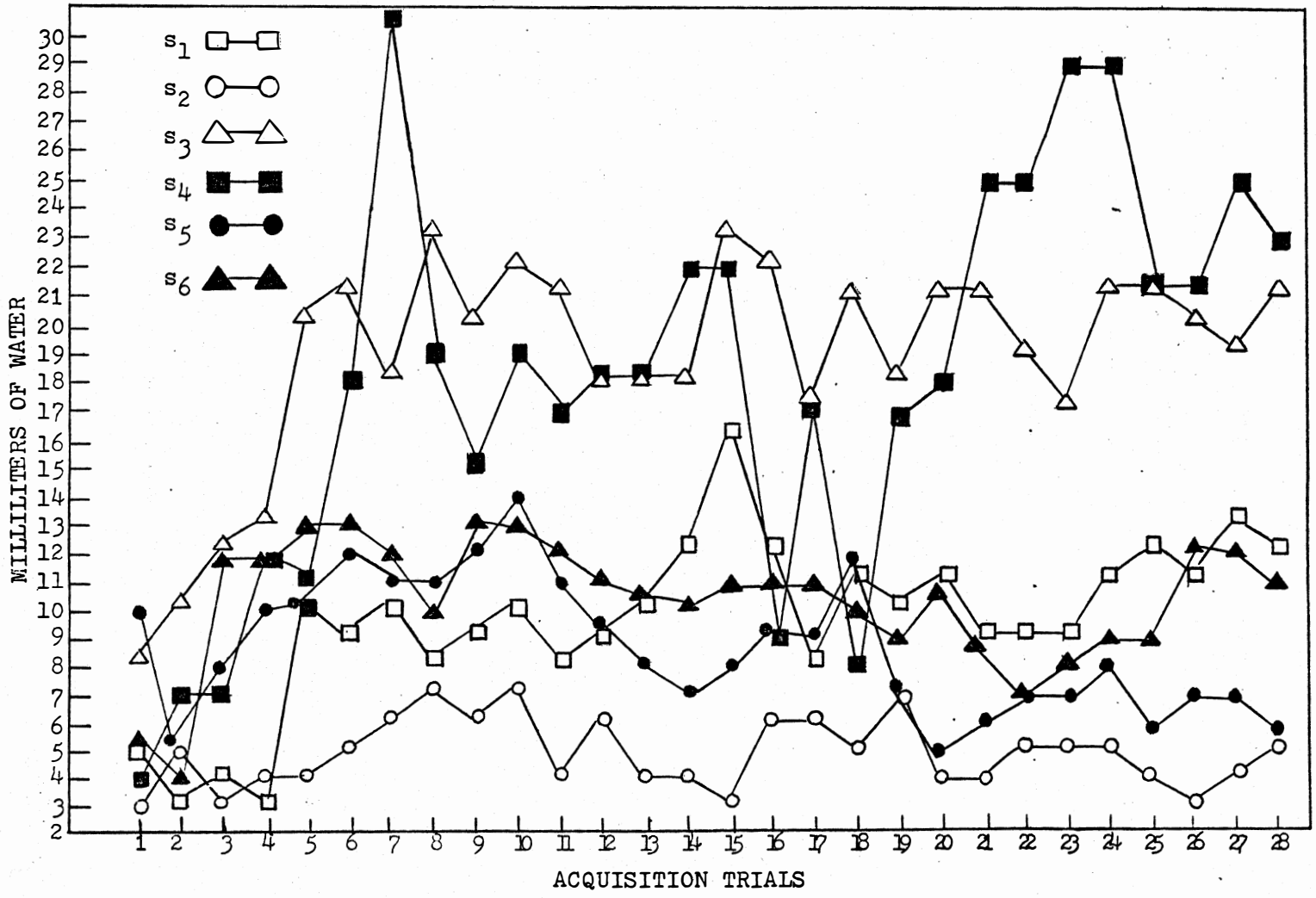

Figure 9. Individual subjects' milliliters water consumption during acquisition trials (b_1), 1-28

(a_2) bar pressed at a mean rate of 500.5 for b_1 as compared to 658.2 during b_2 sessions. Individual rates again were as widely varied during this level as during the acquisition sessions. In spite of significant increases between b_1 and b_2 responses, differences between a_i groups were not significant, thus indicating that drug effects were not responsible for the increase in rate.

The significant difference found by the t-test comparing individual a_1 and a_2 subjects' mean adjusted rates at levels b_1 and b_2 demonstrated the possibility that the a_1 subjects' responses did increase as the result of drug administration. However, this difference was obscured by the design of the experiment and the requirement for analysis of variance, and can be considered neither valid nor a legitimate conclusion.

It must then be assumed that increased amounts of practice at least in part were responsible for increased bar pressing rates at the b_2 level. Individual bar pressing records for sessions 29-49 are illustrated in Figure 10.

Insert Figure 10 about here

Previous reports of the effects of methylphenidate on bar pressing rates indicated varying results.

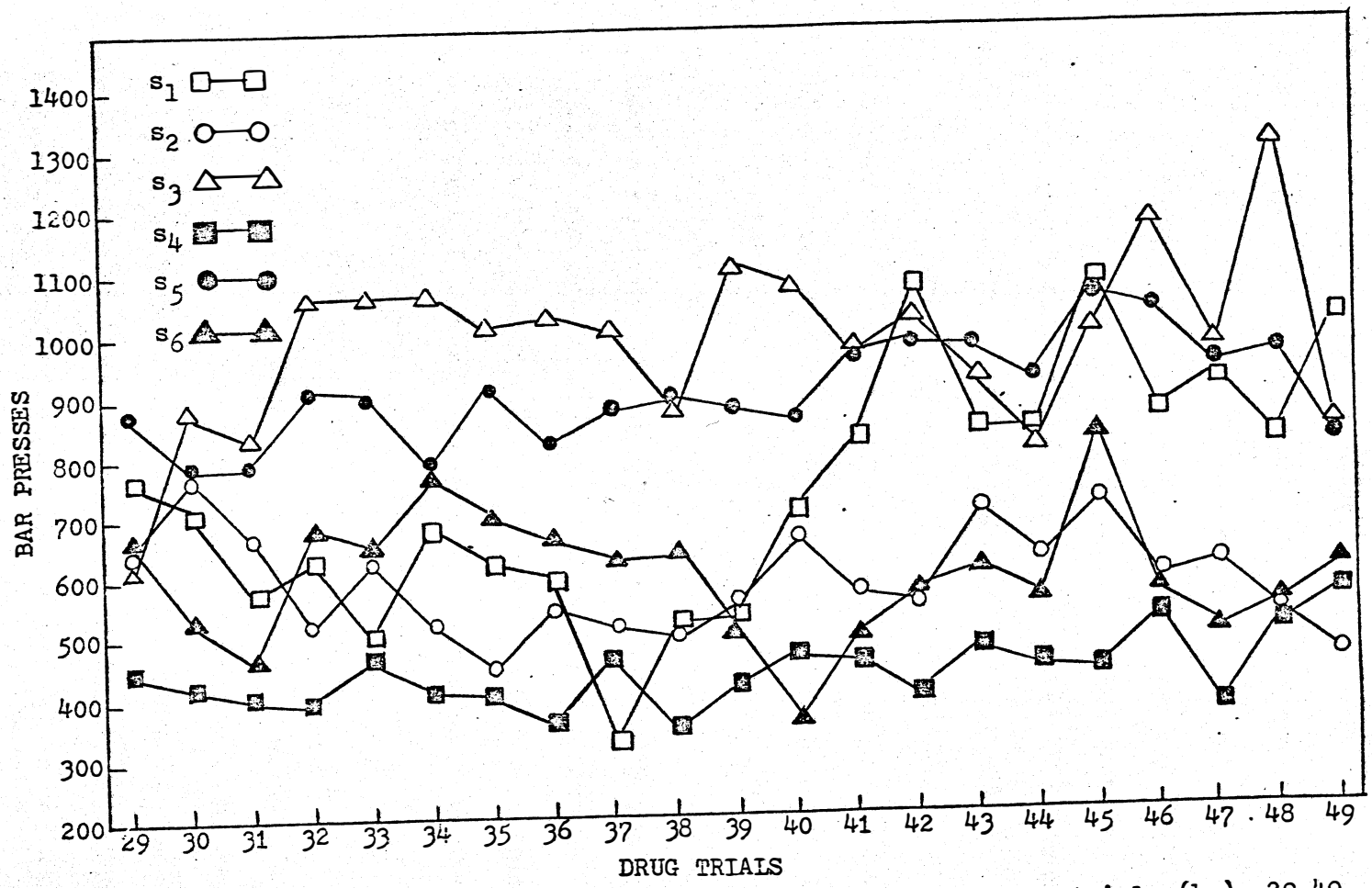

Figure 10. Individual subjects' bar pressing rates during drug trials (b_2), 29-49.

The drug reportedly had a decremental effect on water reinforced bar pressing when subjects were at two low drive levels, but had no effect on a high drive level of responding (Bindra & Mendelson, 1963). Another study indicated that the drug increased the rates of random bar pressing (Tyce, 1968). Methylphenidate has also been reported to increase the rate of reconditioning of a response after an extinction period (Miller & Uhr, 1960). Decreases in low drive condition responding were noted by Mendelson and Bindra (1962) with no effects on high drive condition responding. These authors stated that they had repeatedly observed that methylphenidate was decremental to water, food, or saccharin reinforced responding with drug doses of 2 to 10 milligrams per kilogram. Increased doses yielded greater decrements in the responses. CRF responding was reported to have decreased as a result of the effects of stimulants; however, incremental effects were observed with partial and extinction schedules.

The drug dosage used in the present study, one milligram per kilogram, was determined on the basis of the previously cited research. This particular dosage was selected for its maximal efficiency and minimally confounding effects on the experimental variables.

The effect of methylphenidate on bar pressing with an extinction schedule, according to Mendelson and

Bindra (1962) was incremental. The non-significant, but visible differences between drug groups in the present study might then have been due to the rather low dosage.

Individuals' water intake during b_2 are illustrated in Figure 11. No significant differences were noted between b_1 and b_2 sessions.

Insert Figure 11 about here

In summary, there was no evidence to support the possibility that methylphenidate in the dosage used in this experiment had any influence on SIP unless the results of the t-test are taken into consideration.

Several authors have hypothesized that polydipsia may be the product of frustrative non-reward generated by partial reinforcement. The possibility that an emotional state may have been responsible for excessive drinking with pentobarbitol and amphetamine administration by Falk (1964), Segal, Oden, and Deadwyler (1965c), Segal and Deadwyler (1964b), and Segal and Oden (1968). Both drugs attenuated SIP drinking, but the experimental evidence for the hypothesis of emotional factors was confounded by the effects of the drugs on the central nervous system which altered normal drinking volumes.

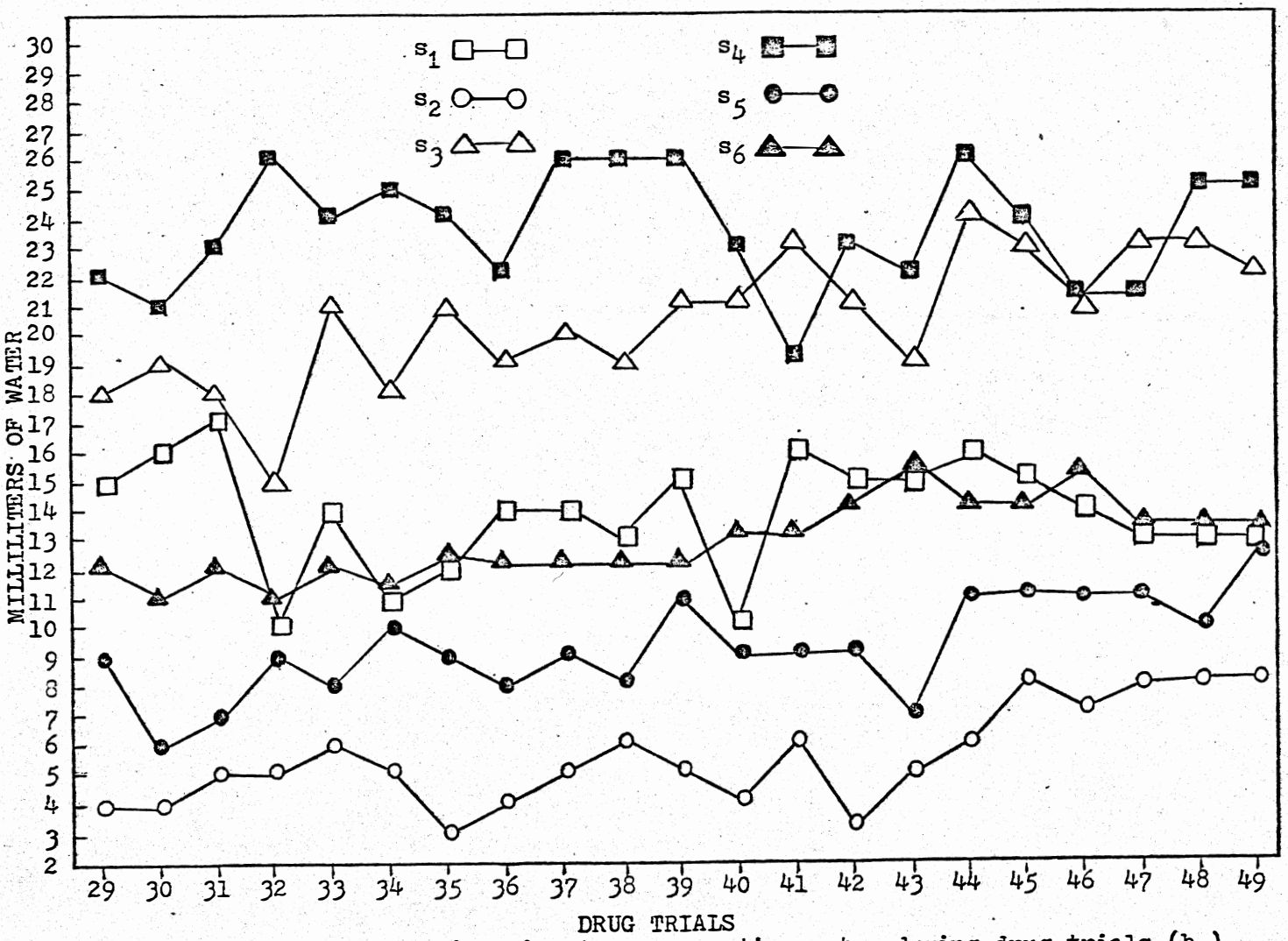

Figure 11. Individual subjects' water consumption rates during drug trials (b_2), 29-49.

The experimental advantage of using methylphenidate was the absence of the andrenergic effects which confounded the preceeding experiments. Thus, it must be concluded that if such an emotional state existed as a motivating factor in the polydipsic subjects, it was not one which was significantly influenced by the effects of methylphenidate at a dosage of one milligram per kilogram.

Effects of Methylphenidate on Extinction of SIP

It has been theorized that polydipsic drinking bursts depend on the delivery of food pellets. The extinction of the excessive drinking in the present study was accomplished by emptying the pellet dispenser. Extinction conditions were maintained for 14 consecutive sessions, trials 50-63. During this treatment (b_3) the subjects generally conformed to the normal extinction pattern characteristic of a variable interval reinforcement schedule. Subjects' response rates decreased during the first extinction session and more rapidly thereafter. For the remainder of the 14 sessions, responding was sporadic and for the most part had essentially ceased.

Mean experimental and control group differences during this treatment did exist, although not at an acceptable level of significance. The mean a_1 group bar pressing rate for level b_3 was 120.33, approx-

imately twice that of the a_2 group mean of 63.86 per extinction session. This visible, but non-significant difference, again, may have been attributable to the action of methylphenidate injections.

A non-significant difference was also noted between a_i groups for mean water consumption. Subjects that recieved drug injections drank a mean 2.52 milliliters of water per extinction session, whereas control subjects consumed almost half that volume, 1.43 milliliters per extinction session.

The data for individual subjects across extinction trials is illustrated in Figures 12 and 13. From these graphs it may be noted that the same wide variety of individual response rates evidenced during previous treatments occurred again for water consumption.

Insert Figure 12 about here

Insert Figure 13 about here

The rather low response rates of subject two were noted previously in both the acquisition sessions and those for drug effect on SIP (b_1 and b_2). During the following extinction trials, this subject again emitted a puzzling behavior. Although bar pressing was

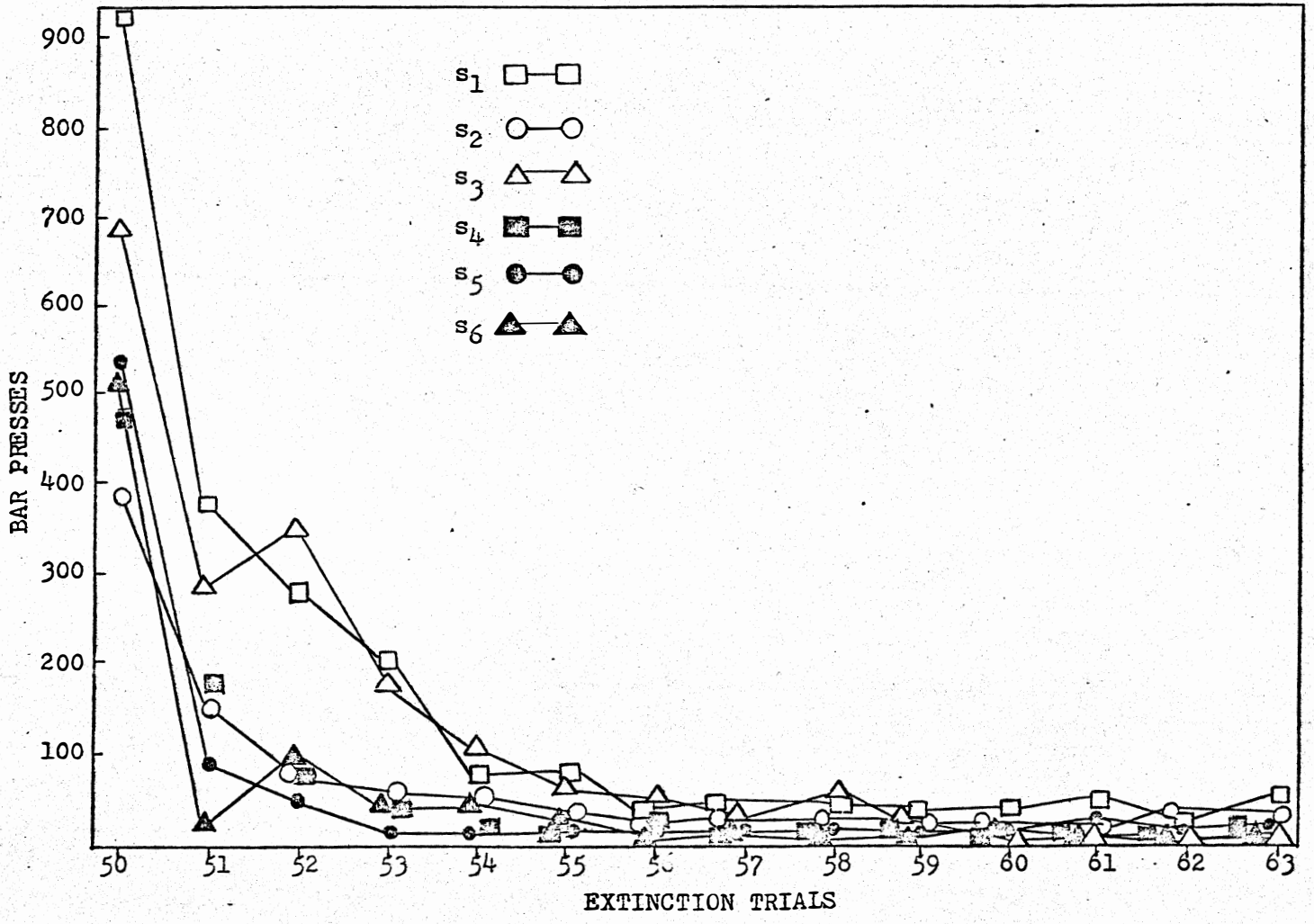

Figure 12. Subjects' bar pressing rates during extinction trials (b_3), 50-63.

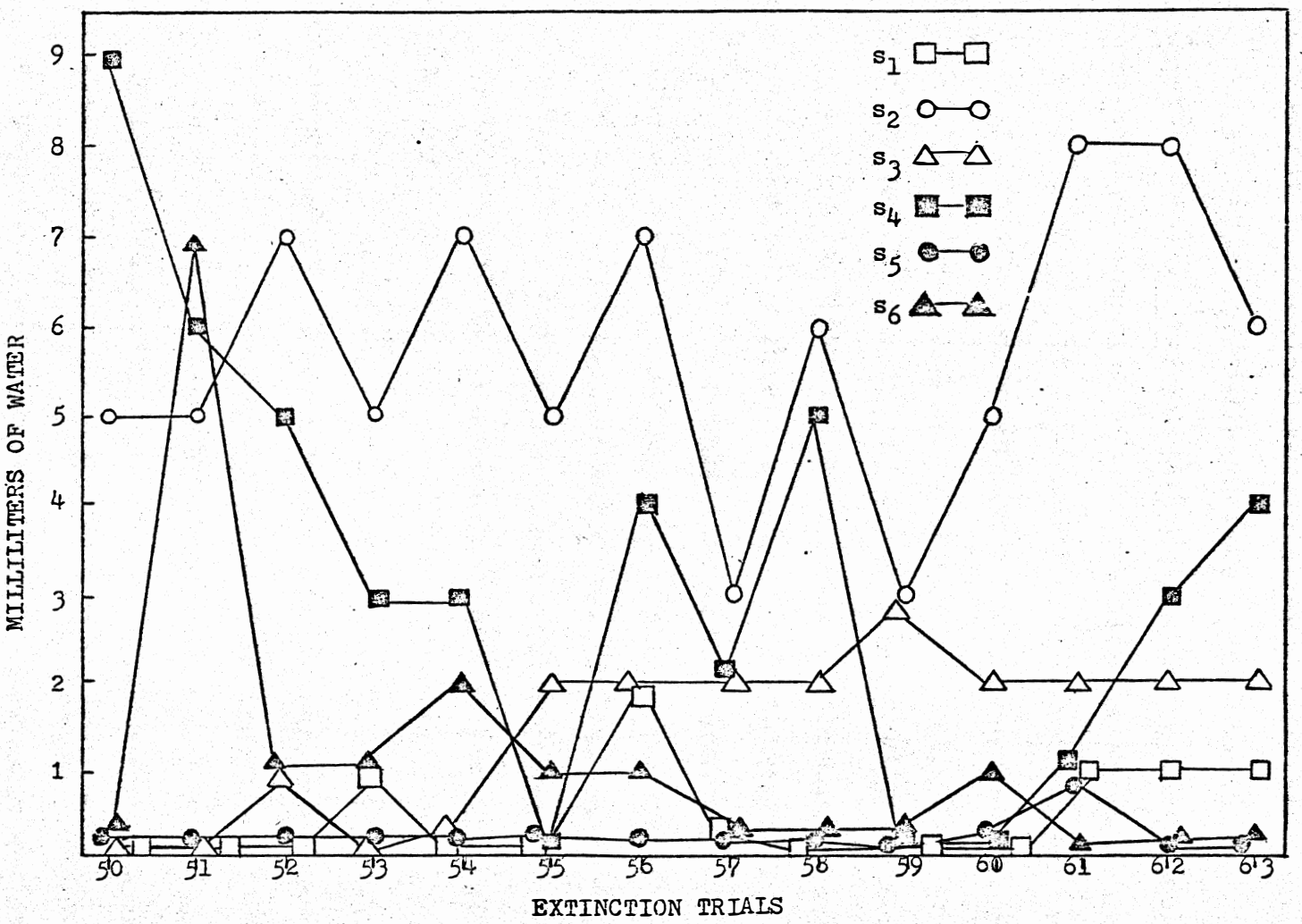

Figure 13. Individual subjects' water consumption during extinction trials (b_3), 50-63.

extinguished in an ordinary manner, mean water consumption in b_3 sessions showed a small increase over mean rates during b_1 and b_2 levels. The mean rates for these sessions were 4.7 and 4.9 respectively, as compared to a mean consumption of 5.7 milliliters of water during extinction trials. To provide a basis for comparison, mean consumption rates for subjects one and three through six during extinction were 0.43, 1.43, 3.21, 0.07, and 1.00 milliliters of water. None of these means was an increase over those exhibited during previous treatment levels. Subject four's higher rate may be explained by the fact that this animal also sustained greater mean consumption rates during previous treatment levels than other subjects. Decreases for all subjects during extinction, except subject two, appeared to be related to the volumes consumed during levels b_1 and b_2.

Only one case in the preceeding historical survey of the literature reported apparent deviant behavior in a polydipsic rat. This instance (Schaeffer & Salzberg, 1967) occurred when one subject out of six "failed to discriminate the experimenter-programmed schedule". The rates of drinking, eating, and the distribution of these responses were substantially different or opposite to those of the five other subjects under a free-fixed interval of 45 seconds for pellets

schedule, and under a number of fixed ratio schedules. The authors stated that polydipsic behavior for such a subject "...may be traced to an adventitious correlation between drinking and food delivery..." (page 1071).

No simple explanation seems to exist for the behavior of subject two in the present experiment. A clearer picture might have been obtained had the animal been observed under a variety of schedules. Although purely speculative, some conclusions may have been drawn had there been an opportunity to change and lengthen the intervals between potential reinforcers for subject two. Such an action would have been based on the theory that polydipsia is a result of the extinction intervals inherent to the variable interval schedule. Falk (1966a) pointed out the importance of interpellet interval length in the production of polydipsia, stating that SIP was dependent upon intervals of 30 seconds or more. On this basis one might speculate that subject two may have had an unusually high tolerance for long intervals, thus explaining the low response rates exhibited furing b_1 and b_2 treatments, and the slight increase of water consumption during level b_3.

In summary, the influence of methylphenidate injections on the extinction of polydipsia produced

no significant effects. However, the data visually suggests that the drug may induce increases in both drinking and bar pressing under extinction conditions.

Implications for Future Drug Research with Polydipsia

To date the investigation of polydipsia and similar schedule-induced behaviors has generated a mass of confusing and often conflicting information mainly concerned with possible causes, variations in responses to schedule changes, distribution of responses, and drug influences on responses. In general, conclusions as to the source of such behavior have been based on either physiological, emotional, or apparent learned factors, all of which have evidence to support them.

The weakest argument seems to be that of an adventitiously or superstitiously learned behavior. A large number of experiments cited in the preceeding sections of this study pointed out the obvious temporal relationship of the bar pressing, eating, and drinking sequence, which would seem to rule out the probability that drinking is totally reinforced and maintained by the external reinforcement of pellet delivery.

The possibility of simple physiological factors such as that of thirst, originally hypothesized by Stein (1964), has never been positively refuted. However, the manipulation of meal size and the substitution of fluid nutrients for pellets has cast some

doubt upon the adequacy of such an argument to answer the questions raised by polydipsia.

Emotional factors engendered by intermittent reinforcement have also been posed to solve the problem. In the opinion of the writer, such explanations seem to be very speculative and difficult to investigate scientifically. Until investigators can provide an adequate definition and method for assessment of a non-specific behavior such as frustration, attempts to explain polydipsia in these terms are no better than the casual labeling which has drawn practitioners of psychology into the historically used circular explanations of emotional disturbances. This anthropomorphism renders the argument useless without the means to demonstrate that an emotional state exists beforehand. Falk (1966a) has neatly avoided all of these pitfalls by calling schedule-induced behaviors "adjunctive"--a label which is defined in terms of a behavioral description which does not attempt an explanation beyond the limits of observation and available technology.

The use of drugs and alcohol to clarify the nature of polydipsia has met with little success to date. The greatest problems have been the widespread effects of drug administration, and the content of alcohol. When the source of behavior may be an interaction of two or more difficult to measure internal

systems, and when the administration of drugs or alcohol may have a number of main and side effects, then the probability of confounding is greatly increased. Perhaps one answer to this dilemma lies in increasing our knowledge of drug effects and improving technology in the area of physiological psychology.

Methodological Implications

As previously mentioned, the results of this experiment would indicate that a low dosage of methylphenidate has no significant effect upon polydipsic consumption of water by rats. These results should by no means be considered conclusive due to several possible variables overlooked by the experimenter in planning the experimental design of the study.

As in any study which depends on statistical manipulation to interpret its data, the results herein were analyzed in terms of group means, or the average behavior of particular subjects. These results were limited by the statistical analysis in that relatively few subjects were employed. The probability of obtaining significant findings would have been increased by increasing the sample size. In addition the effects of individual subject variation, which seemed overwhelming in this experiment, would have been minimized.

Another variable which should be considered was the drug dosage used. The effects or lack of

effects of drug administration on polydipsia would have been much more obvious if dosage levels were varied in some random fashion so as to increase the probability of measuring a specific change in behavior which was clearly due to the drug. Concurrently, the increase in treatment levels would have again contributed to the power of the statistical data analysis.

Although the expansion of experimental design such as was suggested above could become cumbersome, considering the time element, the results would be a better indication of possible drug interaction with polydipsic behavior. Very few of the experiments cited previously have employed any analyses other than simple descriptive statistics.

CHAPTER IV

Summary and Conclusions

The purpose of this experiment was to examine the influence of methylphenidate hydrochloride administration on schedule induced polydipsia in rats.

Six male Charles River rats approximately 130 days old at the beginning of the experiment were used as subjects. They were individually housed with water continuously available, maintained at 80% free feeding weight, and bar trained on a CRF for 45 mg. Noyes pellets.

The variables measured during experimental sessions were bar pressing rate, amount of water drunk, and licking rate including the temporal distribution of these responses.

Polydipsia was allowed to develop during level b_1 of the experiment over 28 daily one hour sessions using a 60-second variable interval reinforcement schedule. Subjects were then randomly assigned and equally divided into an experimental and control group. During level b_2 the experimental group received a 1 mg/kg injection of methylphenidate, and the control group an equal volume of physiological saline solution prior to each of 21 daily, one hour sessions. All other conditions were identical to those during b_1 acquisition trials.

The b_3 level, beginning with trial 50, initiated extinction with all procedures remaining the same

as b_2 except that the pellet dispenser was emptied. This level consisted of 14 daily, one hour trials.

Data from trials 15-28, 36-49, and 50-63, or the last 14 trials from each level of b_j was analyzed for each variable with an SPF 2.3-14 analysis of variance. The effects of acquisition, drug, and drug-extinction trials were the only significant effect found for each of the analyses. No significant differences were found between scores of experimental, a_1, and control, a_2, subjects.

A t-test was used to compare the increases in rate between levels b_1 and b_2 for experimental and control subjects, using b_1 mean responses as baselines. A similar comparison was made of the decreases in rate between levels b_2 and b_3 for experimental and control subjects using b_2 mean response rates as baselines. Of the three variables, only bar pressing was shown to have increased significantly as the result of methylphenidate administration. No significant decreases in performance were found in the comparisons.

A multiple comparison of the means for each variable revealed some differences among levels of b_j. All subjects' bar pressing rates increased significantly from levels b_1 and b_2 after extinction was introduced during b_3.

The mean water consumption scores did not

increase across acquisition and drug trials, but a significant decrease was noted when b_1 and b_2 means were compared with b_3 means.

Some doubt was cast upon the assumption of homogeneity of variance for licking data when an F_{max} proved to be significant for subjects nested in drug and control groups (a_i levels). A conservative F-Test also indicated some discrepancy in the data for licks when it showed insignificance for B treatment main effects. A comparison of means indicated a significant decrease in licking rates only when b_2 and b_3 means were compared.

A detailed examination of the preceeding results led to the following conclusions:

1. The administration of a one mg/kg injection of methylphenidate hydrochloride had no significant effects on the bar pressing and licking rates or water consumption of experimental subjects when they were compared with scores of control subjects recieving injections of saline.
2. Significant differences occurred across trials including acquisition of the response, drug injection with polydipsia, and drug administration with extinction conditions.
3. The data did reveal a significant difference

for experimental and control subjects performance on bar pressing when the data was adjusted to eliminate individual differences and analyzed with a t-test at level b_2.

4. Individual differences among the six subjects were wide, indicating that for future studies it would be wise to include a greater number of subjects to compensate for possible decremental effects on the power of the data analysis.

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APPENDIX

RAW DATA, SUBJECT ONE

TRIAL	BAR PRESSES	LICKS	MILLILITERS
1	385	480	5
2	294	535	3
3	292	797	4
4	237	500	3
5	250	1106	10
6	225	1521	9
7	228	1443	10
8	231	1688	8
9	214	1641	9
10	222	2146	10
11	219	2000	8
12	223	1782	9
13	239	2112	10
14	228	2296	12
15	268	2154	16
16	262	2389	12
17	298	2098	8
18	292	2431	11

RAW DATA, SUBJECT ONE (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
19	279	1932	10
20	272	2188	11
21	277	2116	9
22	287	2398	9
23	288	2189	9
24	330	2230	11
25	365	2660	12
26	382	3107	11
27	504	2963	13
28	587	3128	12
29	769	4019	14
30	713	4233	15
31	586	4540	16
32	631	2916	9
33	520	3064	13
34	695	3474	10
35	639	2942	11
36	606	2900	13
37	334	3105	13
38	535	3475	12

RAW DATA, SUBJECT ONE (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
39	547	3202	14
40	714	3360	9
41	830	3876	15
42	1085	3542	14
43	848	3823	14
44	828	3880	15
45	1005	3377	14
46	851	4050	13
47	968	3589	12
48	813	3327	12
49	1015	3440	12
50	924	40	0
51	385	101	0
52	289	82	0
53	204	191	1
54	70	262	0
55	73	588	0
56	28	689	2

RAW DATA, SUBJECT ONE (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
57	35	587	0
58	42	816	0
59	23	419	0
60	37	585	0
61	40	687	1
62	25	516	1
63	50	510	1

RAW DATA, SUBJECT TWO

TRIAL	BAR PRESSES	LICKS	MILLILITERS
1	247	563	3
2	278	702	5
3	353	872	3
4	282	591	4
5	245	714	4
6	311	1007	5
7	312	1753	6
8	281	1868	7
9	323	1147	6
10	291	1556	7
11	217	786	4
12	231	984	6
13	190	864	4
14	176	914	4
15	152	798	3
16	240	1131	6
17	248	1109	6
18	297	1008	5
19	298	1244	7
20	295	992	4
21	350	989	4

RAW DATA, SUBJECT TWO (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
22	348	1321	5
23	333	1018	5
24	328	1329	5
25	338	1015	4
26	327	1201	3
27	273	874	4
28	357	846	5
29	657	760	3
30	776	899	3
31	666	884	4
32	535	904	4
33	632	1367	5
34	532	1196	4
35	454	891	2
36	554	830	3
37	520	1256	4
38	509	1921	5
39	562	1381	4
40	663	1091	3
41	577	1906	5
42	563	889	2

RAW DATA, SUBJECT TWO (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
43	704	1288	4
44	639	1924	5
45	716	2114	7
46	593	2211	6
47	610	3008	7
48	535	2974	7
49	458	3080	7
50	387	2200	5
51	157	2735	5
52	88	3197	7
53	49	2522	5
54	51	3541	7
55	29	2776	5
56	31	3036	7
57	30	1919	3
58	16	2679	6
59	18	1269	3
60	17	1282	5
61	26	4298	8
62	32	3253	8
63	31	3180	6

RAW DATA, SUBJECT THREE

TRIAL	BAR PRESSES	LICKS	MILLILITERS
1	407	1009	8
2	421	1414	10
3	467	2286	12
4	445	2156	13
5	443	4015	20
6	450	3541	21
7	589	3854	18
8	508	5384	23
9	531	4802	20
10	586	5080	22
11	608	4951	21
12	571	4006	18
13	671	4816	18
14	640	4299	18
15	689	5303	23
16	686	4384	22
17	674	3175	17
18	771	4114	21
19	644	4134	18
20	589	5096	21
21	557	4567	21

RAW DATA, SUBJECT THREE (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
22	572	4038	19
23	499	3587	17
24	467	4065	21
25	488	4270	21
26	583	4185	20
27	513	3748	19
28	561	4755	21
29	626	3843	17
30	883	4256	18
31	844	4151	17
32	1051	3395	14
33	1060	4060	20
34	1059	3629	17
35	1030	4459	20
36	1042	3848	18
37	1007	3629	19
38	887	3321	18
39	1108	2886	20
40	1070	3477	20
41	978	3255	22
42	1043	3544	20

RAW DATA, SUBJECT THREE (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
43	919	4088	18
44	836	3534	23
45	1001	3485	22
46	1182	3486	20
47	983	3821	22
48	1303	2982	22
49	899	3646	21
50	693	450	0
51	290	241	0
52	346	775	1
53	176	340	0
54	108	277	0
55	65	506	2
56	53	654	2
57	29	668	2
58	42	454	2
59	17	556	3
60	14	716	2
61	15	730	2
62	12	879	2
63	7	663	2

RAW DATA, SUBJECT FOUR

TRIAL	BAR PRESSES	LICKS	MILLILITERS
1	347	361	4
2	290	732	7
3	250	1099	7
4	272	1891	12
5	303	1905	11
6	238	2964	18
7	273	3808	43
8	286	5268	19
9	224	4079	15
10	207	5422	19
11	253	4785	17
12	241	4627	18
13	351	5765	18
14	364	6110	22
15	308	6455	22
16	432	2937	9
17	260	5475	17
18	438	3454	8
19	414	6178	17
20	420	6989	18
21	410	8881	25

RAW DATA, SUBJECT FOUR (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
22	383	9433	25
23	337	10759	29
24	310	10703	29
25	314	9535	21
26	407	9600	21
27	395	10264	25
28	313	10510	23
29	454	8960	21
30	436	8827	20
31	414	8576	22
32	410	9683	25
33	475	10824	23
34	430	11269	24
35	423	10796	23
36	377	10146	21
37	472	10005	25
38	353	10545	25
39	422	8940	25
40	478	8040	22
41	460	8280	18
42	413	8808	22

RAW DATA, SUBJECT FOUR (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
43	486	7967	21
44	456	9313	25
45	451	9178	23
46	543	6758	20
47	384	8462	20
48	537	8442	24
49	562	8240	24
50	470	4964	9
51	181	3522	6
52	79	3158	5
53	42	1978	3
54	26	1866	3
55	28	1035	0
56	21	2290	4
57	15	1812	2
58	16	640	5
59	4	398	0
60	11	349	0
61	15	790	1
62	10	1603	3
63	15	2992	4

RAW DATA, SUBJECT FIVE

TRIAL	BAR PRESSES	LICKS	MILLILITERS
1	414	602	10
2	326	1033	5
3	395	1130	8
4	332	2063	10
5	386	1740	10
6	392	1859	12
7	390	1090	11
8	407	1976	11
9	404	1695	12
10	497	2014	14
11	552	1830	11
12	656	1659	9
13	584	1526	8
14	603	997	7
15	545	1720	8
16	623	1802	9
17	619	1572	9
18	698	1336	11
19	713	1554	7
20	716	1091	5
21	747	1300	6

RAW DATA, SUBJECT FIVE (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
22	719	1535	7
23	675	1531	7
24	704	1831	8
25	745	1334	6
26	872	1367	7
27	823	1309	7
28	799	1302	6
29	879	1694	8
30	791	1336	5
31	896	1201	6
32	914	1817	8
33	911	1522	7
34	799	2014	9
35	919	1698	8
36	828	1529	7
37	878	1822	8
38	886	1685	7
39	877	2377	10
40	852	1872	8
41	1008	1706	8
42	1024	1950	8

RAW DATA, SUBJECT FIVE (CONTINUED)

TRIALS	BAR PRESSES	LICKS	MILLILITERS
43	979	1330	6
44	926	2438	10
45	1078	2046	10
46	1042	2354	10
47	949	2406	10
48	954	2307	9
49	816	2673	12
50	542	112	0
51	95	143	0
52	50	197	0
53	22	111	0
54	33	71	0
55	25	33	0
56	15	5	0
57	17	24	0
58	19	101	0
59	22	75	0
60	43	33	0
61	26	127	1
62	16	20	0
63	19	9	0

RAW DATA, SUBJECT SIX

TRIAL	BAR PRESSES	LICKS	MILLILITERS
1	521	868	5
2	468	761	4
3	490	1760	12
4	439	2265	12
5	455	2671	13
6	333	2457	13
7	364	2055	12
8	311	2101	10
9	455	2923	13
10	461	2427	13
11	428	2351	12
12	397	2272	11
13	411	2232	10
14	329	2147	10
15	399	2200	11
16	378	2461	11
17	355	2036	11
18	361	2271	10
19	330	1876	9
20	293	2139	11
21	354	2493	9

RAW DATA, SUBJECT SIX (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
22	385	1798	7
23	320	1865	8
24	452	2144	9
25	382	2492	9
26	528	2732	12
27	494	2839	12
28	850	2894	11
29	652	2477	11
30	536	2379	10
31	470	2765	11
32	685	2369	10
33	654	3609	11
34	778	2586	10
35	700	2905	11
36	666	2870	11
37	638	2731	11
38	642	2537	11
39	543	2611	11
40	361	2933	12
41	503	3340	12
42	571	3108	13

RAW DATA, SUBJECT SIX (CONTINUED)

TRIAL	BAR PRESSES	LICKS	MILLILITERS
43	609	3735	14
44	558	2726	13
45	826	3038	13
46	578	2996	14
47	512	2756	12
48	542	2620	12
49	605	2969	12
50	525	340	0
51	26	32	7
52	93	828	1
53	37	988	1
54	46	600	2
55	24	571	1
56	14	266	1
57	10	133	0
58	4	179	0
59	6	106	0
60	10	264	1
61	6	346	0
62	3	304	0
63	1	426	0