SQUIRREL MONKEY HEART RATE DURING FORMATION OF STATUS ORDERS

DOUGLAS K. CANDLAND, DANA C. BRYAN, BARRY L. NAZAR, KENNETH J. KOPF, AND MARK SENDOR

Bucknell University

Heart rate of male squirrel monkeys was determined by FM telemetry during the formation of status orders assessed with a full pair comparison design on six occasions over a 3-wk. period. Heart rate is related to rank on the status order by a curvilinear function with the middle-ranking animals showing the lowest heart rate during test sessions, but not during base-line measures taken in the home cage. This function is similar to that found previously for chickens establishing dominance orders. Relations between selected squirrel monkey behavior patterns, such as scratching and the penile display, are described.

Many animal societies develop highly ritualized behavioral patterns that are used in the formation and maintenance of dominance or status orders. Some observers suggest that these orders have a survival function by reducing aggression within the society, for once the order is established, overt aggression appears to decrease significantly. If so, the autonomic changes believed to accompany intense emotional states, such as those accompanying aggression, should be related to the establishment, maintenance, and change of position of individual animals within the dominance or status order.

This relationship has been found in domestic chickens, a form of life known for conspicuous aggression during the formation of dominance orders. Working with White Leghorns, Candland, Taylor, Dresdale, Leiphart, and Solow (1969) found that telemetered heart rate was related to the dominance order in three major ways. First, heart rate increased dramatically when birds were first exposed visually to one another. Second, during visual exposure, but before competition was permitted, the birds which were to fight to a standoff or to lose when permitted to compete showed greater increases in heart rate than those which won or failed to compete. Third, the relationship between dominance rank and heart rate when birds were exposed visually to one another, but before they were permitted to compete, was U shaped with the alpha and omega birds showing the highest heart rate.

Because the domestic chicken engages in a highly species-specific aggressive behavior in forming the dominance order, it is possible that the findings relating heart rate to aggression are characteristic only of domestic fowl and closely related species which form dominance order by intense combat between members upon first meeting. In order both to determine the extent to which these findings could be generalized and to document the development of status orders in a nonhuman primate, heart rate was recorded during the development of the status order of the squirrel monkey, a New World primate on which extensive laboratory work, but little field work, has been carried out.

From the studies of Baldwin (1968), DuMond (1967), Ploog, Blitz, and Ploog (1963), Ploog and McClean (1963), Ploog (1967), and Thorington (1968), it is be-
lieved that the male squirrel monkey maintains a loose status order during the non-breeding season of the year. Isosexual relationships are formed, with males spending a majority of their time in proximity to other males. During the breeding season, which lasts approximately 3 mo., a strong status order is established among males, apparently involving use of the "genital display." This display may be described as occurring when one male approaches another and "the displaying monkey bends over its partner seeming to jab the partner frontally with its penis [Ploog, 1967, p. 152]." During the display, the monkeys may be in direct physical contact, or the display may be given from a distance of up to 5 ft. Occasionally the recipient crouches, submissively wrapping his tail around him. The display may be given to another monkey, to a human being, or to the displayers' reflection. Penile erection always accompanies long displays, but it is sometimes absent in displays of short duration. From both field and laboratory observations it has been observed that the monkey which displays and which achieves a sign of submission from the animal to which he displays is dominant over that animal in selection of mate, the ability to steal food from the submissive animal without retribution, and like behaviors commonly associated with dominance.

The purpose of these studies was to determine (a) the relationship, if any, between heart-rate change and the development of status orders in male squirrel monkeys, and to determine (b) the behavior patterns which accompany and, perhaps, determine or limit aggression in the squirrel monkey.

**Method**

**Subjects**

Five male *Saimiri sciureus* were used. All were estimated to be 4½-5½ yr. of age. The weight range of the males was 630-880 gm. The animals were selected from the supplier in such a way as to minimize the possibility of their having been housed together. When removed to the laboratory for environmental conditioning each was housed individually so he could not see other monkeys.

**Apparatus**

An arena similar to that used for chickens by Candland et al. (1969) was used. The arena, 6½ ft. long, 4 ft. deep and 5 ft. high, is shown in Figure 1. Runways composed of ¾-in. wood are faced to form 9-in. squares 2 ft. from the floor.

When all partitions are lowered, animals cannot see one another because the partition marked B is opaque. If B is raised, the animals can see one another (Partitions A and C are of wire mesh) but they cannot approach or contact one another. Two windows, one at either end of the apparatus, were used to permit photographing and videotape recording.

Heart beat signals were detected by E & M self-adhering electrodes attached to an Onyx TSBC FM transmitter placed on the animal's back by a band of surgical tape. The transmitters weighed 16 gm. The assembly was placed on each animal each morning 3 hr. prior to testing. Pilot data on the effects of handling and stressing the squirrel monkey during the placement of the electrode and transmitter assembly showed that heart rate returned to a normal rate of responsivity within approximately 1 hr. The transmitters broadcast over different wavelengths between 88-102 mHz. The signals were received by FM tuners which relayed the signal into two monitors: (a) an oscilloscope used to monitor and tune in the beat (b) printout counters which cumulated the number of signals in 15-sec. blocks. A dipole antenna was used to pick up the transmission.

**Procedure**

Base-line heart rate was measured from all animals during the several weeks preceding the testing procedure. Records were made at different times during the day and under different laboratory conditions (e.g., people in the housing area, little or no noise, etc.) in order to derive a base-line rate representative of different environmental conditions. Prior to testing, animals were placed in the test chamber for varying periods of time in order to habituate the emotionality apparent from handling and from placement in a novel environment.

In order to assess the development of the status order, males were tested in a full pair comparison schedule in which each monkey met each other monkey on each of the testing days. Six such comparisons were made during a 6-wk. period with 1-3 days between the tests. The pair comparison schedules were prepared so that: (a) an animal did not appear in consecutive trials; (b) the side of the test chamber in which the monkey was placed varied; and (c) the pairings differed over...
the six sessions to prevent the monkey from predicting when or with whom he would be paired. The procedure for each pairing within the pair comparison schedule was as follows: One monkey was placed in each end compartment of the test chamber with the partitions lowered so the monkeys could not see one another. Approximately 6 min. were required to adjust the receivers before the trial began. Each trial consisted of five continuous periods during which heart rate was recorded continuously.

The nature and duration of these periods is as follows: (a) a preperiod in which all partitions were closed. The animals could not see each other, (b) a first exposure period, in which the opaque partition was raised, but not the wire partitions. The monkeys could see, but not approach one another. Approximately 6 min. were required to adjust the receivers before the trial began. Each trial consisted of five continuous periods during which heart rate was recorded continuously.

The nature and duration of these periods is as follows: (a) a preperiod in which all partitions were closed. The animals could not see each other, (b) a first exposure period, in which the opaque partition was raised, but not the wire partitions. The monkeys could see, but not approach one another. (c) the competition period, during which the wire partitions were raised, permitting the monkeys free access to one another since all of the partitions were raised, (d) a second exposure period, identical to the first, with the wire screens, but not the opaque screen, lowered, and (e) a postperiod with all partitions lowered, identical to the preperiod. All periods, except for the 5-min. competition period, lasted 2 min. Note that since the preperiod is indistinguishable to the animal from the time used by the experimenters to adjust the receivers, for the monkeys the preperiod lasts 3-8 min. At the conclusion of the trial, the monkeys were returned to their individual cages.

The runways in the apparatus were numbered and color coded to permit the experimenter to record the monkeys' location during each 15-sec. segment of the trial. In addition to location, the frequency of the following behavior patterns was recorded: self-scratching, penile displays, hand, foot, or tail biting, crouching, holding one another, stretching over the runways, and, when the partitions were raised at the onset of the competition period, which animal approached the other.

The exposure and competition sessions were recorded on videotape. The monitor was protected by a Plexiglas partition (Figure 1) which, because of its reflectance, occasionally was responsible for a male's displaying to the reflection. An identical partition at the opposite end of the test chamber was used for motion picture photography of segments of behavior during the trials.

The reflectance at the runways was 8.8 foot-candle and a white noise generator was used throughout the tests in order to minimize any effects of background noise.

Determining the outcome of a trial. Although the penile display is perhaps the most important behavior determining the outcome of meetings of male squirrel monkeys, other behavior patterns occur during these meetings which appear to be related to the establishment of the dominance hierarchy. The most important of these is that the dominant animal assumes an independence in regard to his movements. He is active, and whenever he moves, the submissive animal follows him, usually coming as close to the dominant animal as the latter will tolerate. The determination of the outcome of a contest—a win, tie, or loss—was made on the basis of independence. A winning animal consistently displayed to his opponent, maintained freedom of movement, and was often followed by his opponent. A losing animal did not display or, if he did so, replied to a display from the other animal by submission and either did not move or consistently followed the other animal. A tie resulted when neither animal displayed or showed independence or when both did so equally.
RESULTS

Effects of Handling

The paired comparison procedure required removing the monkeys by net and gloved hand from their individual cages to the apparatus four times during each session. Exploratory data on heart-rate changes resulting from handling show that this procedure is traumatic to the squirrel monkey and produces dramatic increases in heart rate. These increases subside rapidly, however, for heart rate returns to its baseline level within 2–8 min. following gentle handling. Nevertheless, heart rate during the preperiod is approximately 30 bpm higher than baseline. Whether this difference is due to handling, to placement in an unusual environment, or to both factors is not known; however, since the heart-rate increase due to handling alone dissipates in from 2–8 min., it is reasonable to believe that the testing situation is responsible for the increase in heart rate appearing during the pre- and other periods.

Status Rank

Figure 2 shows the change in status rank over the test days. The ordinate shows the number of wins, with a tie computed as half a win. It is evident that the dominance or status order derived from the first pairing bears little relation to the eventual order. Evidently, before an order is established, either sufficient time is required for the animals to recognize one another or the strangeness of the apparatus deters the kind of behavior requisite to establishing an order. By Session 5, black wins all pairings. Orange and yellow consistently defeat blue and red, but vary in regard to the outcome of the contest between themselves. Red and blue are consistently at the bottom of the order, although sometimes red submits to blue. The correlation between weight and dominance order (as determined by the total number of wins) is +1.00, showing that the heaviest animal is also the most dominant. This high correlation disappeared in the year following the dominance determination, although the order did not change. It is likely that weight (and its suggestion of strength) is an important factor in the establishment of the original status order, but that once the order is established, weight changes do not affect dominance relationships.

Status Rank, Heart Rate, and the Genital Display

During the first two test sessions, no convincing relationship appeared between heart rate and status rank. The chamber probably provided emotion-provoking qualities that served to deter interactions and the establishment of dominance, even though the animals had been placed in the apparatus individually during the weeks prior to testing.

During the third test session, activity was high and the number of genital displays increased markedly. Figure 3 shows the number of genital displays given by each animal as a function of test sessions. It is apparent that black and yellow gave the greater number of displays and that genital displays are not given by blue and orange after the first session. Black, the alpha animal, continues to display throughout the sessions, as does yellow.

The plot of the number of genital displays does not show, as some have suspected, that the displays necessarily cease
following submission of the animal displayed to, at least within the number of pairings reported in these observations. Rather, it appears that the displays continue to be given by the dominant animals, but disappear from the behavior of animals low on the dominance orders.

The relationship between heart rate and rank on the order during the first two sessions is inconsistent. By the third session, however, a function appears which is maintained throughout the remaining sessions. Figure 4 shows the relationship between heart rate and rank on the order as determined by number of wins. In all periods a curvilinear function appears forming a J or approximately U-shaped function. The omega squirrel monkey has the highest heart rate, and the midranking monkeys the lowest. These functions appear during all periods after the second test session.

Of special importance is the fact that when animals changed position on the order (e.g., orange and yellow changed, as shown in Figure 2, their heart rates changed accordingly, maintaining the curvilinear relationship. The implication of this result is that when dominance orders change, the heart rate of the animals changing position also changes. It suggests that rank determines the heart rate, rather than the reverse.

**Contest Outcome and Heart Rate**

For the chicken, the first exposure period produced different degrees of increase in heart rate which predicted the outcome of the eventual meeting (Candland et al., 1969). For example, chickens which lost or fought to a standoff showed much higher heart rate during the first exposure period than birds who won or did not fight. This relationship between the outcome of the contest and heart rate during the exposure period is not found with male squirrel monkeys. The heart rate for contests, whether rated as wins, losses, or ties, de-
increased for all animals during the five periods from approximately 245 bpm during the preperiod of 235 bpm during the postperiod. Although the heart rate of winning animals is consistently 5 bpm lower than that of animals who lose or tie, this difference is not statistically significant during any one period, but becomes so only if heart rate during all five periods is combined \( t = 5.24, df = 4, p < .05 \). The heart rate of winning animals is lower than that of those which lose or tie, but the importance of this is mitigated considerably by the fact that this slightly lower heart-rate occurs throughout the trial and is not differentiated for any particular experimental period.

**Relation of Genital Display to Other Behavior**

Observation of the behavior of squirrel monkeys suggests categories which constitute a large part of the animal's behavior, at least under the restricted environmental conditions of this experiment. These categories are self-scratching, huddling, crouching, biting or nibbling the hands or feet, and stretching over the runways. Of these, scratching is clearly the most frequent. There is evidence that frequency of scratching is related to the determination of dominance, for it is most frequent during the first three sessions and then declines rapidly. Frequency of scratching is highest among animals in the middle of the order (yellow and orange) and lowest among the alpha and omega animals. Thus scratching, like heart rate, when related to rank on the order produces a curvilinear-shaped function. No other behavioral category was consistently related to either heart rate or rank on the dominance order.

**DISCUSSION**

There is no doubt that the status order among male squirrel monkey is altered by seasonal variation. It has been reported that when squirrel monkeys are moved into northern climates their annual breeding cycle slowly shifts and eventually reverses itself so that births occur in late summer, rather than in the early months of the year as occurs in the natural habitat (DuMond & Hutchinson, 1967). It is uncertain how long this reversal takes, although it is evident that the rate of the change depends upon the age of the animal at the time of removal to the north and similar parameters. Because of the unknown state of these seasonal variations, it is impossible to identify the seasonal time of testing of the animals used in this study. In this study, the male's status order was assessed during June and July. If the monkeys had reversed their cycle, we would expect this to be the period of most intense status activity for the males, although the observation that the males failed to show the "fatted" condition characteristic of that period (DuMond, 1967) and their youth suggests that the reversal had not occurred.

The fact that rank on the dominance order is related to heart rate by a curvilinear function in species as disparate, both behaviorally and morphologically, as the domestic chicken and squirrel monkey, indicates that the function is of more than species-specific significance. Although the "phylogenetic spread" of the phenomenon is impressive, it would be inappropriate to consider the function as representative of animal life without establishing the relationship between heart rate and dominance or aggression in other species. Nevertheless, the appearance of the function in such different forms of life indicate that it is not inappropriate to consider hypotheses concerning the function; i.e., why would animals both high and low on the order show the higher heart rate? Or, conversely, why should midranking animals show the lowest heart rate? One possibility is that the noradrenalin/adrenalin ratio differs substantially in alpha and omega animals and has the result of generating different forms of behavior (flight or fight) while increasing the heart rate in both cases.

**REFERENCES**


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