JASSS

Stephen Younger (2005)

Violence and Revenge in Egalitarian Societies

Journal of Artificial Societies and Social Simulation vol. 8, no. 4
<http://jasss.soc.surrey.ac.uk/8/4/11.html>

For information about citing this article, click here

Received: 04-May-2005 Accepted: 08-Aug-2005 Published: 31-Oct-2005

Abstract

Discrete agent simulation was used to investigate the role of violence and revenge in model egalitarian societies. A population of 100 agents inhabited a landscape of 20x20 squares containing five sources of food. Agents moved about the landscape in search of food, shared, stole, mated, produced offspring, and ultimately died of old age. Violence and revenge reduced the survival probability of the population and, for surviving populations, replaced hunger as the second leading cause of death after old age. Excluding large segments of the population from violence and revenge significantly improved survival rates. Tolerance to transgressions reduced the number of agents killed in revenge attacks. Higher population density increased the number of revenge deaths but also increased the survival rate of the total population. Decreasing the food supply for a fixed initial population resulted in more deaths due to violence and revenge. Flight from known aggressors enhanced the survival of the total population, at the expense of social cohesion. When killing had a positive social value the survival rate of the total population increased as the number of revenge killings decreased. These results are discussed in the context of ethnographic observations of a number of egalitarian societies.

Keywords:
Violence, Revenge, Egalitarian Culture, Homicide, Population Density, Tolerance, Food Supply

Introduction

1.1

Violence and revenge were significant contributors to mortality in egalitarian cultures, i.e. those without significant hierarchical political structure and where group decisions were reached by consensus. Keeley (1996) concluded that homicide and warfare were more the rule than the exception among indigenous cultures - while the number of homicides per year may have been low in a typical band of 50-100 people, when integrated over many years homicide accounted for several tens of percent of all adult deaths. For the !Kung of the Kalahari, Lee (1979) reported a homicide rate of 29%. For the Gebusi of New Guinea, Knauft (1987) found that about one third of all adult deaths were due to homicide and that victims were almost equally divided according to gender. Among the Waorani of the Amazon, perhaps the most violent group ever encountered, the homicide rate was over 60% (Yost 1981). Almost every male member of the Copper Eskimo tribe was involved in one or more homicides (Keeley 1996). Finally, the Semai of Malaysia, considered among the least violent people on Earth, were particularly brutal when placed in a modern combat situation (Robarchek and Denton 1987).

1.2

There is considerable variation in the attributed causes of violence in different cultures. Among the Gebusi, approximately 80% of all killings were of suspected sorcerers and only about 4% were due to revenge (Knauft 1987). In contrast, Warner (1937), in his classic study of the Murngin of Australia, found that male conflict over women was the principal cause of violence and that revenge was the cause of about 2/3 of all homicides. Lethal competition was a way to reduce the number of unmarried males in that polygamous society. Violence, especially infanticide, was cited by Hayden (1972) as one means for controlling the number of mouths that needed to be fed in areas where food collection required walking a long distance. Even in largely non-material cultures the theft of food was a source of quarrels which could, over time, escalate to lethal proportions. Ferguson (2005) maintains that *all* conflict among the Yanomomo of Venezuela and Brazil was due to competition over scarce manufactured goods coming from the outside.

1.3

Attitudes as to the appropriate victims of violence also varied widely. Boehm (1999), citing Campbell (1975), suggests that murder within the group is proscribed in most moral codes, making it almost a "universal" behavioral norm. However, McCauley (1990) noted that violence between brothers was not uncommon among the Yanomomo and Kelly (1995), in a survey of several societies, observed that "Among egalitarian hunter-gatherers, interpersonal violence tends to occur between individuals within a social group rather than between groups." Even among the Gebusi, Knauft (1987) observed that "homicide takes place primarily within the residential community." The presence of intrafamily and intragroup violence is an apparent contradiction of the sociobiological hypothesis that violence should decrease with increasing strength of kinship, yet it is not uncommon in indigenous societies (Knauft 1987). Intragroup violence should not come as a surprise, however, since in most small indigenous societies everyone was related to everyone else in some way or other so violence was statistically likely to involve a relation. Even intergroup violence could involve close relatives, since group structure among egalitarian cultures was typically fluid, with not infrequent changes of affiliation, some of which changes were mandated by complex mate selection rules.

1.4

Violence was sometimes restricted along gender lines. Otterbein (2000) found in a cross cultural study of violence that 93% of societies killed captured enemy males while only 26% killed women. Part of the reason for this exclusion may be the reproductive value of females in sustaining the society. Another factor, noted by McArthur (2000) among the (less egalitarian) Kunimaipa of Papua-New Guinea was that strict regulations separating men and women in indigenous societies provided few opportunities for violence between the sexes and, while quarrels between women were not uncommon, they were seldom lethal. However, other societies, such as the Gebusi (Knauft 1987), practiced indiscriminant violence and killed men, women, and children with equal frequency.

1.5

Different societies tolerated different levels of transgressions before revenge was permitted. In the case of the Niue Islanders "any challenge, any slight, provokes a violent rage or a terrifying depression. Injured or insulted Nieuans either attack or commit suicide" (Goldman 1970). Contrast this to the Semai, who prized "getting along" above almost all other social virtues and who often ignored bad behavior to prevent conflict. However, tolerance alone did not guarantee fewer deaths over the long terms since repressed animosity could explode in a short-lived but destructive rampage of violence. Some societies had specific mechanisms for diffusing potential hostility at an early stage, before it crossed the line to physical violence, mechanisms which included ridicule and temporary or permanent ostracism of repeated offenders.

1.6

Increasing population density is sometimes cited as a stimulus to violence. This was true for some Polynesian cultures, including (non-egalitarian) Rapa Nui (Easter Island) where the rate of organized violence rose when the sustaining level of the island's environment was approached (Goldman 1970). Dirks (1980), in his study of the social effects arising from famine, found that food shortages often increased the level of aggression within a group, eroding traditional rules of sharing and promoting theft even among close kin. Violence could exacerbate the effect of food shortages; among the Yanomomo food shortages were sometimes the result of violence rather than the cause of it (Chagnon 1983).

1.7

The place of violence in the value structure of indigenous societies varied from the Semai (Robarchek 1990) and the Xingu of Brazil (Gregor 1990), who regarded violence negatively and akin to wild animal behavior, to the Ilongot (Gibson 1990) who saw violence as a hallmark of male strength. Whereas Knauft (1991) wrote that "In complex hunter-gatherers and small scale sedentary societies…negative reciprocity and violence tend to be valued as an important dimension of intergroup relationships," the Buid of Mindoro in the Philippines had no word for courage. Fear and flight were acceptable responses to a threat of violence (Gibson 1990). Whereas running away was a perfectly acceptable response to potential violence among the Buid, it would have been a humiliation for an Ilongot.

1.8

Merely stating that these differences are "cultural" begs the question as to their origin and rationale. Since egalitarian societies lacked strong central leadership that could step in when violence threatened, conflict was primarily interpersonal, i.e. the individuals involved knew one another. Even though violence was primarily dyadic rather than group-to-group, egalitarian peoples seem to have developed norms regarding violence that prevented wholesale escalation into population-threatening destruction. (Inter-group violence did occur in egalitarian societies, but the amorphous nature of the groups made it less likely than inter-personal violence.)

1.9

While nothing can replace the importance of field observations and comparative ethnography, simulation of artificial societies offers a means of testing various assumptions in a controlled manner, often difficult in real societies due to the many ways in which they differ. Relatively little has been done to construct simulation models of violence in egalitarian societies, despite the fact that there exists a rich ethnographic record for some of them. Rather than attempt a detailed model of one specific culture, we studied violence and revenge in a simple artificial society that mimicked some of the more important features of egalitarian societies around the world. Our goal was to identify common characteristics of violence among egalitarian cultures and to use simulation as a means of better understanding those characteristics. Particular attention was given to:

1. How violence and revenge contributed to mortality in egalitarian artificial societies
2. How the exclusion of different subpopulations (e.g. family members, group members, or females) from violence influenced the survival probability of the population.
3. The effect of different levels of tolerance on the destructiveness of revenge.
4. The effect of population density on survival in resource-rich and resource-poor environments.
5. Whether running away from a potential adversary was always a desirable course of action.
6. The relative effect of violence when it had a positive vs. a negative social value

Our results suggest that, while there are indeed many complex differences between egalitarian societies, there are systemic similarities in their approach to violence that are ultimately rooted in the need to survive.

1.10

Simulation has been useful in illustrating the effect of different normative behavior in simple societies. Jaffe (2002) studied altruism in a model society, demonstrating the advantages of cooperative behavior. In a study of sharing among egalitarian peoples, Younger (2005) found that some societies practiced a form of sharing that maximized the network of mutual obligation within the group, an essential component of social cohesion. Jager et al (2001) reported on a study of clustering and fighting in crowds and compared their results to observations of large groups.

Simulation Method

2.1

We used a discrete agent approach to simulate the dynamics of a population living in an isolated environment, such as one might find on a tropical island or in a desert where large distances separate distinct social units. The simulation landscape consisted of a 20 × 20 square grid containing five sources of food. An initial population of 100 agents, equally divided between male and female, was randomly distributed across the landscape and equal numbers of agents were assigned to one of two identical social groups. The simulation proceeded through a series of timesteps, at each one of which each agent decided its own action according to a set of rules that was unchanging throughout the course of the run. The sequence in which different agents acted was scrambled at the start of each new timestep to avoid spurious patterns that might arise as a result of sequential action.

2.2

The agent's need for food increased by one unit per timestep and the agent died if this need exceeded 200 units. The maximum age to which they could live was 4000 timesteps, when they were consider to have died of old age. To avoid having all of the initial agents die simultaneously of old age, the ages of the agents in the initial population were evenly distributed over the range 0 — 2000. Agents mated and reproduced according to rules given below. Each of the simulations reported in this paper was run for a total of 40,000 timesteps (ten agent lifetimes) and twenty runs were performed for each parameter configuration.

2.3

Each of the five food centers had an initial allocation of 100 units and was replenished at a rate of 20 units per timestep. An agent required one food unit per timestep, so the average sustaining capacity of the environment was 100 agents. Food was enduring, so that food units not used in one timestep remained, enabling populations in excess of 100 to exist temporarily. Agents could sense food from a distance of five squares in each direction, enabling them to see nearby food sources but forcing them to explore the landscape to find all potential sources of nourishment. When an agent found a food source that was in supply, it noted the discovery in its personal memory for future reference.

2.4

Food and reproduction dominated the decisions of the agents. This mirrors the theory of Chagnon (1990) who argued that indigenous peoples divided most of their efforts between somatic activities (staying alive) and reproduction. (The same motivators were identified by Malthus (1798) in his study of population dynamics.) Violence occurred not as an end in itself but as a result of an attempt to get food and to avenge past wrongs.

2.5

The agent decision process was as follows: If the need for food was greater than 100 points, half of the maximum need, then the agent tried to find and consume food. If the agent was carrying food that it had previously collected at a food source then it consumed that food and in so doing reduced its hunger. If an agent was located at a food source, it consumed food sufficient to set its hunger to zero and then collected up to 100 units of food to carry with it. This "eat first and then collect for later" type of behavior was noted by Woodburn (1982) as characteristic of the Hadza of Tanzania as well as other hunter-gatherer societies. If the agent was not carrying any food and was not located at a food source, it looked in its memory to find the nearest food source that was in supply and, if it remembered such a source, it moved one square in its direction. If the agent did not know the location of any food source that was in supply, then it moved one square in a randomly chosen direction. The boundaries of the landscape were reflective so that upon encountering the boundary an agent chose another direction in which to move.

2.6

The normative behavior of agent *i* was defined in terms of three parameters: an altruism parameter, A_i, an aggression parameter, G_i, and a fighting ability parameter, F_i, all of which were within the range 0 — 1. These parameters reflect the central roles played by sharing, stealing, and violence in our model. Agents in the initial population were assigned random values of A_i, G_i, and F_i. To reflect the lower fighting ability observed among females in most indigenous societies, the fighting ability parameter of females was restricted to the range $0 < F_i < 0.10$. Other values, of course, could be chosen and might be studied in future work.

2.7

The altruism and aggression parameters determined the likelihood of an agent to share or steal food when it was collocated with other agents. If an agent was carrying food and the ratio (agent hunger / 200) was less than its altruism parameter, then that agent would share what it was carrying with other agents occupying its location. A large altruism parameter meant that an agent would share in most circumstances and a small altruism parameter meant that an agent would share only if it had just eaten and its hunger was very small. The size of a share was simply the amount of food carried by the giving agent divided by the number of agents occupying the same location. Agents of the same group as the sharer received a full share, and agents of a different group received a half share. This difference gave an advantage to being in the group with the largest number of sharing agents.

2.8

An agent that was not carrying food could steal food carried by another collocated agent if two conditions were met. First, the ratio (agent hunger / 200) had to be more than the potential thief's altruism parameter, A_i. Second, the ratio (agent hunger / 200) had to be greater than (1 — G_i). The second requirement meant that hunger was not the only criterion for theft; the potential thief also had to be sufficiently aggressive to attempt to forcibly take food from another agent. Agents with a high aggression parameter were more likely to steal than those with a small aggression parameter.

2.9

If both conditions for theft were met, then the following process was used to resolve the event. Here *i* refers to the active agent and *j* refers to its potential victim. (In what follows, an active agent refers to the agent whose turn it is to act and a passive agent refers to an agent that is not currently taking its turn but is being acted upon by the active agent.)

1. $G_i > G_j$ and $F_i > F_j$: Theft occurs without fighting. Here the acting agent is both more aggressive than its victim and has greater fighting ability. It intimidates the victim into giving up its food without a fight.
2. $G_i < G_j$ and $F_i < F_j$: No theft occurs. Here the acting agent is less aggressive than the defender and has weaker fighting ability. It chooses not to fight.
3. $G_i > G_j$ and $F_i < F_j$: The acting agent is more aggressive than the defender, but has less fighting ability. The acting agent loses the fight and dies. The defending agent suffers no penalty.
4. $G_i < G_j$ and $F_i > F_j$: The acting agent is less aggressive then the defender but a better fighter. It wins the conflict and takes the defender's food. The defending agent loses and dies. The acting agent suffers no penalty.

An analysis of these rules of combat reveals that there are equal chances of theft without fighting, no theft at all, death of the attacking (active) agent, and death of the defending (passive) agent. The lethality of the rules is consistent with observed violent behavior in many egalitarian societies, namely that when violence occurs it is usually fatal. For comparison, we simulated a case where theft occurred but with no violence. The same rules applied as above but no agents died as a result of the encounter.

2.10

Implicit in the action of the agents was that they did not know the characteristics of the other agents and, even after encountering them, they didn't remember them. However, they did keep track of the *actions* of the other agents. A two dimensional interaction matrix, *imx(i,j)*, tallied the history of agent interactions. When agent *i* shared with agent *j*, the amount of food shared was added to *imx(j,i)*. When agent *i* stole from agent *j*, the amount of food stolen was subtracted from *imx(j,i)*. Hence generous agents enjoyed positive interaction matrix elements linking them to other agents and thieves had negative interaction matrix elements. When one agent killed another agent, 4000 points (an agent lifetime) was deducted from the interaction matrix element linking the killer to each of the agents of the victim's social group that were collocated with the killing. A killer could thus lose more than 4000 points if there was more than one observer from the victim's group collocated with the killing event. Since only two quantities were used to construct interaction matrix elements — food shared or stolen and killing — only the relative contribution of the killing penalty was significant. Other values could be used and some were tried in these simulations. Within a very wide range (a factor of ten variation) the specific values did not affect the qualitative conclusions of the study.

2.11

In addition to violence committed in the act of theft, we introduced revenge into some of the simulations. When an agent was collocated with an agent with whom it had a negative interaction matrix element, the acting agent would attempt a revenge killing regardless of the value of its aggression parameter. The result of a revenge killing was decided as follows:

1. $F_{attacker} > F_{defender}$: Attacking agent kills defending agent and 4000 points deducted from interaction matrix elements of collocated agents in same group as defender.
2. $F_{attacker} < F_{defender}$: Attacking agent dies in the attempt at revenge and 4000 points deducted from interaction matrix elements of collocated agents in same group as attacker.

Observation of revenge could start a cycle of such revenge killings, with members of the victim's group taking revenge on the killer, only to have members of the original killer's group take their own revenge later on. Such cycles of revenge are common in many societies and can continue long after the reason for the original attack has been forgotten.

2.12

In most societies, a trivial theft would not result in lethal revenge, but the *accumulation* of many thefts or other forms of insults could provoke a violent response from the aggrieved party. As will be discussed below, we simulated this by including a threshold for when revenge occurred.

2.13

The nonsymmetrical interaction matrix represented a form of normative reputation for the agents: positive interactions (sharing) enhanced reputation and negative interactions (stealing and killing) detracted from that reputation. This reputation was purely individual since victims did not associate their assailants with groups — there was no group labeling. This individual response was characteristic of egalitarian societies in two ways. First, people in egalitarian societies frequently changed group membership so there was little sense of group identity. Second, by definition, egalitarian societies lacked any central authority that could enforce sanctions. Thus, violence between egalitarian social groups was a collection of individual actions, rather than a group-to-group event. There was no sense of self-esteem or prestige in the simulation; diagonal elements in the interaction matrix were set to zero.

2.14

Normative reputation was communicated between collocated agents by averaging the interaction matrix elements linking them to each of the other agents. So, if agents *i* and *j* were collocated they each would adopt a new opinion of agent *k* by averaging: $imx(j,k)_{new} = imx(i,k)_{new} = 1/2\ (imx(j,k)_{old} + imx(i,k)_{old})$. In this way agents obtained information on the normative behavior of other agents without having to interact with those agents. The rationale for using a simple average was that an agent who had no experience of another agent would have no opinion and hence would not be as affected by that agent's past sharing or stealing as much as an agent who had directly experienced those behaviors. Conversely, an agent who had directly experienced an agent's behavior might temper its opinion based on the view, or lack of a view, held by its communicant. It was quite possible for one agent to have a positive opinion and a second agent to have a negative opinion of the same third agent. For example, agent *k* might have shared with agent *i* and stolen from agent *j*, depending on the state of its hunger at the time of those interactions, so agent *i* would have a positive opinion of *k* and agent *j* would have a negative opinion of *k*. The net reputation of an agent in the total population was simply the sum of the interaction matrix elements linking that agent to all of the other agents. Since modifications to the interaction matrix elements were cumulative, reputation included contributions from past as well as current actions.

2.15

Sharing was a universal feature of all known egalitarian societies. In some cases, sharing evened the distribution of food. This was especially true in societies that derived a large portion of their caloric intake from uncertain hunts, especially hunts that involved large game that had to be consumed immediately. (Many hunter-gatherer societies did not practice food storage.) However, sharing has also been observed in societies where the *need* to share was almost completely absent, as in the case of relatively small populations living on food-rich tropical islands. In such cases generosity was still considered a high virtue even though an individual could easily find enough food and materials to maintain life. Younger (2004) proposed that, in those cases, sharing had the function of building a network of mutual obligation within the society by which each individual was connected to and beholden to everyone else. Recognizing that other factors, most notably ties of kinship, contributed to social cohesion in human society, in our sharing-based social model we defined a mutual obligation factor as the sum of all of the interaction matrix elements linking agents in a specific subpopulation. The total mutual obligation for a society thus represented the total amount of sharing less the total amount of theft and penalties for killing that occurred during the simulation. In a population that consisted mostly of agents inclined to share ($A_i > 0.5$), the mutual obligation was positive and in a population that consisted mostly of agents inclined to steal ($A_i < 0.5$), the mutual obligation was negative.

2.16

Female agents chose a mate upon reaching the minimum reproductive age of 1000 timesteps. They selected the unmarried male for whom they had the highest interaction matrix element, i.e. the male with the "best" reputation as we have defined it. Thus the most generous / least violent males were chosen first and the least generous / most violent males were chosen last. Depending on the time dependent demographics of the individual simulation, it was possible for a male to remain single for its entire life, not being chosen by any female. Mating was monogamous (as was common among egalitarian societies) and the female was required to collocate with the male for the remainder of his life. If either mate died, the survivor was free to chose or be chosen as a new mate.

2.17

Mates aged between 1000 — 3000 timesteps could produce offspring. The probability of conception was 0.0045 per timestep, chosen to allow a population to survive but not rapidly overpopulate the landscape given limited food and the finite lifetime of the agents. Offspring appeared immediately, with no gestation period, and were assigned normative parameters as follows:

Altruism parameter, A_i:	1/3 chance of inheriting A_{mother} - 0.1
	1/3 chance of inheriting A_{mother}
	1/3 chance of inheriting A_{mother} + 0.1
Aggression parameter, G_i:	Random assignment
Fighting ability, F_i:	Random assignment

The scheme chosen for the altruism parameter, i.e. modified matrilineal inheritance of the normative character of the mother, represented both the effect of genetic inheritance and the nurturing of the young by the mother. Some variation was introduced into this inheritance, a form of genetic noise. A discussion of the effect of the inheritance of normative characteristics using a simulation method similar to the one used here can be found in Younger (2005a).

2.18

Agents who were successful at finding food and a mate produced more offspring and were more effective at passing along their altruism "gene" to the next generation. However, it is not obvious that sharing agents would necessarily predominate despite the benefit of sharing in enhancing an agent's reputation and the resulting likelihood that it would be chosen as a mate. The reason is that that sharing, while it produced a long term advantage in reputation, resulted in a short term loss in food. In contrast, theft detracted from an agent's reputation but enhanced its short term ability to survive by providing it another potential source of nourishment.

2.19

A method similar to the one used here was employed by Younger (2005) to investigate sharing in egalitarian societies. Extensive parameter studies were conducted to determine the sensitivity of the model to agent lifetime, carrying capacity, maximum hunger, etc. Within a wide range, the qualitative results of the simulation were found to be stable against variations in the parameters.

2.20

Pseudocode describing the main decision routines in the code is given in the Appendix.

Results

3.2

In this section we present the results of eight studies of violence and revenge in the model described above:

- The Effect of Unrestricted Violence and Revenge on Social Performance
- The Effect of Excluding Different Groups from Violence and Revenge
- The Role of Violence and Revenge in Culling Non-Altruistic Agents from the Population
- The Effect of Tolerance Before Revenge
- The Effect of Population Density on the Rates of Violence and Revenge
- The Effect of Induced Famine on the Rates of Violence and Revenge
- Flight from Aggressors as a Means to Mitigate Violence and Revenge
- When Violence Enhances Prestige

Special attention is given to the long-term survival rate of the population, defined as the number of runs (out of a total of 20 for each case) that had a non-zero population at the end.

The Effect of Unrestricted Violence and Revenge on Social Performance

3.3

Table 1 presents the results of simulations for three basic scenarios involving violence and revenge:

1. No violence or revenge.
2. Violence but no revenge
3. Violence and revenge

Table 1: Results comparing the cases of no violence, violence only, and violence plus revenge. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

	No Violence Or Revenge	Violence, but No Revenge	Both Violence and Revenge
Survival rate (%)	100	45	35
Deaths due to old age (%)	72	72	70
Deaths due to hunger (%)	28	6	4
Deaths due to violence (%)	0	22	12
Deaths due to revenge (%)	0	0	14
Total Mutual Obligation	360	410	380

3.4

Without violence or revenge, the total population survived until the end of the run (40,000 timesteps or ten maximum agent lifetimes) in 100% of the runs, a reflection of the high birth rate relative to the finite lifetime of the agents and the food supply assumed in the simulation. Violence and revenge had the effect of reducing the survival probability of the total population, not surprising since these actions reduced the number of agents and hence the pool of available mates. Theft without violence created a hardship for the victim, but it did not directly eliminate agents.

3.5

What is striking from Table 1 is that the percentage of agents who died of old age was nearly constant among the three cases, independent of whether violence only or violence plus revenge was included. When violence was present, it replaced hunger as the second leading cause of death and when revenge was added it took about half the share of violent deaths. Given a finite food supply, a given agent lifetime, and a fixed probability for the production of offspring from collocated mates, only a fraction of the agents lived until their maximum permitted lifetime. One or another mechanism — hunger, violence, or revenge — intervened to control the population.

3.6

Mutual obligation — a measure of social cohesion produced by sharing — increased when violence was added. Engaging in theft carried with it a potential for death of the thief, so agents with a low altruism parameter were preferentially removed from the population leaving a predominance of sharing agents. More will be said about this phenomenon below. While violence decreased the probability for survival of the population, the "quality" of the remaining society, as measured by the degree of mutual obligation, was actually greater, a significant thing given the substantial penalty imposed for killing. (Our model did not include any emotional cost associated with the death of agents, something that is an important factor in real societies.)

The Effect of Excluding Different Groups from Violence and Revenge

3.7

The survival rates for the scenarios that allowed violence were less than 50%, indicating that violence exerted a heavy toll on the population dynamics of the society. However, in contrast to most indigenous societies, the simulations allowed violence and revenge between *any* members of the society, independent of kinship, group affiliation, or gender. One might hypothesize that restrictions on violence that were imposed by real societies were designed to address just this problem. (This decision need not have been a conscious one, but might have come about through social evolution wherein only societies that had such restrictions survived.) As noted above, different cultures had different restrictions on violence, some frowning upon violence within a family group, some on violence within the immediate social unit, and some restricting it along gender lines. We simulated the effect of some of these restrictions by creating exclusion groups that were off-limits to violence, including the immediate family (mother, father, brother, sister, son, or daughter), members of the same group, and females. In the last case, violence was proscribed by or on females in the total population. The results of these exclusion cases are given in Table 2 for the case of violence without revenge and Table 3 for the case of violence with revenge.

Table 2: Results of excluding different segments of the population from violence. "Family" means that violence was forbidden within the family, "Group" within the group, etc. The last column represents a situation where violence was permitted only against males of the other group. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

Subpopulation excluded from violence	None	Females	Group	Family	Group Females	Family Females	Family Group	Family Group Females
Survival rate (%)	45	85	65	30	100	80	55	90
Deaths due to old age (%)	72	70	67	74	70	69	72	68
Deaths due to hunger (%)	6	21	13	9	23	24	18	27
Deaths due to violence (%)	22	9	19	17	7	7	10	5
Total Mutual Obligation	410	340	410	410	350	340	420	360

Table 3: Results of excluding different segments of the population from violence and revenge. "Family" means that violence and revenge were forbidden within the family, "Group" within the group, etc. The last column represents a situation where violence and revenge were permitted only against males of the other group. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

Subpopulation excluded from violence and revenge	None	Females	Group	Family	Group Females	Family Females	Family Group	Family Group Females
Survival rate (%)	35	40	30	10	60	35	55	90
Deaths due to old age (%)	70	75	68	71	71	71	71	74
Deaths due to hunger (%)	4	13	4	3	16	17	18	19
Deaths due to violence (%)	12	3	11	8	3	3	4	2
Deaths due to revenge (%)	14	9	17	19	10	9	7	5
Total Mutual Obligation	380	330	400	420	340	310	430	370

3.8

In each case, the labels of the columns refer to the subpopulations that were *excluded* as potential victims of violence and revenge. The results show that the survival rate of the total population was enhanced when a significant fraction of the population was excluded from violence, hardly surprising from a mathematical standpoint but consistent with observations of indigenous societies that discouraged violence against some segment of the population. When revenge was added to violence, a larger portion of the total population, i.e. both females and group members, had to be excluded from killing for there to be a significant increase in the survival probability of the total population.

3.9

A seeming anomaly in this pattern was that permitting violence within the family sometimes *increased* the survival probability of the total population. For example, when violence and revenge were permitted among all agents but family members, the survival probability was only 10%, but when family violence was allowed the survival probability rose to 35%. The reason was that intra-familial violence eliminated agents who were prone to steal and with whom interaction was frequent due to the requirement for collocation of mated agents.

The Role of Violence and Revenge in Culling Non-Altruistic Agents from the Population

3.10

In some scenarios, the addition of revenge to violence reduced the survival probability of the total population by a factor of two. Revenge was to first order non-productive since, in contrast to violence committed in the act of theft, it exposed the attacker to potential harm with no reward of food. Revenge was not without *any* merit, however, since agents prone to steal became *targets* of revenge and hence could be removed from the population. Over the course of time agents with small altruism parameters were more likely to be killed and hence prevented from passing along their low value of A_i to a subsequent generation. To highlight the role of violence and revenge in culling the number of agents with low A_i, Figure 1 shows the survival rate of the total population and the fraction of agents with $A_i > 0.5$ plotted against the percentage of deaths due to violence and revenge. These plots show one point for each scenario described above, i.e. for each case of groups excluded from violence. They demonstrate that the overall survival of the total population decreased with increasing violence, but that the number of agents likely to share increased with violence. The latter result was not obvious when the simulations were begun, since the short term advantage of theft might well have overcome the long term benefit of a positive reputation.

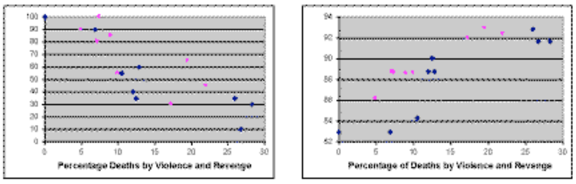

Figure 1. Left: Survival rate of total population vs. percentage of deaths due to violence and revenge. Right: Percentage of agents with Ai > 0.5, i.e. those more likely to share, vs. percentage of deaths due to violence and revenge. Blue diamonds: Violence and revenge. Purple squares: Violence but no revenge

3.11

Figure 2 shows that the mutual obligation within a society tended to increase with the fraction of agents that died as a result of violence or revenge. This was expected since (as shown in Figure 1) more agents likely to share survived at higher rates of violence and since a larger population of agents tending to share contributed more to the interaction matrix elements of those with whom they shared and hence to the total mutual obligation. The deaths of agents who were likely to do harm either through violence associated with theft or through revenge killing caused the overall social cohesion to increase, consistent with Knauft's (1991) comment that "in most simple societies, aggressively self-interested persons may be killed with the consent or active collaboration of the community at large."

3.12

While killing had a large effect on the survival of the total population, it had a smaller effect on mutual obligation since, even with a penalty of 4000 points per observation of a killing, the number of deaths was relatively small so that sharing and stealing dominated mutual obligation.

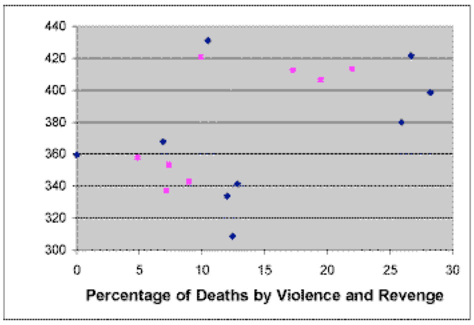

Figure 2. Total mutual obligation vs. percentage of deaths due to violence and revenge. Blue diamonds: Violence and revenge. Purple squares: Violence but no revenge

The Effect of Tolerance Before Revenge

3.13

In a real society, small transgressions such as theft are often tolerated to preserve social accord: not every theft results in a chain of revenge killings. Over time, however, small slights can accumulate, ultimately triggering lethal violence. To investigate this phenomena we performed a series of runs in which revenge was not permitted until the interaction matrix element of the aggrieved party fell below a certain level called the tolerance parameter, *T*. When the interaction matrix element was above this value, no revenge was attempted. For clarity of presentation, we chose a scenario in which revenge produced a significant reduction in the probability of survival, namely the case where violence was forbidden between members of an immediate family or on females but was allowed between members of the same social group. These results are shown in Table 4. To calibrate the significance of different levels of tolerance, recall that the maximum penalty imposed for a single theft was 100 points, the maximum amount of food that an agent could carry and hence lose in a theft. (Since interaction matrix elements were averaged in the communication of normative reputation, the actual interaction matrix element held by an agent may be greater than -100, e.g. -50 for the case where normative reputation was shared between an agent who had one bad interaction and another agent who had no knowledge of the agent in question.)

3.14

Table 4 demonstrates that there were two regimes for revenge: revenge resulting from theft alone and revenge resulting from theft and killing. From $T = 0$ to $T = -50$ the percentage of deaths due to revenge decreased as theft was eliminated as a motivation — the amount stolen combined with the reduction in negative reputation achieved through communication led to interaction matrix elements within the range of tolerance. Note that the survival probability of the total population doubled even for small amounts of tolerance. Violence increased as a low level of tolerance was imposed ($T = -25$) since occasional thefts that occurred without violence did not stimulate revenge and hence the killing of the thief. Between $T = -50$ and -200 both violence and revenge were constant and a result of theft. Between $T = -400$ and $T = -3200$ there were fewer revenge killings and revenge was most likely due to killing since it would have been difficult to accumulate such a negative reputation by theft alone. There was a plateau in the percentage of deaths due to revenge since most agents killed only once or twice, a fact born out by the rates of violence and revenge found in the simulations. For these values of tolerance a small decrease in the deaths due to violence + revenge was compensated for by an increase in the number of agents who died of hunger. Below $T = -4000$ the fraction of deaths attributable to revenge was zero. This does not mean that no agent killed more than once; the averaging of interaction matrix elements during the communication of normative reputation could moderate the individual reputation of such agents. However, it does indicate that no agent killed *many* times.

Table 4: Effect of permitting varying degrees of tolerance before revenge was invoked. In this case violence and revenge were permitted between members of a group and between members of different groups, but not among family members or on females. The last row refers to the case where the revenge was not permitted. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

Tolerance	Survival Rate (%)	Deaths Age (%)	Deaths Hunger (%)	Deaths Violence (%)	Deaths Revenge (%)	Mutual Obligation
0	35	71	17	3	9	310
-25	70	73	16	6	5	350
-50	60	69	22	6	3	360
-101	65	74	16	7	3	360
-200	75	75	16	6	3	360
-400	85	71	22	7	0.8	370
-800	55	69	22	8	0.7	320
-1600	80	69	23	7	1	340
-3200	70	69	23	7	0.6	330
-6400	80	68	23	8	0	330
-12800	70	69	24	7	0	330

No Rev	80	69	24	7	0	340

3.15
A naïve approach to revenge projects an unending series of killings, each to avenge the one before, perhaps ending only with the extinction of the total population. This did not happen for several reasons. First, not every killing in either the simulations or in real societies was witnessed, so it was not always obvious upon whom revenge should be taken. The lack of group labeling in our simulation and in many egalitarian societies required that a specific agent be identified as the perpetrator of a killing and, lacking that identification, the cycle of revenge stopped. A close observation of the simulations revealed that revenge killings occurred in bursts followed by periods of relative quiet, indicating that the chain of revenge was broken. At tolerance levels of $T = -1600$ and -3200, revenge either did not occur or occurred in a single massive burst of killing. In one run, illustrated in Figure 3, only one revenge death occurred for the first 28,000 timesteps but within 100 timesteps thereafter 22 agents died as a result of revenge. This is analogous to observations of otherwise peaceful peoples who could be caught up in a blood lust that was difficult to stop.

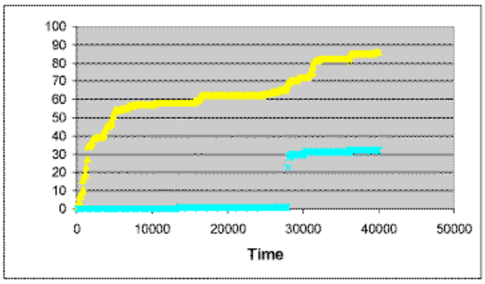

Figure 3. Time history of cumulative deaths due to violence and revenge for one run where the tolerance to revenge was — 3200. Yellow triangles: Violence. Blue crosses: Revenge

The Effect of Population Density of the Rates of Violence and Revenge

3.16
Rising population density is sometimes invoked as a stimulus to violence in human and animal societies where there is competition for food and mates. The idea is that more individuals competing for the same resources would increase the probability of violence. However, higher population densities also allow for more sharing, with the result that the population may benefit from a more even distribution of resources. We investigated these two options by running a simulation for the case where violence was permitted within a group but not within a family or among females and where the food replenishment rate was quadrupled compared to the runs discussed above. This meant that 400 agents were supportable in the same landscape. The results, given in Table 5, show that the survival probability doubled for the higher population density. The higher population density provided more opportunities for mating as well as for interactions that effected a more even distribution of food. There was substantially more revenge killing for the higher population density, once again a result of increased frequency of interaction, but the decrease in the number of agents who starved to death more than offset this increase so that the number of agents who lived into old age actually increased.

Table 5: Comparison of runs with maximum sustainable populations of 100 agents and 400 agents in the scenario where violence and revenge were permitted between members of a group and between members of different groups but not among family members or among females. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

Sustainable population	100	400
Survival rate (%)	35	70
Deaths due to old age (%)	71	78
Deaths due to hunger (%)	17	4
Deaths due to violence (%)	3	3
Deaths due to revenge (%)	9	15
Mutual Obligation	310	420

The Effect of Induced Famine on the Rates of Violence and Revenge

3.17
Our simulation of population pressure assumed that more food was provided to feed the larger population. Thus these results reflect only the relative advantage of increased sharing vs. the relative disadvantage of more theft, violence, and revenge. However, in foraging societies that lacked the means of intensified production, higher population density ran up against the sustaining level of the environment. It was the population relative to the food supply and not just the population density that put the greatest strain on social relations. To test scarcity as a stimulus to violence we performed a series of runs in which the replenishment rate of the five food centers was reduced from 20 units per timestep, one that could sustain a population of 100 agents, to zero over the course of two agent lifetimes. (Every 400 timesteps the replenishment rate of the food centers was reduced by 1 so that, after 8000 timesteps, no food was added.) Without food, the total population disappeared by the end of every run, but our interest was in the fraction of agents who died of hunger vs. the fraction that died of violence and revenge. The results of 20 runs of this scenario are shown in Table 6.

3.18
For the case of a steadily declining food supply, fewer agents — only 23% - lived into old age and more agents died of hunger rather than from violence or revenge. Theft and violence redistributed the available food, but they did not *create* food and thieves eventually starved. Also, in a food constrained environment, few agents carried food but rather consumed it immediately to satisfy urgent hunger, eliminating them as targets of theft and hence violence. However, while the percentage of deaths due to violence and revenge was higher for the decreasing food scenario (22%) than for the constant food scenario (12%), this was partly due to the fact that for the latter the runs that had zero population at the end of the run were not included in the average. When one examines the constant food supply runs that had a population that went to zero before the end of the run, the percentage of deaths due to violence and revenge was 23%, comparable to the case of a decreasing food supply. The number of deaths due to hunger was comparable to the "constant non-zero" case and population extinction was due to the higher rates of violence and revenge in those specific runs, consistent with the trend illustrated in Figure 1. For both the "constant food zero" and the "decreasing food zero" scenarios, violence and revenge contributed to the collapse of the society. These results are similar to the conclusion reached by Dirks (1980) namely that, in times of food scarcity, social norms erode and aggression increases. When scarcity becomes acute, individuals seek their own survival.

Table 6: Relative contributions to mortality of age, hunger, violence, and revenge for a linearly decreasing food supply. Constant Food Nonzero refers to runs that had a non-zero ending population in a constant food landscape. Constant Food Zero refers to runs that had a zero ending population in a constant food landscape, i.e. unsuccessful populations in a food-rich environment. Decreasing Food refers to runs conducted with a linearly decreasing food replenishment rate. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

	Constant Food Nonzero	Constant Food Zero	Decreasing Food Zero
Deaths due to old age (%)	71	59	23
Deaths due to hunger (%)	17	18	56
Deaths due to violence (%)	3	6	5
Deaths due to revenge (%)	9	17	17

Flight from Aggressors as a Means to Mitigate Violence and Revenge

3.19
A common response to potential violence is to flee from the aggressor. Such was the response of the Semai and the Buit when they were threatened by a hostile neighbor. We investigated this option by having agents move one square away when they saw another agent with whom they had a negative interaction matrix element. The results for two possible flight options are shown in Table 7. In the first option, the agent moved away from *any* other agent with whom it had a negative interaction matrix element. In the second option, some tolerance was invoked and the agent only moved away if the interaction matrix element linking it to the other agent was below -101, one less than the worst that could result from a single, directly experienced, theft.

3.20
Flight increased the survival rate of the total population from 35% to 95%, but at a cost to the population that survived. The percentage of agents who starved to death was almost three times higher in the case where flight was enabled. With a lower frequency of agent interaction, less sharing and stealing occurred and this affected the distribution of food in the population. When a tolerance value was introduced, the results were comparable to the case of no flight, indicating that it was a relatively low level of theft that was responsible for most agent avoidance. The very low value of mutual obligation in the case of unrestricted flight was associated with high birth and death rates in these runs — an individual agent did not live long enough to share very often. However, even with tolerance before flight, there was a substantial reduction in mutual obligation when flight was allowed. Of course, in a real society factors such as kinship and personality contributed to social solidarity — our results reflect only the contribution of sharing and stealing.

Table 7: Results of simulations that allowed agents to flee from other agents with whom they had a negative interaction matrix element or an interaction matrix element below that which would result from a single directly experienced theft. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

	No flight	Flight	Flight when Imx < -101
Survival rate (%)	35	95	50
Deaths due to old age (%)	71	37	68
Deaths due to hunger (%)	17	45	17
Deaths due to violence (%)	3	4	4
Deaths due to revenge (%)	9	14	12
Mutual Obligation	310	-267	112

When Violence Enhances Prestige

3.21
In all of the above simulations an agent incurred a penalty to its reputation by killing another agent, making the it less desirable as a mate. What about societies such as the Yanomomo and the Ilongot where violence was esteemed and where a violent individual was *more* likely to find a mate? To investigate this question we performed a series of simulations in which killing *added* 4000 points to the interaction matrix elements of all observers of the same group as the victim. The results, shown in Table 8, show that the survival rate increased significantly when killing was rewarded rather than penalized. The number of revenge killings was lower (since only theft induced revenge) and the mutual obligation for the total population was higher when killing had a positive social value than when it had a negative social value. These results are consistent with the overall trend of survival versus violent deaths illustrated in Figure 1. Thus it was not killing alone, but the social value attached to killing, that affected the survival of the population.

Table 8: Comparison of runs where killing reduced and where it added to the interaction matrix element connecting killer and observer in the scenario where violence and revenge were permitted between members of a group and between members of different groups but not among family members or among females. Each entry represents an average over twenty runs where only those runs that had a non-zero population at the end of the run were included in the average

Modification of interaction matrix element for killing	-4000	+4000
Survival rate (%)	35	80
Deaths due to old age (%)	71	72
Deaths due to hunger (%)	17	21
Deaths due to violence (%)	3	4
Deaths due to revenge (%)	9	3
Mutual Obligation	310	480

Discussion

4.1
Seven principal conclusions can be drawn from the above results:

1. Violence and revenge contributed substantially to mortality and reduced the overall survival rate of the population.
2. Excluding significant segments of the population from violence and revenge improved the survival rate of the total population.
3. Tolerance before revenge increased the survival rate of the total population.
4. Increasing the population density increased the survival rate of the total population, even though revenge killings increased.
5. The rate of violence increased when food scarcity was introduced but many more agents died of hunger than by violence and revenge.
6. Flight from known aggressors enhanced the survival of the total population, at the expense of sharing-generated social cohesion.
7. When killing had a positive social value the survival rate of the total population increased as the number of revenge killings decreased.

4.2
Table 9 compares these conclusions with observations of some egalitarian societies.

Table 9: Comparison of simulations with ethnographic observations

Simulation Result	Ethnographic Observations	Comment
Violence and revenge contributed substantially to mortality and reduced the overall survival rate of the population.	Violent deaths accounted for 10's of percent of the total recorded deaths among the Copper Eskimos, Gibusi, Waorani, and other indigenous peoples.	Violence is a population control mechanism in some egalitarian societies.
Excluding significant segments of the population from violence and revenge improved the survival rate of the total population.	Kapauku excluded females from violence. Little violence among females in Kumaimaipa society. Some primate and human societies proscribe violence within immediate social group.	Many societies discourage violence among significant parts of the population.
Tolerance before revenge increased the survival rate of the total population.	Peaceful societies (e.g. Semai) have high levels of tolerance. Violent societies (e.g. Niue) have low levels of tolerance.	Tolerance reduces the rate of revenge killing.
Increasing the population density increased the survival rate of the total population, even though revenge killings increased.	Keeley (1996) found that population density and the rate of violence were not correlated.	Higher survival rate in simulations a result of more mating opportunities. Simulations omit control mechanisms that limit violence in real societies.
The rate of violence increased when food scarcity was introduced but many more agents died of hunger than by violence and revenge.	Scarcity reduced sharing within a group and, in extreme circumstances, increased antagonism and theft within the group. (Dirks 1980). The Ik of Uganda are a particular example of theft increasing in times of scarcity.	Scarcity of food increased the rate of violence, consistent with ethnographic observations.
Flight from known aggressors enhanced the survival of the total population, at the expense of sharing-generated social cohesion.	Flight was common among the Buid and Semai, where violence was discouraged. It was rare among the Ilongot and Yanomomo where violence was esteemed.	Role of flight depends on the cultural values of the society. Other factors, e.g. kinship, maintain social cohesion in real societies
When killing had a positive social value the survival rate of the total population increased as the number of revenge killings decreased.	Yanomomo and Waorani were violent people and yet survived over many generations.	Rates of violence and revenge can be very high when they are seen as a positive social value and do not inhibit mate selection and procreation.

4.3

While some of these results are intuitive, they were not obvious before the simulations were conducted. For example, the reduced survival probability in simulations involving violence and revenge could have been offset by the rapid depopulation of thieves so that only sharers survived. In fact, this did not happen fast enough to sustain the population. Similarly, tolerance before revenge allowed a thief to steal again without negative consequences so an alternate outcome would have been for tolerance to *reduce* the survival rate of the total population as thieves lived longer and put greater stress on the population.

4.4

Violence and revenge removed individuals from the population, reducing the available mating pool and hence threatening the survival of the population. These mechanisms replaced hunger as the second leading cause of death after old age. The percentage of violent deaths in the simulation (10-30%) was comparable to that found in many real societies, but this similarity becomes less significant when one considers the simplicity of the simulation relative to a real society.

4.5

Data on violence-induced extinctions of egalitarian societies are scarce owing to a lack of written history and the consequent need to rely solely upon the archeological record, perhaps with the contribution of oral histories of neighboring societies. However, the examination of physical remains alone can be unconvincing, since other factors such as changing climate, crop diseases, soil exhaustion, migration, etc may have contributed to the abandonment of the site.

4.6

Since violence was more likely to involve agents prone to steal than those prone to share, the net effect of violence was to preferentially remove agents with a low altruism parameter, increasing the number of sharing agents in the population when normative character is inherited either genetically or through training. This is in accord with Knauft's (1991) comment that some egalitarian societies used violence to remove individuals injurious to the social good.

4.7

Just as in real egalitarian societies, we did not find that theft and violence led to a cycle of revenge that decimated the population. The cycle was broken if no one observed a killing or if tolerance was introduced into the simulation, tolerance that allowed infrequent thefts to be forgiven.

4.8

All egalitarian societies seem to have had some taboo on persons who were unsuitable as targets for violence. Some cultures proscribed violence between members of the same social group (Boehm 1999) while others allowed such violence (Kelly 1995). Some societies placed females off-limits to violence while others made no distinction between men, women, and children (Keeley 1996). Our simulations indicate that a taboo prohibiting violence amongst a significant fraction of the population is important for ensuring survival. Lacking such excluded segments, violence was so pervasive that it caused the total population to collapse in more than 50% of the cases. Exactly what subgroup was excluded was less important than the size of that group. A larger group had to be excluded when revenge was added to violence.

4.9

Some tolerance to transgression was practiced in many egalitarian societies to prevent minor offenses from escalating into society-threatening violence. Younger (2005) discussed the role of tolerance in gift-giving societies with particular attention to the theories of tolerated theft (Blurton Jones 1984) and demand sharing (Peterson 1993). Tolerance was found to be beneficial in avoiding grudges that inhibited otherwise productive interactions between members of a society. On the other hand, repeated small slights could accumulate to produce serious consequences, a result echoed in our simulations where a burst of revenge killing would sometimes occur in an otherwise tolerant population. A similar phenomenon has been observed in several peaceful egalitarian societies wherein violence, once started, could get out of control.

4.10

Keeley (1996) found no correlation between violence and population density, a contrast to our simulation results. We found that increased population density had a net beneficial effect when resources were provided to support the larger population. While the opportunity for violence and revenge increased, so too did the opportunity for beneficial sharing which evened the distribution of food among the agents, enabling them to live longer. There was also a larger mating pool which helped to mitigate occasional sex or age imbalances which could prove fatal to survival. Note that it is not possible to distinguish the effect of population density from that of a larger absolute population — in either case there are more opportunities for interaction.

4.11

We found that killing increased somewhat with food scarcity, consistent with the observations of Dirks (1980) who studied famine in a diverse set of cultures. The Ik of Uganda (Turnbull 1987) are a particularly stark example of the breakdown of normative behavior under the pressure of food scarcity. When some of their traditional hunting grounds were converted into a national park , the Ik were forced into less productive areas. As food became more difficult to obtain, sharing decreased and individuals consumed what they found on the spot. Theft of cattle from neighboring groups became common and the general level of altruism within the population plummeted.

4.12

Flight from agents who had a negative reputation increased the overall survival rate of the population but decreased the mutual obligation, which in our model is a measure of social cohesion. While flight reduced the probability of negative interactions, it also reduced the probability of positive ones. Recall that agents shared or stole partly due to an inherited altruism parameter and partly due to the circumstances in which they found themselves at the time. An agent that stole once, when it was very hungry, would be precluded from sharing in the future if other agents ran away from it. This result contrasts with the behavior of the Semai (Robarchek 1990) who used flight as a means of avoiding violence but who valued group membership as one of the most important things in life. However, our measure of social cohesion only included the effect of sharing and omitted such crucial contributors as kinship, personality, ability, etc.

4.13

The case where violence enhanced rather than reduced the reputation of the individual was of particular interest in that it might help provide a partial explanation for how societies that practiced very high rates of killing still managed to survive. In the simulations, when killing had a negative social value (i.e. when it reduced the reputation of the individual) then homicide rates of several tens of percent, not unusual among egalitarian peoples, greatly reduced the survival probability. This was especially true when revenge was included. A positive view of killing reduced the number of revenge deaths and hence increased the survival probability of the population. This suggests that both the norms governing the application of violence as well as the social value attached to violence may play a role in the continuity of egalitarian societies. A positive attitude to violence was not restricted to warrior cultures alone — Knauft (1987) observed that otherwise peaceful peoples condoned violence if it was seen as a means of ridding the society of undesirable and destructive individuals.

4.14

The simulations reported here do not describe any single culture. Rather, they represent a computational analogy to cross cultural studies that attempt to identify common elements in many societies. Our simulations suggest underlying systemic reason for the norms governing violence and revenge observed in indigenous cultures. Bands of 100-500 people had to regulate violence, and the social value attached to violence, in such a way that interpersonal relations would ensure the procreation of future generations. Different societies did this in different ways, some encouraging violence, some discouraging it, but all surviving societies identified a workable system that allowed for long term survival. The fragility of this system might be illustrated by the difficulty encountered by many indigenous populations upon Western contact. The perturbation of their normative systems, along with other introduced abuses and diseases, not infrequently resulted in major population reductions. This effect was particularly serious in Pacific societies, where Western contact sometimes resulted in population reductions of up to 90% (Campbell 1989). Simulation of such perturbations could be helpful in better understanding the effect of the imposition of outside normative codes on stable indigenous societies.

4.15

Our simulations employed only one possible set of agent parameters and rules, ones that were chosen to produce a stable artificial society in the absence of violence and revenge. One could certainly add more detail, such as making the probability of conception dependent on the nutritional state of the mother, adding variation between individuals, etc. The choice of a rule-based simulation was made to enable cause-effect relationships to be inferred from the results. Other choices of parameters and rules can and should be investigated, including the use of intelligent and/or adaptive agents who learn from their experience. Similarly, other means beyond violence were available to egalitarian peoples to resolve disputes in the absence of central authority. Gossip and ridicule, forms of individual sanctions common for egalitarian lifestyles, controlled bad behavior before it got out of hand. Alternate forms of conflict resolution are an interesting extension to the present work and worthy of future attention. Finally, modeling more than two groups would allow a more realistic assessment of the effect of violence and revenge on inter-group dynamics.

4.16

We focused on violence and revenge in egalitarian societies, those in which individual autonomy is prized and in which central leadership is largely absent. Rosenfeld and Messner (1991) hypothesized that violence within the group might be suppressed as more complex social structures bring alternate, non-violent, means for conflict resolution. However, Otterbein and Otterbein (1965), in a wide survey of indigenous cultures, demonstrated that there is no correlation between the level of political organization and the frequency of revenge killings. This may be because revenge is often a personal attack on an individual rather than a group-sponsored event and hence is only weakly tied to centrally determined group decisions. Simulation might be helpful in addressing the relation between political hierarchy and violence and in particular in the transition between individual violence in an egalitarian society and group violence in an hierarchical one. This subject is under investigation and will be reported in a later paper.

4.17

Finally, it would be interesting to take a case where violence and revenge are major contributors to adult death and use simulations to examine mechanisms for reducing them. For example, alternate normative rule sets could be employed and compared to cultural comparisons of the type done by Robarchek and Robarchek (1992) for the Semai and Waorani, two cultures that lived in similar environments but which had very different patterns of behavior, the former essentially peaceful and the latter exceptionally violent. It is intriguing that the Waorani are highly individualistic, with little social cohesion whereas the Semai believe that their very survival depends on smooth relations within the group. The extension of the concept of mutual obligation as a measure of social cohesion may be a useful mechanism for more detailed studies of specific societies.

Appendix: Pseudocode Describing the Major Routines in the Simulation

Main Agent Decision Routine:

```
FOR each agent:

   IF agent is female, has no mate, and has reached reproductive age THEN
      SELECT male with whom female has highest interaction matrix element
      PLACE mated female at same location as her mate

      IF hunger > 0.5 maximum hunger THEN
      CALL food routine
   ELSE
      CALL movement routine to explore landscape
   END IF

   CALL communications routine

END agent decision routine
```

Food Routine:

```
IF the agent is carrying food THEN eat all of that food

IF the agent is at a food source THEN
      Eat food to reduce hunger to zero
      IF food remains at the food source, collect up to maximum carry capacity
      EXIT food routine
ELSE
      SEARCH memory of agent to find nearest food source with food at time of last observation
      IF agent remembers a food source with food THEN
            MOVE one square in the direction of that food source
      ELSE
            CALL movement routine to move one square in a random direction in search of food
      END IF
END IF

END food routine
```

Movement routine:

```
SENSE the environment by storing the location of all agents and food sources within sensory range

STORE the locations of all food sources, along with the amount of food and the time of observation, in the agent's memory

IF the flight option is enabled AND there is an agent within sensory range for whom the active agent has a negative interaction matrix eleme

IF the agent is searching for food AND the agent is at a food source THEN
      Eat food to reduce hunger to zero
      IF food remains at the food source, collect up to maximum carry capacity
      EXIT the movement routine
ELSE
      IF agent has sensed a food source that has food THEN
            MOVE one square in the direction of that food source
      ELSE
            MOVE one square in a random direction in search of a food source that is in supply
      END IF
END IF
```

Communication routine:

Sharing

```
IF there are other agents at the same location AND the active agent is carrying food AND the ratio (agent hunger / maximum hunger) < the age
      COUNT the number of agents at that location who are not carrying food
      CALCULATE a share as the amount of food carried by the active agent divided by the number of counted agents
      GIVE a full share to agents of the same group as the sharer and one half share to agents of a different group
      ADD the amount shared to the interaction matrix element imx (receiver, sharer) of each agent
END IF
```

Stealing

```
IF there is another agent at the same location who is carrying food AND the active agent is not carrying food AND [(agent hunger / maximum h
      IF active agent has larger aggression parameter AND larger fighting ability parameter THEN
            TAKE all of the food carried by the other agent
            REDUCE the interaction matrix element imx(victim, thief) by the amount of food stolen
      ELSE
            IF violence is permitted between this pair of agents AND the active agent has a larger aggression parameter AND the other agent
                  The active agent is killed
                  DEDUCT an amount equal to an agent lifetime from the interaction matrix elements imx(collocated, killer) for all agents wh
                  EXIT communication routine
            ELSE
                  IF active agent has larger fighting ability parameter and a smaller aggression parameter than the other agent THEN
                        The other agent is killed
                        The food carried by the other agent is taken by the active agent
                        DEDUCT an amount equal to an agent lifetime from the interaction matrix elements imx(collocated, killer) for all age

            END IF
      END IF
END IF
```

Revenge

```
FOR all other agents at the same location as the active agent
      IF the interaction matrix element imx(active agent, other agent) < 0 THEN
            IF the active agent has a higher fighting ability parameter than the other agent THEN
                  The other agent is killed
                  DEDUCT an amount equal to an agent lifetime from the interaction matrix elements imx(collocated, killer) for all agents wh
            ELSE
            The active agent is killed
                        DEDUCT an amount equal to an agent lifetime from the interaction matrix elements imx(collocated, killer) for all age
                  END IF
      END IF
NEXT AGENT
```

Share normative reputation of other agents

```
FOR all other agents j at the same location at the active agent
      FOR all agents k
            IF either the active agent or agent j has a non-zero interaction matrix element imx(agent, k) THEN
            imx(active, k) = 1/2 (imx(active, k) + imx(j, k))
            imx(other, k) = 1/2 (imx(active, k) + imx(j, k))
            NEXT AGENT k
NEXT AGENT j
```

Agent reproduction

```
IF the active agent is collocated with its mate
      AND 0.25 * (agent lifetime) < male age < 0.75 * (agent lifetime)
      AND 0.25 * (agent lifetime) < female age < 0.75 * (agent lifetime)
      AND (RANDOM NUMBER) < 0.0045
      THEN
            SET parameters of a new agent
                  Location is same as parents
                  Group is same as parents
                  Equal probability of male or female
                  Random aggression parameter
                  Random fighting ability parameter
                  Altruism parameter:
                        1/3 chance of mother's altruism parameter
                        1/3 chance of mother's altruism parameter + 0.1
                        1/3 chance of mother's altruism parameter – 0.1
END IF
```

References

BLURTON JONES N G (1984) Delayed Reciprocity and Tolerated Theft: The Behavioral Ecology of Food-Sharing Strategies. *Current Anthropology,* 38. pp. 49-78.

BOEHM C (1999) *Hierarchy in the Forest: The Evolution of Egalitarian Behavior*. Cambridge, MA: Harvard University Press.

CAMPBELL I C (1989) *A History of the Pacific Islands*. Berkeley, CA: University of California Press.

CAMPBELL J (1975) On the Conflicts between Biological and Social Evolution and between Psychology and Moral Tradition. *American Psychologist*, 30. pp. 1103-1126.

CHAGNON, N A (1983) *Yanomomo: The Fierce People.* New York: Holt Reinhart and Winston.

CHAGNON, N A (1990) "Reproductive and Somatic Conflicts of Interest in the Genesis of Violence and Warfare Among Tribesmen". In Hass J (Ed.), *The Anthropology of War*, Cambridge: Cambridge University Press.

DIRKS R (1980) Social Responses During Severe Food Shortages and Famine. *Current Anthropology,* 21. pp. 21-44.

FERGUSON R B (2005) "Archaeology, Cultural Anthropology, and the Origins and Intensifications of War". In Arkush E and Allen M (Eds.), *Violent Transformations: The Archaeology of Warfare and Long-Term Social Change*, Salt Lake City, UT: University of Utah Press.

GOLDMAN I (1970) *Ancient Polynesian Society*. Chicago, IL: University of Chicago Press.

GIBSON T (1990) "Raiding, Trading, and Tribal Autonomy in Insular Southeast Asia". In Hass J (Ed.), *The Anthropology of War*, Cambridge: Cambridge University Press.

GREGOR T (1990) "Uneasy Peace: Intertribal Relations in Brazil's Upper Xingu". In Hass J (Ed.), *The Anthropology of War*, Cambridge: Cambridge University Press.

HAYDEN B (1972) Population Control Among Hunter Gatherers. *World Archeology,* 4. pp. 205-221.

JAGER W, Popping R, and van de Sande H (2001) Clustering and Fighting in Two-party Crowds: Simulating the Approach-avoidance Conflict. *Journal of Artificial Societies and Social Simulation* 4(3) http://jasss.soc.surrey.ac.uk/4/3/7.html.

JAFFE K (2002) An Economic Analysis of Altruism: Who Benefits from Altruistic Acts? *Journal of Artificial Societies and Social Simulation* 5(3) http://jasss.soc.surrey.ac.uk/5/3/3.html.

KEELEY L H (1996) *War Before Civilization: The Myth of the Peaceful Savage*. Oxford: Oxford University Press.

KELLY R L (1995) *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Washington DC: Smithsonian Institution Press.

KNAUFT B M (1987) Reconsidering Violence in Simple Human Societies: Homicide Among the Gebusi of New Guinea. *Current Anthropology,* 28. pp. 457-500.

KNAUFT BM (1991) Violence and Sociality in Human Evolution. *Current Anthropology,* 32. pp. 391-428.

LEE R B (1979) *The !Kung San: Men, Women, and Work in a Foraging Society*. New York: Cambridge University Press.

MALTHUS T R (1798) *Essay on Population*

MCARTHUR A M (2000) *The Curbing of Anarchy in Kunimaipa Society*. Sydney: University of Sydney.

MCCAULEY C (1990) "Conference Overview". In Hass J (Ed.), *The Anthropology of War*, Cambridge: Cambridge University Press.

OTTERBEIN K F and Otterbein C S (1965) A Eye for an Eye, A Tooth for a Tooth: A Cross-Cultural Study of Feuding. *American Anthropologist*, New Series, 67. pp. 1470-1482.

OTTERBEIN K F (2000) Killing of Captured Enemies: A Cross Cultural Study. *American Anthropologist*, 41. pp. 439-443.

PETERSON N (1993) Demand Sharing: Reciprocity and the Pressure for Generosity Among Foragers. *American Anthropologist*, New Series, 95. pp. 860-874.

ROBARCHEK C and Denton R K (1987) Blood Drunkenness and the Bloodthirsty Semai: Unmaking Another Anthropological Myth. *American Anthropologist,* 89. pp. 356-365.

ROBARCHEK C (1990) Motivations and Material Cause: On the Explanation of Conflict and War. In Hass J (Ed.), *The Anthropology of War*, Cambridge: Cambridge University Press.

ROBARCHEK C A and Robarchek C J (1992) "Cultures of War and Peace: A Comparitive Study of Waorani and Semai". In Silverberg J and Gray J P (Eds.), *Aggression and Peacefulness in Humans and Other Primates*. New York: Oxford University Press.

ROSENFELD R and Messner S F (1991) The Social Sources of Homicide in Different Types of Society. *Sociological Forum,* 6. pp. 51-70.

TURNBULL C (1987) *The Mountain People*. New York: Touchstone.

WARNER W L (1937) *A Black Civilization*. New York: Harper.

WOODBURN J (1982) Egalitarian Societies. *Man,* 17. pp. 431-451.

YOST JA and (1981) "Twenty Years of Contact: The Mechanisms of Change in Huao (Auca) Culture". In Whitten N A (Ed.), *Cultural Transformations and Ethnicity in Modern Ecuador*. Urbana, IL: University of Illinois Press.

YOUNGER S M (2005) Reciprocity, Sanctions, and the Development of Mutual Obligation in Egalitarian Societies. *Journal of Artificial Societies and Social Simulation* 8(2) http://jasss.soc.surrey.ac.uk/8/2/9.html.

YOUNGER S M (2005a) Behavioral Norms and the Evolution of Societies, *Proceedings of the AISB Conference 2005* (In press).

Return to Contents of this issue