Affiliation Structures in Groups of Young Children: A Computer Simulation

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Developmental Psychology, 1989, **25**, 805-811.

Abstract

Describes a computer program that simulates the emergence of affiliation networks in preschool groups and examines theoretical issues raised by the model, including general issues of validation. The simulation implies that triadic interactions, although observed in preschool groups, are not essential in the formation of affiliative structures (contra Strayer & Noel, 1986), and that in this age range, therefore, polyadic friendship groupings can be understood as sets of dyadic relationships. The model also demonstrates how group structures can be generated without reference to group-level processes (contrast Hartup, 1983). It also focuses attention on the role played by preference formation in social isolation, by demonstrating that inhibition of preferences can give rise to isolation. The model also suggests that social outcomes are best described by nonlinear functions (cf. Roberts, 1986).

Affiliation Structures in Groups of Young Children: A Computer Simulation

This paper examines the computer simulation of a basic aspect of human social organization-- the development of affiliative structures. Its goals are to examine the theoretical issues raised by the model and to demonstrate the usefulness of computer simulations in the study of social development.

Affiliation and Dominance

Ethological analyses of behavior have generally revealed two basic dimensions of primate social organization: affiliation networks, which reflect the ordered distribution of social preferences and cohesive behaviors within groups, and dominance hierarchies, which function to regulate disruptive or dispersive behaviors (Hartup, 1983; Strayer, 1980). Historically, structures of dominance and affiliation, modified by cultural constraints, have been evident in human societies even on the largest scales of political organization (e.g., Bloch, 1966; Syme, 1968) and economic activity (e.g., Braudel, 1982). Developmentally, stable dominance hierarchies have been shown to emerge in groups of children as young as 15 to 18 months, with stable affiliative networks emerging somewhat later and becoming coordinated with dominance structures during the preschool period (Strayer & Trudel, 1984). Dominance hierarchies apparently continue to be important throughout childhood and adolescence (Hartup, 1983; Savin-Williams, 1976). The sociometric literature suggests that this is true of affiliation also.

Dominance and affiliation structures are both thought to regulate or moderate other types of social behavior. For example, affiliation status has been related to frequency of affiliative behaviors (both initiated and received), attempts at social influence or control, and the distribution of social attention and altruistic behavior in groups (LaFreniere & Charlesworth, 1983; Hartup, 1983; Strayer, 1980), as well as to certain social cognitive variables (e.g., Strayer, Puentes-Neuman, & Tessier, 1987).

Computer modelling

Computer simulations offer several general advantages that make them particularly useful in scientific investigations. First, they have an intrinsic and powerful heuristic function, because they require that underlying assumptions and constructs be stated explicitly. This facilitates their articulation and examination. A second advantage of computer modeling is that successful simulations offer a convincing demonstration of the power of the constructs and theories that they incorporate (and perhaps their limits as well). A third advantage is that a successful simulation can explicitly demonstrate how molecular activities on one level are related to molar phenomena on a larger level. Thus simulations can increase our understanding of emergent properties and the minimum conditions necessary for their appearance. Finally, successful simulations afford the opportunity for manipulating the parameters that they incorporate, that is, for performing experiments that would be difficult or impossible to do in reality.

Computer modelling, as an approach, presents difficulties as well, of course. For example, the need to explicitly formulate underlying assumptions can be difficult in areas in which theoretical relationships are not phrased in the languages of mathematics or symbolic logic. Some of these difficulties will be apparent below, as they affect the model to be described.

The computer simulation of affiliative networks can serve several particular purposes, some related to the general advantages just described.

One is to clarify the types of interaction that constitute a logical minimum for the emergence of group structures. What is necessary in order for interactions to give rise to relationships? Or to social cliques? Triadic experiences, for example, have been proposed as necessary components in the formation of affiliative networks (Strayer & Noel, 1986). Triadic and polyadic interactions are, of course, frequently observed in children's play, and triadic interactions are thought to be essential in the formation of dominance hierarchies (Chase, 1985). However, it is difficult to determine empirically if such exchanges are essential or only peripheral to the emergence of early affiliative networks. In addition, simulations can potentially enhance our understanding of other aspects of group social structure, such as the conditions giving rise to social isolation or neglect.

A second function is to clarify the simplest set of functional categories required to adequately describe the consequences of social interactions. One such set is the tripartite division of social interactions into positive, negative, or neutral (e.g., Charlesworth & Hartup, 1967; Hartup, 1983). This division, derived from learning theory, is analogous to the ethological categorization of behavior as cohesive or dispersive. (Cohesive activity has a high probability of being followed by further social interaction, while dispersive activity has a low probability. A middle range, in which probabilities fail to differ from chance levels, would correspond to "neutral" behaviors.) Is such a simple scheme sufficient to account for the emergence of complex group structures, or does it need to be elaborated, perhaps by differentiating among component behaviors?

Additional questions remain to which a successful simulation can provide at least tentative answers. For example, just how much do positive or negative interactions actually alter the probability of future interactions, and how do these functions change over time? Are initial encounters more important than later ones, as the phenomenon of consolidation suggests (Cairns, 1979)? Or should recent encounters be weighted more heavily than earlier ones?

It is one of the strengths of computer simulations that the process of model construction provides information that helps to resolve such issues. To the extent that concepts and assumptions incorporated into a model are inaccurate, the model will tend to produce discrepant data. Thus by an iterative process of altering and retesting a series of provisional models, initial assumptions can be corrected or replaced until a good match is made with observed data (Bratley, Fox, & Schrage, 1987; Shahin, Iyengar, & Rao, 1984).

The process of validation carries an unusually heavy burden in an area like social development, in which mathematical relationships between factors have not been specified and must therefore be estimated empirically. We will return to issues of validation after describing the model, some details of which will appear arbitrary because the requirement for explicit formulation of concepts and relations outstrips current knowledge.

The Model

Initial parameters

The computer program described here allows the user to set certain initial parameters and the number of groups to be generated with them. These parameters include the size of the group, the number of iterations or opportunities for social interactions, and for each individual in the group, initial probabilities for friendliness, hostility, and gregariousness (i.e., the probability of initiating a social interaction vs. engaging in a solitary activity). Neutral interactions are then set so that the probabilities for a friendly, hostile, or neutral response sum to 1. Because children are assumed to be unacquainted at the beginning of the simulation, initial social preferences are all equal.

These probabilities are stored in separate matrices, whose rows indicate initiating individuals and whose columns correspond to social targets (diagonal values= 0). Initial values change during the course of the program in response to interactions between group members, as described below. Thus initially uniform values diverge as the number of iterations increases: social preferences are formed, and a history of social interactions accumulates.

Generating interactions: the simulation of social process

At each iteration of the program, each group member undergoes the following procedure: (1) Random processes are invoked to determine if the individual will engage in a social interaction or a solitary activity. If a solitary activity is chosen, the program goes to the next group member and step 1 is repeated. (2) If a social interaction is chosen, random processes are invoked to determine a target, given the initiator's preferences. (3) Random processes are again invoked to determine the outcome of the interaction. Because initiator and target each have three types of behavior (positive, negative, and neutral), nine outcomes are possible. The chance of each of these outcomes being selected is the product of the corresponding probabilities for the initiator and the target.

Following Strayer & Trudel (1984), only one sequence is stored to be used later to determine friendships: a friendly initiation that meets with a friendly response. However, as described in Table 1, all outcomes (with the exception of neutral initiation, neutral response) have consequences for future interactions because they change probabilities associated with initiation, selection, and outcomes.

At this point the interaction is finished and the program passes to the next group member. When all group members have been given a chance to initiate an interaction, the process is repeated, beginning again with the first individual, until the number of iterations set by the user is reached. If multiple groups have been requested, parameters are reset to their initial values and the next group is simulated.

Consequences of outcomes

While the values given in Table 1 reflect a long process of empirical adjustment designed to match program output with observed data (following procedures outlined in Bratley, Fox, & Schrage, 1987, and Shahin, Iyengar, & Rao, 1984), several principles also played a part in the structure of this section of the program. Most basically, friendly initiations or responses were thought to be reinforcing in the technical sense of that term: they increased the probabilities that the interaction would recur. Negative interactions were generally thought of as punishing, i.e., as decreasing probabilities. However, these consequences were not applied uniformly: hostile initiations and responses, for example, were assumed to increase the probability for future hostile encounters, following the principle of consolidation (Cairns, 1979) and the observed tendency for negative exchanges to be maintained and to increase over time (Patterson, 1976).

Insert Table 1 about here

To simulate the effects of consolidation, probability changes are relatively large at first, becoming smaller as the number of interactions increases. This was accomplished in two ways. First, all changes occur as a percentage difference between the old value and the limit for that variable. (Because there were no theoretical guidelines, the size of the proportional constant was determined empirically, by a long process of trial and error). Thus increases (or decreases) approach their limits asymptotically, growing progressively less. Secondly, in the case of preferences, these changes are further divided by a value (the square root of the number of iterations) which grows progressively larger, thus making changes late in the simulation smaller than those occurring earlier.

In order to successfully simulate neglected and socially isolated children, it became necessary to incorporate two different functions for defining minimum values for preferences. (In parallel with the sociometric literature, neglected children were defined as those choosing a friend but not themselves chosen by others, while isolated children were defined as those neither choosing nor chosen, using the criteria for significant friendship preference described below.) These two functions (referred to under "LL, lower limit" in the note to Table 1) modify the main functions given in the body of the table. In effect, they approximate a single complex function with a discontinuity at gregariousness= .275. This value marked the approximate bottom third of the groups used to validate the model (ranking children from least to most active), with gregariousness estimated from the relative frequencies of total friendly initiations.

<u>Criteria for friendship</u>

At the end of the program, the matrix mentioned earlier, that of friendly initiations that met a friendly response, is analyzed to determine significant friendship preferences. Following Strayer & Trudel (1984), preferences were determined by chi-square analyses, using a three-step process. First, each matrix was tested by an overall chi-square. If this was significant, each row was tested separately. If the row test was significant, individual cells were tested for positive deviation from the row mean. (All p values less than .01.) Significant individual cells identify preferred others, i.e., friendship choices. Mutual friendships occur when complimentary cells (i,j and j,i) are both significant. Neglected children have no significant column cells (indicating that they are not preferred by others) but do have significant row cells (indicating that they themselves have preferences). Isolated children have no significant column or row cells.

An alternative method for identifying significant cells is to examine standardized residuals in a quasi-independent log-linear analysis. This method is slightly less conservative, however, because in the chi square procedure, significant individual cells will sometimes be rejected because the row test is nonsignificant. The log-linear approach lacks such an intermediate test, and thus tends to identify slightly more individual cells.

Validation

The data used to validate the current model came from classroom observations of 10 naturally occurring groups of children (preschool or day care classes). These groups were originally described in a series of articles by Strayer and his colleagues, who have been interested in issues of affiliation and dominance (Lafreniere, Strayer, & Gauthier, 1984; Strayer, 1980; Strayer & Noel, 1986; Strayer & Trudel, 1983). Two groups were English Canadian (one from Vancouver, BC, another from Waterloo, ON), while the remaining eight were francophone groups from Montreal, Quebec. They varied in size from 14 to 19 and were age-graded (three-, four-, and five-year olds). Focal individual sampling was carried out, typically over a period of four, six, or eight weeks in the spring of the year, after children had a period of four months to become acquainted. Depending on the group, the minimum number of five-minute focal samples varied from 8 to 24 per child. These samples were usually videotaped, although a few groups were coded directly. The coding taxonomy assessed peer social initiations (e.g., turn toward, look, touch, kiss) and responses (e.g., turn away, cry, ignore). Only sequences that could be coded completely (initiator, action, target, and reaction) were used in subsequent analyses. Reported reliabilities exceeded 80%.

The adequacy of simulated data was assessed along several dimensions. The most important parameters were those assessed and discussed in the research literature: friendship choices, mutual friends, and children who are socially isolated or neglected. These parameters were initially tested against values in each of seven groups. When model development was substantially completed, data for three additional groups became available, and final validation procedures were carried out using all 10 groups.

The model successfully estimated major group parameters. As shown in Table 2, estimated total friendships and mutual friendships were close to observed totals in all ten groups. (Estimated totals were derived by averaging across sets of 10 simulated groups.) Paired comparison t-tests failed to detect significant differences in either total friendships ($t = .38$, $df = 9$, $p > .70$) or total mutual friendships ($t = .77$, $df = 9$, $p > .45$).

Insert Table 2 about here

The model also correctly estimated the number of neglected and socially isolated children. There were 19 neglected children in the observed groups (range, 0 to 4) and a mean of 19.0 in 10 sets of simulated groups (range 0 to 5 across all 100 groups); paired comparison $t = 0.0$, df=9, $p = 1.0$. Isolates totaled 18 in the observed groups (range 0 to 5) and averaged 16.1 in the 10 sets of simulated groups (range 0 to 4), paired comparison $t = .30$, df=9, $p > .75$.

Analyses were also carried out to ascertain how well the model estimated the number of friends and mutual friends per child when data were pooled across all groups. Even at this larger level of analysis, with its increased power, simulated data fit observed values. As shown in Table 3, t-tests comparing 163 real children with 1,630 simulated children indicated that mean values for friends and mutual friends were not significantly different in the two groups.

Insert Table 3 about here

In addition, overall tests failed to detect heterogeneity of variance between simulated and observed data, for both friendship choices ($Z = 0.69$, $p > .49$, two-tailed) and mutual friends ($Z = 0.71$, $p > .47$, two-tailed). Together with the failure to detect mean differences, these results indicate that the program successfully simulates the population from which the observed samples were drawn (within the boundaries imposed by the power of the tests). Following Devore (1982, pp. 311-313), Z tests rather than F tests were used to compare variances because Z tests do not assume that data are normally distributed while F is sensitive to violations of this assumption.

Although overall tests failed to detect heterogeneity of variance, for total friends, z-tests of proportions indicated that the program produced slightly more dual preferences than it should ($z = 2.51$) and slightly fewer single preferences (z= 2.54). Absolute differences were small, in keeping with the non-significant overall test: on average in a group of 15 children, one individual was incorrectly credited with two friendship choices rather than one.

Discussion

Validation

Validation is a critical process in model construction, especially when, as here, the underlying theoretical framework is not precisely quantified. As mentioned earlier, it is a strength of modelling that even when initial assumptions must necessarily be arbitrary, the simulation itself provides feedback about their correctness.

This self-correcting process, however, is not without problems. One difficulty concerns the criterion observations. A model is clearly no more trustworthy than the data used to validate it. Thus the initial selection of criterion observations is critical.

A different type of problem is encountered when a model, as here, meets most but not all of the tests proposed for it. Because a model, like any theory, is a simplified version of reality, we know prior to testing that its output will not match observations exactly. Discrepancies at some level are inevitable.

How serious must such discrepancies be before a theory is disconfirmed or a simulation revised? Clearly this is a matter of judgement, which turns in part on the centrality or importance of the parameter, and the practical uses to which the theory or simulation will be put (Bratley et al., 1987). Thus the same discrepancy will appear to be unimportant or serious, depending on other factors. In the present case, the statistical significance of the discrepant parameter (relative frequency of one friendship choice vs. two choices) is ambiguous because the corresponding overall test is nonsignificant. Even if statistically reliable, the discrepancy would remain conceptually unimportant because it has not been addressed in previous theoretical or empirical writings. And on a practical level, the discrepancy would be important only for certain fine-grain analyses, because it affects, on average, only one individual in a group of moderate size, and then only to the extent of slightly over-estimating the integration of this child into the affiliation network. It does not affect the total friendships formed in a group or the average number of friendships per child.

A third type of difficulty is perhaps more serious because it is inherent in the process of model building and theory construction, and it is more difficult to detect. Even a validated theory can be incorrect.

There is a presumption that any mathematical model that accurately simulates observed data reflects in its components and their relationships the components and causal relationships that physically underlie the observations that have been modeled. This presumption reflects the belief that a mathematical model (or for that matter, any theory) whose components and processes are at variance with actual components and processes will necessarily produce data that are discrepant with observed data, and thus be revealed as false.

However, it is possible for a mathematical model to generate very good approximations to observed data even though it incorporates ideas profoundly at variance with the actual structure of the phenomena it seeks to simulate. The classic example is the mathematical model of planetary movement proposed by Eudoxus and used by Ptolemy as the basis of his physical model of planetary motion (Lloyd, 1970, 1973). When such a model is supported by wider ideas and theoretical constructs, it becomes more difficult to recognize and correct its inaccuracies.

Thus the model presented here, even though successfully validated against 10 independent groups, might best be considered as incorporating tentative solutions whose trustworthiness varies according to the trustworthiness of the theories it incorporates. It is a first simulation of affiliation; it is not a definitive simulation.

Better simulations, of course, are identified by comparison with other models. Although the current simulation was compared with the provisional models that preceded it (as noted earlier), these comparisons are not presented here because of their inconclusive nature, which stems from the very large number of possible alternative models. For example, an indefinite number of new models can be generated by changing the values presented in Table 1. Thus the current model is only one among many similar models, with no guarantee that it is the best in its group. Rather, the validation process can only tell us at best that it is in the subset of models with a good fit. The most interesting comparisons, of course, would be with structurally different programs (e.g., with one incorporating triadic social interactions). However, given the indefinitely large number of such programs, each generated by a permutation of other values and parameters, any finding of "no improvement" would be inconclusive at best. Published simulations, however, present a different case, because they specify an unique alternative. The current simulation is presented with the hope that it will stimulate others to write programs that will replace it, and which will in turn be replaced by other, even more accurate, simulations.

Thus the current model, like all simulations, can make no claim to being optimal. It is, however, a workable model because it has been successfully validated, and this allows us to draw some tentative conclusions concerning the theories incorporated into it. We will now briefly consider some of these.

Social processes: Triadic interactions.

While triadic interactions are observed in preschool groups and have been thought to serve important functions in the formation of affiliative networks (Strayer & Noel, 1986), the model implies that it is not necessary to invoke triadic processes in order to account for group affiliative structures. To the contrary, it appears that for preschool children, polyadic affiliative structures are best understood as aggregates of dyadic relationships.

It is certainly possible that triadic processes may become more important with age. The work of Piaget (1983; Piaget & Inhelder, 1969) demonstrates that young children have difficulty in recognizing and coordinating multiple points of view, especially in complex situations such as group play. However, just as group play becomes more coordinated in the period between preschool and middle childhood, triadic and polyadic interactions may become more crucial in friendship formation: Friendship choice may be increasingly tempered by how well the child functions in the context of the clique as well as one-on-one.

This issue of the emergence and role of polyadic processes in friendship formation may be a particularly fruitful area for the interplay of modelling and empirical research. Observations of older children may reveal ways in which affiliative networks are increasingly influenced by the group milieu in which they emerge. Modelling, in turn, can help specify the most economical theoretical interpretation of these findings.

Socially isolated children.

Because traditional sociometric methods utilize only nominations received, social isolation necessarily reflects only the state of not being preferred by one's peers. In contrast, the observational methods and analytical procedures on which this paper is based utilize both received and initiated interactions in determining social structure. From this point of view, social isolation is equally the result of not being preferred <u>and</u> not preferring. The distinction may be important. For example, although Dodge (1983), among others, has reported behavioral differences in the interactions of children who subsequently are preferred or not preferred by peers (on the basis of sociometric nominations), the evidence may well be most applicable to the question of mutual friendships. Inappropriate social behaviors may explain why friendship choices aren't reciprocated by the target child; it is more difficult to see how they can account for lack of preference on the part of the initiator. Given that isolated children have the <u>same number</u> of successful friendly exchanges as other children with low rates of initiation, the question from a structural point of view is why these exchanges are distributed evenly across the group rather than focussed on one or two group members, as they usually are. As noted earlier, in order to successfully simulate social isolation and neglect, special steps had to be taken to inhibit preference formation in less active children (i.e., to more evenly distribute their preferences across other group members).

By demonstrating that lack of preferences, independently of quality of peer interaction, can lead to social isolation, the model complements ethological/observational approaches, which also implicate preferences. Thus the role of preference formation in social isolation, which has been largely neglected in the traditional sociometric literature, appears to merit research attention.

Emergent group structures.

Both affiliative networks and dominance hierarchies can be thought of as emergent social structures, that is, structures that are only apparent on the level of the group, and which only emerge over time, as they are co-constructed by group members. The development of group structures has often been thought to require group-level processes of some sort (e.g., Hartup, 1983).

In contrast, the model demonstrates how group structures such as affiliation networks can arise out of strictly dyadic interactions. That friendships should arise out of individual interactions is of course no more startling than the notion that learning results from experience. The challenge in both cases, however, is to specify the underlying processes. Thus the model does something of fundamental importance: it shows us explicitly and in detail how molecular social processes can give rise to molar social phenomena. In doing so, it suggests that we need to be cautious in assuming that group processes always need to be invoked in order to account for group structures.

Functional consequences of interactions

The model supports the contention that tripartite schemes for categorizing the functional consequences of social interactions are sufficient minima for understanding the formation of basic group structures (in the sense that more complex schemes are not needed). The model extends such schemes by suggesting that changes in probability should be specified by nonlinear functions, although the exact nature of these functions and the behavioral mechanisms to which they correspond remain unclear (cf. Roberts, 1986). This approach could also be used to test tripartite schemes by looking for an adequate two-fold model.

Consolidation and development

As described earlier, the model incorporates the principle of consolidation. Early choices and interactions, good and ill, lead to later friendships or lack of friendships, and as these early patterns become established with time, they become more difficult to change.

While the success of the simulation supports the notion that consolidation is an important factor in friendship formation and the stability of affiliative networks, it is important to note that the model does not address discontinuities such as changes in individual friendship choices over time and the ultimate fate of affiliative networks. Nor does it address developmental issues, since age and age-related changes are not incorporated into the model. Such topics would be a natural extension of the present work.

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Author Notes

I would like to express my gratitude to Fred Strayer, who very generously provided the original affiliation matrices used to validate this computer simulation. Copies of the program (and original code written in True Basic) can be obtained by sending a note to the author at WLRoberts@Cariboo.bc.ca.

Table 1.

Changes in Probabilities as a Consequence of Type of Interaction.

Initiation-Response	Consequences
1. Friendly-Friendly	Pf(i,t)= Pf(i,t) + .25*(.95 - Pf(i,t)).
	Pp(i,t)= Pp(i,t) + .35*(.50 - Pp(i,t))/ $\surd$(iteration).
	$P_g(i) = P_g(i) + .001*(1 - P_g(i))$.
	$P_f(t,i) = P_f(t,i) + .25*(.95 - P_f(t,i))$.
	$P_p(t,i) = P_p(t,i) + (.35*(.50 - P_p(t,i))/ \surd(\text{iteration})$.
	$P_g(t) = P_g(t) + .001*(1 - P_g(t))$.
2. Friendly-Hostile	$P_f(i,t) = P_f(i,t) - .05*P_f(i,t)$.
	$P_p(i,t) = P_p(i,t) - .25*(P_p(i,t) - LL)/ \surd(\text{iteration})$.
	$P_g(i) = P_g(i) - .005*(P_g - .02)$.
	$P_h(i,t) = P_h + .10*(.40 - P_h)$.
	$P_f(t,i) = P_f(t,i) - .10*P_f(t,i)$.
	$P_h(t,i) = P_h(t,i) + .20*(.40 - P_h(t,i))$.
3. Friendly-Neutral	$P_f(i,t) = P_f(i,t) + .15*(.95 - P_f(i,t))$.
	$P_p(i,t) = P_p(i,t) + .15*(.50 - P_p(i,t))/ \surd(\text{iteration})$.
	$P_f(t,i) = P_f(t,i) + .25*(.95 - P_f(t,i))$.
	$P_p(t,i) = P_p(t,i) + .25*(.50 - P_p(t,i))/ \surd(\text{iteration})$.

(table continues)

Initiation-Response	Consequences
4. Hostile-Friendly	$P_h(i,t)= P_h(i,t) - .10*(P_h(i,t) - .01)$.
	$P_p(i,t)= P_p(i,t) + .10*(.50 - P_p(i,t))/ \sqrt{}(iteration)$.
	$P_g(i)= P_g(i) + .001*(1 - P_g(i))$
	$P_p(t,i)= P_p(t,i) - .25*(P_p(t,i) - LL)/ \sqrt{}(iteration)$.
	$P_f(t,i)= P_p(t,i) + .10*(.95 - P_f(t,i))$.
5. Hostile-Neutral	$P_h(i,t)= P_h(i,t) + .10*(.4 - P_h(i,t))$.
	$P_p(t,i)= P_p(t,i) - .25*(P_p(t,i) - LL)/ \sqrt{}(iteration)$.
6. Hostile-Hostile	$P_h(i,t)= P_h(i,t) + .10*(.40 - P_h(i,t))$.
	$P_g(i)= P_g(i) + .001*(1 - P_g(i))$.
	$P_p(i,t)= P_p(i,t) - .25*(P_p(i,t) - LL)/ \sqrt{}(iteration)$.
	$P_p(t,i)= P_p(t,i) - .25*(P_p(t,i) - LL)/ \sqrt{}(iteration)$.
	$P_g(t)= P_g(t) + .001*(1 - P_g(t))$.
	$P_h(t,i)= P_h(t,i) + .20*(.40 - P_h(t,i))$.
7. Neutral-Friendly	$P_f(i,t)= P_f(i,t) + .25*(.95 - P_f(i,t))$.
	$P_p(i,t)= P_p(i,t) + .35*(.50 - P_p(i,t))/ \sqrt{}(iteration)$.
	$P_g(i)= P_g(i) + .001*(1 - P_g(i))$.
	$P_f(t,i)= P_f(t,i) + .20*(.95 - P_f(t,i))$.
	$P_p(t,i)= P_p(t,i) + .25*(.50 - P_p(t,i))/ \sqrt{}(iteration)$.
	$P_g(t)= P_g(t) + .001*(1 - P_g(t))$.

(table continues)

Initiation-Response	Consequences
8. Neutral-Hostile	$P_h(i,t) = P_h(i,t) + .10*(.40 - P_h(i,t))$. $P_p(i,t) = P_p(i,t) - .25*(P_p(i,t) - LL)/\sqrt{(iteration)}$. $P_g(i) = P_g(i) - .005*(P_g(i) - .02)$. $P_h(t,i) = P_h(t,i) + .10*(.40 - P_h(t,i))$. $P_p(t,i) = P_p(t,i) - .25*(P_p(t,i) - LL)/\sqrt{(iteration)}$.
9. Neutral-Neutral	no changes

Notes:

P_f = probability matrix for friendly initiation or response.

P_h = probability matrix for hostile initiation or response.

P_p = probability matrix for preferences.

P_g = probability matrix for initiating a social interaction (gregariousness).

i = initiator index; t = target index.

LL = lower limit = .115 - .005N when gregariousness is greater than .275, or .102 - .003N when gregariousness is less. When group size (N)= 14, these functions yield values of .05 and .06 respectively.

Constraints. The probability of initiating an interaction is not allowed to fall below .02 or to rise above 1. An upper limit of .95 is set on friendliness and .40 on hostility, and the sum of friendly, hostile, and neutral probabilities must equal 1. In addition, preferences for all other group members must sum to 1 for each individual.

Following the changes detailed in the table, the altered matrices are adjusted to reflect these constraints. The value originally changed as a consequence of the interaction is only altered if all other values have reached their lower limit.

Table 2.

Model Validation: Observed and Estimated Values for Number of Friendships and Number of Mutual Friends per Group.

Group	N	Total Friendships	Mutual Friends
Simon Fraser	14	17	6
Salami A	14	13	8
Saltimbanque A	14	18	10
Simulation Group 1	14	16.9	8.6
Simulation Group 2	14	17.4	10.6
Simulation Group 3	14	17.3	9.2
Salopette A	15	21	16
Simulation Group 4	15	21.5	12.8
Salami B	16	16	8
Saltimbanque B	16	25	14
Simulation Group 5	16	21.5	13.4
Simulation Group 6	16	20.0	12.2
Saltimbanque C	18	31	18
Salopette B	18	23	12
Simulation Group 7	18	28.8	17.6
Simulation Group 8	18	28.1	17.6

(table continues)

Group	N	Total Friendships	Mutual Friends
Waterloo	19	42	28
Salopette C	19	27	14
Simulation Group 9	19	34.2	21.8
Simulation Group 10	19	33.0	20.6

Note: Observed data are from Strayer (1980), Strayer & Trudel (1984), Strayer & Noel (1986), and LaFreniere, Strayer, & Gauthier (1984). Estimated values are averages from sets of 10 groups.

Table 3.

Model Validation: Pooled Means and Standard Deviations for Friendships and Mutual Friendships per Child

Variable	Mean	Standard Deviation
Total Friendships		
Observed (N= 163)	1.43	1.02
Simulated (N= 1,630)	1.46	.98
t = .418, df = 1,791, *p* > .67		
Mutual Friendships		
Observed (N =163)	.82	.88
Simulated (N = 1,630)	.88	.85
t = 1.035, df = 1,791, *p* > .30		

Note: Observed means and standard deviations were derived from 10 groups of preschoolers reported in Strayer (1980), Strayer & Trudel (1984), Strayer & Noel (1986), and LaFreniere, Strayer, & Gauthier (1984). Means and standard deviations for the model were derived from 100 simulated groups whose Ns matched the actual groups (14 to 19 children).

Table 4.

Model Validation: Distriution Analyses.

Variable		χ^2	p
Total Friendships			
N with 0 Friends:			
Observed:	20		
Simulated:	23.2	0.51	>.40
N with 1 Friend:			
Observed:	41		
Simulated:	31.9	2.02	>.15
N with 2 Friends:			
Observed:	35		
Simulated:	46.1	3.52	>.06
N with 3 or 4 Friends:			
Observed:	19		
Simulated:	13.8	1.42	>.20
Mutual Friendships:			
N with 0 Mutual Friends:			
Observed:	49		
Simulated:	48.0	.02	>.80
N with 1 Mutual Friend:			
Observed:	40		
Simulated:	41.2	.04	>.80

(table continues)

Variable		χ^2	*p*
N with 2 Mutual Friends:			
Observed:	20		
Simulated:	22.2	.24	>.60
N with 3 or 4 Mutual Friends:			
Observed:	6		
Simulated:	3.6	.96	>.30

Notes: Observed data are from Strayer (1981) and Strayer & Trudel (1984). Simulated values are averages from 10 sets of 7 groups.