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Effects of Dominance Rank on *d*-Amphetamine-Induced Increases in Aggression

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MARTIN, S. P., E. O. SMITH AND L. D. BYRD. *Effects of dominance rank on* d*-amphetamine-induced increases in aggression.* PHARMACOL BIOCHEM BEHAV **37**(3) 493–496, 1990.—Previous research has suggested that certain social factors, e.g., dominance rank, can determine the behavioral effects of drugs in individual members of a social group. In the present experiment, the effects of *d*-amphetamine were studied in two adult male monkeys with dominance rankings that changed during a reorganization of the social hierarchy in a captive group of stumptail macaques (*Macaca arctoides*). A range of doses of *d*-amphetamine was administered to each subject, and dose-effect curves were determined before and after group reorganization and stabilization. The data revealed drug effects which were dependent upon dose and the social rank of the animals. When either subject occupied the highest ranking or alpha position within the dominance hierarchy, rate of aggressive behavior initiated by the subject was several times greater than when that monkey occupied a lower position within the dominance hierarchy. Moreover, for either subject, the dose-effect curve was shifted to the right when the monkey was highest in the dominance hierarchy. Finally, aggression initiated by the drug-treated subject was directed more frequently toward adult members of the group when the subject was highest in the hierarchy and toward nonadult animals when the subject was lower in the hierarchy. These data support the hypothesis that the dominance position of an animal in a group can be a determinant of the behavioral effect of certain drugs.

Aggression *d*-Amphetamine Dominance rank Stumptail macaques

SEVERAL investigators have reported that the effects of drugs in group-living nonhuman primates can be determined by the dynamics of the social situation (6, 8, 14, 16–18). For example, different behavioral effects of *d*-amphetamine have been reported for animals occupying different positions within the dominance hierarchy of a group (13,23). Previously, we described effects of *d*-amphetamine on affiliative and aggressive behaviors in captive, group-living Old World monkeys and suggested that the dominance rank of an individual subject influenced changes in aggressive behavior following drug administration (22). Acute administration of a range of doses of *d*-amphetamine increased the rate of aggressive behavior initiated by the highest- and lowest-ranking monkeys, but had little or no effect on mid-ranking monkeys. The largest increase in rate of aggressive behavior occurred in the highest-ranking or alpha animal in the group. Rate of aggression in that monkey increased in direct relation to dose and, at the highest dose studied, rate increased to more than 30 times control values.

Typically, dominance hierarchies in captive, group-living, Old World monkeys tend to be stable over time (3). Occasionally, however, the dominance hierarchy may undergo reorganization spontaneously or following a salient event. This paper describes a reorganization that occurred following the removal of one mid-ranking male monkey from a group of 38 animals and reports changes in the effects of *d*-amphetamine on the behavior of two monkeys that experienced significant changes in dominance rank or social position during the reorganization. After the reorganization, the male that had ranked second lowest in the hierarchy prior to the reorganization moved to the highest-ranking (alpha) position in the group, and the male that had been the highest-ranking animal moved down to the second-ranking (beta) position. The removal of one animal and the resulting reorganization provided an opportunity to test within the same subjects the hypothesis that dominance rank or position can affect the expression of drug-induced behavioral changes.

METHOD

Subjects

Two adult male stumptail macaques (*Macaca arctoides*), 9 and 12 years of age, served as subjects. The two lived within a heterogeneous group comprising 38 animals, including males and females ranging in age from newborn to old adult (>20 years).

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The group was housed in a large, 28.4 × 32.7 m outdoor area with access to an environmentally controlled 4.4 × 12.2 m indoor area (19) [see Smith and Byrd (21) for details of the enclosure]. Prior to reorganization of the dominance hierarchy, monkey M-13 was the highest-ranking of five adult males in the group, and monkey M-24 was near the bottom of the hierarchy with only one adult male ranking lower. After reorganization, monkey M-24 was the highest-ranking and monkey M-13 was the second-ranking animal in the group.

Procedures

All animals were restricted to the outdoor area on a prescribed daily schedule, weather permitting, where subjects 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 (20). Subjects were observed and data were recorded during 15-minute test periods at preselected, postinjection times using the focal-animal sampling technique described by Altmann (1). This technique involves recording all occurrences of behaviors initiated by an individual subject during each sampling period. In the present experiment, aggressive behavior initiated by drug-treated males toward other members of the group was studied. Aggressive behavior was defined as activity which could cause physical injury, signal the potential for harm, or result in preferential access to objects or events within the environment.

Subjects were trained to enter a capture device positioned along one side of the compound (19) and to extend an arm through a circular opening in one wall of the device according to procedures described previously (4, 5, 15). *d*-Amphetamine sulfate was dissolved in sterile normal saline (0.9%), and the resulting solution was injected intramuscularly in a volume of less than 1.0 ml in the upper arm. Each of several doses (0.01, 0.03, 0.1 and 0.3 mg/kg) was studied two times in each subject in an unsystematic order. In addition, 0.56 mg/kg was studied in monkey M-13. Sodium chloride solution (0.9%) served as a control (placebo) injection. On a given day, each subject received either a drug injection, a saline (placebo) injection or no injection; however, only one monkey, the experimental animal for that day, received the drug. Persons responsible for data collection did not know whether saline or drug was administered to the monkey designated the focal animal for that day. A given animal was the experimental subject and received *d*-amphetamine no more than once per week. Immediately after receiving an injection, subjects were released into the outdoor compound and data collection began. The initial observation period encompassed the entire first hour post-injection; thereafter, 15-minute observation periods began at 105, 120, 150, 165, 195 and 210 minutes postinjection.

The foregoing protocol was followed prior to the reorganization of the group and repeated again after reorganization for both male subjects, M-13 and M-24. Reorganization of the group occurred during a period of 13 weeks, and drug administration was not resumed until group organization was stable and ranking of the adult males was consistent for a period of three successive months. Positions of individual animals within the dominance hierarchy were determined and verified on the basis of results of agonistic encounters among members of the group under baseline or nondrug conditions. An independent measure of dominance rankings was obtained monthly by recording successes and failures in paired competition among group members for preferred food items, and by analyzing outcomes of aggressive, agonistic encounters. The average monthly correlation of rankings by independent observers was .89, i.e., $r = .89$. All statistical tests of the data were considered significant if $p \leq 0.05$.

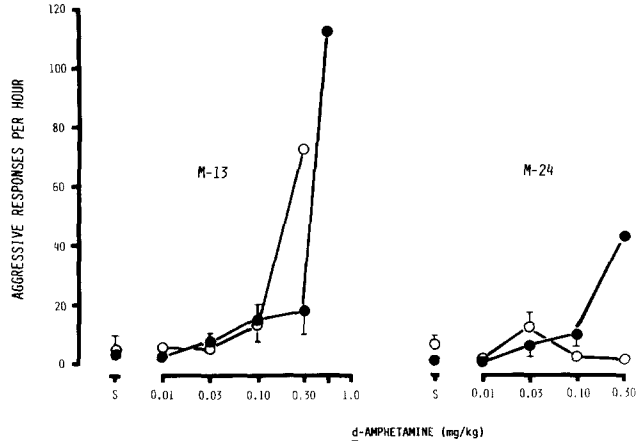

FIG. 1. Effect of *d*-amphetamine dose on the initiation of aggressive behavior by two monkeys when either was the highest-ranking monkey in the group (filled circles) or a lower-ranking monkey (unfilled circles). Each data point is the mean ± SEM based on two administrations of each dose (except for 0.56 mg/kg that was administered only once to M-13). Data points to the left of the dose-effect curves (at S) were obtained when saline was administered as a control.

RESULTS

Mean rates of occurrence of aggressive behavior initiated by the two males were determined for each subject following drug or saline administration based on observations conducted during the period 90–180 minutes postinjection, a period that encompassed the maximum drug effect. During three administrations of saline, both subjects exhibited low rates of aggression. For monkey M-13, control rate was 4.4 aggressive acts initiated per hour as the alpha monkey and 3.1 acts per hour as a lower-ranking monkey; for monkey M-24, control rate was 1.6 aggressive acts per hour as the alpha monkey and 6.3 acts per hour as a lower-ranking monkey. There was no indication that control rate was related to dominance position for either subject.

When *d*-amphetamine was administered prior to the reorganization, both subjects displayed dose-dependent changes in aggressive behavior. The lowest dose (0.01 mg/kg) produced little or no change in aggressive behavior for either subject. Over a wide range of doses, however, increases in dose resulted in increases in aggression that were especially pronounced for monkey M-13 (Fig. 1). The dose-effect curve for this subject was relatively monotonic with aggression increasing in direct relation to dose up to a maximum increase after 0.56 mg/kg. For M-24, the lowest-ranking male in the group, the dose-effect curve was of an inverted U-shape with a maximum rate of aggression after 0.03 mg/kg and lesser rates after 0.1 or 0.3 mg/kg.

During the second phase of the experiment after monkey M-24 had assumed the highest dominance position in the group and M-13 was in a lower (beta) position in the hierarchy, redetermination of the individual dose-effect curves revealed changes in *d*-amphetamine's effects for both subjects. Relative to the earlier determinations, the dose-effect curve for M-24 shifted to the right and the curve for M-13 shifted to the left (Fig. 1). Following the change in dominance position, for example, M-24 displayed enhanced increases in aggression that previously had characterized only M-13. When M-24 was the highest-ranking monkey, the greatest enhancement of aggression occurred after a dose (0.3 mg/kg) that previously decreased aggression. The result of this change in drug effect was a shift of the dose-effect curve to the right by approximately one log unit.

TABLE 1

AGGRESSIVE BEHAVIOR INITIATED TOWARD ADULT AND NONADULT GROUP MEMBERS

Subject		Adult	Nonadult	
		Highest-Ranking		
M-24	Observed	147.00	17.00	$\chi^2=5.12$, $p\leq0.05$
	Expected	136.12	27.28	
M-13	Observed	34.00	21.00	$\chi^2=0.08$, n.s.
	Expected	34.65	19.80	
		Lower-Ranking		
M-24	Observed	2.00	2.00	$\chi^2=8.24$, $p\leq0.05$
	Expected	3.68	0.36	
M-13	Observed	66.00	120.00	$\chi^2=1687.21$, $p\leq0.05$
	Expected	172.98	7.77	

The shift in dose-effect curve was opposite in direction for monkey M-13, concomitant with a change to a lower dominance position in the group for this monkey. A lower dose had a large enhancing effect on aggression when M-13 became a lower-ranking monkey, and the consequence was a shift of the dose-effect curve to the left (Fig. 1). Comparison of the sets of curves for the two subjects showed, therefore, that when the subject occupied the highest position of dominance in the group, the dose-effect curve was to the right of the position of the curve obtained when the subject occupied a lower-ranking position.

The shifts in the dose-effect curves were complemented by changes in the patterns of aggressive behavior exhibited by monkeys M-13 and M-24. When the latter was a low-ranking animal, monkey M-24 directed significantly more aggressive behavior than expected to nonadult members of the group based on saline rates of aggression and number of adult and nonadult monkeys in the group. When M-24 became the highest-ranking member of the group, however, the pattern of aggression changed and M-24 directed more aggression toward adult members of the group (Table 1). Similar changes in the pattern of aggression and in the recipients of the aggression were characteristic of monkey M-13; aggression toward nonadults increased and was significantly greater when M-13 was displaced into a lower position in the dominance hierarchy.

DISCUSSION

The data presented here provide additional evidence that *d*-amphetamine can produce orderly, dose-dependent changes in aggressive behavior in individual monkeys within a social group. Over a wide range of doses, *d*-amphetamine resulted in marked increases in aggression initiated by the drug-treated monkey toward other members of the group. Although a relatively large number of studies have described the effects of *d*-amphetamine on conditioned behavior and on spontaneous locomotor activity in a variety of animal species, fewer studies have characterized the behavioral effects of the drug in a social context. The present data complement earlier reports showing the orderly modulation of social behavior via amphetamine in monkeys, and they further enlarge a growing data base that identifies primate social groups as desirable models for studying the effects of drugs on socio-behavioral interactions.

The present data also provide additional evidence using a within-subject paradigm that dominance rank can have effects on drug-induced changes in aggressive behavior. These findings are consistent with other reports that social rank can influence drug effects on behavior (2, 7, 9, 10, 12, 18, 24). Previously, we reported that dominance rank influenced drug effects on behavior in a social group. The conclusion was based on comparisons made among animals occupying different positions of dominance in a stable group of monkeys. There was no attempt to disrupt the stability of the group or to alter the dominance positions of individual subjects (21,22). In the present study, however, changes in *d*-amphetamine's effects on aggression were demonstrated in individual subjects when their respective positions of dominance in the group were different before and after group reorganization, and each subject served as its own control. More specifically, the dose-effect curve for monkey M-24 shifted to the right as that subject moved from the lowest position in the hierarchy to the position of highest-ranking (alpha) male in the group. Concurrently, the dose-effect curve for monkey M-13, the displaced dominant male, shifted to the left relative to its position when that monkey was highest-ranking. The similarity of the dose-effect curves for the two subjects when each was the highest-ranking or alpha animal indicated that the effect of the drug was dependent upon position within the dominance hierarchy. Therefore, the present results showing changes in drug effects within individual subjects support our earlier findings based on comparisons among subjects at different positions in the dominance hierarchy (22) that the effect of *d*-amphetamine on the initiation of aggressive behavior is a function of the dominance position of the subject. Apparently, the alpha position imposes a different set of behavioral characteristics and influences compared to lower-ranking positions. The similarity in results with individual subjects as their own controls indicates that the alpha position in a social group of nonhuman primates can represent a major determinant of a drug's effects independent of the particular organism occupying the dominant position.

An equally important outcome of the present study is the finding that *d*-amphetamine can influence the pattern or distribution of aggressive behavior initiated by the drug-treated monkey. For both subjects, M-13 and M-24, greater aggression toward adult members of the group was associated with being the dominant (alpha) monkey in the group, and greater aggression toward non-adult monkeys was associated with being a lower-ranking monkey. However, modulation of both the rate and the pattern of aggressive behavior by *d*-amphetamine is a finding that reinforces our view of the importance of social or group factors in the expression of drug effects.

Although the effects of *d*-amphetamine on aggression were monotonic over the range of doses studied when the subject was the dominant monkey in the group, laboratory experience with *d*-amphetamine suggests that increasingly higher doses of the drug would eventually have resulted in a decrease in aggressive behavior. The inverted U-shaped dose-effect curve is characteristic of the behavioral effects of psychomotor stimulants when studied over a sufficiently wide range of doses (11). The decision to limit doses to those reported in the present study was predicated on observation of the enormous increase in aggressive activity in M-13 after one administration of 0.56 mg/kg and our concern that doses greater than 0.3 mg/kg might precipitate a state of widespread aggression within the group that could endanger individual monkeys and preclude completion of the study. Nevertheless, the range of doses studied was adequate to determine that the effects of *d*-amphetamine were qualitatively similar whatever the dominance position of the two subjects studied. The data suggest that there was a change in sensitivity to the drug associated with change in dominance position in the group.

There is little reason to presuppose that the drug effects observed were a direct result of the particular monkey removed from the group, although the two phenomena were related indi-

rectly. Monkey M-06 was a mid-ranking male in the group that had to be removed due to health reasons, specifically weight loss. The status of M-06 in the group and his interactions with other group members have been described (15, 21, 22). His removal allowed the development of an alliance between M-24, who was low-ranking, and M-10, who was the second-highest ranking male under M-13. The alliance between these two monkeys was sufficient to depose M-13 and permit M-24 to assume the role of alpha monkey during a period of 13 weeks. It is reasonable to speculate that a similar sequence of events might have transpired if M-10, rather than M-06, had been removed because M-24 could have developed an alliance with M-06 and used that relationship to depose M-13. Obviously, more studies with *d*-amphetamine will be necessary to confirm this finding, and studies with other drugs will be required to determine whether the phenomenon is drug-specific.

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