DOI: http://dx.doi.org/10.7551/978-0-262-31709-2-ch090

Sim*ian*World - A Study of Social Organisation Using an Artificial Life Model

Sue Attwood, Lola Cañamero and Rene te Boekhorst
Adaptive Systems Research Group, University of Hertfordshire,
College Lane, Hatfield, Hertfordshire, AL10 9AB

s.c.attwood@herts.ac.uk, l.canamero@herts.ac.uk, r.teboekhorst@herts.ac.uk

Abstract

In studies of social behaviour it is commonly assumed that individual complexity is the origin of intricate social interactions. In primates for example, social complexity is attributed to their intelligence and it is argued by many that the cognitive capacity of primates are especially manifest in the way they regulate their social relationships. Whereas the complex societies of non-human primates are considered to be as a direct result of their cognitive abilities this assumption is not made about social insects. In the absence of certain cognitive abilities their complex societies and structurally sophisticated nests are thought to arise from self-organisation. Since it is unlikely that cognitive capacities are all-or-nothing, usually integrating a range of mechanisms, it is possible that different species use similar cognitive mechanisms resulting in different behavioural outcomes.

Introduction

When observing and analysing complex systems, such as social structure, scientists tend to use separate explanations for each observed part or component of that system. Furthermore, they tend to explain the cause of complex patterns of behaviour observed at a higher lever (such as the relationship or the group) as if it resides within individuals, Hemelrijk (2004). In studies of social behaviour it is commonly assumed that individual complexity is the origin of intricate social interactions. In primates for example, social complexity is attributed to their intelligence and it is argued by many that the cognitive capacity of primates are especially manifest in the way they regulate their social relationships, Tomasello and Call (1997). In contrast, the complex organisations of social insects with large colonies and structurally sophisticated nests (honey bees for example) are not attributed to intelligence, their cognitive abilities are known to be limited and so any complex traits displayed are thought to arise from self-organisation, Hemelrijk and Puga-Gonzalez (2012). Explaining aspects of behaviour as different intelligent or rational decisions, leads scientists to come up with theories to integrate these separate aspects. The problem with such theories is that they tend to be complicated and assumption loaded. There are considerably more possible reasons why cognitive capacity might not be found than there is evidence of their existence. Until such evidence is found the most parsimonious assumption should be that species, closely related or not, that show similar solutions to similar problems are likely to use similar cognitive mechanisms. It is therefore, theoretically possible that different species achieve similar outcomes in different ways and that unique outcomes do not always mean unique processes, de Waal and Ferrari (2010).

This paper describes an individual-orientated, agent-based model called Sim*ian*World. Sim*ian*World can be reasonably called an example of Artificial Life, *Artificial* because it is not designed to be in close correspondence with any previously observed life forms; *Life* because it expands our observable universe with entities who “live lives” in which we can observe patterns normally pre-eminently associated with real life, Hogeweg (1988).

As is typical for Artificial Life, the present study uses a bottom-up approach to generate hypotheses and alternative explanations for complex behaviour and social relationships in terms of simple behavioural rules, limited cognitive assumptions and environmental structure.

Sim*ian*World incorporates a simplified version of some aspects of animal behaviour and represents a kind of caricature. The advantage of a caricature is that by exaggerating patterns they become more visible, Hemelrijk (1999). In contrast to the naturally incomplete explanation of animal behaviour, Sim*ian*World’s complete description allows us to establish what factors and dynamics are responsible for the emergent social patterns. If patterns of behaviour happen to correspond to those observed natural systems new hypotheses for existing explanations may be derived from the model. Such hypotheses are often counter-intuitive and innovative.

Non-Human Primates as Study Objects

To understand the role of positive and negative affect-based interactions in the formation of social relationships as a response to internal state and environmental conditions, non-human primates are good study objects. This is because the social organisation of many nonhuman primate species relatively simple compared to that of humans but complex enough to be interesting. Primates have varied and diverse ways of expressing themselves socially and form various kinds of relationships. Furthermore, studies of non-human primates have illustrated the link between negative and positive affect-based interactions and social structure by relating dominance hierarchy to despotic and egalitarian societies.

From the observation that most primates live in groups, the rational deduction is that sociality must be a beneficial trait. The main advantage of group life is assumed to be protection, either against predators, van Schaik (1983) or against conspecific rival groups, Wrangham (1987). Competition plays an important but different role depending on your viewpoint. To van Schaik, competition for food with other group members is an inevitable consequence of group life and this, together with its benefits, determines optimal group size. Wrangham (1980; 1987), in contrast, sees competition between groups as the ultimate cause of sociality, in that large groups can displace smaller ones from vital resources. van Schaik combined within-group and between-group competition in an extended model, van Schaik (1989), to arrive at more detailed predictions on social relationships. He also added two different types of competition, contest competition, which occurs when individuals compete directly over resources, and scramble competition, which is based on the assumption that individuals lose resources because other group members have already used them. From the resulting combinations, van Schaik drew up a classification of primate social systems into competitive regimes. The matching types of social organisations in terms of "despotic" or "egalitarian" societies, Vehrencamp (1983), are then interpreted as predictions. For example, if ecological conditions lead to contest competition between groups, the formation of alliances will be important and therefore dominants must relax contest competition within the group. Otherwise subordinates might either refrain from taking any risks in between-group contests or even defect to another group, van Hooff and van Schaik (1992). Thierry et al. (2004) suggests that macaques are a particularly good model genus for studying the above model of primate social organisation. There are approximately 21 genetically closely related macaque species that can be classified both by diet (type of food available), distribution of food and by social relationships (despotic or egalitarian), Thierry (2006), van Hooff and van Schaik (1992).

Artificial Life Models of Primate Social Organisation

te Boekhorst and Hogeweg (1994) used individual oriented models of "artificial apes" to study the formation of social groups based on simple gender differences in looking for food (by females) or females (by males). Limited manipulations of the rules and the environmental conditions lead to the emergence of chimpanzee-like or orangutan-like group structures. The model thus arrived at alternative explanations for observed social structure without the need of either neo-darwinist assumptions about kinship selection, reciprocal altruism and optimal foraging theory or conjectures about sophisticated cognitive capacities. Hemelrijk (1999), has shown that dominance hierarchy, spatial social structure (with dominants in the centre of the group and subordinates at the periphery) and social organisation (despotic versus egalitarian societies) all emerged in an artificial world in which the behaviour of the agents was steered by only a few basic social rules (if lonely approach others, if others are too nearby either flee or chase them away), limited cognitive capacity (chase away another agent if its perceived dominance is lower than that of your own) and simple social dynamics (dominance of an individual increases especially if it wins by accident against expectation). The model also resulted in similarities and new insights about the relationship between aggressive behaviour, dominance and social structure as found in the macaque species studied by Thierry.

In summary, the above mentioned Artificial Life models studied either the effect of food type and food distribution on the composition of groups, but did not address social relationships, te Boekhorst and Hogeweg (1994) or they studied the emergence of social relationships and structures based on dominance interactions but without modelling food resources, Hemelrijk (1999). As such they incompletely addressed the framework of van Schaik (1989). One of the objectives of this research is to combine the social aspects of the Hemelrijk model with ecological resources modelled by te Boekhorst and Hogeweg (1994).

Higher-levels of Affective States

The above mentioned Artificial Life models adopt a very simple implementation of affective states and affect-based interactions (mainly leading to group members moving away or staying close to other agents). However, in real life affective states are more complex and include for example emotions, drives, pleasure, pain, attitudes, moods and values. At this point it is important to distinguish between motivations and emotions. Motivational states such as hunger and thirst, for example, are drives that constitute urges to action based on internal needs related to survival and are seen as homeostatic processes which maintain a controlled physiological variable with a certain range. Emotions however, can be regarded as second-order modifiers or amplifiers of motivation, Cañamero (1997). Neurobiology attempts to characterise emotions as complex reflexes that regulate control mechanisms to excite or inhibit response to stimuli - both internal and external.

Motivational and emotional mechanisms have been attributed with complementary roles - while motivation is concerned with the operations of appetitive processes that try to activate action as a response to deprivation, emotion is derived from processes that try to stop ongoing behaviour i.e. it is concerned with satiation and equilibrium, Cañamero (1997). Disciplines as diverse as psychology, neurobiology, and philosophy have studied the nature of emotions. These diverse disciplines have focused on different aspects of emotional phenomena, sometimes proposing incompatible theories about them. However, they all share the same underlying idea: that emotions, whatever they are, have an adaptive value – they serve a purpose. This hypothesis is known as the functional view of emotions, Cañamero (2001). Attempts to integrate higher level affective states into agent architectures has been receiving increasing attention in Artificial Life and Cognitive Science. Proposed reasons for this, Cañamero (2001), are that affective agent-based systems can be used in the following ways:

1. As a test bed for theories about affective states in animals and humans, a synthetic approach that complements analytical studies of natural systems.

2. To explore the role that affective states plays in biology in order to develop and exploit mechanisms that ground and enhance autonomy, adaptation and social interactions.

Implementation of Affective States in the Sim*ian*World Model

The Sim*ian*World agent architecture consists of motivational states and behaviours. There are two homeostatic variables that correspond to the internal resources of energy and sociability. Together these variables represent the internal state of an agent and each has an "ideal state" (i.e. a set point or norm value). The degree to which each variable deviates (the error) from this ideal state constitutes internal stimuli and directly influences agent behaviour. The agent's motivational states are abstract representations of a propensity to behave in a particular way as a result of a combination of internal and external stimuli.

The Agent Architecture

External stimuli comes in two forms, the first of which is clumps of food. By eating the food agents modify both the external environment and their own internal level of energy. The other type of stimulus is the agents themselves. The presence of other agents stimulates social behaviours (like groom and attack for example) that modify the agent's internal level of sociability.

So, the motivational state is the mechanism that corrects the level of error in the homeostatic variables representing physiology through the execution of appropriate behaviours. How the agents react in social situations such as eating or resting for example, and how they interact, will largely depend on the distribution pattern of food (the amount, distribution and renewal rate of food can be closely controlled). Interactions can be of either a positive nature, like grooming for instance or be negative in nature, as in the case of an attack. When calculating motivation intensity and thereby activating a behaviour it is fundamental to define a rule combining external and internal stimulus. Sim*ian*World uses the following method:

1. The motivation j is calculated in the following way: For each motivation j:
   - i Calculate the intensity of the motivation's drive, proportional to the error of its homeostatic variable $v(e_{v_j} \in [0, 1])$
   - ii Calculate the effect of the presence of external stimuli k influencing the intensity of the motivation j (an increased incentive): $s_{k_j} \in [0, 1]$
   - iii $m_j = e_{v_j} + (s_{k_j} \times e_{v_j})$ is the final intensity of j

The motivation with the highest intensity is selected and an appropriate behaviour activated.

2. The error is calculated in the following way:
   - i Calculate the distance between the set point and the limit: $ld_v = abs(l_v - p_v)$
   - ii Calculated the distance between the actual variable and the set point: $vd_v = abs(v_v - p_v)$
   - iii Calculate the normalised error

$$e_v = \begin{cases} vd_v/ld_v & if\ ld_v > abs(l_v - v_v) \\ 0 & otherwise \end{cases}$$

The way in which motivation and behavioural intensity are combined is a problem that has been extensively researched by ethologists. citetA24 demonstrated that a simple adaptive rule, Cue $\times$ Deficit: $m_j = s_{k_j} \times e_{v_j}$ gives the behaviour of an agent both opportunism and persistence.

The problem with this rule is the lack of motivational arousal in the absence of external stimuli. This model would prove fatal in models in which the motivational state leads to the selection of appetitive[1] behaviours.

Therefore Sim*ian*World uses the following extension to the formula proposed by Tyrrell (1993):

Deficit + Cue $\times$ Deficit: $m_j = e_{v_j} + (s_{k_j} \times e_{v_j})$

[1] Animal searching behaviour. The variable introductory phase of an instinctive behaviour pattern or sequence, e.g., looking for food or looking for others.

Behaviour	Homeostatic Variables	
	Energy	*Sociability*
Eat	↑	with others ↑ alone ↓
Groom (source)	↑	↑
Groom (target)	↓	↑
Attack (source)	↓	↓
Attack (target)	↓	↓
Find Others	↓	↓
Find Food	↓	↓
Wander	↓	↓
Avoid	↓	↓
Rest	↓	with others ↑ alone ↓

Table 1: Behaviours and their Effect on the Homeostatic Variables

Using the above method agents select a behaviour most likely to satisfy their immediate needs. For instance an agent whose energy level is satisfied (above the set point or norm value) but whose level of sociability is low may seek other agents (Find Others). However, finding others uses energy and at some point the agent may need to alter its behaviour. Every agent's levels of energy and sociability are calculated at each time tick, time ticks are regulated using the GetTickCount function in C^{++} which returns the system time in milliseconds. The sequence in which each agent is scheduled to activate its selected behaviour is reordered at each time tick.

Agents in Sim*ian*World are "individuals" possessing a behavioural repertoire that includes sensing their local environment, changing the environment and changing their own position in the environment. Each agent is initialised with the set point values of energy and sociability, in addition they are given a random starting position on the grid and a random direction. The grid squares that immediately surround each agent are designated as personal space with a further number of grid squares designated as their vision range, see Figure 1. The behaviours modelled by Sim*ian*World are: eat, attack, groom, wander, rest, find food, find others and avoid others, see Table 1.

The System Architecture

The system architecture has two elements; the agents and a simple ecology. The agents are homogeneous and live in a flat, boundary restricted world, their territory. The landscape has no features apart from clumps of food. The size of the territory can be altered but for the all the simulations

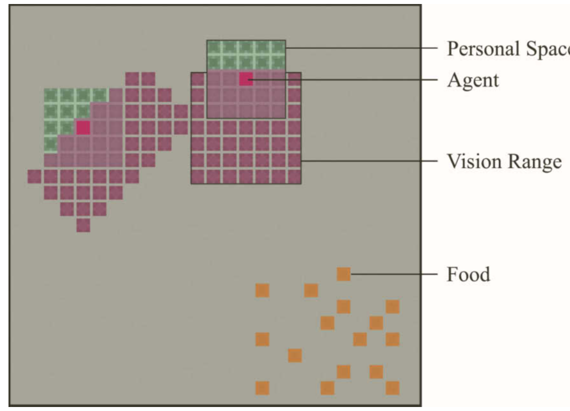

Figure 1: Snapshot of agents in Sim*ian*World

run to date this has been set to the maximum size of 130 x 115 (14950 grid locations). Agents can move in any direction – randomly choosen when the boundary is reached. The amount and distribution of food can also be closely controlled through the interface, as can the population size and vision range of the agents. There is a full graphical display of the simulated environment that shows the agents (displaying their field of vision is optional but is costly in terms of visual rendering) position within the grid and the location of food clumps, see Figure 2.

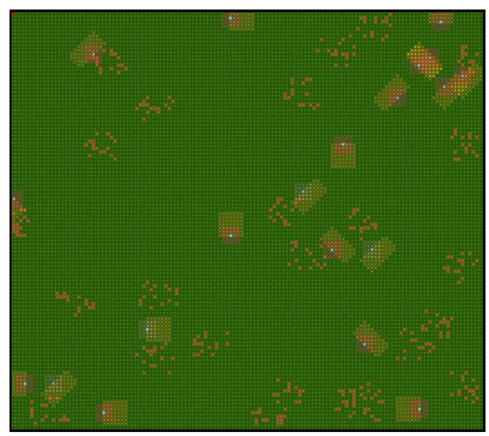

Figure 2: The Graphical Interface

Experimental setup

As a first experiment, we investigated the possible relationships between on the one hand measures of distribution and amount of food and on the other hand the reciprocation of dominance interactions (as a reflection of negative affect) and friendship interactions (as a reflection of positive affect). Reciprocation was crudely measured as the correlation coefficient between row and column totals of "dominance" and

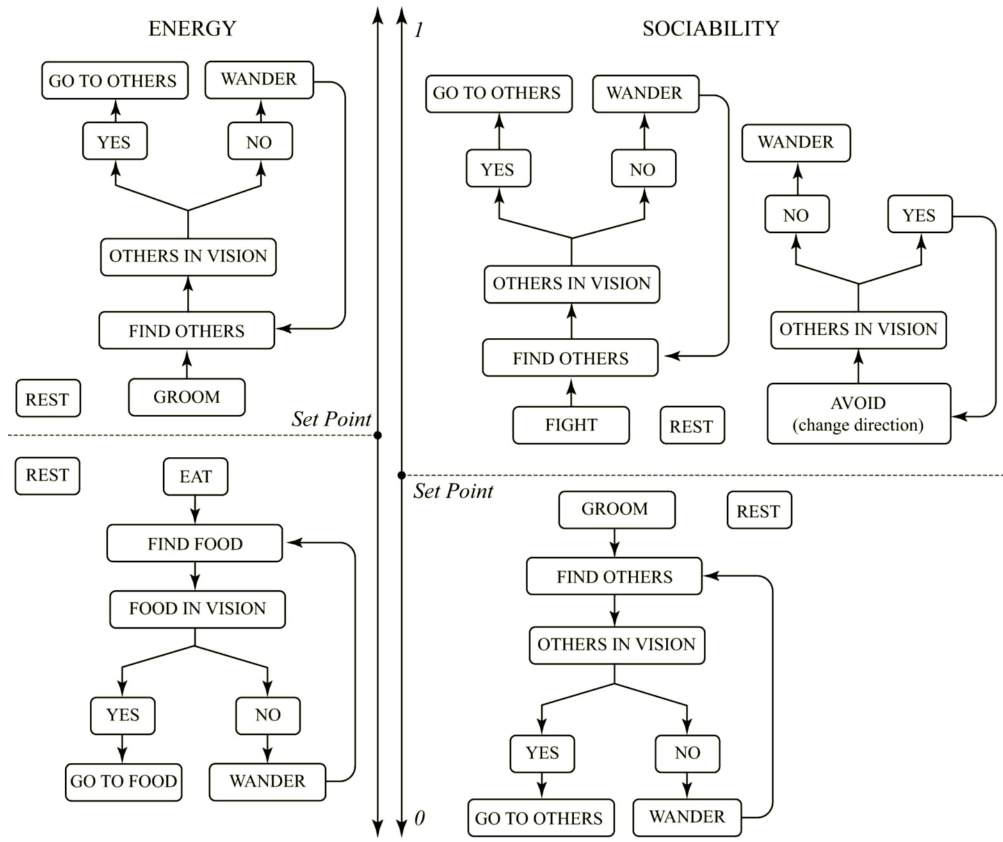

Figure 3: The Sim*ian*World Architecture

"friendship" matrices. These correlation coefficients were calculated for the following environmental conditions:

1. A large amount of food highly clumped
2. A small amount of food highly clumped
3. A large amount of food widely distributed
4. A small amount of food widely distributed

The distribution of food in clumps is calculated in a very simple way, the amount of food (set to between 1 and 500 grid squares occupied by food) is divided by the distribution level of food (set to between 1 and 25). Thus, 400 grid squares of food, divided by a distribution factor of 5 produces 5 clumps of food in 80 grid squares. At the start of a simulation, each clump begins at a randomly chosen grid square about which the required number of grid squares of food are closely grouped. Food is "consumed" by agents and can be renewed, rejoining a previously established clump at set time intervals (ticks). All the above mentioned variables are set at the start of a simulation run through an Options panel in the interface. The renewal rate of food is dependent on each combination in order to maintain initial conditions where possible.

For each of the 4 environmental conditions 5 runs were conducted with a population of 10 agents and 5 runs with 20 agents (40 runs in total). Each run consisted of 26010 time ticks and at every time tick each agent's internal state was assessed and an appropriate behaviour executed. During each run and at every time tick the agent's spatial position, behaviour, levels of sociability and energy were recorded. In addition, at intervals of 600 time ticks during the run a log was taken of all the positive and negative interactions and these were stored in the form of a matrix.

Each time two agents meet, their interactions were characterised as either negative or positive and these outcomes are summarised respectively in a "dominance" and a "friendship" matrix. The values of the cells in the matrix, reading from left to right, are the frequencies by which a row-labeled agent initiated an interaction with a column-labeled agent. Reading from top to bottom, the values are the frequencies by which a column-labeled agent received an interaction from row-labeled agents.

Accordingly, row-totals are the total frequencies agents started interactions irrespective the identity of the receivers, and column-totals are the overall count of interactions agents received (summed over all the initiating agents). In this sense a positive correlation between row and column totals implies that agents that initiated more interactions also received more of those interactions and thus functions as a crude measure for reciprocity.

Results

Although there were four different environmental conditions each tested with both large and small populations only some produced results that could be considered interesting. Interesting in the sense that the emergent social patterns indicated either despotic or egalitarian social structures.

1. With a large amount of food and a small population (10), negative reciprocation of dominance interactions implies agents initiate a greater number of "aggressive" interactions than they receive. Thus indicating a more "despotic" social structure. See Figure 4.

2. With large clumps of food and a large population (20) there is a negative reciprocation of dominance interactions. This implies that under these conditions agents ***tend*** to initiate more "aggressive" interactions than they receive. Indicating a more "despotic" social structure (results are not significant p = 0.06). See Figure 5.

3. With a low amount of food and a large population (20), negative reciprocation of friendship interactions implies agents tend to initiate a greater number of "friendly" interactions than they receive (results are not significant p = 0.09). See Figure 6.

Conclusion

Models of Artificial Life have in the past been used to study the effect of food type and food distribution on the composition (fission/fusion) of groups, te Boekhorst and Hogeweg (1994), but did not include any details of social relationships. They have also been used to study the emergence of social relationships and structures based on dominance interactions but without modelling food conditions, Hemelrijk (1999). The main objective of this research is to combine aspects of social relationships and ecological resources in one model and to study the structure of the societies that emerge.

One specific aim of this research is to relate the results of future tests to that of social structures found in nature (macaques).

Work to date has concentrated on building an individual-orientated, agent-based software prototype(Sim*ian* World) that uses an Artificial Life approach that incorporates a simplified version of some aspects of animal behaviour. In contrast to the naturally incomplete explanations of animal behaviour, the model's complete description allows us to establish what factors and dynamics are responsible for emergent social patterns.

	Pearson Correlation Coefficients	
	low amount	high amount
	-0.546	-0.395
low clumping	0.014	-0.266
	0.102	-0.566
	-0.246	-0.648
	-0.362	-0.694
	-0.608	-0.057
high clumping	-0.234	-0.479
	0.191	-0.503
	-0.495	-0.580
	0.303	-0.584

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Clumping	0.016	1	0.016	0.197	0.663	4.494
Amount	0.417	1	0.417	5.292	0.035	4.494
Interaction	0.002	1	0.002	0.019	0.892	4.494
Within	1.262	16	0.079			
Total	1.696	19				

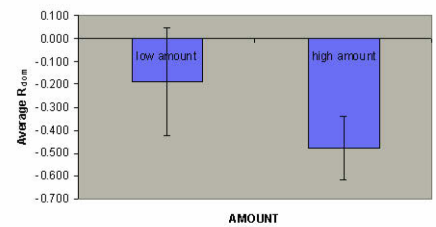

Figure 4: Analysis of Dominance Reciprocity under 4 Environmental Conditions (small population)

If patterns of behaviour happen to correspond to those observed natural systems new hypotheses for existing explanations may be derived from the model. Such hypotheses are often counter-intuitive and innovative. Sim*ian*World studied the impact of food availability (profuse/scarce) and distribution (clumped/dispersed) on the types of affective, dyadic relationships agents developed. This was based on the hypothesis that competition for resources in an environment influences the types of society (egalitarian or despotic) that emerge - results were statistically significant for reciprocity of social relationships when there is a large amount of food available and the population is relatively small. Negative reciprocation of dominance interactions implied that agents initiated a greater number of aggressive interactions than they received indicating a more despotic social structure. It is planned to include in the model a second order modifier in the form of a hormone-like mechanism. This will introduce a more biologically plausible sigmoid rather than a linear decrease/increase of the levels of energy and sociability, and will be designed to influence levels of aggressive versus friendly behaviour which characterise the types of social relationship of egalitarian or despotic societies. It is hoped that results will show statistical significance in tests for reci-

	Pearson Correlation Coefficient	
	low amount	high amount
	-0.533	-0.171
low clumping	-0.401	-0.380
	-0.438	-0.343
	-0.336	-0.366
	-0.590	-0.214
	-0.163	0.262
high clumping	-0.491	0.063
	-0.178	-0.444
	-0.260	-0.535
	-0.010	-0.195

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Clumping	0.166	1	0.166	4.072	0.061	4.494
Amount	0.058	1	0.058	1.423	0.250	4.494
Interaction	0.016	1	0.016	0.399	0.536	4.494
Within	0.652	16	0.041			
Total	0.893	19				

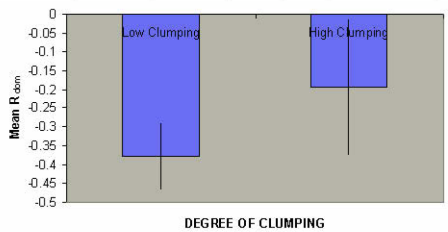

Figure 5: Analysis of Dominance Reciprocity under 4 Environmental Conditions (large population)

	Pearson Correlation Coefficient	
	low amount	high amount
	-0.619	-0.811
low clumping	-0.630	-0.610
	-0.895	-0.788
	-0.809	-0.511
	-0.953	-0.553
	-0.887	-0.811
high clumping	-0.872	-0.610
	-0.806	-0.788
	-0.739	-0.511
	-0.515	-0.550

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Clumping	0.000	1	0.000	0.020	0.891	4.494
Amount	0.070	1	0.070	3.329	0.087	4.494
Interaction	0.000	1	0.000	0.016	0.900	4.494
Within	0.335	16	0.021			
Total	0.405	19				

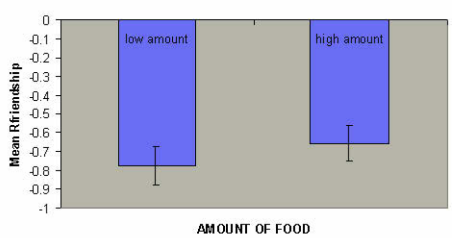

Figure 6: Analysis of Friendship Reciprocity under 4 Environmental Conditions (large population)

procity and bi-directionality of social relationships.

References

Cañamero, L. (1997). Modeling motivations and emotions as a basis for intelligent behaviour. In Johnson, W., editor, *Proceedings of the First International Symposium on Autonomous Agents*, pages 148 – 155.

Cañamero, L. (2001). Emotions and adaptation in autonomous agents: A design perspective. *Cybernetics and Systems: An International Journal*, 32 : pages 507 – 529.

de Waal, F. B. M. and Ferrari, P. (2010). Towards a bottom-up perspective on animal and human cognition. *Trends in Cognitive Sciences*, 14 : pages 201 – 207.

Hemelrijk, C. (1999). An individual-oriented model on the emergence of despotic and egalitarian societies. *Proceedings of the London Society*, 266 : pages 361 – 369.

Hemelrijk, C. (2004). The use of artificial-life models for the study of social organization. In Thierry, B., Singh, M., and Kaumanns, W., editors, *Macaque Societies. A Model for the Study of Social Organization*, pages 295 – 313. Cambridge University Press.

Hemelrijk, C. and Puga-Gonzalez, I. (2012). An individual-oriented model on the emergence of support in fights, its reciprocation and exchange. *PLOS ONE*, 7.

Hogeweg, P. (1988). Mirror beyond mirror, puddles of life. In Langton, C., editor, *Artificial Life, SFI Studies in the Sciences of Complexity*, pages 297 – 316. Addison Wesley.

te Boekhorst, R. and Hogeweg, P. (1994). Self-structuring in artificial "CHIMPS" offers new hypotheses for male grouping in chimpanzees. *Behaviour*, 130 : pages 229 – 252.

Thierry, B. (2006). The macaques: A double-layered social organization. In Campbell, C., Fuentes, A., MacKinnon, K., Panger, M., and Bearder, S., editors, *Primates and Perspective*, pages 195 – 218. Oxford University Press.

Thierry, B., Singh, M., and Kaumanns, W. (2004). *Macaque Societies. A Model for the Study of Social Organization.* Cambridge University Press.

Tomasello, M. and Call, J. (1997). *Primate Cognition.* Oxford University Press.

Tyrrell, T. (1993). *Computational Mechanisms for Action Selection.* Centre for Cognitive Science, University of Edinburgh.

van Hooff, J. and van Schaik, C. (1992). Coalitions and alliances in humans and other animals. In Harcourt, A. and de Waal, F., editors, *Cooperation in Competition: the Ecology of Primate Bonds*, pages 195 – 218. Oxford University Press.

van Schaik, C. (1983). Why are diurnal primates living in groups? behaviour. *Behaviour*, 87 : pages 120 – 144.

van Schaik, C. (1989). The ecology of social relationships amongst female primates. In Standen, V. and Foley, R., editors, *Comparative Socioecology, the behavioural ecology of humans and other mammals*, pages 195 – 218. Oxford: Blackwell.

Vehrencamp, S. (1983). A model for the evolution of despotic versus egalitarian societies. *Animal Behaviour*, 31 : pages 667 – 682.

Wrangham, R. (1980). An ecological model of female-bonded primate groups. *Behaviour*, 75 : pages 262 – 300.

Wrangham, R. (1987). Evolution of social structure. In Smuts, B., Cheney, D., Seyfarth, R., Wrangham, R., and Struhsaker, T., editors, *Primate Societies*, pages 195 – 218. University of Chicago Press.