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The Logic of Social Sharing: An Evolutionary Game Analysis of Adaptive Norm Development

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Although norms can potentially serve useful constructs to understand human minds, being fundamentally social in evolutionary as well as cultural senses, there are as yet no useful psychological theories of adaptive norm development. This article provides an illustrative model about how a norm emerges in a society. We focus on the "communal-sharing norm" in primordial societies, a norm designating uncertain resources as common properties to be shared with other members. Based on anthropological findings, we develop a theory about how the communal-sharing norm emerges and is maintained. Then, using evolutionary computer simulations, we test several hypotheses about the conditions under which the norm will dominate social resource sharing. We further test behavioral implications of the norm, demonstrating that uncertainty involved in resource acquisition is a key factor that triggers the psychology of sharing even in highly industrialized societies. Finally, we discuss the importance of norm construct for analyzing the dynamic relation between minds and society.

The notion of "social norm" has a distinctive status in modern psychology. Although the concept has been one of the most central constructs in other social sciences such as sociology, law, political science, and anthropology (e.g., Axelrod, 1986; Coleman, 1990; Cooter & Ulen, 1996), its theoretical status in psychology has been less firm. Despite an early emphasis on this notion (Asch, 1952; Jacobs & Campbell, 1961; Sherif, 1936), even in modern social psychology, the role of social norm construct for explaining behavior is often criticized. Some theorists argue that in many realistically complex social contexts, a variety of social norms are potentially applicable to a given social situation, some of which are mutually incompatible. Thus, unless we can tell which norm is actually operating in the situation in advance, the value of social norm as an explanatory construct for behavior is limited (Darley & Latané, 1970; Krebs & Miller, 1985).

However, rather recently, the social norm and other collective constructs have been gaining renewed interest. One manifestation is the growth of cultural psychology that emphasizes dynamic processes between minds and society; collective constructs such as norms, conventions, values, and customs are core concepts in this discipline (e.g., Cohen, 2001; Markus & Kitayama, 1991; Nisbett & Cohen, 1996; Triandis, 1994). The emergence of evolutionary psychology maintaining that, as a group-living species, our minds are tuned to be socially adaptive (e.g., Barkow, Cosmides, & Tooby, 1992; Campbell, 1975), is also an impetus for the resurgence of social constructs. As Cialdini and Trost (1998) argued, because the existence of social norms is one of the most essential characteristics of group lives, this construct may have a great potential to understand humans as fundamentally social animals. Sharing such a perspective, we aim to provide a model analysis of the emergence and maintenance of a social norm in this article, using a formal method called "evolutionary game analysis" (Maynard Smith, 1982).

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Social Norm as an Emergent Property from Autonomous Interaction

Although norms have been conceptualized in various ways by a variety of researchers, Cialdini and Trost's (1998) definition in a recent review article is one of the clearest. According to their definition, "Social norms are rules and standards that are understood by members of a group, and that guide and/or constrain social behavior without the force of laws. These norms emerge out of interaction with others; they may or may not be stated explicitly, and any sanctions for deviating from them come from social networks, not the legal system" (p. 152).

Put differently, norms are socially-shared rules that emerge and are sustained through people's autonomous interaction without formal regulating authorities or forces such as laws.

This definition highlights emergence and sustainability of social norms as core issues for any theory of norms. That is, to elaborate the norm construct fully, we need to understand how social norms can emerge voluntarily through people's interaction without external regulating forces (although as noted by some theorists, the norms can eventually be manifested in more formal sanctions such as explicit laws; cf. Axelrod, 1986, p. 1106). This theoretical perspective is shared by other social scientists (e.g., Axelrod, 1986; Coleman, 1990), yet we do not have a reasonable theory about norm development. For example, most social psychological research has studied development of arbitrary, adaptively-irrelevant norms such as conformity to a response norm for the visual autokinetic effect or to transient fashions or fads (e.g., Jacobs & Campbell, 1961; Latané & L'Herrou, 1996; Sherif, 1936). Such a focus on arbitrary norms may have inadvertently led us to assume that social–cultural learning per se is a sufficient mechanism for norm development. Although social–cultural learning is vitally important for norm development (Boyd & Richerson, 1985), a more fundamental question may be why some beliefs are acquired socially and are maintained as a shared rule, whereas other beliefs are not. A theory of norm development must address this question explicitly, explaining why particular behavioral–cognitive patterns (and not other patterns) proliferate in a society and are maintained as shared rules and standards.

Toward such a theoretical end, this article develops a theory about how a well-defined social norm, the "communal-sharing norm" (Kaplan & Hill, 1985; Kaplan, Hill, & Hurtado, 1990), is realized in a sustainable manner across many independent societies. This is a norm about social exchange, designating uncertain resources as common properties to be shared with other members of a social group. Our purpose here is to illustrate how a useful theory about norm-emergence can be developed, with the communal-sharing norm as a guiding example. In this article, we start with anthropological findings about the communal-sharing norm in basic, primordial societies. Based on these findings, we develop a theory about how the communal-sharing norm emerges and is maintained, using a game-theoretic method called "evolutionary game analysis" (Gintis, 2000; Maynard Smith, 1982). We then test several behavioral implications of the communal-sharing norm in highly industrialized societies such as the United States and Japan. Finally, we discuss importance of social-norm construct as a conceptual tool to analyze the micro–macro relation between individual minds and society systematically, viz., a useful theoretical device to link psychology to other social sciences.

Communal-Sharing Norm in Hunter–Gatherer Societies

Anthropological Findings About Sharing

Sharing important resources such as food widely beyond direct kin is one of core features characterizing human societies. Although a primitive form of food sharing is known in several primates including chimpanzees, bonobos, and capuchin monkeys (see de Waal, 1996, for a comprehensive review), no primates other than humans have a broad social-sharing system. Indeed, Issac (1978) argued that the social-sharing system played vital functions for hominids to evolve into the human species in its present form. Likewise, evolutionary psychologists claim that the need for social exchange and sharing promoted evolution of domain-specific cognitive mechanisms, such as a cheater-detection algorithm (Cosmides, 1989) and Machiavellian intelligence (Byrne, 1995).

Research on social exchange and sharing in basic, primordial societies to explore its origin and early forms has been a prime agenda in anthropology. Among various studies, Kaplan & Hill's (1985; Kaplan et al., 1990) observation of the Ache (pronounced Ah-chay) foragers living in the lowland subtropical eastern Paraguay is particularly pertinent to this article. These researchers found that food transfers among the Ache show markedly different patterns between hunted games (e.g., peccary, monkey, deer) and collected resources (e.g., vegetables, fruits). Hunted game, especially when large in package sizes, tends to be shared widely across many community members beyond the acquirer's family. Although a substantial portion of collected resources is still given to nonfamily members, hunted game is much more likely to be the target of communal sharing, in terms of both "depth" (the proportion of the food given away to nonfamily members) and "breadth" of sharing (the number of nonfamily members who receive the share; cf. Gurven, 2002). Related findings have also been obtained for other hunter–gatherer societies (cf. Cashdan, 1989; Gibson, 1988; Woodburn, 1982). These observations suggest that the properties of the resources affect deeply how they may be transferred among community members. Although the principle of kin-sharing essentially operates for collected resources, sharing across the entire community is often observed for hunted game. This raises the theoretically important question as to why different sharing norms emerge and are maintained for different resources. More specifically, why is hunted game shared communally across many band members beyond the acquirer's direct kin (cf. Hamilton, 1963)?

"Communal Sharing as Risk Reduction" Hypothesis

Kaplan and Hill (1985) explained the difference in terms of the degree of uncertainty involved in resource acquisition. Although provision of collected resources (e.g., vegetables, fruits) is relatively stable, acquisition of meat is a highly variable, uncertain prospect. On average, there is a 40% chance that an Ache hunter will come back empty-handed (Kaplan et al., 1990). It is thus essential for them to manage the variance associated with meat-acquisition, securing a stable supply of the resource. Storage by freezing is an obvious individual solution to reduce the uncertainty, but such a technique is not readily available in hunter–gatherer societies. Other storage methods such as drying and smoking meat may result in nutrient loss. Kaplan and Hill (1985) argued that, instead, the sharing system functions as a collective risk-reduction device. By including more individuals in the risk-pooling group, the variance in food supply decreases exponentially. Once established and maintained, the sharing system that includes many individuals can buffer the variance in the resource supply collectively.

The risk-reduction hypothesis is intuitively appealing. Yet, we think that this explanation still leaves one critical problem unanswered—the problem of egoism in social dilemmas (cf. Dawes, 1980; Hardin, 1968; Messick & Brewer, 1983). According to Hawkes, O'Connell, and Blurton Jones (2001), hunted meat, especially when large, is often regarded as a common property in hunter–gatherer societies; the process of meat distribution is more like appropriation from the public domain (see also Woodburn, 1998). Then, what if some individuals behave as egoists who just share other people's acquisitions but are never willing to share their own acquisitions with others? Those egoistic individuals should be better off than those who are loyal to communal-sharing norm. If such egoists, who outperform the loyal individuals in terms of individual fitness, proliferate in a group, then the social-sharing system should inevitably collapse. The risk-reduction explanation per se is incomplete in this sense, because it is silent about how the emergence and proliferation of such egoists is precluded in the group. A seemingly "obvious" mechanism to solve this puzzle would be social sanctioning, but as we discuss later in detail, the maintenance of such a sanctioning mechanism requires elaborate safeguards of its own.

Tolerated-Theft Hypothesis

A different anthropological explanation that is free from the public-goods problem is a tolerated-theft hypothesis (Bliege Bird & Bird, 1997; Blurton Jones, 1984, 1987; Hawkes, 1992). This hypothesis explains social sharing as a consequence of contests over the acquired resource. A common feature of hunter–gatherer societies is a lack of "privacy;" it is highly difficult to conceal acquisitions of food from other people's eyes (cf. Cashdan, 1989). Now, imagine a situation where an acquirer of a resource is challenged by another individual having failed to obtain the resource ("nonacquirer" hereafter). Suppose also that each individual's utility function for the resource is marginally diminishing, as assumed in economics and psychology. Then, the gain (i.e., increase in utility) that the nonacquirer receives by snatching one unit of resource from the acquirer should be larger in value to the nonacquirer, than the loss that the theft causes for the acquirer. One unit of the resource is more valuable for the nonacquirer than the acquirer. This means that the nonacquirer will be willing to bear a larger fighting (or other punishment) cost to snatch one unit of resource than the acquirer will accept to defend the same one unit of the resource. Given this asymmetry, it is adaptive for the acquirer to avoid the contest with the nonacquirer and "tolerate the theft." Because such an asymmetry exists until both parties hold the same amount of the resource, communal sharing should be the result.

The tolerated-theft hypothesis explains how the state of communal sharing is a result of the individual-level self-maximizing adaptation. The explanation is logically coherent and intuitively plausible for sharing in a pairwise situation (i.e., one acquirer and one nonacquirer). However, what if we apply this model to a group situation composed of more than two individuals? In an n-person group situation, the asymmetry in resource level can be defined $\binom{n}{2}$ for pairs. However, given multiple pairs, "equal-sharing" solutions in specific pairs do not necessarily terminate the contest process in the group, as long as asymmetries remain between other individuals. The pairwise tolerated-theft solution can logically lead to infinite contests in the group; there must be some collective termination mechanism for the potentially endless contests. We think that a generalized communal-sharing norm is a prime candidate for such a collective termination mechanism. Indeed, in the Ache society, sharing of uncertain resources is conducted in an orderly manner, and the hunter who has acquired the game is expected to behave modestly (Kaplan & Hill, 1985; see also Cashdan, 1989). People seem to share beliefs about what to do with uncertain resources—a genuine communal-sharing norm.

To recapitulate, the risk-reduction hypothesis explains why people value the communal-sharing rule, but leaves the issue of its sustainability in the society, where there may be "egoists," unanswered. In contrast, the tolerated-theft hypothesis explains why a state of communal sharing may emerge, but ignores the fact that such a sharing often reflects an expressible, generally-shared rule (cf. Fiske, 1992). Thus, to combine these two explanations, we need a theory about how the communal-sharing norm can emerge and be maintained as a socially-shared rule in primordial environments. We now apply evolutionary game analysis to develop, explicate, and justify such a norm.[1]

An Evolutionary Game of Communal-Sharing Norm

Evolutionary game analysis is a game-theoretic approach initially proposed by Maynard Smith (1982) in evolutionary biology and later introduced into social sciences by Axelrod (1984; Axelrod & Hamilton, 1981). This approach represents various behavioral–cognitive properties of individuals as strategies in a game, and examines how each of the strategies performs in the game, against other strategies, in terms of net profit. Different from the classical game theory, this approach does not assume "rational actors" with unlimited information-processing capacity. Instead, analogous to biological evolution, the evolutionary game theory assumes that a strategy, which may be limited in terms of information-processing capacity yet performs better than other strategies in terms of net profit, proliferates gradually in the population. In social scientific applications, such changes are not necessarily evolutionary but may reflect, most notably, social imitative learning of successful strategies in a group (Gintis, 2000).

Evolutionary game analysis enables systematic analysis of theoretical issues such as whether the interaction among individual behavioral–cognitive strategies leads to a stable collective state (similar to an equilibrium), in which the population is dominated by a certain strategy (or a set of strategies) and no further changes occur. Because a social norm refers to a socially-shared (and valued) stable set of behavioral–cognitive properties (Cialdini & Trost, 1998), this approach is suited to analyze how a particular norm can emerge and sustain in a society. Although still new to psychology, evolutionary game analysis is a powerful tool theoretically to analyze how a sociocognitive system develops.[2]

Overview of Our Model: Two Main Assumptions

Now we propose an evolutionary game model of the emergence and maintenance of the communal-sharing norm in basic, primordial environments. Before explaining behavioral strategies in the game, let us define two main characteristics of our model.

First, how shall we operationalize uncertainty in the model? High uncertainty is a key feature characterizing the acquisition of valuable resources (e.g., hunted meats) in primordial environments. There are individual differences as to hunting skills, yet luck still explains a large variance of a hunter's performance (Cashdan, 1989; Kaplan et al., 1990). Given this, we operationalize such uncertainty by asynchronicity in successful resource acquisition among members (Gurven, 2002). Because resource acquisition is a highly variable process, the number of individuals who luckily acquire the resource at one time point is quite small, whereas most individuals remain unsuccessful. This operationalization is consistent with Kaplan and Hill's

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[1] Food-sharing in hunter–gatherer societies is currently the topic of a vigorous debate in anthropology, and various theoretical models have been proposed (see Winterhalder, 1997, for a review). Besides the theories discussed in this article, two other theories are notable. Reciprocal altruism theory (e.g., Gurven, Allen-Arave, Hill, & Hurtado, 2000; Trivers, 1971) views a food transfer between two nonkin individuals as a conditional exchange conducted within the pair repeatedly—meat for meat, meat for help in emergency, and so forth. This theory assumes that an acquirer shares the resource with other individuals in a pairwise, one–to–one manner ("restricted exchange;" Ekeh, 1974), rather than providing it to the community as a public property ("generalized exchange;" Ekeh, 1974; Kameda et al., 2002). Costly signaling theory (e.g., Smith & Bliege Bird, 2000; Sosis, 2000) maintains that an individual's hunting and sharing activity often serves as an honest and reliable signal (Zahavi, 1975) about the individual's desirable qualities such as vigor, stamina, good intention, and so forth. Individuals with these qualities are more likely to be selected as mates or allies, which provides an incentive for the individuals to share. These theories, including the one proposed in this article, make differential predictions about details of actual food-transfer patterns (e.g., who demands social sharing most vigorously, what kind of sanctioning is viable) and about forms of potential free-riding in food provision (e.g., who goes out for hunting, who engages in sanctioning). These predictions should be examined empirically in future work. However, because our purpose here is to present a model analysis of adaptive norm development using communal sharing as an illustration (rather than to differentiate the specific theories about food transfers), we do not discuss these predictions in this article. Interested readers are referred to, for example, Gurven (2002), Kameda et al. (2002), and Smith and Bliege Bird (2000).

[2] See Liebrand and Messick (1996) for recent applications of evolutionary games to the emergence of joint cooperation in social dilemmas. Although not necessarily focusing on the emergence of sharing norms, some of the models in the volume used the aforementioned evolutionary algorithm, rather than the classical game-theoretic approach, to consider "evolvability" of cooperative strategies in an *N*-person setting. The model we develop in this article shares this feature.

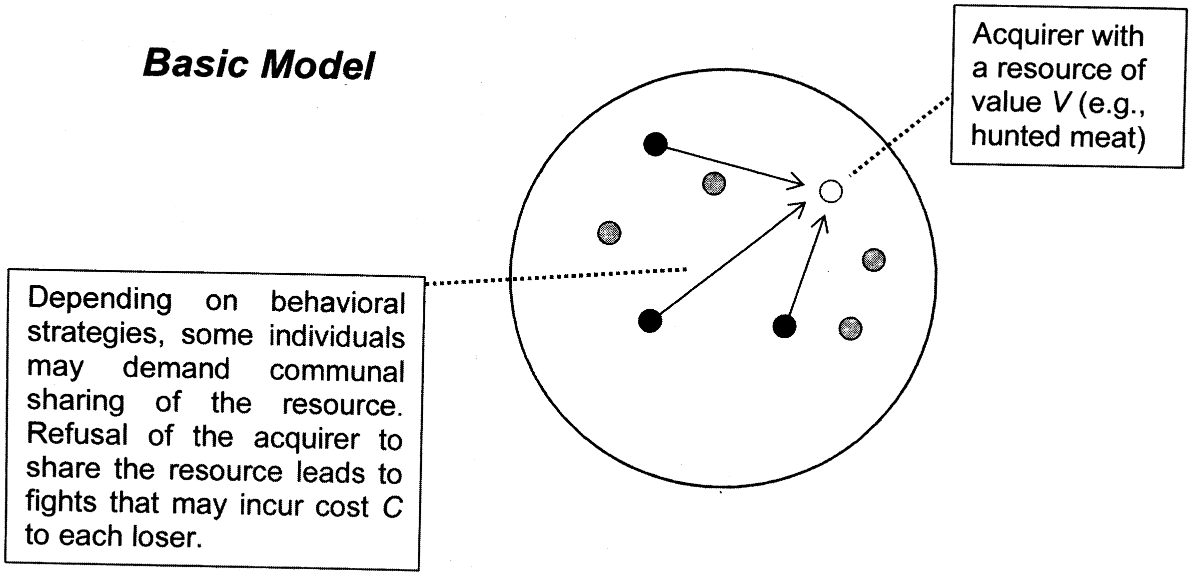

Figure 1. A schematic representation of the evolutionary game of communal sharing.

(1985) view that communal sharing reduces high variance in resource acquisition statistically.

Second, in line with the tolerated-theft hypothesis, we assume that nonacquirers can challenge the acquirer to share the resource. The difference from the tolerated-theft model is that such challenges are not conducted on a pair-by-pair basis where the acquirer and a nonacquirer interact to "share" the resource just between the two. Instead, we assume that nonacquirers demand communal sharing of the resource, designating the resource to be common property. In other words, we conceptualize a potential contest between the acquirer and nonacquirers as a conflict about whether the resource should be private or public property (cf. Hawkes et al., 2001). This assumption reflects the aforementioned problem in the original tolerated-theft hypothesis that pairwise "sharing" can lead to endless contests in a group setting.

Figure 1 summarizes these two assumptions graphically. We presume a social situation in which, after an individual luckily acquires a resource of value *V*, individuals engage in social interaction over the resource as determined by their respective behavioral strategies. If some nonacquirers demand communal sharing of the resource and the acquirer declines it, then contests arise over the resource that incur cost, *C* (e.g., physical injury), to each loser. With these two key features in mind, let us define behavioral strategies in the following section.

Four Basic Behavioral Strategies

When high uncertainty is involved in resource acquisition, an individual always faces two kinds of decision problems: How to behave when the individual happens to be an acquirer of resource? And, how to behave when the individual happens to be a nonacquirer? As shown in Table 1, we formulate four basic behavioral strategies in the game, as a combination of two substrategies under each of these two situations.

The four cells in Table 1 specify how an individual adopting a given strategy (named "communal sharer," "egoist," "saint," or "bourgeois," respectively) behaves with reference to uncertain resource acquisition. These behavioral strategies differ in their underlying "ideology" about what to do with uncertain resource—to be privatized or to be communalized. For example, a communal sharer is the purest supporter of the communal-sharing ideology, provisioning resource that he or she has acquired as a common property and demanding communal sharing of resource that another individual has acquired. An egoist and a saint are located somewhere between the two poles. An egoist claims private ownership of the resource that he or she has acquired, but demands communal sharing of resource acquired by another.[3] A saint is a mirror image of the egoist, provisioning his or her resource as a common property but granting another acquirer's private ownership. Finally, a bourgeois's ideology is exactly the opposite of the communal-sharing ideology, claiming private

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[3] Notice that an egoist defined here demands communal sharing of resource that another individual has acquired. An egoist does not try to snatch resource from the acquirer to monopolize it (another preliminary analysis confirmed that such a "hardcore egoist" is selected against right away), but to realize communal sharing of the resource. These egoists are supporters of the communal-sharing ideology as to resource that another individual has acquired. It may be possible to view these egoists as "weak-minded" communal sharers who are tempted to claim private ownership when they themselves acquire resources.

Table 1. *Four Behavioral Strategies in the Evolutionary Game Model of the Emergence of a Communal-Sharing Norm Under Uncertainty*

		When in the *nonacquirer* role	
		Demanding communal-sharing	**Granting another acquirer's ownership**
When in the *acquirer* role	**Provisioning as a common property**	Communal sharer	Saint
	Claiming private ownership	Egoist	Bourgeois

ownership as an acquirer and granting another acquirer's private ownership; so, a bourgeois respects the ideology of private ownership consistently whether or not the self is an acquirer.

Computation Algorithm of the Model

Defining individual strategies this way, we need to specify a computation algorithm about how these strategies interact in the game. The algorithm is composed of two phases: resource-acquisition phase and resource-processing phase.

Because we are concerned with a highly uncertain situation, we assumed that the probability of two individuals simultaneously acquiring the resources was negligible in our model. Thus, in the acquisition phase, one individual was randomly designated as an acquirer of a resource of value V (cf. Figure 1).How the resource is handled in the group following the acquisition depends on the acquirer's strategy and the nonacquirers' strategies. This corresponds to the resource-processing phase. If the acquirer claims private ownership (i.e., bourgeois's and egoists) and some of the nonacquirers demand communal sharing of the resource (i.e., egoists and communal sharers), fights arise over the resource that incurs cost C to each loser. We assumed that if and only if the acquirer won all of the fights against those who demanded communal sharing, that acquirer could privatize the resource; otherwise, the resource was shared evenly among the nonacquirers who demanded sharing plus the acquirer. For simplicity, we presumed that all individuals' fighting abilities were identical.

In other cases, no fights about the resource arise in the group. If all nonacquirers in the group grant the acquirer's ownership immediately (i.e., bourgeois and saints), the resource belongs solely to the acquirer. Also, if the acquirer is ready to provision the resource as a common property on requests (i.e., saints and communal sharers), the resource is shared evenly among those who demand communal sharing plus the acquirer.

The focus of our initial analysis is to see if communal sharers perform better than individuals with the other three strategies in terms of net profit and, therefore, proliferate in a group. Is the communal-sharing norm indeed realized in a stable manner in the group? In the following section, we first report an analysis of most general questions concerning simple forms of the strategies. We then examine an important issue that is not addressed in the first analysis, viz., the issue of "free-riding" in norm enforcement (Olson, 1965). As can be seen in Cialdini and Trost's (1998) definition, the issue of enforcement is essential for any theory of social norms (Boyd & Richerson, 1992; Coleman, 1990). Thus, by a series of computer simulations, we examine if the communal-sharing norm is indeed realized in a stable manner even when considering the further possibility of free-riding in norm enforcement.

A Formal Analysis of the Basic Strategies

In the evolutionary game, there are two criteria to evaluate how well a given strategy (x) behaves compared to other strategies. The first criterion is called *evolutionary stability.* Suppose there is a situation in which a group is composed only of individuals with the focal strategy, x. Now a question arises concerning if such an all-x group is robust enough to block a small number of individuals with another strategy (y) from intruding into the group. Does strategy x outperform strategy y in terms of average profit? If strategy x actually outperforms strategy y, it can block y's intrusion into the group, analogous to biological "competition" for an ecological niche. If strategy x is dominant in this sense over all other strategies in the game, then strategy x is called an *Evolutionarily Stable Strategy (ESS).*

The second criterion is a mirror image of the first, called *evolvability.* This time, strategy x is the intruder trying to intrude into the environment of a group composed of another strategy (y). If a small number of individuals with strategy x can outperform y, then x can "evolve" (i.e., intrude and proliferate) in the group. This criterion is concerned with evolvability of strategy x in groups composed of another strategy (see Gintis, 2000; Maynard Smith, 1982, for a comprehensive discussion about these success criteria).

To examine whether a given strategy x indeed satisfies the two criteria, we need to compare expected payoffs between x and each of other strategies in a pairwise manner. Because there are four strategies in the game, there are six pairs for comparison. In our first analysis, we compared expected payoffs between two strategies of each pair, varying parameters of the model (group size *G*, resource value *V*, fighting cost *C*) and the intruder–defender role systematically. We have provided the equations for these comparisons in Appendix A.

Results of the Formal Analysis: Dominance of the Communal-Sharing Strategy

The formal analysis (see Appendix A for details) revealed that communal-sharing strategy is a unique ESS in the game for a wide range of parameters. When a group is composed of communal sharers, it blocks a small number of individuals with another strategy (saint, bourgeois, egoist) from intruding into the group. Specifically, from the equations in Appendix A, it can be shown that an individual with any other strategy who tries to intrude into a group of communal sharers obtains lower expected payoffs than the communal sharers, if the following parameter condition is satisfied:

$$C > \frac{0.5^{G-1}(G-1)}{(1-0.5^{G-1})(G-2)}V. \qquad (1)$$

To illustrate, when a group is composed of 10 people ($G = 10$), communal-sharing strategy is ESS if $C > 0.0022V$ in the game, that is, if cost *C* (e.g., physical injury) associated with fighting over the resource (e.g., meat) is larger than 0.22% of the resource value *V*. Given that fighting cost such as physical injury tends to be substantive (sometimes even risking a life), this boundary condition is highly marginal. Notice also that when group size *G* gets larger, this condition becomes more marginal; the right-hand side of equation 1 quickly approaches 0. In other words, for a very broad range of parameters, communal-sharing strategy is evolutionarily stable.

Then, what about evolvability of communal sharing strategy when it is rare and in the role of intruder? The formal analysis revealed that, even when rare, communal-sharing strategy can intrude and proliferate in a group of saints unconditionally, and a group of egoists in the identical (broad) parameter range as specified in equation 1. Intrusion into a group of bourgeois's is possible if

$$C \leq \frac{G}{2G-4}V. \qquad (2)$$

This parameter range is less marginal than the range specified by equation 1. On the surface, this may seem to limit evolvability of communal-sharing strategy into a group of bourgeois's in the specific parameter range. However, as can be easily verified in Appendix A, a group of bourgeois's is vulnerable to the intrusion by saints unconditionally. Given that communal sharers can intrude and proliferate in a group of saints unconditionally (discussed earlier), they can intrude into a group of bourgeois's in an indirect, two-step manner. Even when direct intrusion is impossible (when equation 2 is not met), communal sharers can intrude into a group of bourgeois's in the two-step manner with the "guide" of saints.

To summarize, the formal analysis shows that communal-sharing strategy is the only strategy in the game that satisfies the two criteria (evolutionary stability and evolvability) simultaneously for a broad parameter range.

Why is Communal-Sharing Strategy Dominant?

It is easy to explain why communal-sharing strategy is dominant in the first analysis. When resource acquisition is highly uncertain, the nonacquirers necessarily exceed the acquirers in number by a wide margin at any time point. In such a situation, individuals who are loyal to the communal-sharing ideology when in the nonacquirer role (i.e., communal sharer and egoist) can enjoy an advantage in numbers with respect to fighting cost, *C*; when refused to access the resource, these individuals can distribute the fighting cost among themselves statistically, whereas enhancing the probability of winning the fights collectively. In contrast, an individual who claims private ownership as an acquirer (i.e., bourgeois and egoist) is quite unlikely to win all these challenges to privatize the resource, although quite likely to bear the heavy fighting cost. Accordingly, an egoist, whose expected payoff is exactly identical to that of a communal sharer when in the nonacquirer role (by demanding communal sharing of the resource), suffers from own behavior to privatize the resources he or she acquires. Therefore, a communal sharer achieves the highest net profit among the four strategies in the game.

Before closing this section, we should acknowledge that some of the model's assumptions may be much simpler than reality. For example, in reality, there can be more than one acquirer at one time point; individuals may differ in their hunting or fighting abilities; conflicts between acquirer and nonacquirers may take a collective (one-to-many) form rather than a series of one-to-one fights; and so forth. However, the key point here is that high uncertainty associated with resource acquisition necessarily yields a situation where the nonacquirers outnumber the acquirers by a wide margin at any time point. It is this discrepancy in number between the haves and have-nots that provides an advantage for communal sharers to perform better than individuals with other strategies. Thus, as far as this basic relation holds, alternations of the simplifying assumptions to more "realistic" complex ones do not affect the main conclusions of the analysis.

Enforcers of the Norm Versus Free Riders: First Computer Simulation

The results of the first evolutionary game analysis indicate that a communal-sharing norm may indeed evolve in a sustainable manner when uncertainty in resource acquisition is high. Yet, is this analysis theoretically sufficient? Let us complicate the first analysis by considering the "free-rider problem" (Olson, 1965).

Free-rider problem. A free rider refers to a person who enjoys a benefit of a social system without bearing cost to maintain it. For instance, imagine a system of "vigilance committees" in the old Wild West. A vigilance committee serves the public interest by securing safety equally for everyone in a town. The operation of the vigilance committee is costly in terms of money, time, and physical risk. Then, what happens if free riders, who "endorse" the vigilante actions but do not participate, appear in such a situation? Such free riders do not bear the costs but they enjoy the social benefits of the vigilantes, thus, they are better off than individuals who honestly bear the costs. The logic of the evolutionary game implies that, under many conditions, those free riders will proliferate in the group, eventually causing the collapse of the nonfree riders and the norms they promote.

This general logic is applicable to the maintenance of the communal-sharing norm as well. Recall how we defined behavior of those who demand sharing when they happen to be nonacquirers. We presumed that not only communal sharers but even egoists, who are selfish when in the acquirer role, are equally cooperative in enforcement of the communal-sharing norm, ready to punish a violator of the norm (cf. Footnote 3). However, what if free riders exist among those "demanders," who endorse the communal-sharing norm but are less willing to enforce the norm to its violators? If other individuals enforce the norm successfully, the free riders can enjoy the fruits of the others' costly efforts without bearing the enforcement burden (fighting cost, *C*) at all. As in the example of a vigilance committee, the logic of evolutionary game implies that such free riders will proliferate in the group, causing the eventual collapse of the communal-sharing norm. Thus, a problem with our initial analysis is that it neglected the free-rider problem, by assuming that all individuals who demand communal sharing are equally and fully willing to enforce the norm.

To confirm this reasoning, we conducted a computer simulation modifying the original model by incorporating individual differences in willingness to bear the cost for norm-enforcement. In this simulation, we started out with an initial state in which a group was composed only of communal sharers. However, different from the first analysis, we now permit individual differences in the willingness to enforce the norm. When in the nonacquirer role, some communal sharers are less willing to punish the violators of the norm than other communal sharers. We allowed random "mutations" in behavioral strategies to emerge with a small probability in this all-communal-sharer-group.[4] Our focal question here is whether communal-sharing strategy is still an ESS: Is the communal-sharing norm sustainable when free riders exist? We have provided the algorithm used in this modified analysis in Appendix B.

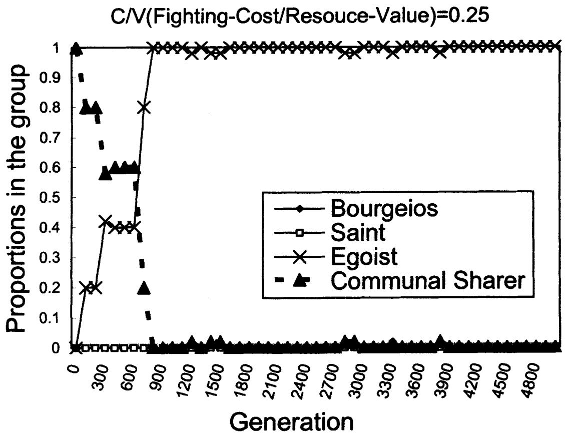

Figure 2. Collapse of the communal-sharing norm when there exist nonenforcing free riders (first computer simulation).

Results. Figure 2 displays representative results of the first simulation. This figure shows proportions of the four behavioral strategies over time ("generations") in a 10-person group, when the ratio of fighting cost *C* to resource value *V*, *C/V*, was 0.25. Notice that the aforementioned formal analysis assuming no free riders predicts that communal-sharing strategy is an ESS for these parameter sets (cf. equation 1).

However, with the passage of time, the initial communal-sharing system gradually collapsed. Instead, the group was eventually dominated by egoist–free-rider hybrids, who claimed private ownership when in the

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[4] In an evolutionary game analysis using computer simulations, a behavioral strategy is often represented by a "gene" or a "set of genes." For example, each strategy in Table 1 can be represented by two genes, specifying how to behave as an acquirer and as a nonacquirer, respectively. Analogous to actual inheritance, a random "mutation" may occur to these genes with a small probability in each "generation." The notion of mutation is used to check if a given strategy is an ESS. A random mutation to genes provides an opportunity for a small number of individuals with other strategies to emerge in the group. It then becomes possible to check whether the focal strategy can block the "evolution" of those mutants in the group in terms of net profit. See Axelrod (1984, 1986) and Lomborg (1996) for examples and a more comprehensive discussion of this technique.

acquirer role, and who demanded communal sharing of the resource but were not willing to enforce ("fight for") their demand when in the nonacquirer role. In other words, when some of the communal sharers are less enthusiastic than others about norm enforcement, the communal-sharing system cannot be sustained.

Is the Free-Rider Problem Solvable?

The free-rider problem arises from the fundamental fact that a social norm is essentially a "public good" (Hardin, 1968). At least some individuals can benefit from a public good without incurring a cost for its maintenance, as in the example of the vigilance committee. Thus, the free-rider problem in norm enforcement is one of the central issues for any theory of norm development (Boyd & Richerson, 1992; Coleman, 1990).

It is often argued that social sanctioning is a solution to the free-rider problem. Let us go back to our illustrative case: Some norm enforcers may sanction the free riders by blocking their access to communally-shared resources. Although such sanctions may look like a solution, the identical logical problem that applied to the basic four-strategy case applies recursively: Among the norm enforcers, who incur the additional sanctioning costs for excluding the nonenforcing-free riders from social sharing? Exclusion of those free riders from communal sharing may also be costly (e.g., fights with the free riders). However, at the same time, successful exclusion of the free riders from communal sharing is beneficial to all norm enforcers. A new, but structurally identical free-rider problem, "2nd-order free-rider problem" (Axelrod, 1986; Yamagishi, 1986) arises here.

To illustrate, suppose that there are two types of norm enforcers. One type is intolerant; in addition to their willingness to punish a direct violator of the communal-sharing norm (e.g., egoist, bourgeois), these individuals are ready to bear additional costs for excluding the nonenforcing free riders from social sharing. The other type is tolerant; this type is willing to punish the direct violator of the norm, but does not punish the free riders. (See Figure 3 for a summary for the distinctions within the class of individuals who endorse the communal-sharing ideology when in the nonacquirer role.)

Notice that the tolerant enforcers can be seen as "2nd-order free riders" who benefit from costly efforts of the intolerant enforcers trying to exclude the nonenforcing "1st-order free riders" from social sharing. In other words, the tolerant enforcers should always be better off than the intolerant enforcers in terms of net profits.

Now, what happens if we apply this logic to the sustainability of the communal-sharing system? Suppose that again we start with an all-communal-sharer-group while allowing for mutants to emerge with a small probability. The logic of the evolutionary game implies that if the intolerant communal sharers disappear from a group because of their fitness disadvantage, then the tolerant communal sharers will be wiped out by the nonenforcers, who are eventually wiped out by the egoists. In other words, a domino-like collapse of the communal-sharing system is expected logically, even if social sanctioning against the 1st-order free riders is originally present.

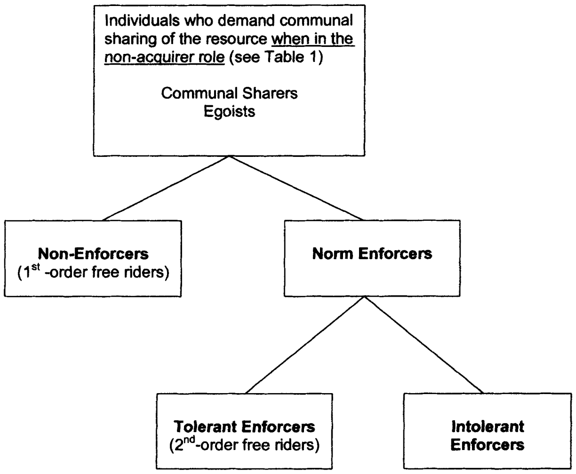

Figure 3. An overall summary for the distinctions within the class of "demanders," who endorse the communal-sharing ideology when in the nonacquirer role.

Possibility of a Sustainable Communal-Sharing Norm

Second- (and higher-) order free riding is an essential problem for the maintenance of any general social norm. Although there have been several theoretical attempts to solve this puzzle (e.g., Axelrod, 1986; Boyd & Richerson, 1992; Yamagishi & Takahashi, 1994), no general solution has been reached. In this article, we show that the problem of 2nd-order free riding is solvable at least for social sharing in an uncertain environment. Through two additional computer simulations, we demonstrate that the communal-sharing norm is "evolvable" and sustainable, when acquisition of resource is uncertain as for the Ache and other hunter–gatherer societies.

Throughout the following simulations, we introduce the aforementioned distinction within the class of norm enforcers between tolerant and intolerant individuals (see Figure 3). Our second simulation assumes a "behavioral rationality" about how the nonenforcers (1st-order free riders) react to the intolerant enforcers. As explained later, we think that behavioral rationality of 1st-order free riders is a key to solve the potential problem of 2nd-order free riding in communal sharing. The third simulation relaxes this rationality assumption and tests if the communal-sharing norm is still "evolvable" and sustainable.

"Behavioral Rationality" of 1^{st}-Order Free Riders: Second Computer Simulation

Recall the definition of nonenforcing free riders; these are individuals who just "endorse" the communal-sharing norm but do not punish its violators when in the nonacquirer role (see Figure 3). Now, why would these free riders avoid fighting with direct violators of the norm, such as egoists and the bourgeois's? At least two "psychological motives" may be relevant: (a) fear of a fight, and (b) greed, exploiting norm-enforcers' costly efforts (cf. Van de Kragt, Orbell, & Dawes, 1983; Yamagishi & Sato, 1986).

Given these two motives, let us speculate how these free riders may react, when refused access to the resource by the intolerant enforcers: how likely will the free riders fight back against the intolerant enforcers? From the first motive ("fear"), fights with the intolerant enforcers should be feared even more than fights with the direct violators of the norm, because of the relative risk involved. If such free riders enforced the communal-sharing norm against its direct violators at the outset, they could distribute fighting costs broadly with other individuals who demanded sharing (see the top box in Figure 3). However, when they free-ride and are challenged later by the intolerant enforcers, those free riders must distribute the full fighting costs just among themselves. Because the free riders are a subset of "demanders" by definition (cf. Figure 3), the actual risk (expected fighting cost) involved is much higher in the latter case, whereas the stake in the fight (share of resource) is identical. Thus, fights with the intolerant enforcers should be more threatening to free riders than fights with the direct violators of the norm. At the same time, from the second motive ("greed"), free riders should be inclined to exploit other free riders' efforts to fight with the intolerant enforcers, just as they selfishly avoid the fights against the direct violators of the norm.

The aforementioned reasoning suggests that, if those nonenforcing-free riders are "rational" in terms of cost-benefit assessment, then their propensity to fight with direct violators of the sharing norm (p_1) should be greater than (or equal to) their propensity to fight back against the intolerant enforcers, who block their access to the resource (p_2). We label this relation $p_1 \geq p_2$, the "behavioral rationality of 1^{st}-order free riders."

The behavioral rationality of free riders has an important implication for the solvability of the 2^{nd}-order free-rider problem in communal sharing. Again, recall the definition of 1^{st}-order free riders. These are individuals who just endorse the communal-sharing norm but are not willing to enforce the norm themselves. In other words, their propensity to fight with direct violators of the sharing norm (p_1) is small by definition (cf. Appendix B). Now, given the behavioral rationality ($p_1 \geq p_2$), their propensity to fight back against the intolerant enforcers (p_2) when blocked to access shared resources should be even smaller, almost negligible.

What does this mean to the sustainability of the communal-sharing system? The behavioral rationality assumption implies that those free riders tend to retreat (i.e., p_2 is negligible) in the face of the intolerant enforcers' refusals. Then, the intolerant enforcers can exclude the free riders from social sharing efficiently, by only threatening punishment ("bluffing") and not actually engaging in the costly fight. This allows the intolerant enforcers to survive, because there is no effective difference in net profits between the intolerant and tolerant enforcers. The 2^{nd}-order free-rider problem is thus avoidable, and nonenforcing 1^{st}-order free riders are effectively eliminated. With the assumption of free rider's behavioral rationality ($p_1 \geq p_2$), the communal-sharing norm should be sustainable.

To test this reasoning, we conducted a second computer simulation with the assumption of free rider's behavioral rationality, while keeping other aspects of the model identical to the first simulation (see Appendix C for the algorithm). Figure 4 displays representative results of this simulation.

Figure 4(a) displays results when we started out with a group initially composed of all intolerant, norm-enforcing communal sharers (cf. Figure 3). The simulation parameters used were exactly identical to those used in the simulation reported in Figure 2, where group size was 10 and the ratio of fighting cost C to resource value V, C/V, was 0.25. Here again, random "mutations" in behavioral strategies could emerge with a small probability.

The difference from Figure 2 is clear. The initial communal-sharing system that collapsed over time in Figure 2 was sustainable against egoist mutants; with the assumption of free rider's behavioral rationality, the aforementioned domino-like collapse of the communal-sharing system did not occur. Figure 4(b) examined "evolvability" of the communal-sharing norm. Here, we started out with the "worst" condition where a group was initially composed only of tolerant, least-enforcing ($p_1 = 0.1$) egoist hybrids (cf. Appendixes B & C)—agents with the "most vicious" behavioral properties. The communal-sharing norm was indeed evolvable from zero. Figure 4(c) displays complementary results to Figure 4(b). We again started out with the identical "worst" condition, but did not allow for intolerant enforcers to emerge by random mutation. The communal-sharing norm did not evolve when intolerant enforcers could not emerge.

To test the robustness of the result patterns as observed in Figures 4(a) and 4(b), we further conducted a sensitivity analysis varying the parameters of the model (group size G, and the ratio of fighting cost C to resource value V, C/V) systematically. The sensitivity analysis indicated that the communal-sharing system is indeed quite robust for a wide range of parameters. For exam-

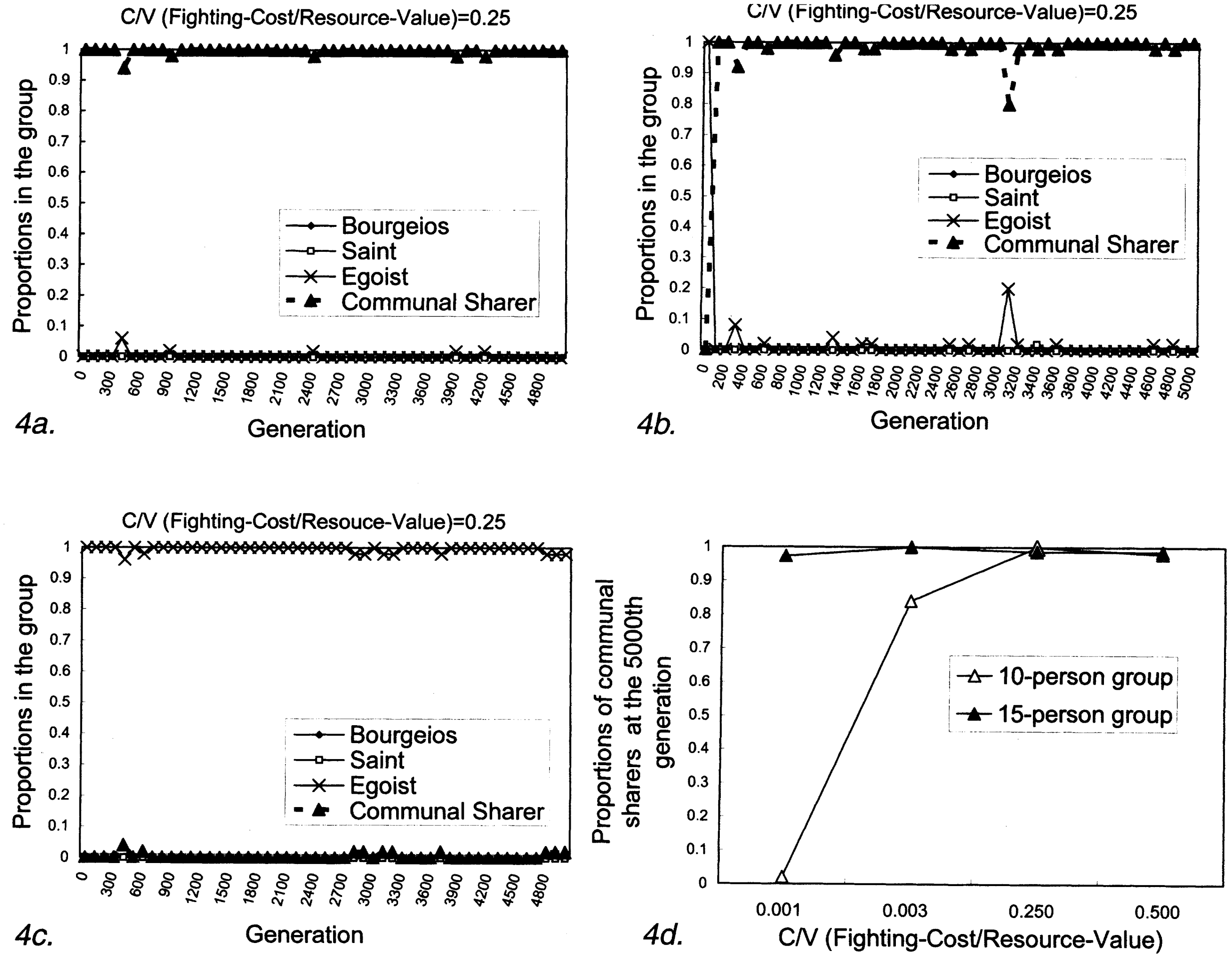

Figure 4. These are the results of the second computer simulation. All nonenforcing free riders exhibit "behavioral rationality" ($p_1 \geq p_2$; see text for explanation): (a) cases starting with a group were initially composed only of intolerant communal sharers; (b) cases starting with the "worst case" group were initially composed of tolerant, least-enforcing egoists; (c) cases were identical to (b) except that intolerant enforcers can never emerge by mutation; and (d) a sensitivity analysis was conducted examining the robustness of the communal-sharing system under various parameter conditions.

ple, as shown in Figure 4(d), the communal-sharing system is sustainable and is also evolvable in a 10-person group, even when $C/V = 0.003$ (fighting cost C is only 0.3% of resource value V—an unrealistically "severe" parameter condition as discussed earlier; cf. equation 1).

These results confirm our reasoning. Despite the potential problem of 2nd-order free riding, the communal-sharing norm is "evolvable" and sustainable in an uncertain environment. The presence of intolerance toward nonenforcing free riders in the group prevents the domino-like collapse of the communal-sharing norm.

Emergence of Free Rider's "Behavioral Rationality:" Third Computer Simulation

As shown in the second simulation test, if the 1st-order free riders exhibit behavioral rationality ($p_1 \geq p_2$), intolerant enforcers can enter and thrive in the group, enabling the communal-sharing norm to evolve and dominate (Figure 4b). We believe that this is a behaviorally plausible assumption that has a rational ground, but it may still be possible to criticize this assumption as arbitrary. The intolerant enforcers can enjoy the benefit of "bluffing" (i.e., only threatening punishment and not actually engaging in the costly fight), if and only if the free riders believe the threat and retreat. Then, what if those free riders do not believe the threat? What if they have no built-in "rational" tendency to avoid fights against the intolerant enforcers?

To address these points, we conducted a third simulation without the "rationality" assumption. We dropped the restriction on the relation between the two fighting propensities ($p_1 \geq p_2$) of the 1st-order free riders. The two propensities were initially set independently; thus, there could be "irrational" cases ($p_1 < p_2$), in which free riders were more aggressive against intolerant enforcers (e.g., "calling their bluffs") than against direct violators of the norm—those free riders did not take the intolerant enforcers' threat seriously.

Figure 5 displays representative results of the third simulation. The simulation parameters were exactly identical to the previous cases in Figures 2 and 4. Figures 5(a), 5(b), and 5(c) correspond to Figures 4(a), 4(b), and 4(d), respectively. The results of the second simulation were replicated, indicating that even if the rationality assumption was not initially built in, the communal-sharing system was still evolvable and sustainable.

Does this mean that the assumption of "behavioral rationality of 1st-order free riders" is unnecessary to solve the potential problem of 2nd-order free riding in communal sharing? Figure 5(d) displays the relations between the two fighting propensities (p_1 and p_2) over time in the simulation reported in Figure 5(a). Because we set the two propensities independently, the proportion of 1st-order free riders who satisfied the behavioral rationality ($p_1 \geq p_2$) was almost equal to the proportion of those who behaved "irrationally" ($p_1 < p_2$), at the outset. However, the figure shows that such a balance rapidly disappeared over time and that almost all individuals in the group eventually behaved consistent with the rationality.

As repeatedly emphasized, nonacquirers outnumber acquirers by a wide margin at any time point in an uncertain environment. Thus, if a nonacquirer joins norm-enforcement activities against a small number of acquirers trying to privatize the resource, the nonacquirer could enjoy the advantage in numbers and reduce the expected fighting cost substantially. However, if the individual decides to free ride and is challenged later by intolerant enforcers, such an advantage in numbers is lost. The individual must now bear a larger expected fighting cost, whereas the stake in the fight (share of resource) is identical. In other words, if having to fight, fighting with norm violators at the outset is more economical than postponing the fight until challenged by intolerant enforcers. Thus, in the uncertain environment, the "irrational" free riders, who react more aggressively against in-

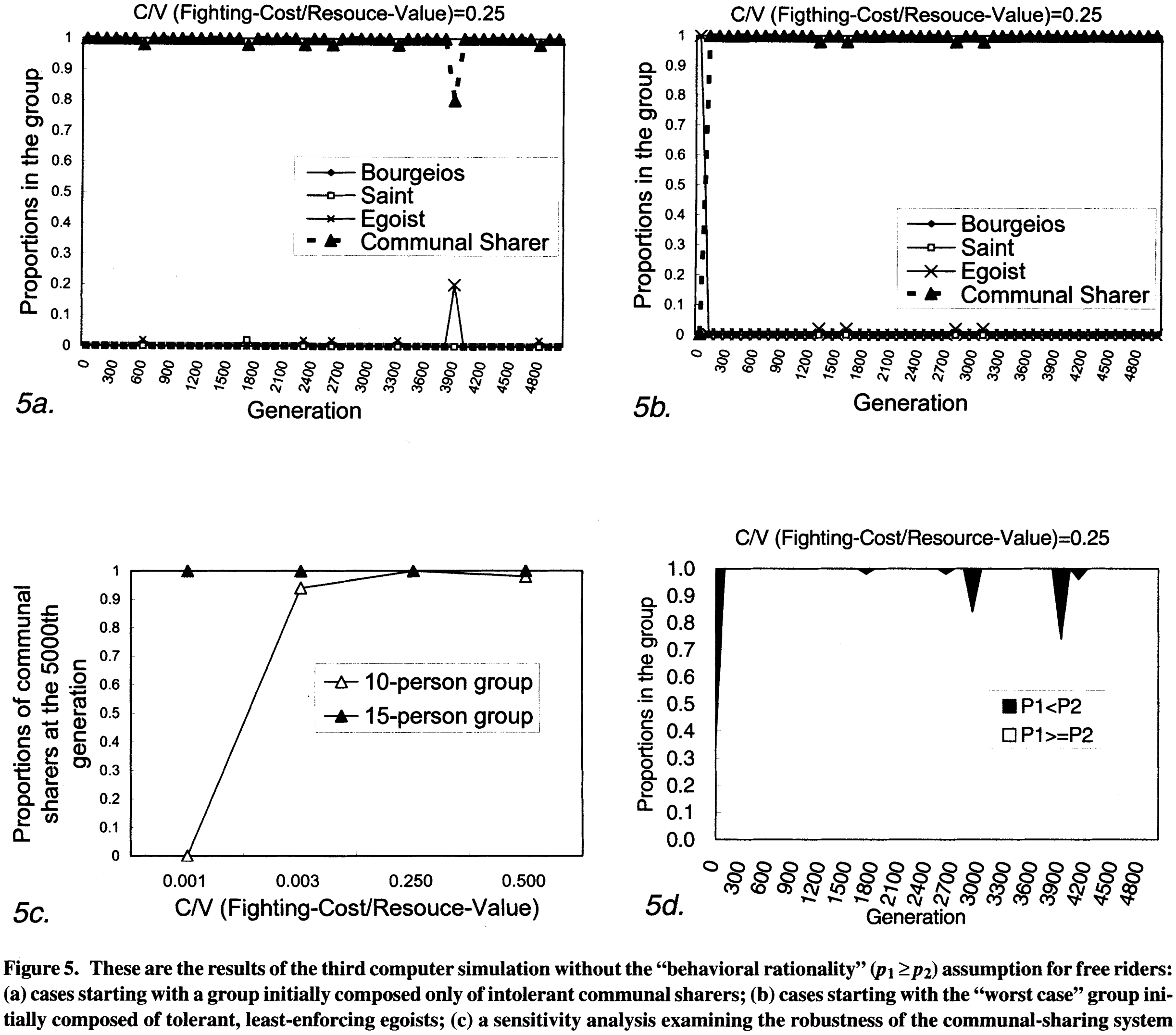

Figure 5. These are the results of the third computer simulation without the "behavioral rationality" ($p_1 \geq p_2$) assumption for free riders: (a) cases starting with a group initially composed only of intolerant communal sharers; (b) cases starting with the "worst case" group initially composed of tolerant, least-enforcing egoists; (c) a sensitivity analysis examining the robustness of the communal-sharing system under various parameter conditions; and (d) relations between the two fighting propensities (p_1, norm-enforcement probability; p_2, probability of fighting back against intolerant enforcers) over time.

tolerant enforcers than against direct violators of the norm ($p_1 < p_2$), are less fit compared to the "rational" free riders who tend to believe the intolerant enforcers' threat ($p_1 \geq p_2$). Accordingly, the behavioral rationality of free riders emerges naturally over time. This feature allows the intolerant, norm-enforcing communal sharers to function effectively without actually bearing the costs for preventing free riders from social sharing. Infinite regress to the 2nd- and higher-order free riding in norm enforcement is avoidable under the uncertain environment, due to the sustainability of intolerant communal sharers in a society.

Behavioral Experiments on Psychology of Social Sharing: Demonstrations of "Windfall as a Common Property Effect"

The theoretical analysis shows that the communal-sharing norm is evolvable and sustainable in a primordial environment, where uncertainty in resource acquisition poses a critical adaptive problem for survival. Interestingly, although we live in industrialized societies where such uncertainty is reduced by various social systems (e.g., production technologies), our own contemporary attitudes and behaviors toward a resource may also be affected by uncertainty involved in its acquisition. For instance, we seem to have a "psychology of sharing" to use windfall money, more often than money acquired by hard labor, for social purposes such as treating friends or donations to charities. Although the identical fungible resource (money) is under consideration in both cases, different psychological processes seem to be triggered, depending on how the resource is acquired.

Of course, this phenomenon may simply reflect a modern ideology of labor theory of value ("money earned without making effort has little value"). However, our evolutionary game analysis suggests another explanation. The key factor for triggering such a psychology of sharing may be the uncertainty associated with the acquisition of the money, rather than the absence of effort. As Cosmides and Tooby (1992) argued, it may be the case that "information about variance in foraging success should activate different modes of operation of these (cognitive) algorithms, with high variance due to chance triggering a psychology of sharing" (p. 213, parentheses added).

To test this possibility, we have recently conducted vignette experiments in which the uncertainty factor was manipulated independently of the effort factor (Kameda, Takezawa, Tindale, & Smith, 2002; Studies 1–3). Participants were provided with a series of imaginary scenarios in which they (or a friend) obtained some money, either (a) contingent on investing substantial effort; (b) unexpectedly (i.e., high outcome-variance due to low contingency between effort and outcome) but after investing substantial effort; or (c) unexpectedly with almost no effort. The following is an example scenario used.

> Certain and high-effort condition
>
> An acquaintance requested you to fill out application forms for a prize giveaway. It was a tedious job to fill out the form. You completed 50 forms in total. Your acquaintance paid you $100 for this service.
>
> Uncertain and high-effort condition
>
> You decided to apply for a prize giveaway. Although it was a tedious job to fill out the application forms, you completed 50 of them to increase your chances to win. Later, you found that you won a prize of $100.
>
> Uncertain and low-effort condition
>
> You decided to apply for a prize giveaway and submitted one application form. Later, you found that you won a prize of $100.

Participants were then asked to rate their willingness to share the money with a friend (or the extent to which they would demand some share from a friend) on 7-point scales. Notice that the modern notion of property rights makes no distinction about the legitimacy of the entitled ownership among the three conditions. However, if uncertainty triggers psychology of sharing, there should be a difference among the conditions, especially between the certain and high-effort and the uncertain and high-effort conditions although the amount of effort invested was identical.

Figure 6 displays results of this experiment using Japanese and American undergraduate students. Although the Japanese sample generally showed a larger sharing-tendency than the American sample, the predicted pattern was evident. Participants' mean willingness to share was higher in the uncertain and high-effort condition than in the certain and high-effort condition, $F(1, 174) = 22.76$, $p <$ 001, in the Japanese sample; $F(1, 314) = 4.10$, $p < .05$, in the American sample by planned contrasts. This comparison was also significant for participants' "willingness to advocate sharing" tendencies, $F\ (1, 174) = 16.80$, $p < .001$, in the Japanese sample; $F\ (1, 322) = 5.19$, $p < .05$, in the American sample. Further, even when statistically controlling for the participants' personal ideologies about labor value or distributive justice (equality or equity), these effects were still significant.

We also conducted a laboratory experiment to manipulate the experienced uncertainty in actual money-acquisition directly (Kameda et al., 2002; Study 4). In this study, 65 Japanese undergraduate stu-

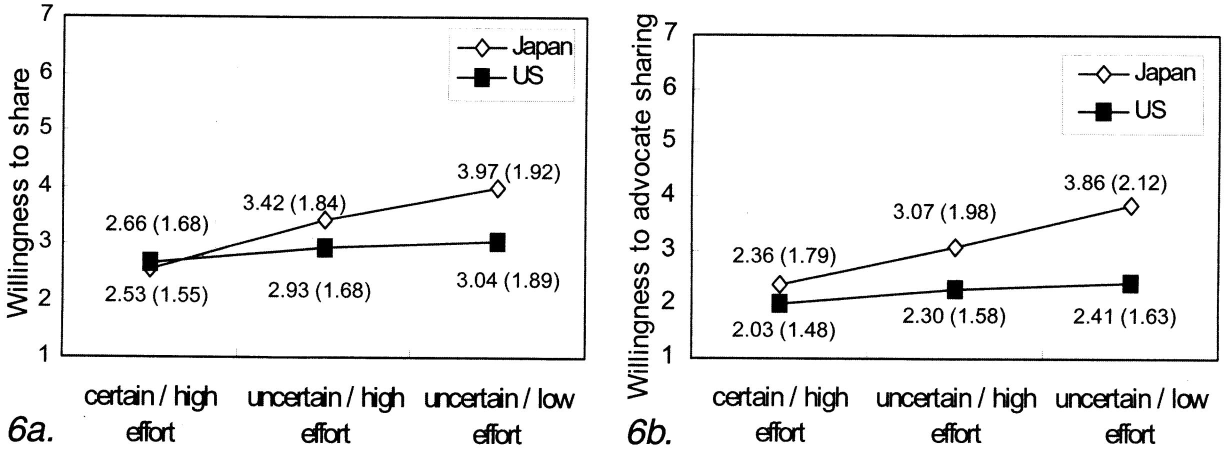

Figure 6. A cross-national experiment on (a) willingness to share and (b) willingness to advocate sharing, as a function of uncertainty of acquisition and invested labor in resource acquisition.

dents worked on 30 arithmetic problems individually. Before they actually started working, the reward for solving one problem correctly was decided either in a deterministic manner ("As a unit reward per problem, we have five conditions ranging from 5 yen to 25 yen. You have been assigned to the 25-yen per problem condition."), or in a stochastic manner by "using a roulette wheel of fortune" with the same unit-reward range. In both conditions, participants received 750 yen as a final reward. At the end of the experiment, they were solicited to donate some money to help participants in another, unrelated experiment. Figure 7 displays the distributions of individual donations in the two conditions. Participants in the uncertain, stochastic condition showed more sharing than those in the certain, deterministic reward condition. The difference was significant, $z = 1.81$, $p < .05$ (one-tailed) by Mann–Whitney *U* test.

These results, of course, do not imply that other factors such as invested efforts, modern distributive ideologies, different cultural–societal values, and so forth, are irrelevant to actual social sharing. These results also do not mean that high-variance information is the strongest predictor of sharing breadth and depth (cf. Gurven, 2002). What was demonstrated is that, even controlling for these factors, our minds are still sensitive to uncertainty information associated with resource acquisition; high-variance information in "foraging success" seems to be an essential ingredient of a computational algorithm that underlies social sharing. Whether such a psychological mechanism has been acquired either evolutionarily (cf. Cosmides & Tooby, 1992) or for historical–cultural reasons remains to be seen, but the game model we have developed suggests that individuals with such a cognitive algorithm may be more fit than others in an adaptive environment.

Social Norm as a Micro–Macro Linkage Between Minds and Society

In this article, we showed how a theory about norm emergence may be developed, with the communal-sharing norm as a guiding illustration. Our metatheoretical perspective throughout this article has been adaptive or functional (cf. Cialdini & Trost, 1998). As expressed in our formal analysis, we view a social norm as emerging from the autonomous interaction of individuals who are motivated to be adaptive, and profit-seeking in their social and natural environment. Such an adaptive perspective, especially the perspective focusing on the individual-level adaptation, highlights the key theoretical issues in norm development, including subtle problems of "1st- and 2nd-order free-riding," norm-enforcement, and sustainability of intolerance toward nonenforcers at various levels—es-

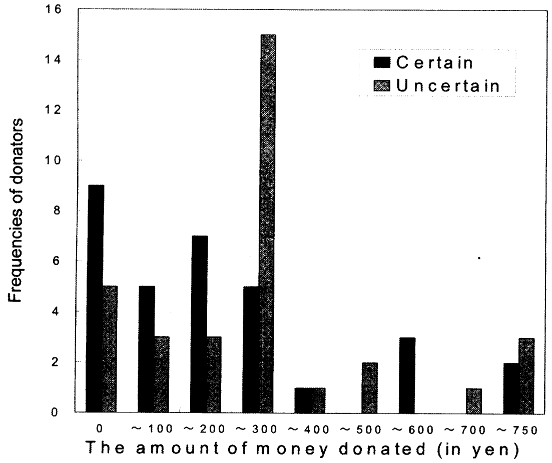

Figure 7. Changes in the donation pattern as a function of uncertainty involved in the acquisition of money.

sential notions for any theory of injunctive or punitive norms (Coleman, 1990). We believe that the conceptual framework as illustrated in this article is particularly useful to consider these issues in a systematic and rigorous way.

Of course, there are other kinds of social norms, such as fashions or conventional norms, the contents of which are largely arbitrary and determined by the social fact that they are shared widely within the society (Cialdini & Trost, 1998; Nowak, Szamrej, & Latané, 1990). Although the scope of this article did not address these conventional norms directly, the adaptive framework may be useful to tackle those conventional norms as well. For example, our basic susceptibility to "social sharedness" (Kameda, Tindale, & Davis, in press) or other types of social influence and social comparison (Festinger, 1954) may have some adaptive (perhaps even evolutionary) basis. Exploring the psychological mechanisms underlying the emergence and persistence of conventional norms from the adaptive perspective is a promising research direction. Although some preliminary work exists to explore these issues (cf. Henrich & Boyd, 1998; Kameda & Hastie, 2002; Kameda & Nakanishi, 2002), many important theoretical and empirical questions are still open, awaiting future systematic investigations.

Given the fundamental fact that we are group-living species, the thesis that our minds are socially adaptive seems a reasonable metatheoretical assumption (Barkow et al., 1992; Campbell, 1975). Social norms that link microlevel cognitions of individuals to a macrolevel social condition, in a mutually-constrained, dynamic manner (as we have demonstrated using the evolutionary game analysis), capture an essential characteristic of such group life. In this sense, we believe that the notion of social norm can serve as one of the central and most useful constructs in psychology, while linking psychology to other social sciences in an integrated way, as envisioned by early social theorists.

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Appendix A
Expected Payoff to Each Strategy

This appendix provides the equations for comparing expected payoffs between two behavioral strategies. Because we have four strategies in the game (Table 1), there are six pairs for comparison. In the following equations, we denote expected payoff for an individual with strategy x as $U(x)$. $U(x)$ is the sum of three components, namely, (expected payoff if the self is an acquirer) + (expected payoff if another individual with the same strategy, x, is an acquirer) + (expected payoff if another individual with the other strategy, y, is an acquirer).

As stated in the text, conflicts arise if the acquirer of a resource claims private ownership while the nonacquirers demand communal sharing. We assumed that, in such a case, the acquirer could privatize the resource if and only if he or she wins all of the one-to-one fights against those who demanded communal sharing. For simplicity, we also assumed that all individuals' fighting abilities were identical. Thus, if there are r individuals who demand communal sharing in the group, the probability of the acquirer's successfully privatizing the resource is given by 0.5^r; otherwise, the resource is shared equally among $r + 1$ individuals, viz., r nonacquirers who demand sharing plus the acquirer.

The following equations are based on these assumptions. We denote group size as G, resource value as V, fighting cost for a loser as C, number of communal sharers in the group as *NCs*, number of bourgeois's as *NBr*, number of egoists as *NEg*, and number of saints as *NSt*.

Communal-sharers versus bourgeois's

To illustrate, suppose that the group is composed of communal sharers and bourgeois's. Expected payoff to a communal sharer, $U(Cs)$, is calculated as follows. When the self happens to be an acquirer, he or she shares the resource with other communal sharers evenly (notice that bourgeois's who value private ownership do not join the sharing)—thus the expected payoff in this case is $\frac{V/NCs}{G}$. Likewise, when another communal sharer acquired the resource, the expected payoff to the communal sharer is given by $\frac{(NCs-1)(V/NCs)}{G}$. Finally, when a bourgeois acquired the resource, the communal sharer receives an even share of the resource unless all of the communal sharers are defeated by the bourgeois's, $\frac{V(1-05^{NCs})}{NCs+1}$, while potentially bearing a cost accruing from personal loss in the series of one-to-one fights, $C\frac{1}{NCs}\sum_{r}^{NCs}05^{r}$. Aggregating these elements, we get

$$U(Cs)=\frac{V/NCs}{G}+\frac{(NCs-1)(V/NCs)}{G}+\frac{NBr}{G}\bullet\{\frac{V\cdot(1-0.5^{NCs})}{NCs+1}-C\bullet\frac{1}{NCs}\sum_{r}^{NCs}0.5^{r}\}.$$

where $NCs + NB\ r = G$.

A bourgeois can privatize the resource that he or she acquired, if he or she wins all of the fights against communal sharers. Otherwise, he or she is forced to share the resource evenly with the communal sharers while bearing a cost accruing from loss in the fight. Thus, we get

$$U(Br)=\frac{0.5NCsV+(1-0.5NCs)(-C+\frac{V}{NCs+1})}{G}.$$

Communal sharers versus egoists

$$U(Cs)=\frac{V/G}{G}+\frac{(NCs-1)(V/G)}{G}+\frac{NEg}{G}\bullet\{\frac{V\cdot(1-0.5G-1)}{G}-C\bullet\frac{1}{G-1}\sum_{r}^{G-1}0.5^{r}\}.$$

$$U(Eg)=\frac{0.5^{G-1}V+(1-0.5^{G-1})(-C+\frac{V}{G})}{G}+\frac{NEg-1}{G}\bullet\{\frac{V\cdot(1-0.5^{G-1})}{G}-C\bullet\frac{1}{G-1}\sum_{r}^{G-1}0.5^{r}\}+\frac{NCs(V/G)}{G},$$

where $NCs + Neg = G$.

Communal sharers versus saints

$$U(Cs)=\frac{V/NCs}{G}+\frac{(NCs-1)\cdot V/NCs}{G}+\frac{NSt\cdot V/(NCs+1)}{G},$$

$$U(St)=\frac{V/(NCs+1)}{G},\text{ where } NCs + NSt = G.$$

Bourgeois's versus egoists

$$U(Br)=\frac{0.5^{NEg}V+(1-0.5^{NEg})(-C+\frac{V}{NEg+1})}{G}$$

$$U(Eg)=\frac{0.5^{NEg-1}V+(1-0.5^{NEg-1})(-C+\frac{V}{NEg})}{G}+\frac{NEg-1}{G}\bullet\{\frac{V\cdot(1-0.5^{NEg-1})}{NEg}-C\bullet\frac{1}{NEg-1}\sum_{r}^{NEg-1}0.5^{r}\}+\frac{NBr}{G}\bullet\{\frac{V\cdot(1-0.5^{NEg})}{NEg+1}-C\bullet\frac{1}{NEg}\sum_{r}^{NEg}0.5^{r}\},$$

where $NBr + NEg = G$.

Bourgeois's versus saints

$$U(Br)=U(St)=\frac{V}{G}.$$

Egoists versus saints

$$U(Eg)=\frac{0.5^{NEg-1}V+(1-0.5^{NEg-1})(-C+\frac{V}{NEg})}{G}+\frac{NEg-1}{G}\bullet\{\frac{V\cdot(1-0.5^{NEg-1})}{NEg}-C\bullet\frac{1}{NEg-1}\sum_{r}^{NEg-1}0.5^{r}\}+\frac{NSt\cdot V/(NEg+1)}{G},$$

$$U(St)=\frac{V/(NEg+1)}{G},\text{ where } Neg + NSt = G.$$

Appendix B

Model Incorporating Free Riders (First Computer Simulation)

This model is identical to the basic model, except that an individual's norm-enforcement when in the nonacquirer role (confronting the violator of the norm) is determined according to his or her "norm-enforcement probability," p_1. By definition, p_1 is fixed at 0 for those who always grant the acquirer's private ownership (i.e., bourgeois's and saints), but it can range from 0.1 to 1.0 for those who demand communal sharing when in the nonacquirer role (i.e., communal sharers and egoists). The communalized resource, however, is shared not only among the norm-enforcers (i.e., individuals who have participated in the enforcement activity), but also with those who just "endorse" the norm, but without enforcement. In other words, the communalized resource is equally accessible by all individuals who endorse the communal-sharing ideology, more or less (with $p_1 > 0$, but not necessarily $p_1 =$

1). Therefore, individuals with small p_1s are more likely to behave as free riders than individuals with large p_1s.

We conducted an evolutionary computer simulation to evaluate the performance of each strategy. To represent individual strategies, two "genes" were used in the simulation: a gene controlling how to behave when in the acquirer role, and a gene controlling variations in probability of norm enforcement when in the nonacquirer role, p_1. The first gene had two alleles (claiming private ownership of a resource that one acquired or provisioning it as a communal property), and the second gene had 11 alleles (norm-enforcement probabilities when in the nonacquirer role, ranging from 0 to 1.0 by a step of 0.1). Combinations of these two genes allowed us to implement four basic behavioral strategies of Table 1 in the simulation, along with individual variations in the norm-enforcement tendency ($p_1 = 0$ for bourgeois's and saints, whereas $p_1 > 0$ for egoists and communal sharers). At the start of simulation, we assigned these genes to *G* individuals. In each round, one of the *G* individuals was randomly chosen as an acquirer of the resource. As explained in the text, social interaction over the resource continued until the fate of the resource was settled (i.e., privatized or communalized). This process constituted one round. With the same set of *G* individuals, 40,000 rounds were played. After 40,000 rounds, *G* individuals were ranked from high to low in terms of net payoff, and their genes were reproduced probabilistically according to the rank ("selection"). The higher the rank of an individual, the more likely were the individual's genes to be reproduced. We used a standard gene-reproduction procedure in the genetic algorithm literature (see Grefenstette, 2000, p. 23, for the algorithm). Finally, a "mutation" occurred to each individual's genes with the probability of 0.025. That is, an individual's "communalizing" allele at the first locus may mutate to a "privatizing" allele with the probability of 0.025, and vice versa. Independently from the mutation to the first gene, mutation to the second gene could also occur with the probability of 0.025. When mutation occurs, an individual's original value for p_1 changes to one of the other 10 values randomly. The aforementioned process constituted one "generation." We traced changes in proportions of the four behavioral strategies in the group over 5,000 generations.

For the analysis reported in Figure 2, we started out with a 10-person group ($G = 10$) initially composed only of communal sharers. Although these individuals provide resource when in the acquirer role (all having the "communalizing" allele at the first locus), their norm enforcement probabilities when in the nonacquirer role, p_1s, were generated randomly from a uniform distribution ranging from 0.1 to 1.0. This procedure allowed individual differences about their willingness to enforce the communal-sharing norm when in the nonacquirer role. Starting from this initial state, we conducted five simulation-runs in total by the aforementioned procedure. Figure 2 displays average data of these five runs.

Appendix C
Model Incorporating the Tolerant–Intolerant Distinction (Second and Third Computer Simulations)

Model C is an extension of Model B. We added two new genes, one regulating the tolerant–intolerant distinction against nonenforcing free riders, and the other regulating variations in the free riders' propensities to fight back against the intolerant enforcers. The former gene had two alleles (tolerant or intolerant) and was activated only when an individual behaved as a norm enforcer (cf. Figure 3). Besides confronting a direct violator of the communal-sharing norm (i.e., egoists and bourgeois's), the intolerant enforcers were committed to exclude free riders from sharing, although they might have to bear an additional fighting cost, *C*. It was assumed that, when such intolerant enforcers existed in a group, the free riders could access the resource only if they won all the fights against the intolerant enforcers; otherwise, the communalized resource was shared evenly just among norm enforcers including tolerant as well as intolerant enforcers. The latter gene had 11 alleles (probability of fighting back, p_2, ranging from 0 to 1.0 by a step of 0.1), and was activated only when an individual behaved as a free rider and was refused to access the resource by the intolerant enforcers. Selections of and mutations to these genes occurred in the same manner as in Model B. Other features of the simulation algorithm were also identical to Model B.

In the second simulation, we started out with a restriction so that $p_1 \geq p_2$ ("behavioral rationality" of 1st-order free riders). For each individual, we generated a norm-enforcement probability, p_1, randomly from a uniform distribution ranging from 0.1 to 1.0, and then assigned a fighting-back probability, p_2, randomly so that $p_1 \geq p_2$. The third simulation removed this restriction and generated the two fighting propensities, p_1 and p_2, independently.