RESEARCH REPORTS

Proximity, Sociality, and Observation: The Definition of Social Groups

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It seems likely that individuals would be especially attuned to the kinds of social grouping that typically occur in their own species. Consider for example a male hamadryas baboon who herds females when experimentally transferred to a savanna baboon troop (cf. Kummer 1968). He acts as if he is establishing and protecting a harem, and responds to females in terms of whether or not they are members of his harem. When the females enter estrus, however, it is clear that the savanna males do not behave as if this harem exists; this "group" of females that is recognized by the hamadryas male is apparently not recognized by the savanna males.

Among the Anthropoidea all but three genera are thought to form more or less stable social groups. Exceptions are the orang-utan, believed to be genuinely asocial, and spider monkeys and chimpanzees, where social grouping is the norm but where the size and composition of groups fluctuate daily or even more often (see, for example, Rodman 1973; Goodall 1973; Klein and Klein 1977). Probably no one would argue that the remaining anthropoids exhibit closed social groups with no immigration or emigration. Nevertheless, researchers have focused on the discontinuities between groups, for example by emphasizing the behavioral mechanisms that function in territorial defense, and thus perhaps have sometimes reified the notion of "group" more than is justified by the available data.

We examine some of the aspects of animal behavior that researchers might be perceiving when they report that groups exist. First, we suggest several ways that group membership can be operationalized. Then we systematically evaluate each in terms of how well it minimizes the discrepancies between group assignments made by one group of field-workers and proximity data on the same population recorded by another. Thus, this is a study of the process by which observations and inferences about social behavior are made.

We emphasize that, though the data in this paper derive from observations of mantled howler monkeys, *Alouatta palliata*, we do not wish to make strong claims about their behavior. The data set is small and somewhat problematic. Our primary purpose here is to explore some theoretical issues in the definition of social groups.

DEFINITIONS

Primatologists have used various combinations of contact, proximity, behavioral synchrony, social orientation, genealogy, and aggression to delineate group membership or group boundaries. In order to minimize human cognitive biases we believe that the definition of group membership should be formalized.

In this paper we use only co-occurrence data, a kind of proximity data, to define group membership. We explicitly disregard data on aggression, display, or other agonistic or group-isolating behaviors for the following reasons: (1) If individuals are group members *because* they often occur together, and exhibit agonistic behavior toward individuals with whom they rarely co-occur, then agonism is best regarded as symptomatic of grouped structure, not as causing or defining it. (2) If agonism is the norm between individuals that rarely co-occur, co-occurrence and agonism matrixes contain approximately the same information. (3) Some researchers have found that agonism is more frequent among the members of a single group than among members of different groups (Kurland 1977), because group members interact frequently. (4) Co-occurrence is more frequent than agonism and thus could provide a suitable data base for group assignments with a smaller commitment of field time.

In general, a consideration of the rates of any social behavior, whether agonistic or affiliative, depends on some measure of the opportunities for those behaviors. Proximity or co-occurrence are such measures, and their analysis is thus prerequisite to any more detailed study of social behavior.

Proximity Data:
The Co-occurrence Matrix

To simplify discussion, imagine a data matrix where each entry represents the amount of time that individual *i* spends in the company of individual *j*. We can call this a co-occurrence matrix. Also, we assume that the population can be partitioned into one or more nonoverlapping subsets: it consists of groups *(G, H, I,* etc.), and each individual monkey (*i, j, k, l, m,* etc.) belongs to one and only one group. Our basic framework for defining groups is:

> On the basis of co-occurrence, monkey *m* could be said to belong to group *G* if it spends more time with monkeys that are in group *G* than with other monkeys that are not.

This definition is too vague to be applied directly, but it can be made more precise in several ways, depending on what one means by more "time," "other" monkeys, and "with."

Operationalizing "Time" and "Other"

In defining "time," we distinguish between the total amount of time and the average amount of time that *m* interacts with each member of *G*. Whether "more time" in the above definition means "more total time" or "more time on average" will often make a difference in how individuals are assigned to groups. If, for example, a person spends more total time with nonfamily members than with family members, he or she would not be considered a member of the family group under a total-time operational definition of group membership. However, because families are fairly small groups, the average amount of time that an individual spends with each family member is often greater than the average amount of time he or she spends with each nonfamily member, and thus the individual would be considered a member of his or her family group when averages are used.

In defining "other," we distinguish between "out-group" and "criterion-group." This distinction can be illustrated by an anthropologist who interacts more with nonanthropologists than with members of her own department, even though she interacts more with members of her own department than she does with members of any other single department. Her "out-group" includes all nonanthropologists, but her "criterion-group" is the single other department with which she interacts most. Thus, if we say she is an anthropologist if she spends more time with anthropologists than with others, it will be important who these others are. If the comparison is to the out-group, she is not an anthropologist, but if it is to the criterion-group, she is.

In this paper, monkey *m*'s out-group includes all monkeys not in *G*. Its criterion-group is the one other non-*G* group with which *m* most frequently interacts, for example, *H*. Under the out-group definition of "other," *m* is not in *G* if he spends more time with out-group than with *G*, and under the criterion-group definition he is not in *G* if he spends more time with *H*.

Since these two dimensions, "time" and "other," are independent, they can be combined to form four distinct criteria for evaluating group membership (Table 1). Additional definitions may occur to the reader. We chose these four because they seem relevant, cognitively salient, and formally tractable.

Operationalizing "With":
Co-occurrence and Cosociality

The ideal co-occurrence matrix is one in which the ij^{th} entry represents the propensity of monkeys *i* and *j* to spend time together. Basically, there are three types of data that derive from three different data collection strategies: continuous, instantaneous, and ad libitum sampling (cf. Altmann 1974). Continuous samples yield actual *amounts* of time spent in various states, for example, the state of co-occurring with another individual. Instantaneous samples yield a *count* of the times that a subject is observed in each state. Either type of data can be used as co-occurrence data.

Researchers using continuous or instantaneous sampling often employ a probabilistic schedule to ensure that each animal has a known chance of being observed. Those who do not, or those who employ ad libitum sampling, must correct for "observer location bias," which results from the observer's tendency to watch certain animals more than the rest. In these cases, a different kind of data is produced, which we call *co-observation* data. We

Table 1. Four definitions of group membership.

"TIME"	"OTHER" Out-group	Other-group
Total	D1: A monkey is in group G if it *interacts more* with monkeys in G than with monkeys *not in G.*	D2: A monkey is in group G if it *interacts more* with monkeys in G than with monkeys in *any other group.*
Average	D3: A monkey is in group G if it interacts more *on the average* with monkeys in G than with monkeys *not in G.*	D4: A monkey is in group G if it interacts more *on the average* with monkeys in G than with the monkeys in *any other group.*

"Time" refers to average or total; "other" refers to co-occurrence or co-social data.

distinguish this sort of data, which is merely a record of the number of times each pair was observed together, from co-occurrence data proper, in which each datum represents some abstract propensity of two monkeys to be in one another's presence. The effect of observer location bias can be removed (approximately) by using a procedure developed by students of D. S. Sade at Northwestern University. The transformation is:

$$c_{ij} = no_{ij}/(o_{i.} + o_{j.} - o_{ij}), \tag{1}$$

where o_{ij} represents the number of co-observations of monkeys i and j, $o_{i.}$ is the number of times monkey i was seen, $o_{j.}$ is the number of times monkey j was seen, n is the total number of observations, and the result, c_{ij}, is the estimated propensity of i and j to co-occur. This transformation is important, since the data used below are co-observation data derived from ad libitum samples, and must be adjusted for observer location bias.

Co-occurrence is one way to operationalize the concept of "with," but not the only way. Another possibility is to substitute for simple co-occurrence the more elaborate concept of *co-sociality* (Kurland 1977:50ff.). For example, imagine an unfriendly individual that rarely interacts with others. This individual might logically be assigned to the group he or she interacts with most, even though the amount he or she interacts with that group is lower than the amount some other more sociable out-group individual interacts with that group. While humans may intuitively adjust for such differences in sociality, Kurland has proposed a formula to convert the co-occurrence data into what we call a co-sociality matrix. Kurland's formula (13) in our notation becomes

$$s_{ij} = c_{ij}/(c_{i.} + c_{j.} - c_{ij}), \tag{2}$$

where c_{ij} is the co-occurrence of i and j, $c_{i.}$ is the total amount that i interacts with others, and s_{ij} is the co-sociality of i and j. That is, s_{ij} represents the propensity of i and j to associate after adjustments have been made for their different levels of sociality. Notice that equation 1 is syntactically very similar to equation 2. This is merely coincidental; the former converts co-observation data to co-occurrence data, and the latter converts co-occurrence data into co-sociality data.

We consider co-sociality to be a special case of co-occurrence in which individual differences in sociality have been factored out. These two definitions of "with" add a third dimension to our definitional framework. That is, D1 through D4 can be applied to either co-occurrence or co-sociality data.

EXPERIMENT 1

Methods

Beginning in 1972, and through June of 1973, R. W. Thorington and J. W. Froehlich captured, measured, uniquely freeze-branded, and released a large number of mantled howler monkeys *(Alouatta palliata)* on Barro Colorado Island (Froehlich and Thorington 1981). At the time of capture, the authors noted the "group" with which the animal was found, and subsequently released it near that group. These assignments to what Froehlich and Thorington call troops are subsequently used by them as units of analysis. Thorington provided both troop membership records and individual branding codes to Gaulin who collected ad libitum co-observation data on these marked animals (Table 2). Gaulin and his assistant systematically walked the trails in the northeast corner of Barro Colorado for ten weeks, beginning ten days after Thorington and Froehlich had finished marking for the season. Each monkey sighted was recorded as having been "co-observed" with all others present, so long as it was within approximately 8 m of its nearest neighbor.

In experiment 1 we try to fit Thorington's troops, the co-observation data, and the definitions together, using this procedure: we take the prior assignment of monkeys to troops to be correct for all monkeys but one. Then we determine which, if any, of the group definitions classifies the remaining monkey in the group that is consistent with Thorington's prior assignment. This is repeated for each monkey, so that each definition receives a score equal to the number of monkeys it classifies consistently (0 to 17). Two types of data (co-occurrence and co-sociality) crossed with four definitions yield eight trials. This procedure is modeled after Allen's PRESS (Mostellor and Tukey 1977).

Results

The results of experiment 1 are displayed in Table 3. The columns represent the four group membership definitions, and the rows either co-occurrence or co-sociality data. Cell entries are the number of monkeys (out of 17) consistently classified. Note the following:

Definition 3 (D3) is slightly superior. It could match more closely what humans do intuitively when they put monkeys in groups.

Adjusting for individual differences in sociality has little effect. This suggests either that humans use some grouping criterion that is a mixture of co-occurrence and co-sociality, or

Table 2. Raw co-observation data on Barro Colorado howler monkeys.

			3	5	8	9	10	12	13	16	17	21	22	24	25	26	27	28	31
ad	F	3	4	1	1	0	0	2	2	0	2	2	1	0	0	2	1	0	2
ad	M	5	1	5	0	2	0	1	3	0	1	4	4	0	1	3	2	0	3
ad	F	8	1	0	7	0	0	3	1	0	2	3	2	0	1	1	2	1	2
inf	M	9	0	2	0	3	0	0	2	0	0	3	3	0	0	2	0	0	3
ad	F	10	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0
juv	F	12	2	1	3	0	1	9	1	2	3	3	3	0	1	1	3	4	1
ad	M	13	2	3	1	2	0	1	10	0	1	6	7	0	1	4	1	0	7
ad	M	16	0	0	0	0	1	2	0	6	0	1	0	0	0	0	3	2	0
ad	F	17	2	1	2	0	0	3	1	0	3	3	2	0	0	1	2	0	1
ad	M	21	2	4	3	3	0	3	6	1	3	13	8	0	1	4	4	0	7
ad	F	22	1	4	2	3	0	3	7	0	2	8	12	0	1	4	2	1	7
ad	F	24	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ad	M	25	0	1	1	0	0	1	1	0	0	1	1	0	2	0	1	1	1
juv	F	26	2	3	1	2	0	1	4	0	1	4	4	0	0	7	0	0	3
ad	M	27	1	2	2	0	1	3	1	3	2	4	2	0	1	0	7	0	2
ad	F	28	0	0	1	0	0	4	0	2	0	0	1	0	1	0	0	5	0
ad	F	31	2	3	2	3	0	1	7	0	1	7	7	0	1	3	2	0	11

Column labels are monkey id. numbers. Row labels give, in addition to id., the monkey's age (adult, juvenile, or infant) and sex. Each off-diagonal entry is the number of occasions on which the row-column pair was co-observed. Each time two or more monkeys were observed, each individual present was recorded as having been co-observed with all others present if it was within approximately 8 m of its nearest neighbor. Entries on the diagonal are the total number of times a monkey was seen.

Table 3. Results of experiment 1.

	D1	D2	D3	D4
OCC	6	7	10	7
SOC	5	7	10	8

OCC and SOC indicate the application of equations 1 and 2 respectively. D1 through D4 refer to the group membership definitions presented in Table 1. Cell entries count the number of monkeys "consistently" classified.

Table 4. Results of experiment 2.

Treatment			D1	D2	D3	D4
Count	0.0	OCC	6	7	10	7
		SOC	5	7	10	7
	0.1	OCC	7	8	10	7
		SOC	6	9	10	8
	0.5	OCC	8	9	9	7
		SOC	8	10	10	8
	1.0	OCC	10	10	9	7
		SOC	10	11	11	8
	5.0	OCC	11	11	11	5
		SOC	11	11	12	6
Root	0.0	OCC	7	9	8	4
		SOC	7	8	9	6
	0.1	OCC	10	10	8	5
		SOC	9	11	10	6
	0.5	OCC	11	11	8	5
		SOC	11	11	11	8
	1.0	OCC	11	11	9	7
		SOC	11	11	11	8
	5.0	OCC	11	11	11	4
		SOC	11	11	13	6
Log	0.0[a]	OCC	6	3	7	6
		SOC	10	7	11	5
	0.1	OCC	6	4	10	6
		SOC	7	7	11	6
	0.5	OCC	8	5	10	6
		SOC	7	4	10	5
	1.0	OCC	6	8	8	6
		SOC	7	9	10	6
	5.0	OCC	11	11	10	5
		SOC	11	11	10	5

Treatment refers to the unique combination of data transformation, start, and data conversion. OCC and SOC indicate the application of equations 1 and 2 respectively. After OCC and SOC, a Start of between 0.0 and 5.0 is added. Then, either no transformation (Count), square root (Root), or base 10 logarithm (Log) is taken. D1 through D4 and cell entries are as in Table 2.

[a] For Log, .001.

that these monkeys did not differ significantly in sociality.

The prior group assignments do not match the data very well for any combination of group definition and data conversion. The best combination consistently classifies less than 60% of the monkeys.

EXPERIMENT 2

Methods

The data collection strategies discussed above, continuous, instantaneous, and ad libitum sampling, produce "count" (of instances) or "amount" (of time) data. Statisticians customarily reexpress such data using logarithm or square root transformations because the transformed values better satisfy the assumptions implicit in using such statistics as the arithmetic mean. Another adjustment made to count data is to add a small "start" constant to each datum, especially in small sample situations (Tukey 1977:59ff.; Hays 1973:809).

In experiment 2 we see if any of these technical data treatments improve the fit between intuitive assignment and co-observation data. We repeat experiment 1 using starts of 5.0, 1.0, 0.5, 0.1, and 0.0 on the co-occurrence and co-sociality matrixes, on the log of each matrix, and on the root of each matrix. Three transformations by five starts by two kinds of data by four definitions yield 120 trials.

Results

The results of experiment 2 are shown in Table 4. Treatment refers to a unique combination of data transformation (count, root, or log), start, and data conversion (co-occurrence or co-sociality). The principal results are:

Definition 3 remains superior for counts and logs, but definition 2 is slightly better when the square root transformation is used.

Disregarding definitions 1 and 4 (because they work so poorly), the prior group assignments are more consistent with co-sociality than with co-occurrence data.

Roots are the superior data transformation over a variety of starts and conversions.

Finally, despite the slight improvement produced by these more-sophisticated data treatments, at best only 65% of the monkeys are consistently classified.

EXPERIMENT 3

Methods

One of the things we have learned from experiments 1 and 2 is that the prior group assignments do not correspond particularly well to the co-observation data. Thus an important question is, Can the monkeys be assigned to groups in *any* way that will fit the co-observation data? To answer this question we use the single-link (a.k.a. minimum or connectedness) clustering method (Hartigan 1975, 1979) on the empirical co-occurrence data to assign each monkey to a group. The resulting empirical group assignments (using Thorington's identification numbers) are

<3,8,12,16,17,27,28>
<5,9,13,21,22,26,31>
<10>
<24>
<25>

which can be contrasted with Thorington's groups:

<3,8,9,12,16,17,24,25,26,27,31>
<5,13,21,22>
<10>
<28>

We "measured" the similarity of the above two sets of group assignments and found them to be quite different (Bernard et al. 1979). Therefore it seemed reasonable to explore whether the empirical groups fit the co-occurrence data better than the intuitive ones. To do this, we compare these empirical groups to the data in the same manner as in experiment 2.

Results

When the techniques of experiment 2 are repeated to classify monkeys into these empirical groups we do find a much closer fit between group assignment and co-occurrence (Table 5). Of course one might expect close agreement when the group assignments and the classifications are based on the same data, but this is not necessarily the case. First, the definitions themselves play no part in the clustering process, and second, if there were no genuine groups to be found in the co-occurrence data, then the fit between the data and empirical groups would be no better than that found in experiment 2. In Table 5 one can see the following:

Table 5. Results of experiment 3.

Treatment			D1	D2	D3	D4
Count	0.0	OCC	13	13	17	15
		SOC	14	14	17	13
	0.1	OCC	12	13	17	15
		SOC	13	14	17	13
	0.5	OCC	11	13	15	12
		SOC	12	14	17	13
	1.0	OCC	10	13	14	10
		SOC	10	13	17	13
	5.0	OCC	3	13	14	6
		SOC	3	13	17	10
Root	0.0	OCC	12	13	16	10
		SOC	12	13	17	12
	0.1	OCC	10	13	14	9
		SOC	10	13	17	13
	0.5	OCC	8	13	14	9
		SOC	8	13	17	13
	1.0	OCC	5	13	14	10
		SOC	4	13	17	10
	5.0	OCC	0	10	14	6
		SOC	0	10	17	10
Log	0.0[a]	OCC	17	11	17	14
		SOC	5	4	9	6
	0.1	OCC	17	11	17	14
		SOC	6	5	9	6
	0.5	OCC	17	13	17	14
		SOC	9	7	12	3
	1.0	OCC	12	13	16	12
		SOC	12	13	17	12
	5.0	OCC	0	10	13	8
		SOC	0	10	17	12

See legend for Table 4.
[a] For Log, .001.

Definition 3 is generally superior to other definitions, often reaching the perfect fit of 17 consistently classified monkeys.

Although the empirical group assignments are based on co-occurrence data they actually fit co-social data better for counts and roots. In the case of log transformations they fit co-occurrence and co-social data equally well.

No single transformation dominates overall, though counts and roots might be judged to be slightly superior to logs.

The most important conclusion from experiment 3 is that there are real groups in the data.

DISCUSSION

The four definitions proposed above, although superficially similar, do yield strikingly dissimilar results when used to compare group assignments, whether by field-workers or by clustering programs, with co-occurrence data. Thus our first conclusion is that an explicit definition of group membership is essential. Not only do carefully operationalized definitions behave differently from one another, so presumably do intuitive ones. Moreover, the behavior of intuitive definitions is essentially unpredictable.

Since this is primarily a theoretical paper, it seems worthwhile to consider how results such as these can be interpreted, even though, in this case, our conclusions must be tempered by the fact that they are based on a small data set and consider only one species.

In experiment 2, while no definition performed very well, D2, "a monkey is in group *G* if it interacts more with monkeys in *G* than with monkeys in any other group," and D3, "a monkey is in group *G* if it interacts more on the average with monkeys in *G* than with monkeys not in *G*," performed about equally well overall. One possible conclusion from this is that primatologists use a combination of D2 and D3 in recognizing groups. In experiment 3, however, D3 is clearly superior; this means that the groups in the data are D3 groups. The relative success of D2 and failure of D3 in experiment 2 could indicate that there is some unconscious human intrusion of D2 criteria into the group assignment process.

Given the superior performance of D3 in experiment 3 we speculatively explore what it might tell us about how the monkeys themselves discriminate groups. Because D3 is an out-group definition we suggest that these monkeys do not recognize the existence of groups other than their own. If they did we would expect some pattern in their behavior to reflect the existence of their criterion-group, in other words, D2 or D4 should have more consistently classified the monkeys. Second, D3 is based on average rather than total amounts of interaction. In a total-time definition, the interaction between a pair of individuals is, in a sense, extended to all other members of their groups; this seems to assume that the individuals recognize the groups and their membership. However, since D3 is an average-time definition, the opposite might be true for these monkeys; they might not recognize the groups and their membership, they simply recognize individuals. The fluid grouping that results would be consistent with the adjustment of group size to resource patch size previously reported for this population (Gaulin et al. 1980; Leighton and Leighton 1982).

It remains to be seen whether additional data will support these interpretations for the Barro Colorado *Alouatta,* or if they will generalize to other primates. There is considerable work to be done on the problem of how individuals, human or otherwise, perceive social environments and make judgments about them. The methods developed in this paper provide some theoretical tools with which such questions can be answered objectively.

NOTES

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Language, the Brain, and the Question of Dichotomies

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In 1981, Bradshaw and Nettleton reminded the large and growing community of scientists and scholars concerned with the study of the human brain that the weight of modern evidence argues against rigid dichotomies in the interpretation of hemispheric functions—particularly the shopworn verbal/nonverbal distinction—and in favor of continuities, differences in degree rather than in kind. That they found such a reminder necessary, in view of the data that have for years presented strong and increasing challenge to such schemes, is an unfortunate commentary on an apparently irresistible human urge, to which science is certainly not immune, to erect grand explanatory edifices on limited and often contradictory evidence. Since the early 1960s, we have been bombarded by an amazing and seemingly endless array of dichotomous models purporting to account for certain functional differences between the human cerebral hemispheres. Broad "qualitative," "processual," and even "stylistic" distinctions have been proposed and debated. To mention some of the more prominent schemes, differences between the left and right hemispheres have been characterized as verbal versus visuospatial (Kimura 1961), as analytic versus holistic/gestalt (Galin 1974; Nebes 1978), propositional versus appositional (Bogen 1969, 1975), serial versus parallel (Cohen 1973), focal versus diffuse (Semmes 1968), and a plethora of others, including at least one three-way formulation: propositional-appositional-dialectical (TenHouten and Kaplan 1973; Kaplan and TenHouten 1975; TenHouten 1976). More broadly, especially in the popular press, we have witnessed characterizations (caricatures?) of the analytic, chronic logic-chopping, "talking" left hemisphere, and the intuitive, esthetic, "feeling" right hemisphere.

At their best, such schemes have probably contributed something to our understanding (although it has never been very clear to me exactly what). In combination with the intriguing findings of "split-brain" researchers, they have certainly been of peculiar fascination to some anthropologists, who seem to believe them to hold simple answers to perplexing questions