Pharmacology Biochemistry & Behavior, Vol. 20, pp 973–977, 1984 © Ankho International Inc Printed in the U S A. 0091-3057/84 $3 00 + 00

BRIEF COMMUNICATION

Comparison of Sucrose-Sucrose to Sucrose-Ethanol Concurrent Responding in the Rat: Reinforcement Schedule and Fluid Concentration Effects[1]

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Received 9 May 1983

SAMSON, H. H. AND K. LINDBERG. *Comparison of sucrose-sucrose to sucrose-ethanol concurrent responding in the rat. Reinforcement schedule and fluid concentration effects* PHARMACOL BIOCHEM BEHAV **20**(6) 973–977, 1984 — Rats maintained at 80% of their ad lib body weight were trained on a two bar concurrent fixed ratio 8-fixed ratio 8 schedule with sucrose solutions presented at schedule completion. When the solutions were available on the same schedule of reinforcement, rats consistently responded more on the lever associated with the higher sucrose concentration over either less concentrated sucrose solutions or water. However, when a preferred 20% sucrose solution was placed on a high fixed ratio requirement (FR64) and a less preferred 2% sucrose solution remained on the lower ratio requirement (FR8), the rats were observed to increase their responding on the lever associated with presentation of the 2% sucrose solution. Response rates for the low concentrated sucrose solution increased to levels comparable to those seen when that solution was paired with water. These results were compared to prior studies using ethanol and sucrose as the available fluids.

Concurrent schedules Sucrose Drug self administration Rats

BEHAVIORAL pharmacology has used the concurrent schedule approach to determine drug effects or drug choice under a variety of reinforcement conditions [2, 10, 11, 14, 15, 19, 21, 23]. The main concern in many of these studies has been the evaluation of the reinforcing properties of drugs, with the question to be examined whether or not an animal prefers food to drug, or drug A to drug B, or one dose of drug over another.

The reinforcing properties of oral ethanol self administration in the rat have been explored using these concurrent procedures [19, 21, 22, 23, 24]. Many properties of ethanol reinforcement have been shown to be similar to food reinforcement, such as schedule effects [17,21], food deprivation effects [17, 18, 22], and changes in response rates due to the quality and/or quantity of the reinforcers presented [19, 23, 24].

In one of the above studies [23] using ethanol (5%) and sucrose (5%) as the two concurrently available reinforcers, increasing the fixed ratio requirement of the preferred sucrose resulted in increased ethanol responding. Not only did ethanol responding increase in this condition, but it exceeded that found when ethanol was the preferred substance (i.e., when paired with water). Why this increased ethanol responding occurred was unclear.

The results could not easily be interpreted in terms of either a reward magnitude or a schedule "matching" effect which traditionally are used to explain similar effects of schedule manipulations using food reinforcement [1, 12, 13, 26] (see [23,24] for a more complete discussion of this problem). Several possibilities existed to account for the ethanol-sucrose findings. The increased ethanol responding could have been a result of incentive contrast effects [9]; i.e., switching of responding to the more easily attainable but less preferred substance. However, in most contrast studies [16], switching from a preferred reinforcer to a less preferred one most often results in negative (i.e., decreased responding) and not the positive contrast effect observed in the ethanol-sucrose study [23]. Another possible explanation was that by increasing the sucrose FR schedule, a schedule-induction condition resulted, but the pattern of ethanol responding observed was much different from what would have been expected from a standard schedule-induced drinking condition [8].

An important question raised by the results from the

[1]Supported in part by grants from the Alcohol and Drug Abuse Institute, University of Washington.
[2]Supported by Research Scientist Development Award (KO2 AA00066) from the National Institute on Alcohol Abuse and Alcoholism.

ethanol-sucrose study is to what extent the results were dependent upon these two specific fluids. Was there any specific function that could be attributed to ethanol, or would a similar schedule manipulation effect occur with the presentation of any two reinforcers that generated a similar preferential responding pattern? To explore this question, the following experiment was performed using two concentrations of sucrose rather than ethanol and sucrose as the available fluids presented.

METHOD

Animals

Six adult, male rats (Long-Evans strain) were housed individually in standard rodent hanging cages. Artificial illumination was provided on a 12 hr on-12 hr off cycle. Room temperature was maintained at 23°C. Prior to the start of operant training, the animals' body weights were reduced to 80% of their ad lib feeding weights by restricting the amount of food available. The rats were maintained at these weights for the duration of the experiment by providing limited daily food rations. Water was available in the home cage at all times except as noted below

Apparatus

The operant chambers and their enclosures have been previously described in detail [21]. Briefly, the chambers consisted of two operant levers and two fluid delivery systems (R. Gebrands model No. B-LH, 0 1 ml dipper size). The dippers were programmed so that when operated, they presented 0.1 ml of fluid for 3 seconds. Each lever was associated with one dipper. Schedule control and data acquisition was with an Apple microcomputer. Number of lever presses, dipper operations, fluid reservoir decreases and cumulative responses were recorded for each daily session.

Procedure

Following weight reduction, each animal had a single daily session in the operant chamber, Monday through Friday. During the initial part of the experiment, sessions were 15 minutes long. The rats were shaped to press one lever (lever A) on a continuous reinforcement schedule with 20% sucrose (w/v) in tap water as the fluid presented. During this time, the second lever (lever B) was removed from the chamber. To facilitate lever press shaping, the animals were water restricted to one hour daily access in the home cage The one hour availability occurred immediately after the daily operant session. The reinforcement schedule was then gradually increased to a Fixed Ratio schedule of 8 (FR8). Water deprivation was discontinued when responding on a Fixed Ratio schedule of 2 (FR2) became stable. When stable FR8 responding was reached on lever A, it was removed and the training procedure repeated for lever B.

When stable responding was established on lever B, the following series of manipulations were followed to first, determine appropriate sucrose concentrations needed to produce matched response rates to the prior ethanol-sucrose condition and second, to match the manipulations used in this prior ethanol-sucrose study. In Phase 1, both levers were placed in the chamber with the 20% sucrose solution available at either lever. A concurrent FR8 FR8 reinforcement schedule was in effect for the daily 15 min session. At all times in the concurrent situation, a 3 sec changeover delay was in effect (see [21] for a more complete discussion of the use of the delay procedure).

After obtaining stable concurrent FR8 FR8 responding, Phase 2 was initiated During this stage of the experiment, the sucrose concentration of one of the two available solutions was manipulated. A 20% sucrose solution was always one of the alternative choices in this phase. First a 5% sucrose solution was paired with the 20% sucrose (3–6 sessions). Then water was the concurrently paired solution (6–9 sessions). Following this, a 1% sucrose solution was used (4 sessions), and finally a 2% sucrose solution was the other available fluid (5 sessions). The position of the 20% sucrose solution was alternated from the left to right dipper from session to session. At the start of the sessions with water as the alternative choice in Phase 2, the length of the daily sessions was changed from 15 to 30 min. All following sessions were 30 min long for the remainder of the experiment.

In Phase 3, which immediately followed Phase 2, the FR schedule requirements were manipulated in addition to the sucrose concentrations. As in Phase 2, solution position was alternated daily. Rats No 3 and No 5 had the following schedule manipulations. First, 20% sucrose was available on a FR64 concurrently with a 2% sucrose solution on a FR8 (7 sessions). Following this, a 2% sucrose solution on a FR8 was concurrently paired with water on FR8 (8 sessions) Rats No. 2, 4 and 6 received the following schedule manipulations. First, 20% sucrose on FR16 was concurrently paired with a 2% sucrose solution on FR8 (5 sessions). Then a 20% sucrose solution on FR64 was paired with a 2% sucrose solution on FR8 (10 sessions). This was then followed by pairing a 2% sucrose solution on FR8 with water on FR8 (8 sessions). Finally, for all rats the concurrent pair of 20% sucrose and 2% sucrose on a FR8 FR8 schedule was employed (7 sessions). Thus, five animals completed the same sets of conditions throughout the experiment except in Phase 3, where rats No. 2, 4 and 6 received an extra set of concurrent conditions

RESULTS

Of the six animals that started the experiment, five completed the entire set of manipulations. One animal (No 1) became ill after the end of the original baseline training procedure and was discontinued

At the end of Phase 1 (20% sucrose available at both dippers, with a FR8 FR8 concurrent schedule in effect), all of the five animals showed a marked lever preference. This was expected, as there was no advantage for the animal to switch from lever to lever. Three of the animals had a right lever preference while the remaining animals preferred the left lever. The average total responding on both levers (±SD) for each animal for the last 10 sessions of Phase 1 were: rat No. 2—847 (65); rat No. 3—721 (26); rat No. 4—483 (125); rat No 5—532 (99), and rat No. 6—626 (77). These response levels resulted in from 6 to 11 ml of 20% sucrose being presented in any given 15 minute session

In Phase 2, in which the 20% sucrose was paired with different alternative fluids, a difference between one animal and the remaining four became apparent. As can be seen in Table 1, the shift from 20% on both levers to the concurrent 20% sucrose-5% sucrose FR8 FR8 situation resulted in little change in total lever presses, but one of the five animals (No. 4) failed to break the strong bar preference that had occurred in Phase 1, and thus did not follow the 20% sucrose as it alternated levers over sessions. This was demonstrated by

TABLE 1

MEAN (±SD) RESPONSES DURING PHASE TWO

20% Sucrose- 5% Sucrose FR8 FR8 (15 min Session)

Rat	20%	5%	Total
2	770 (212)	132 (182)	902
3	483 (238)	241 (178)	724
4	192 (244)	143 (97)	335
5	486 (103)	249 (116)	735
6	471 (188)	258 (222)	530

20% Sucrose- Water FR8 FR8 (30 min Session)

Rat	20%	Water	Total
2	1209 (224)	102 (50)	1311
3	936 (180)	77 (50)	1013
4	802 (328)	65 (29)	867
5	1074 (157)	115 (37)	1189
6	714 (431)	190 (138)	904

20% Sucrose- 1% Sucrose FR8 FR8 (30 min Session)

Rat	20%	1%	Total
2	824 (251)	195 (216)	1019
3	1131 (95)	49 (13)	1180
4	1189 (109)	56 (34)	1245
5	974 (177)	58 (11)	1032
6	729 (314)	250 (168)	979

20% Sucrose- 2% Sucrose FR8 FR8 (30 min Session)

Rat	20%	2%	Total
2	898 (398)	165 (157)	1063
3	1011 (47)	37 (16)	1048
4	547 (264)	113 (76)	660
5	730 (150)	172 (80)	902
6	549 (389)	237 (227)	786

TABLE 2

MEAN RESPONDING IN PHASE THREE

20% Sucrose- 2% Sucrose FR8 FR8 Concurrent

Rat	20%	2%	Total	% 2% Responding
2	898	165	1063	15 5
3	1011	37	1048	3 5
4	547	113	660	17 1
5	730	172	902	19.1
6	549	237	786	30.2

20% Sucrose- 2% Sucrose FR16 FR8 Concurrent

Rat	20%	2%	Total	%2% Responding
2	1203	180	1383	13.0
4	1154	40	1194	3.4
6	716	98	814	12 0

20% Sucrose- 2% Sucrose FR64 FR8 Concurrent

Rat	20%	2%	Total	% 2% Responding
2	668	679	1347	50.4
3	1376	466	1842	25 3
4	1444	126	1570	8 0
5	587	408	995	41 0
6	509	201	710	28 3

2% Sucrose-Water FR8 FR8 Concurrent

Rat	2%	Water	Total	% 2% Responding
2	904	82	986	91 7
3	587	185	772	76 0
4	477	88	565	84.4
5	388	202	590	65 8
6	383	319	702	54 6

this animal having almost equal responding for both solutions as compared to the marked preference (as determined by % responding) for the 20% solution by the remaining animals (Table 1).

Since for the remaining concurrent determinations in Phase 2, the length of the daily sessions was increased from 15 minutes to 30 minutes, all animals showed an increase in total responding at this point in the experiment (Table 1). The next solution to be tested in this phase against the 20% sucrose was water. All animals showed a marked preference for the sucrose solution as indicated by the relative lever pressing for the two solutions (Table 1). Unlike the preceding test with 5% sucrose, all animals followed the sucrose as it alternated from side to side across sessions. However, examination of the daily response patterns for animals No. 4 and No. 6 showed that on sessions in which the sucrose was paired with the nonpreferred lever, total responding was decreased. At both the 20% sucrose-1% sucrose and the 20% sucrose-2% sucrose pairing in Phase 2, all animals again showed major responding on the 20% sucrose lever. However, particularly at the 2% pair situation, several animals showed a lever preference that lowered the responding for 20% sucrose on those sessions in which it was associated with the nonpreferred lever.

Table 2 presents the responses for the 20% sucrose-2% sucrose condition during the schedule manipulation in Phase 3 in which the 20% sucrose response requirement was changed from a FR8 to FR64. For the two animals that first had the FR changed to 16, no major effect in responding was noted except for an increase in 20% responding (Table 2). Only when the response requirement was increased to FR64 was a clear effect present (Table 2). For three of the five animals (No. 2, 3, and 5), a marked increase in 2% responding occurred. In one animal (No. 4) there was a marked increase in total responding, all of which was for the 20% sucrose. In the remaining animal (No. 6) there was little change in either total responding or in the responding for the 20% sucrose, which therefore resulted in a marked decrease in the number of 20% sucrose reinforcements presented.

Following the schedule manipulation, all animals were then tested for 2% sucrose preference to water, by using a concurrent 2% sucrose-water FR8 FR8 condition. Animals No. 2, 3 and 4 all showed a clear preference for the 2% sucrose by responding on the appropriate lever each day and following the 2% sucrose as it was switched day to day. During this time for these three animals, the bar preference was still seen, however, as the amount of 2% responding varied a great deal depending upon the lever with which it was associated on a particular day. For the remaining two animals (No. 5 and 6) no clear preference for 2% was appar-

ent after the ninth session. Both these animals had a pronounced bar preference and this predominated in the response pattern with a failure to switch levers and follow either fluid.

The final experimental condition was the concurrent 20% sucrose-2% sucrose FR8 FR8 pairing to determine if prior responding levels for this condition could be recovered. All animals showed responding for the 20% very similar to the first test, following it as it switched levers across sessions. However, the animal which in the first test failed to follow the 20% because of a lever preference (No. 6), now showed a clear 20% sucrose preference, with little lever preference.

DISCUSSION

While not the direct purpose of this study, the data from Phase 2 provided information on response patterns when two different concentrations of sucrose were available concurrently on equal reinforcement schedules. All animals showed preference (i.e., greater and appropriate lever responding) for the higher concentration of the sucrose pair presented (except one animal (No. 6) at the 20–5% pairing). Thus this study supports previous findings that have related sucrose preference to concentration [1, 4, 5, 6, 20, 25]. Phase 2 provided the needed data concerning response rates for different sucrose concentration pairs in order to match concurrent FR8 FR8 response rates to those observed in the prior ethanol-sucrose studies [23]. Response rates in the range of 18 to 34 responses per minute for the 20% sucrose with rates from 1 to 8 responses per minute for the concurrently paired 2% sucrose provided the closest match to the prior ethanol-sucrose rates of 16–46 responses per minute for 5% sucrose and 1–3 responses per minute for the concurrently available 5% ethanol. Thus, the 20%–2% sucrose pairing was used for the schedule manipulation (Phase 3) part of the experiment.

During the schedule manipulation phase, complex interactions in response patterns occurred when the schedule for the preferred 20% sucrose was increased to FR64. Increases in responding for the alternative substance (2% sucrose) accompanied by either an increase (rat No. 3) or decrease (rats No. 2 and 5) in the responding for the 20% sucrose were observed (Table 2). As well, these three rats showed different patterns of schedule effects upon total responding (Table 2). The remaining two rats either decreased or did not change response patterns for the 2% sucrose. Thus no single explanation can account for the response changes observed. One difference between the three animals for which a schedule manipulation resulted in response increases and the two animals for which it did not, was the baseline response levels for 20% sucrose prior to the schedule increase. As can be seen in Table 2, the total number of responses for the animals that showed the increase (rats No. 2, 3 and 5) were higher than for those that did not (rats No. 4 and 6). Only further studies can determine if this original baseline difference can account for the observed schedule manipulation differences.

Comparison of these results with our prior study on ethanol-sucrose concurrent schedule manipulations [23] reveals several differences. While there were very similar relative ratios of responding for either ethanol or 2% sucrose when equal concurrent schedules of reinforcement were in effect, during the increased FR requirements in the ethanol-sucrose study, consistent decreases in preferred fluid responding occurred such that ethanol responding increased to over 80% of the total responding [23]. As discussed above, in the present study when the FR requirement for the 20% sucrose was increased, variable effects occurred on 2% sucrose responding. However, even for those rats that increased 2% responding, the percent of total responding for 2% sucrose did not exceed 50% (range 8–50%) (Table 2). It would appear, therefore, that one major difference between these studies was the decreased responding for the preferred solution that occurred in the ethanol-sucrose concurrent studies Comparable decreases for the 20% sucrose did not occur in the present study. Both of these studies examined responding over approximately the same number of sessions with very comparable absolute total responding rates, so length of time on the changed schedule or absolute response rates cannot account for the observed differences.

The present study suggests that part of the previously observed increase in ethanol responding was not necessarily due to some specific property of ethanol, but can occur for any given set of reinforcers presented in a concurrent situation when the more preferred of the pair becomes more difficult to obtain. This result would not be expected from an incentive contrast hypothesis [9] However, the extent and pattern of increased alternative responding was different in the two studies, suggesting that additional factors (i e , properties of the available reinforcers) besides the schedule manipulation may be involved. The complex manner in which reinforcer quality and scheduled availability interact with previous reinforcement history and response strength remains to be elucidated, but it is clear from this study that increased behavior for less preferred substances can be one result.

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