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Effects of Cocaine and *d*-Amphetamine on Sustained and Selective Attention in Rats

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GRILLY, D. M., G. C. GOWANS, D. S. McCANN AND T. W. GROGAN. *Effects of cocaine and* d-*amphetamine on sustained and selective attention in rats*. PHARMACOL BIOCHEM BEHAV **33**(4) 733–739, 1989.—The effects of cocaine and *d*-amphetamine were compared in two attention-loading tasks. Cued by the position of a light, rats were food-reinforced for pressing one of two levers in a 2-choice, discrete-trial procedure. In the "sustained attention" task, the cue light was illuminated for a brief period (1.8 sec or less) at the beginning of each trial. In the "selective attention" task, the cue light remained on until a level press, while a blinking light over the incorrect lever served as a distractor. In the sustained attention task, low doses of *d*-amphetamine (0.25 mg/kg SC) and cocaine (2.5 mg/kg SC) enhanced accuracy; some doses of *d*-amphetamine (0.75 mg/kg SC) and cocaine (1.25 and 2.5 mg/kg SC) also reduced choice latencies. In the selective attention task, the lower doses of these drugs had no effect on accuracy, the highest dose of *d*-amphetamine (1.25 mg/kg SC) disrupted accuracy, and all doses of the drugs reduced choice latencies. The time to retrieve food was increased in a dose-dependent fashion by both drugs in both tasks. These results indicate that, other than differences in potency, cocaine and *d*-amphetamine induce similar behavioral effects in attention-loading tasks, with improvement or interference with performance dependent on the dose and the type of attention demanded of the task.

Sustained attention Selective attention Choice behavior Cocaine *d*-Amphetamine Rats

IT is commonly reported that amphetamine and cocaine, at least acutely and in moderate amounts, are capable of enhancing mood and self-confidence, increasing concentration, initiative, and motor output, and reducing the effects of fatigue on human performance in relatively simple tasks (13,25). Amphetamine and cocaine also have similar behavioral profiles in animals, share some biochemical actions (e.g., inhibition of catecholamine uptake), and can substitute for each other in drug discrimination paradigms (5, 8, 11, 12, 24). In humans, amphetamine's ability to facilitate task performance in attention-loading tasks at low doses has led to its clinical use in the attentional deficit disorder (2, 13, 26). There is, however, a lack of empirical evidence as to whether cocaine, like amphetamine, can enhance performance in tasks heavily dependent on attention (1).

Because attention, i.e., the ability to perceive or notice certain stimuli but ignore others, is fundamental to performance in stimulus discrimination tasks, it seems reasonable to assume that some doses of amphetamine and cocaine may facilitate accuracy in such tasks. There are several situations in which amphetamine has been shown to facilitate discrimination task accuracy in animals at low doses (in the order of 0.5 mg/kg *d*-amphetamine) while disrupting task performance at higher doses (in the order of 1–3 mg/kg) (3, 7, 10, 17). However, most studies with animals have found that amphetamine generally disrupts accuracy in discrimination tasks (23). Factors such as task complexity, level of training, and compatibility of the task requirements and amphetamine-induced behaviors appear to be important in determining whether or not amphetamine facilitiates or disrupts discrimination performance (14–16, 22, 23).

Although the literature on cocaine's effects on choice behavior is much less substantial, there is some evidence that the same conclusions may apply with respect to cocaine. For example, Castellano (4) first trained mice to swim towards either the light or the dark side of a water Y-maze and then tested the effects of cocaine on performance. Cocaine was found to disrupt performance at a much lower dose when the mice were trained to swim towards the light side (initially the preferred side) than when they were trained to swim towards the dark side. In a later study, Castellano (5) investigated the effects of cocaine on acquisition in the same Y-maze. In this case, cocaine had no effect on mice reinforced for swimming towards the light side, whereas low doses of cocaine (5–10 mg/kg) significantly enhanced acquisition accuracy when the mice were reinforced for swimming towards the dark side. These experiments indicated that low doses of cocaine: 1) facilitated accuracy when baseline accuracy was low; 2) had no effect on accuracy when baseline accuracy was at moderate levels; and 3) had no effect or disrupted accuracy, depending on the task requirement, when baseline accuracy levels were already high.

One factor that may influence the effects of amphetamine and cocaine on choice behavior in discrimination tasks is the degree to which task performance is dependent upon different types of attention. At present the term attention is applicable to a wide

variety of activities and has a variety of different meanings to investigators whose main interest is in such fields as hearing, visual perception, speeded performance, etc. (20). Selective attention (or concentration) is required when an organism is confronted with two or more simultaneous stimuli, and it must respond to one while disregarding the other(s). Sustained attention (or vigilance) is required when an organism must maintain a readiness to respond to a simple stimulus when it occurs periodically over time.

In tasks in which discriminative stimuli occur periodically over time, accuracy is determined jointly by these two attentional processes, and treatments that influence accuracy may do so by affecting either process. With respect to the psychostimulants amphetamine and cocaine, it is our belief that the questions of which type of attentional processess are affected and whether these drugs affect them similarly have not been adequately addressed.

Thus, the present experiment was designed to compare the effects of cocaine and *d*-amphetamine on these two major subdivisions of attention. Rats were first trained to steady-state performance levels in two variations of a discrete-trial, two-choice task in which a light appearing over one of two levers served as a cue for the correct response (i.e., the response that resulted in food reinforcement) and were then tested following administrations of cocaine or *d*-amphetamine. In the "sustained attention" task, the cue light was periodically illuminated for a brief period (e.g., 1.0 sec), and the first lever-press following cue light termination was recorded. In the "selective attention" task, both the cue light over the correct lever and a distractor light (a blinking light) over the incorrect lever were simultaneously illuminated and maintained until a lever-press occurred. To equate the difficulty of the two tasks and to reduce the possibility that drug effects on accuracy would not be obscured by "basement" or "ceiling effects," accuracy was maintained between 75–87% correct in the tasks prior to drug testing. This was accomplished by manipulating the duration of the cue light in the sustained attention task or the ratio of the "on" to "off" time of the distractor light in the selective attention task.

METHOD

Animals

Male Sprague-Dawley rats (purchased from Hilltop Lab Animals) were used. At 100 days of age their individual weights were determined and maintained at these levels (mean = 330 g, range = 310–370 g) through food restriction. Water was available at all times in their cages. The animals were maintained in a 22°C, 50% humidity facility under a 12-hr light-dark cycle (lights on 0800 hr). Test sessions were conducted between 1100 and 1800 hr.

Apparatus

Two operant chambers were interfaced with Apple IIe 64K microprocessors, which controlled experimental events and collected data. Two levers were located at one end of the chambers. Located between the two levers was a food tray, into which single 45-mg food pellets were delivered as reinforcers. A microswitch was activated when the rat's head was inserted into the opening. The cue lights were located directly above each lever, and a house light was located in the middle of the ceiling. Further details of the apparatus can be found in (9).

Procedure

During training and drug testing sessions, there was no illumination in the room containing the operant chambers. Trials began with the house light in the chamber coming on. Prior to cue light presentation, the rat had to have its head out of the food tray and had to refrain from pressing either lever for 1.0 sec. The cue light above one of the levers was then illuminated (there was a minimum of 1.7 sec between house light onset and cue light onset). A single press of either lever turned the cue light off. If the lever beneath the cue light was pressed, food was delivered (accompanied by a 40-msec light presentation inside the food tray), and 1.0 sec after the rat inserted its head in the food tray, the house light was turned off. If the other lever was pressed, the house light was turned off. Intertrial intervals were between 7 and 10 sec. The position of the cue light was randomly determined except that there were no more than six successive trials with the light present in the same position and, within a session, the total number of trials with each cue did not differ by more than two.

When an animal reached a criterion of at least 95% correct in two successive 100 trial sessions, it began training (three to five 100-trial sessions per week) on either the sustained attention task or the selective attention task. In the sustained attention task, the task was changed so that the cue light was illuminated for 1.8 sec, and the first lever press following cue termination was recorded. The training of the animal continued until it met the criteria for testing, i.e., its overall percentage of correct responses was maintained between 75 and 87 over four successive 100 trial sessions without a change in cue light duration. If an animal's accuracy exceeded 87% in two successive sessions, the cue light duration was decreased by 0.6 sec; if the animal's percentage of correct responses dropped below 75% for two successive sessions, the cue light duration was increased by 0.3 sec. This "titration" training procedure continued until the animal met the criteria for testing, and the animal began the drug treatment phase of the experiment.

In the selective attention task, a "distractor" light was added. That is, the cue light was illuminated over the correct lever as before; at the same time a blinking light was illuminated over the incorrect lever. Initially, the "on" time of the distractor light was set at 0.11 sec, and the "off" time was 0.29 sec. A minimum of three "on-off" cycles had to occur before a lever-press was recorded. The animals continued their training under these conditions. Once the animal met the criteria for testing, i.e., the animal's overall percentage of correct responses was maintained between 75 and 87 over four successive sessions without a change in the characteristics of the distractor light, the animal began the drug treatment phase of the experiment. If it exceeded 87% for two successive sessions, the duration of the distractor light "off" period was reduced by 0.04 sec. This training procedure continued until the animal met the criteria for testing, and the animal began the drug treatment phase of the experiment. Most animals were exposed to two drug treatment phases: one consisted of a series of cocaine exposures, and the other consisted of a series of amphetamine exposures (not all animals were tested in both phases because their performance levels did not meet the criteria for testing). In each drug treatment phase, drug-test sessions of 100 trials each were conducted five to seven days apart. To establish that baseline performance was comparable over the treatment phase, the animals were always tested the day prior to drug test days. The animals were not injected on these pretest days. (Animals were not run on other days.) If an animal's percentage correct responses was below 75 or above 87 in the pretest session, it was tested again on the following day without injection. If the percentage correct was again below 75 or above 87, the animal was removed from the drug phase and returned to the training phase until it met the criteria for testing. The animal was then returned to the drug testing phase and tested under all drug doses of that phase.

In summary, each animal was exposed to all the drug treatments in each phase with a constant cue light duration in the

sustained attention task or with a constant ratio of the on to off time of the distractor light in the selective attention task (the data from the previous tests were not used). The average number of training sessions on the sustained attention task prior to the first drug series was 21.9 (SD = 8.8); in the selective attention task it was 21.8 (SD = 7.0). The average number of training sessions with the same stimulus conditions in effect prior to the first drug phase was 9.3 (SD = 3.9) in the sustained attention task and was 10.1 (SD = 6.4) in the selective attention task. Thus, in addition to the animals in the two tasks meeting the same accuracy criteria prior to drug testing, the amount of training required in the two tasks prior to drug testing was very similar.

In the cocaine series, doses of cocaine HCl of 1.25, 2.5, and 5.0 mg/kg were administered SC, and doses of cocaine HCl of 10.0 and 15.0 were administered IP (to prevent skin lesions that can occur with SC injections of these doses of cocaine). All cocaine doses were administered 15 min prior to testing. In the amphetamine series, doses of *d*-amphetamine sulfate of 0.25, 0.75, and 1.25 mg/kg were administered SC 30 min prior to testing. Drugs were diluted with 0.9% saline, and solutions were prepared so that all injections were given in volume of 1.0 ml/kg. All doses are expressed as the salt. In the control sessions, saline was injected. In the selective attention task, 12 animals were tested and were exposed to all cocaine and amphetamine treatments. In the sustained attention task, 16 animals were tested; 13 of them were exposed to all cocaine treatments, and 15 of them were exposed to all amphetamine treatments.

RESULTS

The following behavioral measures were derived for each animal under each condition and drug phase: 1) percent correct responses (accuracy); 2) median choice latency (time between cue light offset and lever-press in the sustained attention task or time between the end of the minimum three on-off cycles of the distractor light and the lever-press in the selective attention task); and 3) median food retrieval latency (time between lever-press and food tray entry). The individual scores were then used to derive group mean values and for statistical analyses. The latter consisted of planned comparisons between saline treatment and all drug treatments (two-tailed *t*-tests for repeated measures).

To establish whether baseline accuracy levels changed systematically across each drug series, average percentage correct in the pretest sessions prior to the drug treatment days (six for cocaine and four for amphetamine) were derived. For the sustained attention task, the averages (± 1 SD) for cocaine pretest sessions 1–6 were 80.6 (4.4), 82.9 (4.1), 82.5 (4.4), 81.5 (5.8), 81.4 (3.5), and 85.0, (3.8), respectively; for amphetamine pretest sessions 1–4, the averages (± 1 SD) were 79.7 (4.0), 83.3 (5.5), 81.1 (6.1), and 81.3 (5.0), respectively. For the selective attention task, the averages (± 1 SD) for cocaine pretest sessions 1–6 were 81.3 (4.4), 82.8 (5.1), 82.1 (6.0), 81.6 (5.9), 81.2 (7.0), and 83.5 (5.6), respectively; for amphetamine pretest sessions 1–4, the averages (± 1 SD) were 82.7 (4.2), 81.5 (5.1), 82.6 (5.9), and 83.9 (5.4) respectively. These averages indicate that baseline accuracy levels were fairly consistent across both series in both tasks. (The average accuracy levels reported above are slightly lower than the saline values depicted in Fig. 1 because accuracy levels tend to decrease somewhat when an animal is not tested for several days.)

The dose-related effects of cocaine and amphetamine on these behavioral measures in the two tasks are depicted in Fig. 1. In the sustained attention task, both drugs exerted biphasic effects on accuracy. That is, the lower doses (0.25 mg/kg amphetamine and 2.5 mg/kg cocaine) induced statistically significant increases in accuracy, whereas the higher doses (1.25 mg/kg amphetamine and

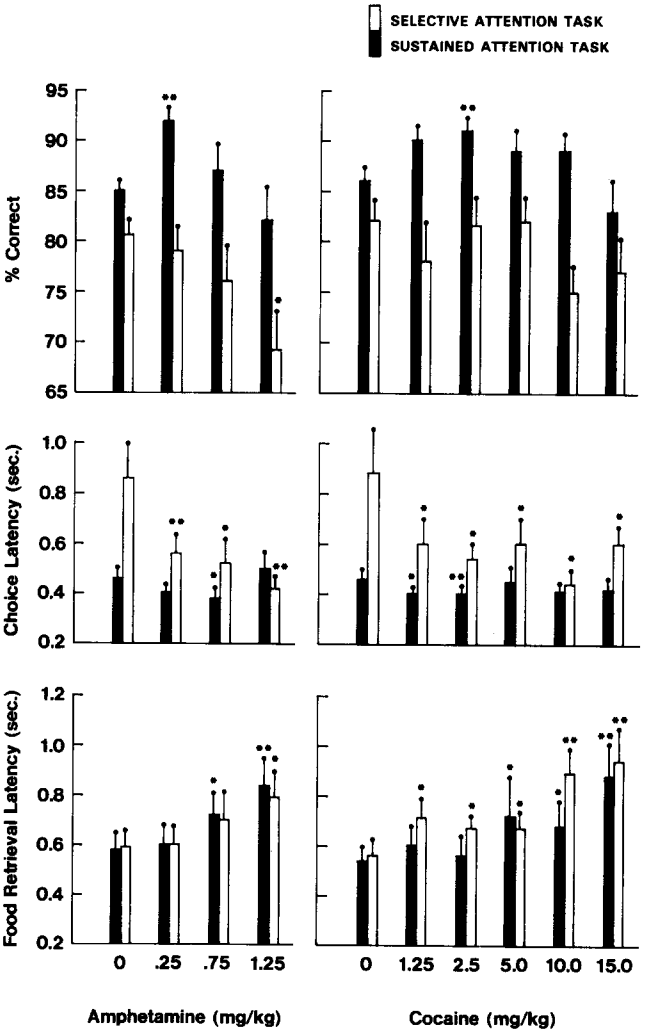

FIG. 1. Dose-related effects of cocaine and *d*-amphetamine on sustained attention (solid bars) and selective attention (open bars) task performance. For each measure the bar represents the mean (+S.E.M. is indicated by the vertical line over each bar). Cocaine and *d*-amphetamine were administered 15 and 30 min, respectively, prior to testing. *$p<0.05$, **$p<0.01$ as compared to saline (0 mg/kg).

15 mg/kg cocaine) disrupted accuracy in some animals (i.e., decreased accuracy below 70%) and enhanced accuracy in others (i.e., increased accuracy above 90%). The enhanced accuracy with the lower doses of these drugs occurred regardless of the animal's baseline (saline) accuracy levels. Following 2.5 mg/kg cocaine, average accuracy was 89.6% in animals with baselines below 85% and was 93.3% in animals with baselines above 85%. Following 0.25 mg/kg amphetamine, average accuracy was 90.4% in animals with baselines below 85% and was 93.6% in animals with baselines above 85%. However, as one might expect with measures with a ceiling, animals with the lowest baseline levels exhibited proportionally greater increases in accuracy than animals with the highest baseline accuracy levels.

The lower doses of both drugs also significantly decreased choice latency. As was the case with the accuracy measure, the higher doses induced variable effects on choice latency. Finally, both drugs increased food retrieval latencies in a dose-dependent fashion.

Accuracy in the sustained attention task is inversely related to

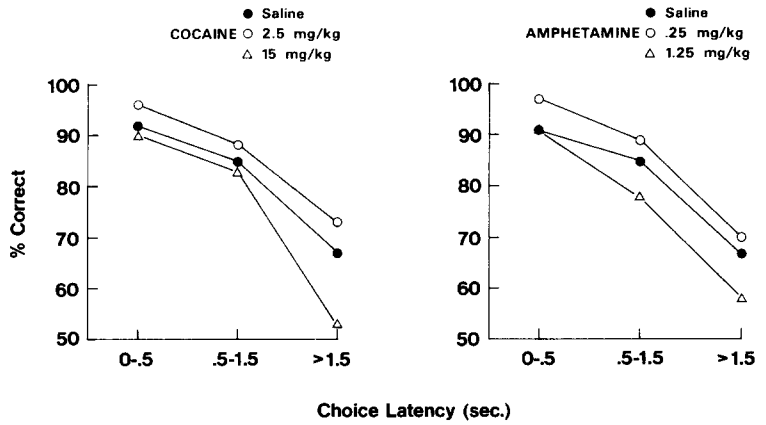

FIG. 2. Effect of selected doses of cocaine (left panel) and *d*-amphetamine (right panel) on percentage correct choices as a function of choice latency in the sustained attention task.

choice latency (9), i.e., the longer the choice latency, the lower the probability of a correct choice. Therefore, we further analyzed percent correct as a function of choice latency for the doses of amphetamine and cocaine that facilitated accuracy and for the highest doses of these drugs. As shown in Fig. 2, the lower doses increased group mean percent correct in all choice catagories. Conversely, the higher doses slightly decreased the percent correct in all catagories. To statistically verify that accuracy and choice latency represented independent effects of the low doses of amphetamine and cocaine, we determined whether a reliable difference in accuracy remained after the variance attributed to choice latency differences was factored out by way of analysis of covariance. With choice latency treated as a covariate and drug treatment (saline vs.drug) and trials (100) as factors, there was still a reliable difference between saline and 0.25 mg/kg amphetamine, $F(1,14)=5.24$, $p<0.05$, and between saline and 2.5 mg/kg cocaine, $F(1,12)=6.69$, $p<0.05$. These tests indicate that accuracy was improved independently of these drugs' effects on choice latency.

In the selective attention task, there was no indication that accuracy was enhanced by the lower doses of either amphetamine or cocaine, but accuracy was significantly decreased by the highest dose of amphetamine. Although the two highest doses of cocaine tended to reduce accuracy, the effect was not statistically significant.

Further analyses of the effects of the largest doses of amphetamine and cocaine on selective attention task performance were conducted in order to determine: 1) whether the lack of a significant effects of cocaine on accuracy was the result of its effects on the test session duration; and 2) whether the accuracy deficits noted with amphetamine (and perhaps cocaine) were associated with its enhancing response bias and/or perseveration. With the 15 mg/kg dose of cocaine, it was observed that the session duration of several of the animals was considerably longer than it was in the saline test sessions (saline mean = 21.8 min, SD = 1.2 vs. 15 mg/kg cocaine mean = 34.0 min, SD = 20.0). Furthermore, almost all of this increase occurred at the beginning of the cocaine session—primarily in 4 of the 12 rats. Thus, it was possible that these animals were responding in the drug session after the effects of the drug had dissipated considerably. To assess the extent to which this delay in responding may have obscured a disruptive influence on accuracy, we reanalyzed accuracy in the animals using a maximum session duration of 23 min. That is, only those trials completed within 23 min were analyzed. This restriction eliminated two rats from the analysis because one rat did not respond at all for first 54 min of the cocaine session and the other responded on only 7 trials—an insufficient number to reliably assess the effects of cocaine on accuracy. For the remaining 10 rats, the number of trials performed during the 23-min cocaine session ranged from 31 to 100 trials, and the average percent correct responses was 75.4%. In the saline session, the average percent correct was 83.0%. This difference was statistically significant, $t(9)=3.06$, $p<0.025$. [A $t(9)=3.32$, $p<0.01$, was obtained when the saline accuracy scores were based on the same number of trials used to derive accuracy scores for cocaine.]

This analysis indicated that 15 mg/kg dose of cocaine did reliably decrease accuracy when session duration was held constant. Similar analyses were performed on data for 1.25 mg/kg amphetamine in the selective attention task and for 1.25 mg/kg amphetamine and 15 mg/kg cocaine in the sustained attention task. The 1.25 mg/kg dose of amphetamine did not significantly affect session duration in either task, and no further analysis of accuracy was done. Although 15 mg/kg cocaine increased session duration (mean = 30.6, SD = 18.8) in the sustained attention task, when the accuracy scores were adjusted on the basis of a 23-min session duration, there was still no significant effect of cocaine on accuracy.

To assess the effects of cocaine and amphetamine on response bias, we first determined for each rat which lever was chosen most frequently during the pretest sessions. The percentage of responses to the preferred lever during saline sessions was then compared to the percentage of responses to that lever during the drug test sessions. A measure of response perseveration was also derived using a probability of response repetition measure (14), which is defined as the number of trials during which the rat responded on the same lever on which it responded during the immediately preceding trial, divided by the total number of trials minus 1.

With respect to bias, 1.25 mg/kg amphetamine significantly increased the percentage of preferred lever presses [saline mean = 58% vs. amphetamine mean = 67%, $t(11)=3.47$, $p<0.01$]. There was also a tendency for 15 mg/kg cocaine to increase responses to the preferred lever (saline mean = 57% vs. cocaine mean = 63.6%), but the effect was not significant (with all trials or with only trials completed in 23 min). Both drug treatments significantly increased the response perseveration measure [$ts(11)=2.47$ and 2.50 for amphetamine and cocaine respectively, $p<0.05$].

Choice latency was significantly reduced in the selective attention task by all doses of both amphetamine and cocaine. In contrast to the sustained attention task, in the selective attention

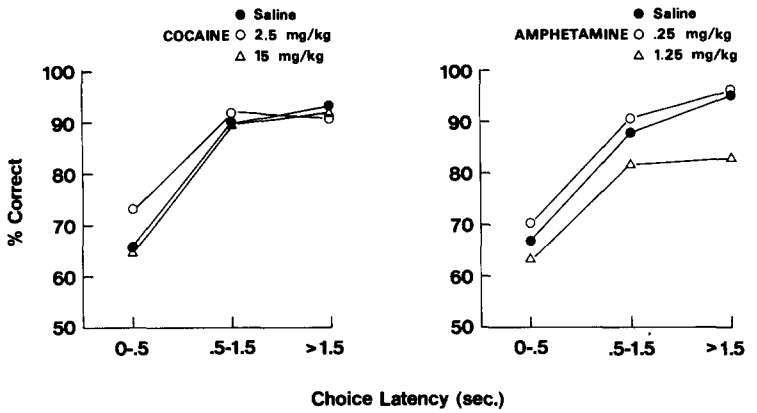

FIG. 3. Effect of selected doses of cocaine (left panel) and *d*-amphetamine (right panel) on percentage correct choices as a function of choice latency in the selective attention task.

task, accuracy is directly related to the length of the choice latency. That is, the longer it takes the animal to make a choice, the higher the probability of a correct choice. To determine whether or not the drugs exerted effects on accuracy independently of their effects on choice latency, we further analyzed percent correct as a function of choice latency for the doses of amphetamine and cocaine that facilitated accuracy in the sustained attention task and for the highest doses of these drugs. As shown in Fig. 3, neither the low nor the high dose of cocaine appeared to exert an effect on accuracy at any of the choice categories; the same results were obtained when we analyzed only those trials that occurred within the first 23 min of the test session. Although the 1.25 mg/kg dose of amphetamine did appear to decrease accuracy in all choice latency categories, particularly when choice latencies exceeded 1.5 sec, when choice latency was factored out with an analysis of covariance, the effect on accuracy did not reach statistical significance, $F(1,11)=3.94$, $p>0.05$.

As was the case in the sustained attention task, the food retrieval latencies in the selective attention task were increased in a dose-dependent fashion by both drugs.

DISCUSSION

The results of the present study suggest that in choice tasks the type of attentional process demanded of the task is an important factor in whether amphetamine or cocaine facilitate or interfere with choice beahvior. In the sustained attention task (i.e., the task that we anticipated accuracy would be predominantly, but not exclusively, dependent on attending to simple information for a period of time), amphetamine and cocaine induced dose-dependent biphasic effects on accuracy. Task accuracy was significantly enhanced with low doses of these drugs, while the higher doses appeared to reduce accuracy in some animals and increase it in others. We did not use doses of amphetamine higher than 1.25 mg/kg or of cocaine higher than 15 mg/kg because preliminary tests indicated that doses higher than these often suppressed responding altogether in many animals for considerable lengths of time. In such cases, the effects on accuracy within animals were highly variable, a tendency that was apparent with the highest doses used in the present study (see discussion below). However, in these preliminary tests, several animals displayed even greater deficits in accuracy following higher doses than those evidenced in the animals of this study. Thus, it is likely that accuracy in the sustained attention task would be disrupted in all animals if doses of amphetamine or cocaine somewhat higher than used in the present study were administered.

The lower doses of cocaine and amphetamine also significantly reduced choice latencies in the sustained attention task. This may have been a factor in the enhanced accuracy with these drugs, because shorter choice latencies are generally associated with a higher proportion of correct choices in this task. However, there are two aspects of the results that make it unlikely that the enhanced accuracy was solely due to the shorter choice latencies. First, some doses of these drugs (e.g., 0.75 mg/kg amphetamine) that significantly reduced choice latency did not significantly enhance accuracy. Second, when percent correct was analyzed as a function of choice latency, with the lower doses of amphetamine and cocaine, percent correct was higher than with saline treatment regardless of choice latency.

These results contrast with those obtained in the selective attention task (i.e., the task that we anticipated performance would be predominantly, but not exclusively, dependent on the ability to focus on a single source of information in the presence of other competing sources). The low doses of amphetamine and cocaine that enhanced accuracy in the sustained attention task had no effect on accuracy in the selective attention task. Furthermore, the high dose of amphetamine, which had variable effects on accuracy in the sustained attention task, significantly decreased accuracy in the selective attention task. The 15 mg/kg dose of cocaine did not appear to systematically reduce accuracy when based on 100 trial sessions. But because several animals administered this dose of cocaine did not begin responding in the task for several minutes, the effect on accuracy may have been attenuated in these animals by the time they began performing the task. This explanation is supported by studies indicating that cocaine is rapidly eliminated from the rat brain with a biological half-life of about 24 min (21) and that the behavioral effects of cocaine in the rat (at doses comparable to those used in the present study) dissipate rapidly between 15 and 30 min after administration (6,19). Furthermore, when we subsequently analyzed accuracy using a maximum session duration, there was a significant reduction in accuracy following 15 mg/kg cocaine.

Some of the drug-induced accuracy deficits observed in the selective attention task may have occurred because of the ability of these drugs to decrease choice latency, since shorter choice latencies were generally associated with a lower proportion of correct responses in this task. Other factors were likely to have played a role in the accuracy deficits because reduced choice latencies also occurred with doses of amphetamine and cocaine that did not decrease accuracy. Also, the 1.25 mg/kg dose of

amphetamine appeared to decrease accuracy in all choice categories (see Fig. 3), and the effect was most pronounced at the longest choice latencies. This phenomenon did not appear to have occurred with cocaine.

The highest doses of amphetamine and cocaine were also found to increase response bias and/or perseveration, and this may have been a factor in the accuracy deficits observed in this study. Similar observations have been reported in several previous studies investigating the effect of amphetamine on choice behavior [e.g., (7, 14, 22)]. However, as noted in previous studies, decreases in accuracy were not always accompanied by an increase in response perseveration or bias, indicating that augmentation in these areas is neither a necessary nor sufficient condition for the disruption of stimulus control by psychostimulants.

As would be predicted with anorexic drugs, food retrieval latencies were increased in a dose-dependent fashion with both amphetamine and cocaine, and the effect of these drugs on this measure was essentially the same in both tasks. The low doses of amphetamine and cocaine that enhanced accuracy in the sustained attention task had no effect on food retrieval latencies, indicating that the effects on accuracy were not attributable to changes in food-related motivation. However, a decrease in food-related motivation may have been a factor in the accuracy deficits in the selective attention task.

Previous studies have noted that the type and magnitude of the effect of amphetamine or cocaine is dependent on the task difficulty or complexity. If the task is very simple, such that choice performance is already at a very high level, then it may be difficult to demonstrate a facilitative effect of psychostimulants on accuracy. If more complicated test paradigms are used, particularly if enhanced motor output is nonadaptive, then even low doses of psychostimulants may lead to suboptimal performance (4, 5, 18). Thus, psychostimulants may only enhance choice behavior in moderate difficulty tasks. However, as demonstrated in the present study, task difficulty is not necessarily the most important determinant of the magnitude or type of effect induced by psychostimulants in choice tasks. In both tasks baseline levels of choice performance were comparable, while the type of effect induced by amphetamine or cocaine was quite different. In the task requiring the animal to be ready to process the relevant information and respond as quickly as possible after its occurrence, low doses of these drugs enhanced accuracy. In the task in which response readiness was not critical, but where withholding responding until selection between stimuli could be made was critical (i.e., a situation in which enhanced motor output could be nonadaptive), low doses of these drugs did not enhance accuracy and higher doses reduced it.

Finally, except for a 10-fold difference in potency (and, of course, duration of effect), amphetamine and cocaine induced very similar behavioral profiles in the two tasks. The difference in potency but similarity of behavioral profiles is in accord with previous studies directly comparing *d*-amphetamine and cocaine with respect to schedule-controlled responding in the mouse (8), locomotion and rearing behavior in rats (24), discriminative stimulus properties in rats (12), avoidance responding in rats (11), and acquisition of a discrimination in a Y-maze in mice (5).

Although the present study demonstrated that amphetamine and cocaine can enhance performance in some choice tasks, it is not clear how these results pertain to the fatigue or boredom factor commonly cited as being important for the performance-enhancing properties of psychostimulants like amphetamine. That is, it has been suggested that the beneficial effects of psychostimulants on human performance are most notable when performance has deteriorated through fatigue or boredom, presumably because psychostimulants bring performance back to baseline levels (1,13). Thus, it is possible that some aspect of our procedures (e.g., testing the rats during the light phase of the light-dark cycle) resulted in suboptimal performance levels and that low doses of amphetamine and cocaine brought the performance up to levels that would normally have been obtained under optimal conditions. We are presently exploring this possibility.

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