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d-Amphetamine Induced Changes in Social Interaction Patterns

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SMITH, E O AND L D. BYRD d-*Amphetamine induced changes in social interaction patterns* PHARMACOL BIOCHEM BEHAV 22(1) 135–139, 1985 —The behavioral effects of *d*-amphetamine were studied in a group of stumptail macaques in a large outdoor enclosure *d*-Amphetamine altered characteristic patterns of aggressive and affiliative behaviors in adult males that received the drug Each monkey that received *d*-amphetamine increased its aggression toward non-adult animals in the group and decreased aggression toward adult members In subjects for which genealogy was known, *d*-amphetamine increased aggression toward kin-related members of the group and decreased aggression toward non-kin monkeys. The effects of the drug on affiliative behaviors were less uniform and, therefore, less conclusive Three subjects decreased affiliation and two increased affiliation toward non-adult monkeys. The results demonstrate that *d*-amphetamine can alter substantially the behavior of drug-treated members of a group and, in addition, that the drug can indirectly affect specific subsets of the group even though they did not receive the drug.

Stumptail macaques *d*-Amphetamine Aggressive behavior Objects of aggression

THE effects of *d*-amphetamine on behavior have been studied in a variety of species and with a number of different research protocols [7,13]. Although individual subjects studied in isolation have provided considerable knowledge about the behavioral effects of this and other drugs, recent research suggests that drug effects can also be influenced by the social environment of which the subjects are a part. For example, the effects of *d*-amphetamine can be influenced by the hierarchical or dominance position of a subject within a social group [19], and *d*-amphetamine can have qualitatively different effects on affiliative and aggressive behaviors in the same subjects in a group [20].

In a previous report, we characterized the effects of a range of doses of *d*-amphetamine on the rate of occurrence of aggressive and affiliative behaviors initiated by adult male monkeys living in a social group [20]. Over a wide range of doses, *d*-amphetamine decreased affiliative behavior in all drug-treated subjects, yet the drug increased aggressive behavior in the high- and low-ranking subjects. An extension of that work, the present report describes changes in social interactions, i e , changes in the pattern or distribution of aggressive and affiliative behaviors toward specific members of the group, associated with *d*-amphetamine administration. The report identifies recipients of the behaviors and quantitates changes in the amount of aggressive or affiliative behavior directed toward recipients.

METHOD

Subjects

The experimental subjects were five adult male stumptail macaques (*Macaca arctoides*), weighing between 13.8 kg and 22.9 kg, and ranging in age from 5 to 11.5 years. The subjects were members of a heterogeneous group of 37 animals that included 5 adult males, 18 adult females, 3 subadult females, 3 juvenile males, 2 juvenile females and 6 immatures. The group was confined within a 28.4×32.7 m outdoor area with access to an environmentally-controlled, 4 4×12.2 m indoor area via two metal tunnels [21] The positions of the five male subjects within the dominance hierarchy of the group ranged from the highest- to the lowest-ranking

Procedures

All animals were restricted to the outdoor compound on a prescribed daily schedule, weather permitting, where each group member could be observed from a tower located 4.27 m above one side of the compound Data characterizing the behavior of individual animals were collected and stored in a digital format using a microprocessor-based data collection device, the Datamyte 900, as described previously [18] Subjects were observed and data were recorded during 15-minute test periods at preselected, post-injection times using the focal-animal sampling technique described by Altmann [1] The focal-animal sampling technique permits the recording of all occurrences of various behaviors of an individual monkey during each sampling period. In this manner, a descriptive record can be obtained of an individual animal's behavior and of its interactions with other members of the group. In the present experiment, aggressive and affiliative behaviors initiated by drug-treated males toward other members of the group were studied. Affiliative behaviors

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TABLE 1

EFFECTS OF *d*-AMPHETAMINE ON AGGRESSIVE OR AFFILIATIVE BEHAVIORS INITIATED BY EACH OF FIVE ADULT MALES TOWARD ADULT VERSUS NON-ADULT MEMBERS OF THE GROUP

Subject	*d*-Amphetamine Dose		Non-adult	Adult	χ^2	*p*
			Aggressive Behaviors			
M-13	0 56 mg/kg	Expected	45 9 ↑	118 1 ↓	0 50	≤0 50
		Observed	50 0 ↑	114 0 ↓		
M-10	0 03 mg/kg	Expected	17 1 ↑	39 3 ↓	1 37	≤0 30
		Observed	21 0 ↑	35 0 ↓		
M-06	0 03 mg/kg	Expected	32 3 ↑	53 6 ↓	16 12	≤0 001
		Observed	50 0 ↑	35 0 ↓		
M-24	0 03 mg/kg	Expected	3 1 ↑	35 5 ↓	123 88	≤0 001
		Observed	22 0 ↑	17 0 ↓		
M-18	0 01 mg/kg	Expected	26 9 ↑	70 1 ↓	21 40	≤0 001
		Observed	47 0 ↑	49 0 ↓		
			Affiliative Behaviors			
M-13	0 56 mg/kg	Expected	6 3 ↓	30 7 ↑	7 58	≤0 01
		Observed	0 0 ↓	37 0 ↑		
M-10	0 30 mg/kg	Expected	25 2 ↓	58 8 ↑	2 94	≤0 10
		Observed	18 0 ↓	66 0 ↑		
M-06	0 30 mg/kg	Expected	15 2 ↑	110 5 ↓	3 27	≤0 10
		Observed	22 0 ↑	105 0 ↓		
M-24	0 30 mg/kg	Expected	6 0 ↑	54 6 ↓	6 80	≤0 01
		Observed	12 0 ↑	48 0 ↓		
M-18	0 30 mg/kg	Expected	9 7 ↓	78 3 ↑	1 57	≤0 25
		Observed	6 0 ↓	82 0 ↑		

were defined as any positive or affectionate behavior, or any behavior that was an attempt to safeguard another animal Aggressive behaviors were defined as behaviors which could cause physical injury, signal the potential for harm, or result in preferential access to objects or events in the environment.

d-Amphetamine was dissolved in sterile normal saline (0 9%) and the resulting solution was injected intramuscularly in a volume of less than 1 0 ml Sodium chloride solution (0 9%) served as a control (placebo) injection. Except for the highest dose (0.56 mg/kg) studied in monkey M-13 and the lowest dose (0 003 mg/kg) studied in monkey M-18, each dose was studied three times in each subject in an unsystematic order

In order to inject the drug without alarming or exciting the animals, each of the five male subjects was trained to enter a small cubicle along one side of the outdoor compound [17] and to extend an arm through a circular opening according to procedures devised previously [3, 4, 15] On a given day, each subject received either a drug injection, a saline (placebo) injection or no injection, however, only the experimental animal for that day received the drug. Persons responsible for data collection did not know whether saline or drug was administered *d*-Amphetamine was administered two days per week, but a given animal was the experimental or drug subject no more than once per week Immediately after completing the injections, the subjects returned to the compound and data collection began The initial observation period encompassed the entire first hour post-injection, thereafter, 15-minute observation periods began at 90, 150, 210 and 330 minutes post-injection

RESULTS

Mean hourly rates of occurrence of affiliative and aggressive behaviors initiated by the male subjects following drug or saline administration were determined for each subject based on data obtained during the eight post-injection observation periods Full dose-effect functions describing those data were reported previously [20]. In brief, the data on affiliative and aggressive behaviors initiated by the drug-treated animals showed overall monotonic decreases in affiliative behaviors by all five subjects as dose increased, and biphasic changes in aggressive behaviors in some subjects To keep the mass of data at a manageable level for the present report, data presentation is limited to the dose of *d*-amphetamine that produced the maximum change in aggressive or affiliative behavior for each subject *d*-Amphetamine can have differential effects depending on the dominance position of the drug-treated subject [20], and,

TABLE 2

EFFECTS OF d-AMPHETAMINE ON AGGRESSIVE AND AFFILIATIVE BEHAVIORS INITIATED BY TWO ADULT MALES TOWARD KIN VERSUS NON-KIN MEMBERS OF THE GROUP

Subject	d-Amphetamine Dose		Kin	Non-kin	χ^2	p
			Aggressive Behaviors Initiated			
M-18	0 01 mg/kg	Expected	6 72 ↑	89 28 ↓	13.78	≤0.001
		Observed	16 00	80 00		
M-24	0 03 mg/kg	Expected	8 58 ↑	30 42 ↓	1 75	≤0 20
		Observed	12 00	27 00		
			Affiliative Behaviors Initiated			
M-18	0 30 mg/kg	Expected	26 40 ↓	61 60 ↑	12 83	≤0 01
		Observed	11 00	77 00		
M-24	0 30 mg/kg	Expected	23 40 ↑	36 60 ↓	4 05	≤0 05
		Observed	31 00	29 00		

therefore, the dose that produced maximal effects differed among the subjects in the present experiment. Chi-square goodness-of-fit tests were used for all analyses; effects were considered significant if $p \leq 0.05$.

Age Analysis

The purpose of the present study was to describe effects of *d*-amphetamine on the directionality of affiliative and aggressive behaviors and to determine if the recipients of these behaviors represented special subsets of the larger social group First, data were analyzed to determine if behavior was directed consistently toward non-adult as compared to adult members of the group and whether *d*-amphetamine altered the directionality of aggressive and affiliative behaviors Adults were defined as individuals four years of age and older, and included those individuals that were reproductively mature. Non-adults included all monkeys less than four years of age To apply the Chi-square test, the number of aggressive and affiliative interactions expected were determined based on the number of individuals in an age class and on frequencies of behavioral interactions following saline administration.

Table 1 summarizes data for the five males that received *d*-amphetamine. Although maximum increases in aggressive behaviors occurred at different doses for each of the five subjects, *d*-amphetamine uniformly increased aggressive behaviors toward non-adult members of the group and decreased aggressive behaviors toward adult monkeys in the group. The significance of the drug-induced changes was reflected in the results of the Chi-square tests, as shown in Table 1 The greatest redirection of aggressive behavior occurred in the three mid- and low-ranking animals, where values of $p \leq 0$ 001 were obtained.

When the data were analyzed in a similar manner for maximum decreases in affiliative behaviors, a contrasting pattern resulted (Table 1). Three subjects decreased affiliative behaviors toward non-adult animals in the group and increased affiliative behaviors toward adults, and two subjects showed an opposite effect. The significance of the changes in recipients of affiliation yielded values of $p \leq 0.01$ for two of the five subjects when evaluated by Chi-square tests. However, none of the changes in affiliative behaviors was as large as the changes in recipients of aggressive behaviors.

Genealogical Analysis

To determine whether the recipients of aggressive or affiliative behaviors could be differentiated on the basis of blood relationship, data were examined for those drug-treated monkeys whose genealogy was known. Subjects for the genealogical analysis were monkeys M-18 and M-24, the two adult males that were born into the group and, therefore, the only two for which exact genealogy was known Other group members were classified as kin-related or non-kin-related based on matrilineal records. Using rates of affiliative and aggressive behaviors under saline conditions and relative numbers of kin versus non-kin individuals in the group, expected rates of behavior for monkeys M-18 and M-24 were derived as shown in Table 2. Following the administration of *d*-amphetamine, both monkeys showed an increase in rate of aggressive behaviors toward kin-related animals and a decrease in aggression toward non-kin individuals.

d-Amphetamine also produced a significant change in recipients of affiliative behaviors following the administration of 0.30 mg/kg *d*-amphetamine. Statistically significant results were obtained for both subjects, indicating significant departures from expected values, but the effects were opposite in direction (Table 2) Monkey M-18 increased affiliative behaviors toward non-kin and monkey M-24 increased affiliative behaviors toward kin-related individuals.

DISCUSSION

The data presented here show that *d*-amphetamine can have pronounced effects on the expression of aggression and affiliation among animals living in a large, heterogeneous social group. When compared to the pattern of aggression and affiliation under baseline, non-drug conditions, significant changes in rates and in objects or recipients of the behaviors were found for both classes of behavior following administration of the drug.

Although previous research has revealed much regarding the effects of *d*-amphetamine on the behavior of individuals comprising various types of groupings [13], none has involved a group that yielded the type of analysis presented here When the objects or recipients of aggressive behaviors were analyzed by age, for example, an unequivocal pattern based on age was revealed Aggression directed toward young animals in the group increased for all five subjects following *d*-amphetamine administration Moreover, the magnitude of the effect was inversely related to dominance position of the subjects in the group, with the highest-ranking male showing the smallest effect and the low-ranking males the largest effect Differences in the statistical significance of the effects relative to dominance positions of the subjects indicated further that the magnitude of the effects might be due, in part, to the social position of each subject These data are consistent with other reports showing that the behavioral effects of various drugs may be a function of the dominance position of the drug-treated subject Wilson *et al* [23] reported that *d*-amphetamine decreased food retrieval in high-ranking subjects and increased food retrieval in lower-ranking subjects In other food competition tests, Lovell *et al* [12], Grove *et al* [8] and Bellarosa *et al* [2] found increased food capture by subordinate animals when either the entire group or only the dominant animal was administered *d*-amphetamine In other studies, Haber *et al* [9,10] reported that *d*-amphetamine administration increased submissive behavior in low-ranking animals Finally, Schlemmer and Davis [16] found rank-mediated changes in behavior following chronic *d*-amphetamine administration in small groups of stumptail macaques

Changes in the directionality of affiliative behaviors following drug administration were less uniform among the five subjects Three of the subjects decreased and two increased the frequency of affiliative behaviors directed toward young animals in the group A possible basis for this difference in effect among the five subjects was not readily apparent The two subjects that increased affiliative behavior toward non-adult members of the group were in the low-middle positions of the dominance hierarchy, but there was little else to indicate that dominance position of the subject was a major determinant of the drug effect on affiliation Indeed, we reported previously that *d*-amphetamine decreased affiliation uniformly and independently of dominance position in the group [20].

Of substantial interest in the present experiment were data showing that kin-related animals were more likely than non-kin-related animals to be targets of aggressive behaviors following *d*-amphetamine administration Kinship groups have been shown to form strong interactional subunits for all primate species where kinship relations among members of a social group were known [5, 6, 11, 14, 22] This fact has been well documented by behavioral primatologists, but a detailed analysis of drug-induced behavioral changes in group-living animals with a known network of genealogical relations has not been reported Although this phenomenon might normally be explained by greater spatial proximity to kin vs non-kin, proximity did not account for the results when the data were corrected for a greater absolute number of non-kin animals Furthermore, drug vs non-drug comparisons were made against the saline control rate The data were convincing in that both of the subjects with known genealogical histories exhibited the same pattern of increased aggression toward kin members of the group. That *d*-amphetamine had opposite effects on affiliation for the same two subjects indicates that there are probably other complex variables regulating the expression of affiliation in a socially-living primate

The data reported here focus attention on the importance and value of studies to determine the effects of drugs on behaviors occurring naturally within a complex social group The data show that the drug *d*-amphetamine not only increases the rate of aggressive behavior initiated by drug-treated members of the group, but that the drug-induced increase in aggressive behavior is distributed differentially among the various members of the group The two characteristics that we have identified in this report as determinants of the expression of aggression are age and relationship of the recipients of the aggressive behavior Younger, non-adult members of the group and kin-related members of the group received increased aggression following *d*-amphetamine administration Finally, whereas previous reports have shown that *d*-amphetamine can affect differentially the *rate* of occurrence of aggressive and affiliative behaviors in group-living monkeys, the present report shows that *d*-amphetamine can significantly alter normal *patterns* of social relationships among adult and non-adult monkeys in a group Disruption of patterns of social interactions can be as dramatic and as important as alterations in the rate of occurrence of naturally-occurring behaviors

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