The Evolution of Metanorms:
Reproduction, Extension, and Insight

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Abstract

Axelrod’s (1986) evolutionary computational model of metanorms was replicated and extended. Results were generally supportive of the original, with extensions increasing the number of generations resulted in increased stability and convergence to levels not achieved in the original. Replications of the groups game (two groups differing in numbers and power) yielded outcomes that were mixed, as the results depended on where group affiliation mattered, for group affiliation determined who would be punished. Metanorms emerged only if group affiliation was inhibited at the Norms game level. Meta-vengeance increased efficient implementation of metanorms supporting a dual-utility requirement for efficient metanorm emergence.

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Norms play essential roles in regulating aspects of social behavior in groups. Norms are viewed as quasi-formal rules and often “instruct strangers and convey to children” how to behave in specific situations from a particular groups’ perspective – norms are models of (situationally) correct behaviors that ostensibly afford some benefit to the referent group (Brown, 1995) and are found in virtually all human societies (Eibl-Eibesfeldt, 1989). When interpreted as guiding standard rules of behavior within an organization, norms influence much of organizational decision making (March 1996). Norms, as opposed to laws in our perspective, are often unwritten and generally do not emerge through an explicit democratic or other formal governing mechanisms.¹

What processes that do (or can) account for norms depends on how one defines norms, the level of specification, and in many cases, the particular function a norm serves in the context of the referent group (Brown, 1995).² Our interpretation of norms is in line with what are often called social norms reflecting their socially-situated (and socially-shared) definition and level of informality, differentiating them from legal and moral norms, or habits and fads (Brown, 1995; Elster, 1989b; Hechter & Opp, 2001; Tuomela, 1995). In addition to their relative institutional informality, universal acceptance, and (presumed) benefit to the group, another property of social norms is that their violation will bring extra-legal sanctions; that is, violation of a norm is likely to engage some sort of punishment from the referent group, directly or indirectly (e.g., Coleman, 1990; Dalton, 1948; Hackman, 1992; Wendel, 2001; Whyte, 1955).³ Thus, the components of acceptable behavior within the group are largely defined and enforced by intra-group processes, and it is presumed that sanctions, in whatever form invoked, have an impact on the decision to deviate from a norm. A

¹ However, the relationship between norms and laws can be intricate and substantial (Ellickson, 1991; Horne, 2000; McAdams, 1997-1998).
² Although many writers conceive of the general nature of social norms, they sometimes disagree on their substantive characteristics, how they emerge, the methods of analyzing norms, typologies and so forth, often by disciplines (see Hechter & Opp, 2001). For example, Elster (1989a) views social norms as not rational in the sense that they are not followed because of the outcomes they will produce (i.e., they are simply “followed” without regard to any prospect of future reward or loss), but this aspect is disputed by Hardin (1995) who argues that “the push of self-interest might determine very many features of norms, including their forcefulness and their form or structure” (p. 108). It is clear that one can find norms that have no apparent social value (at least to the observer) as well as those that do, and even some that have distinctly maladaptive social values (e.g., Stead, MacAskill, MacKintosh, Reece & Eadie, 2001). Examples are often snapshots in the life of a norm and may not indicate its historical role in the group, nor its viability in the future.
³ By extra-legal direct punishment we eliminate specific legal remedies, such as arrest, prosecutions, and lawsuits; rather, the nature of the sanctions are seen as nonlegally enforceable but socially punitive (e.g., shunning, gossip, verbal reprimands) where social capital within the group rises and falls, be it power, reputation, information, or where membership in the group itself is threatened. Indirect punishment can be interpreted as negative feelings (e.g., guilt, shame) that are derived from a social context and serve as sanctions or threats of sanctions, such as an “internalized sense of duty” (McAdams, 1997-1998, p. 340). The net effect of any (or all) of these sanctions is assumed to be known to, and calibrated by, all members of the group. In Hardin’s (1968) phrasing, this is “mutual coercion, mutually agreed upon.”
norm is not a norm unless there is some sanction for its violation (Coleman, 1990, Ch. 11; Gibbs, 1966; Horne, 2001).4

It is given that social norms exist, that they often influence behavior and perceptions of behavior, and that they play a broad variety of important social functions within small groups (Marques, Abrams & Serodio, 2001), within communities and neighborhoods (Ellickson, 1991), within professional communities (Wendel, 2001), within corporations (Rock & Wachter, 2001), within nations (Posner, 2000), and even between nations (Tarzi, 2002). The focus of this paper is to investigate how a simple structural model of social adaptation and sanctions can account for how cooperation norms emerge, spread, prevail, change, or fail in the culture of a small organization of computational agents. It is a straightforward agent-based game where cooperation matters.

The approach we take to study norms is based on extending the theoretical work of Axelrod (1986) who demonstrated how an evolutionary approach could simulate the emergence, maintenance, and displacement of norms in a group of agents. According to Axelrod, “a norm exists in a given social setting to the extent that individuals usually act in a certain way and are often punished when seen not to be acting in this way” (1986, p. 1097). The evolutionary component was metaphorical as the entities simulated were actually likelihoods of behavioral choices under specific circumstances – behaviors (realized as procedures), not organisms, were evolving. The concept of the social evolutionary process itself (as defined by a genetic algorithm in this case), however, was less metaphorical and more a plausible representation of a societal action and response apparatus underlying the emergence of specific behavioral choices – people tend to copy successful behaviors and tend to avoid unsuccessful behaviors in a group setting when social goals are relevant in a broad variety of contexts (Axelrod, 1984; Bandura, 1977; Cialdini, 2000; Hackman, 1992; Kahan, 1997). Over time, there is both an exogenous and endogenous “push and pull” of influences and competition for dominance (or even survival) of behaviors in the group that determines the spread and stability of norms.5

4 Note the asymmetric nature of how this is cast – punishment of violations – as opposed to (or inclusive of) reward for non-violations. In the perspective taken in this paper, one is not generally rewarded for compliance to a norm (except that sanctions are not imposed) because of the costly nature of both monitoring and rewarding individuals (often most of the group) for “behaving as expected” except, perhaps, under initial learning conditions (see Ellickson, 1991, p. 209). It has been argued for sometime that the distinction between reward and punishment in the context of a sanction is difficult (e.g., Simon, Smithburg & Thompson, 1950, Chapter 9, note 7). Posner and Rasmusen (1999) explore the sets of common sanctions and their efficacy in enforcing norms.

5 Social pressure to conform is one of the earlier phenomena addressed in modern social psychology (see Festinger, Schachter & Back, 1950) with salient demonstrations well-documented in the literature of classic studies such as Asch (1956) and Milgram (1974). There is also growing evidence that the tendency for copying behaviors in a group setting in general (i.e., imitative learning sans explicit instruction) could be a function of our evolutionary heritage that facilitates the cultural transmission of information (Boehm, 1997; Dugatkin, 2000; Tomasello, 1999), which is related to more general arguments proffering the emergence of culture itself (directly or indirectly) as influenced by components of biological evolution (Boyd & Richerson, 1985; Byrne & Whiten, 1997; Tooby & Cosmides, 1992) and how evolution and culture may interact (Aiello & Wheeler, 1995; Laland, Odling-Smee & Feldman, 2000). Although strong conformism can certainly yield norm stability without sanctions (Boyd & Richerson, 1985), in this paper we explicitly consider a dual utility model of egoism and social pressure in the manner posited in AMG.
Axelrod explored the *Metanorms game* where a unique tiered approach structured the influence of norms monitoring defectors (and punishing them) from an $N$-person Prisoner’s Dilemma game, and included the specifications of metanorms that influenced how failure to enforce norms of cooperation would be punished. The findings of AMG can be quickly summarized. We begin with a brief explanation of the games.

The Metanorms game first begins with the Norms game. In the Norms game, an agent chooses either to defect with gains to itself and losses to the rest of the group of (other) agents, or to not defect (cooperate) thus not harming the group, but also not receiving any gains for itself. If an agent defects, all other agents have a chance to detect that defection and then must make a choice to *sanction* the defecting agent (impose a cost) or not, but sanctions incur a cost to the delivering agent. The individualistic payoff structure of the basic game is biased toward defection (egoism), so agents eventually develop a preference to defect at the expense of the group and avoid a preference to sanction those who defect. The defection strategy spreads rapidly within the group and soon becomes stable over the duration of the trials.

There are three characteristics of the Norms game that collectively make it a distinctive approach to the study of norms. First, the agents are in a type of *social dilemma*, which is a decision situation in which “each member of a group has a clear and unambiguous incentive to make a choice that – when made by all members – provides poorer outcomes for all than they would have received if none had made the choice” (Dawes & Messick, 2000, p. 111). Individually, each agent in the Norms game prefers to defect, as that would be the dominant strategy if no other agents mattered, based on the individual payoff structure. However, the negative externalities imposed by defection are not a desirable set of outcomes for the group. In fact, if all agents defected each would suffer a loss based on the $N-1$ other agents, so the preferred strategy of defection is a *group deficient* solution.

Second, the substance of the solution to this social dilemma is instituted as an opportunity to impose *sanctions* by members of the same group — a mechanism for norm enforcement. Sanctions are effective solutions to social dilemmas from several perspectives (e.g., Boyd & Richerson, 1992; Falk, Fehr & Fischbacher, 2001; Voss, 2001), but sanctioning generally incurs a cost to the punishing agent as well as the agent that is punished, so the risk of free-riding (not to sanction) can be substantial, therein defining the

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6 The rationality and informational assumptions and processes mechanisms (agent-based evolutionary process modeling) thus differentiate this approach from game-theoretic models (e.g., Bendor & Swistak, 1998). The relation between computational and game-theoretic models has not been explored to a great extent (see Prietula & Watson, 2002).

7 There are many variant forms and incantations of social dilemmas such as modifications to prisoner’s dilemmas, common pool resources, commons dilemmas, and incorporating a broad array of constructs such as rational expectations, moral hazards, free-riding, social traps, social loafing, and crossing a variety of disciplines such as evolutionary anthropology, biology, economics, sociology, and psychology (Alchian & Demsetz, 1972; Dawes, 1980; Goetze, 1994; Hardin, 1968; Heckathorn, 1996, 1998; Kolkock, 1998; Komorita & Parks, 1996; Lichbach, 1996; Olson 1965; Ostrom, 1998; Schelling, 1978).
sanctioning problem. As Dawes (1980) points out, “Sometimes, in fact, it is not even possible to avoid a dilemma by reward or coercion, because the costs of rewarding people for cooperating or effectively coercing them to do so exceed the gain the society derives from having everyone cooperate than defect” (p. 175). Indeed, this is exactly what occurs in the Norms game; each agent could invoke a sanctioning strategy, but this strategy does not survive over time. The social mechanism of copying the best performing strategy (as will be explained) dooms the imposition of sanctions, as the agents who do not sanction perform best and those who do sanction quickly learn that sanction does not pay.

Finally, the agents in this simulation have negligible knowledge of social context or contacts; that is, there are no provisions for reputation or contracting, no memories of prior histories of interactions, no ability for extended reciprocities (beyond the specific episodic opportunities to be described), no ability to look forward (no shadow of the future), no ability for backward induction, and no abilities to distinguish one agent from another. The agents in this simulation are quite simple as are their mechanisms for selecting strategies and behaviors. They are minimally cognitively and socially rational (Carley & Newell, 1994) seeking only to earn benefits for themselves and to fit in the group (i.e., be acculturated) by copying the most successful behaviors – by being conformists (Henrich & Gil-White, 2000).

So how can a norm against defection arise within this group of egoists? The problem resides not in the use of sanctions, but in the choice to (not) impose sanctions. In effect, this is a second-order free rider (or public goods) problem (Coleman, 1990, pp. 270; Oliver, 1980). The answer proposed by Axelrod is based on defining a second type of norm – a metanorm – that specifies that those agents who do not sanction defectors should be sanctioned themselves. The concept of a metanorm as a solution to the second-order free rider problem has been proposed in a variety of forms (Axelrod, 1986; Coleman, 1990); however, the metanorm

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8 In general, explanations for why agents sanction at a cost have been variations (and even combinations) of altruism as a type of biological (or sociobiological) construct where no direct reward is neither expected nor gained (Cosmides & Tooby, 1992; Ernst & Simon, 2002; Hamilton, 1963; Piliavin & Chang, 1990; Sober & Wilson, 1998; Trivers, 1971), reciprocity as a fundamental strategy influenced by groups or biology or both, where benefits are expected either in the short or long run, directly or indirectly (Henrich & Boyd, 2001; Nowak & Sigmund, 1998; Sethi & Somanathan, 2003; Sober & Wilson, 1994), or even egalitarianism as a biological mechanism (Boehm, 1997). Arguments focusing on the potential influences, costs and difficulties of monitoring have also been put forth (Hechter, 1984). As we will argue, agents sanction in this model because of two forces: desire to maximize their own rewards (egoism) and desire to adopt the best performing strategies in the group (social pressure). We focus, therefore, on the group level, which only “sees” the behavior product and not the process or mechanism that creates the product (Sober & Wilson, 1998, p. 156).

9 The type of social dilemma characterized by the Norms game is also called an externality trap (Cross & Guyer, 1980) that occurs “whenever the activities that one individual pursues produce consequences for both himself and others, and when the rewards and punishment which shape the behavior of one individual do not match the payoffs which that behavior brings to others” (p. 104). The solution proposed is to alter the payoff structure such that one “converts the trap to a trade-off” where welfare costs are more accurately reflected, such as having a polluting company pay for pollution (Cross & Guyer, 1980, p. 113). In the Norms game, the solution is not to alter the payoff structure of individual agents directly, but to incorporate another choice (sanctions) into the payoff structure that would reflect impact the total welfare of the choice across the remaining group members.

10 In a very real sense, these agents simply reflect (or reflect simply) Harsanyi’s (1969) postulate of economic and social-acceptance, where “people’s behavior can largely be explained in terms of two dominant interests: economic gain and social acceptance” (p. 524). This is also similar to the concept of a dual utility (or mixed motive) function explanation of certain social dilemmas in political science (Margolis, 1982; Rothstein, 2001; Udéhn, 1993).
solution has also been criticized as it “pushes the problem to a higher order” (Henrich & Boyd, 2001), it involves substantial circularity in reasoning regarding commitment and monitoring where “the process unravels at both ends” (Ostrom, 1990), or it is restricted to small, close-knit communities (Lichbach, 1996). Nevertheless, work by Boyd and Richerson (1992) suggests that the use of sanctions against defection under certain circumstances can yield what they call moralistic strategies “which cooperate, punish noncooperators, and punish those who do not punish noncooperation can be evolutionary stable” (p. 173). This is the substance of the Metanorms game.12

The Metanorms game extends the Norms game by a second round allowing agents to evolve a strategy to detect and punish an additional type of behavior: agents that do not punish defectors. In the Metanorms game (and contrary to the Norms game) a norm against defection does emerge: individualism is reduced and cooperation is increased. Thus, only an additional single level of monitoring-the-monitors is sufficient to generate the spread, and sustain the existence, of a behavioral norm to quash levels of individualistic behaviors (defections) that could hurt the group. Contrary to predictions of infinite regress and Nth order free-rider issues, cooperation emerges from a solution of using two norms that are based on the same pay-off structure. It was not the pay-off structure that was allowed to vary, but the level of tolerance for defections in general (for defectors and for shirkers) across group members as a replicated strategy based on the pay-off structure. In a sense, it is shows that norms can emerge if the group values defection from enforcement the same way it values defections from cooperation, and this valuation is the same within the group.13 Consider Coleman’s (1990) story of how such metanorms can arise in the London financial district to mitigate against investment bankers to defect from a code of ethics, which impacts the entire community:

The first norm must be something like this: “Do not engage in transactions with a party who has violated the code of ethics.” And that norm must be backed up by sanctions, which in such an informal community may necessitate another norm, something like the first: “Do not engage in transactions with a party who engages in transactions with a party who has violated the code of ethics.” ...Such a normative system is difficult to maintain unless the community is very close and very homogeneous in interests. (p. 116)

11 In fact, the simulation presented here is viewed as a simple model of a small, close-knit community where peer pressure matters. The metanorm is embedded within the same group of agents; that is, these agents are self-policing (versus an appeal to an external authority) and use the same payoff structure.

12 In Kollock’s (1998) framework of solutions to social dilemmas, it is a combination of strategic (social learning) and structural (sanctions) remedies.

13 As will be explained, the group itself adapts to punishment levels appropriate for its members’ pay-off structure – the frequency of sanctioning as defined by individual likelihood of sanctioning (vengeance) – so that the cost of sanctioning is spread approximately equally across group members which results in parametric homogeneity in the group.
There are four primary thrusts in this paper. First, we replicate the primary study of the AMG of the Norms and Metanorms games. Second, we extend two key parameters of the AMG model to test the sensitivity of the results to those parameters. The parameters chosen, as will be explained, were (1) the number of observations (read “runs”) per experimental manipulation, and (2) the length of allowed generations per evolutionary period assessment. The reasons for this are based on fundamental empirical principles – increasing the number of observations increases the power of the study and increasing the duration of the observations (trials) reveals the variation of effects over time.\(^{14}\) Third, we test the correlated vengefulness hypothesis (our title) that was proposed in the original AMG study. This hypothesis asserts that for norms to exist there should be a correlation between the vengefulness (realized as punishment) toward a socially undesirable behavior (defection) and the vengefulness (realized as punishment) toward those not punishing that behavior (shirkers). In the original Metanorms game the two punishment decisions were based on the value of a single strategy construct (vengefulness), thus presumably confounding the two types of enforcement mechanisms. We decouple the two types of vengefulness so that each can strategically evolve separately in the Metanorms game. The question addressed is this: Vengefulness addresses sanctioning against defectors and shirkers (non-enforcement of norms), but are these two separate problems that are best addressed by two separate (vengefulness) strategies?\(^{15}\) Finally, we re-examine the Groups game (our title) played in AMG. This was a version of the Metanorms game but composed of two different groups of agents that differed in group size and power (i.e., effects of punishment) – it was the Strong group versus the Weak group. In the original study, group affiliation mattered for both the Norms and Metanorms games. Defection in the Norms game only hurt members of the opposite group, and defectors could be sanctioned only by members of the opposite group. On the other hand, shirking (free-riding) in the Metanorms game was sanctioned only by members of the same group. The findings of AMG suggested that metanorms were required to alleviate the shirking that emerged even in the Strong group and thus allow the emergence of a stable norm against defection. We replicate the original study (additional increasing the replications and lengthening the generations) and extend it in the following two ways: (1) altering where group affiliation matters (i.e., the Norms level, the Metanorms level, or both), and (2) once again decoupling the two types of vengeance in the Norms and Metanorms games. The former manipulation explores how group allegiances support or mitigate norms; the latter manipulation explores whether two types of vengeance can more efficiently support or mitigate norms.

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\(^{14}\) If we accept the equivalence between replications (runs) and observations (sample size), then increasing the number of observations allows us to increase the precision with which parameters can be estimated (other things being equal), thus increasing the power of the study (Cohen, 1988). Increasing the length of the simulation/generations allows us to address findings that question the duration strategy viability in dynamic games where any particular strategy has a non-zero chance of extinction (e.g., Young & Foster, 1991).

\(^{15}\) There is a slight issue about what “correlation” might actually mean in this context. We interpret to mean that vengefulness is necessary to invoke sanctions for both kinds of norms (i.e., sanctions cannot be ignored in one or the other) and that there is a single utility-like function (i.e., level of vengeance) that can efficiently (or perhaps even successfully) account for a dual-norm structure.
Norms and Metanorms Game Descriptions

In AMG, twenty agents were faced with the following three decision situations: (1) an *N*-person Prisoner’s Dilemma decision as the core, where each agent, upon its turn, chooses whether to defect or not, resulting in differential gains to the agents, (2) a basic Norms game decision, where each agent chooses whether or not to punish a defector, if that defector is observed, and (3) a Metanorms game decision, where each agent chooses whether or not to punish a shirking agent (an agent who did not punish an observed defector). Agents in AMG behave in each of these decision situations according to their particular decision strategy. Strategies are defined in a 2-dimensional construct space where one axis is **boldness** — likelihood to defect in the *N*-person Prisoner’s Dilemma decision. The other axis is **vengefulness** — the likelihood of punishing an agent detected for either defection or non-punishment. For every agent, boldness or vengefulness can take on one of eight values, ranging from 0/7 to 7/7.

As noted, the Norms and Metanorms games employ simplifying assumptions that distinguish it from similar games. The games are played among agents who are equally likely to encounter opportunities to defect and to observe defections, as both detection and defection rely on the same exogenous probability value randomly drawn for that particular event. What differs is each agent’s decision of what to do when such opportunities are presented based on the values of their strategy constructs (boldness, vengefulness). The dynamics for change in an agent’s strategies are based on a simple replication algorithm of the most successful strategies in the population.

Reproducing the Basic Results

The first step was to reproduce the primary study of AMG. This involved running the Norms game and the Metanorms game with the parameters used in the original paper (see Figure 1). The algorithm is presented in the Appendix.

The Metanorms game was played with the same constraints and parameters as the Norms game (i.e., constant population at twenty agents, 100 generations, five replications).

Analysis

To facilitate the analysis, a space of possible strategies was characterized in terms of a 2 by 2 categorical grid by using a value of 3.5 (midpoint between 0 and 7) as the breakpoint between two levels of a strategy (low and

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Note that these are hypothetical constructs that define a point a strategy space and whose values will change over time. The actual behaviors (i.e., defections, punishment, or non-punishment) are decisions that are based on the values of these constructs and the context in which they are applied.
This would then define the following four basic types of strategies based on the possible low-high combinations in a two-dimensional strategy-space: \(^{17}\)

1. **Docility**\(^{18}\) – Low vengefulness and low boldness.
2. **Norm (against defection)** – High vengefulness and low boldness.
3. **Defection** – Low vengefulness and high defection.
4. **Turbulence** – High vengefulness and high boldness.

Figure 2 presents the results of the Norms and the Metanorms games. For each run, a general arc (arrow) depicts the movement from the initial average strategy value of the population (open circle) to the final average strategy value on the 100\(^{th}\) generation (closed circle). Table 1 summarizes the results in terms of the average strategy values of the population emerging on the 100\(^{th}\) generation for both games (identified in the upper left column header, “Final Generation”).

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The results are similar to those described in AMG for both games. AMG originally observed three general areas of behavioral outcomes in the Norms game from five separate simulation runs as evidenced by their positioning in the strategy space (Figure 2). The results show that three of the five runs resulted in Defection strategies, one resulted in Docility, and one resulted in the Norm against defection (Table 1). In the Metanorms game, all five replication runs resulted in an evolved Norm against defection (Table 1). The results of the Metanorms game were also similar to those found by AMG, though the values of the vengefulness components of the agents’ strategies are not as extreme as those demonstrated by AMG.

An additional analysis was conducted to gain insight into the strategy dynamics throughout the 100 generations for both games. After each generation was concluded, the average strategy score for the generation was classified according to the taxonomy. The frequencies of each evolved type are reported as percentages in the lower segment (All Generations) of Table 1. For the Norms game, the most frequently evolved strategies for each generation were Defections (40.8%), followed by Docility (34.6%) and Norm (24.6%) strategies. For the Metanorms game, the most frequently evolved strategy was the Norm against defection (98.0%).

Given the analysis of the evolving strategies, it is also important to examine the effects of these strategies on the performance of interest – defections. In Figure 3, the number of defections (averaged over the five replications) is shown for each generation. As can be seen, there is an increasing dominance of defection

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\(^{17}\) These are approximations defined by neighborhoods of dominance by the regions specified in Table 1. As we shall see, these neighborhoods are sufficient to describe the temporal patterns of strategies adopted by the group over the time scales presented.

\(^{18}\) Docility is an adaptation of Simon’s (1991) interpretation of the concept, where he defines docility as a trait of an agent “to be tractable, manageable, and above all, teachable,” and that docile agents (or people) “tend to adapt their behaviors to norms and pressures of societies” (p. 35). Whether docility reflects a true genetic component or not is open to debate (Cohen, Axelrod & Riolo, 2004; Henrich, 2004).
in the Norms game, but a significantly lower level emergence of defections in the Metanorms game. In addition, there is actually significantly higher variance in the defection rates for the Norms game ($F^*(1, 998) = 487.5, p < .001$). Metanorms indeed inhibit defections.\(^{19}\)

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By the end of the $100^{th}$ generation in the Norms game, the average defection rate for the population is 66.7%, whereas the average defection rate for the population in the Metanorms game is 5.5%. These are population averages; so rapid shifts in strategies define significant changes boldness/vengefulness values over a short period. This raises two interesting questions. How stable are the evolved strategies in the Norms and Metanorms games over extended time frames? How do these strategies impact defections over extended time frames? These questions were addressed by extending key parameters in the simulation.

**Extensions**

Two parameters of the simulation were manipulated to determine the sensitivity and stability of the original results, and to explore the behaviors in detail for additional insight into the processes involved in the evolution of strategic behaviors in both types of games. The manipulations made in the Norms and Metanorms games were the following: increasing the number of *replications* per game, and increasing the number of *generations* allowed for the evolution of strategies.\(^{20}\)

**Increasing Replications**

As previously noted, five replications were used in the original AMG study – defining the five data points in prior Figure 2. Given the possible influential nature of initial conditions, an issue arises concerning the influence of additional replications on the general findings of the Norms and Metanorms games:

- Would increasing the number of *replications* have an impact on the Norms and Metanorms games results?

The Norms and Metanorms games were rerun increasing the number of replications according to following schedule: 10, 100 and 1000 replications per game. Table 2 summarizes the full results in terms of the counts and percentages for the $100^{th}$ generation (Final Generation) and over all 100 generations (All Generations) categorized by the strategy type.

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\(^{19}\) The theoretical maximum for defections in this game is 80 defections per generation. This is the number of opportunities (four), times the number of agents (20), but is actually attenuated by the impact of pressures to defect (boldness), the likelihood of detection ($s$), and the subsequent impacts of enforcement based on defection decisions and interacting population dynamics.

\(^{20}\) These can actually be considered less as modifications to the games *per se* and more as manipulations to the experimental situation surrounding the games. In an empirical sense, these two manipulations could be viewed as both extending the experimental sampling period and incorporating more experimental observations, while retaining the experimental manipulations intact.
Increasing the number of replications provides a better sampling of possible distributions of strategies that can evolve within the games by 100 generations. For the Norms game, Table 2 (upper) shows that over all 1000 replications, most of the strategies evolved by the 100th generation are Defection strategies (79.3%) followed by Docility (12.1%) and Norm (8.6%). For the Metanorms game, Table 3 (upper) shows that over all 1000 replications, by the 100th generation, Norm against defection strategies dominate (96.5%).

When including the strategies evolved over all 100 generations across all replications, the results of the Norms game shown in Table 3 (lower) indicate that most of the evolutionary time (over 1000 replications) is still spent with strategies of Defection (48.7%), but substantial proportions also include Docility (33.1%) and Norm (18.1%) strategies. For the Metanorms game, Table 3 (lower) indicates that most of the time (over 1000 replications) is spent with Norm strategies, which is almost identical to the 100th generation results (96.4%).

The trace of how average Boldness and Vengefulness values unfold by the 100th generation (and revealing potential oscillations and other trends) is shown in Figure 4 and includes replication sets of 5, 100, and 1000 for comparative purposes. In the Norms game (upper), increasing the number of replications results in substantially different outcome paths for the Boldness and Vengefulness scores. Although it may be expected that the variance and movement in the population averages decreases when using more replications, there is an interesting effect moving from 100 to 1000 replications in the Norms game (Figure 4, upper). At 100 replications, Vengefulness is equivalent to Boldness; however, using 1000 replications, Boldness significantly exceeds Vengefulness (F (2, 1197) = 87.9, p < .0001). At 100 replications, the average strategy values suggest Docility (Boldness = 3.0, Vengefulness = 2.5), but at 1000 replications, the average strategy values suggest Defection (Boldness = 5.3, Vengefulness = .8). For the Metanorms game, there is an expected decrease in variance by increasing replications, but the overall effects on Boldness and Vengefulness are equivalent.

Figure 5 shows the defections per generation for the 100th generation, averaged over 1000 replications, and includes the plot of 5 and 100 replications for comparative purposes. As can be seen (in comparison to prior Figure 3), increasing the replications reduces the variance in the average number of defections per generation for the Norms game, but has little added effect in the Metanorms game beyond 100 replications. By the 100th generation, the average percent of defections increased from 66.7% (5 replications) to 73.3% (1000 replications).
Note that despite the high variation in \textit{strategy values} evident in prior Figure 4, the levels of \textit{defection rates} are virtually the same, converging by the 100\textsuperscript{th} generation. This suggests an important interaction between the dynamics of the shifts in strategies that flow through the population and the timeframe over which these dynamics are allowed to play out. The next section addresses this issue.

\textbf{Increasing Generations}

The adoption and rejection of strategic behaviors implies dynamic and complex interactions among agents over specific timeframes. In the original AMG study, each game was given 100 generations to evolve the final strategies and, ideally, these were assumed to be stable.\textsuperscript{21} Given the dynamic components of agent interaction (and random elements of the genetic algorithm), a question arises concerning the influence of extending the number of generations on a general finding of the games:

- Would increasing the number of \textit{generations} allowed for strategy evolution have an impact on the Norms and Metanorms games results?

The issue addressed by this question speaks to the emergence of evolutionary stable strategies that tend to dominate other strategies within the parameters set forth by the Norms and Metanorms games. In the present context, an evolutionary stable strategy is operationally defined as a strategy (i.e., combination of Boldness and Vengefulness values) that tends to dominate (i.e., be successfully be adopted by the group) over specific time frames.\textsuperscript{22} To examine this, the two games were played again as described, but with one alteration — the number of generations per run was increased from 100 to 1000 (the set of replications was repeated at 5, 10, 100, and 1000).

Table 3 presents the categories of final strategies set at the 1000\textsuperscript{th} generation and categorizations of all 1000 generations across replication levels for the Norms and Metanorms games. In comparing the final (1000\textsuperscript{th}) generation results in Table 3 (upper) with the Norms game data for final (100\textsuperscript{th}) generation results in the previous section (prior Table 2, upper), extending the generations increased the dominance and distinction

\textsuperscript{21}There is actually an important point to be made here with respect to time (i.e., generations) as a resource (directly or indirectly). It is possible to set some arbitrary generation \(g_n\) as the upper limit of adaptation if there are some exogenous factors in play that impact the (social) evolutionary process around some arbitrary generation \(n\) (e.g., \(n = 100\)), such as days in a school term or duration of a group task. In this paper, however, we explore the relative behaviors and their relative stability over an extended time scale beyond 100 generations.

\textsuperscript{22}From an evolutionary game theory perspective, evolutionary stable strategies (ESS) are defined by Maynard Smith (1984) as follows: “If a large population consists of individuals adopting the ESS, then any mutation causing individuals to adopt some other strategy will be eliminated from the population by natural selection” (p. 95). However, the dynamics of the games here are not based on evolutionary game theory, but on computational models of psychological (and social) processes. Research suggests that individuals rarely accommodate rational models or achieve Nash equilibria in many social dilemma games (Ledyard, 1995; Ostrom, 1998) or, in our case, agents need not even be consistent (i.e., an agents’ correct expectations of another agent’s behavior), thus making the application of evolutionary game theory in general, and ESS in particular, somewhat problematic (Lomborg, 1996; Mailath, 1998). The use of the “strict ESS” in models as this (and even in those ascribing to evolutionary game theory form) have given rise to criticism, resulting in variations and alternatives to Maynard Smith’s ESS (e.g., Bendor & Swistak, 1995; Lomborg, 1996; Lorberbaum, Bohning, Shastri & Sine, 2002; Michod, 1999). Our approach is similar to Young’s (1998) phrase \textit{stochastically stable} for a state that “is more likely to be the norm at any given time” (p. 18).
of the Defection strategy in the Norms game (from 79.3% to 99.7%). Comparisons with the 100th generation, Metanorm data reveals that the Norm (against defection) strategy dominance remains strong (from 96.5% to 96.0%).

Comparing the distributions over all 1000 generations (Table 3, lower) the trends are paralleled. For the Norms game, the proportion of time the group spent with a Defection strategy increases dramatically (from 48.7% to 92.6%) with equally dramatic percentage drops in Docility strategies (from 33.1% to 4.7%) and Norm strategies (from 18.1% to 2.5%). For the Metanorms game, the strategies are again essentially equivalent (96.8% in both).

Figure 6 illustrates the average changes in population values for the two strategy dimensions over 1000 generations across replications of 5, 100 and 1000 for the Norms game (upper) and the Metanorms game (lower). In the Norms game, increasing the number of generations affords a better estimate of long-term convergence of stable strategy levels. Furthermore, generations interact with the replications in that lower replications require longer generation cycles to converge. Replications values of 100 and 1000 basically approach the long-term Boldness value exceeding 6 after 150 and 180 generations respectively. Using only five replications, that same Boldness value is achieved after 510 generations. For the Metanorms game, increasing the generations had little added effect on the results.

Figure 7 shows the defections per generation averaged over 5, 100, and 1000 replications for 1000 generations. The defection rate for the Norms game stabilizes above 90% after 340 generations with 1000 replications, 360 generations with 100 replications, and after 510 generations with five replications. The defection rate in the Metanorms game stabilizes much earlier near 6%, where this rate is first achieved with replications of 100 and 1000 (at the 60th generation), followed by replications of five (80th generation). We can see that increasing the number of generations allows for more accurate estimations of defection rates for the two games over extended generations and, like the related strategy values of Figure 6, generations and replications interact.23

23 To reveal the suspected associations and confirm the strategy categories, a cluster analysis was conducted of all strategies over all 1000 generations for the Norms and Metanorms games across 1000 replications. The results indicated that clusters correspond highly with the strategy categories and reveal the underlying strategies dissemination throughout the group over time. The Norms analysis shows two strong clusters for its dominant strategy, Defection (81.2%, 11.2%) with clusters for Norm (2.9%) and Docility (4.4%). The Metanorms analysis indicates all cluster groups reflecting the Norm (100%).
Correlated Vengefulness (Decoupling Metavengeance)

Under the current model, agents evolve vengefulness levels that are used to decide whether to punish defectors (vengeance) and to decide whether to punish shirkers (metavengeance). In the original paper, AMG hypothesized that linking these vengefulness strategies by using the same vengefulness values (as done in the prior simulations) was the key to sustaining the norm against defection:

The trick, of course, is to link the two kinds of vengefulness. Without this link, the system could unravel. An individual might reduce the metavengeance level while still being vengeful and then later stop being vengeful when others stopped being metavengeful. (Axelrod, 1986, p. 1102).

Consequently, the following question was posed:

- Would **decoupling** vengefulness from metavengeance have an impact on the Metanorms game results?

To explore this, a set of simulations was run that allowed a third strategy dimension – Metavengeance – to evolve independently. All other constraints and procedures were carried out as the basic Metanorms game, with 1000 replications and 1000 generations. Comparisons of defections (reflecting the norm) and shirking (reflecting the metanorm) revealed that decoupling the components had a significant effect in increasing both the average percentage of defections (slightly) from 6.4% to 6.9% (F(1, 1998) = 4.54, p < .05), and the average number of decisions not to shirk (substantially) from .74 to 2.22 (F(1, 1998) = 6.35, p < .05).

The average strategy values evolving over 1000 generations are shown in Figure 8, which compares Boldness values and Vengefulness values that are **coupled** (2d) to those that are **decoupled** (3d) and evolve independently. Boldness values decrease slightly but significantly from .36 to .40 (F(1, 1998) = 4.98, p < .05); however, there is a distinct difference in Vengefulness values. When Vengefulness and Metavengefulness are decoupled (3d), Vengefulness values (against defectors) decline from 5.2 to 4.9 (F(1, 1998) = 43.3, p < .001), as do Metavengefulness values (against shirkers), from 5.2 to 3.0 (F(1, 1998) = 2125.7, p < .001).

In terms of the categorization scheme, when the two types of vengefulness values are coupled, the strategy against defectors was an emergent norm against defection and a norm against shirking. However, when vengefulness is decoupled, **two** types of norms emerge: a norm against defection (Vengefulness) and a separate norm against shirking (Metavengefulness).
The Groups Game

The Groups game (our title) consisted of a slight variation to the Metanorms game where two different agent groups were defined and differed in number and power reflecting advantages of one group over the other. The first group (Strong) consisted of 20 agents and the second group (Weak) consisted of 10 agents, where both group population size’s were held constant. Differences in power were reflected in the patterns of punishment and the relative impact of punishment on scores.

For the Norms game, a defection by a member of one group only hurt the members of the other group, so detected defectors are punished only by the members of the other group. For the Metanorms game, an agent shirking the punishment of a defector (from the other group) is only punished by members of the same group to which it belongs. Additionally, Strong agents punishing Weak defectors retained the original punishment score of $P = -9$, but Weak agents punishing Strong defectors was lowered to $P = -3$. However, for each generation, Strong agents learned only from Strong agents and Weak agents learned only from Weak agents, where strategies were evaluated and spread solely within groups. All other values and procedures remained the same, and vengefulness values were coupled as in the original study.

The original findings reported in AMG were as follows.

Resistance to punishment and increased size can help a group, but only if there are metanorms. Without metanorms, even members of the stronger group tend to be free riders, with no private incentive to bear enforcement costs. This in turn leads to low vengefulness and high boldness in both groups. When metanorms are added, it becomes relatively easier for the strong group to keep the weak group from being bold, while it is not so easy for the weak group to keep the strong one from defecting. (Axelrod, 1986, p. 1003)

Thus, without metanorms there should be high defections in both groups. The inclusion of metanorms should reduce the defections in the weak group but less reduction should occur in the strong group. The original Groups game consisted of (presumably) five replications and 100 generations. Given the findings of the previous sections, we elected to reproduce and extend the Groups game by playing 100 replications with 1000 generations each (for presumably sufficient stability) in order to determine if such extensions would induce results similar to the findings of the Metanorms game extensions.

The results of the analysis of the Norms game, shown in Figure 9, revealed that 100% of the strategies adopted by the 1000th generation were Defections for both groups, where Boldness and Vengefulness quickly emerged stable strategy values (earlier by the Strong group, later by the Weak group). The analysis of the Metanorms game is somewhat more involved, as the Groups game can be played in the Metanorms game (i.e., punish shirkers from same group, but punish defectors from either group), in the Norms game (i.e., punish
shirkers from either group, but punish defectors from the other group), or in both games (i.e., punish shirkers from the same group, but punish defectors from the other group).

When the Groups game is played in the Norms game, a norm (against defection) is defined in terms of the Vengefulness level of one group and the Boldness level of the other group, and that norm is evaluated in terms of the defection level of the other group’s agents (recall that defection only hurts members of the other group). When the Groups game is played in the Metanorms game, a metanorm is defined as the Vengefulness of one group and the Boldness level of the same group, and that metanorm is evaluated in terms of the number of shirking incidents within the same group (recall enforcement of a metanorm is done only within a group).

Thus, where the Groups game is played determines how norms and metanorms are defined and their potential impact on the emergence and stability of strategies, and the distribution of punishment and enforcement costs. This lead to the following question:

- How would varying the location of group contexts impact the results of the Norms and Metanorms games?

We ran a total of four sets of simulations (100 replications, 1000 generations each), varying where the Groups game was played: in the Norms game, in the Metanorms game, in both games, and in neither game. The evolved strategy values of Boldness and Vengefulness are shown in Figure 10. The subsequent impact on the emergence of a norm against defection is revealed by examining the average defection rate across replications over all generations. The four comparative defections graphs are presented in Figure 11.

The analysis of the evolved strategies for the Metanorms game indicated both support and discrepancies between the findings of AMG and the results. In the two figures, the graphs on the left (Both Games, Norms Game) show relatively high levels of Boldness (Figure 10) and defection percentages (Figure 11), while the graphs on the right (Metanorms Game, Neither) clearly show emerging norms against defection with low Boldness and high Vengefulness values (Figure 10) and correspondingly low levels of defection (Figure 11). This suggests that under the original AMG parameter values, the critical component determining the emergence of a stable norm against defection in the Groups game is whether or not groups matter at the

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When groups do not matter in either game, this degenerates into the basic Metanorms game (played with 30 agents) and was used as a benchmark.
The emergence of stable metanorms that control defections is compromised when defectors behave as a group.  

When groups do not matter in the Norms game (Figures 10 and 11, right column), defections hurt all other agents equally and any agent can punish any (detected) defector. This leaves the group’s strategies vulnerable to invasion by metanorms, as the cost of shirking exceeds that of defection and vengefulness levels can drive enforcement of both the norm and metanorm. There is no discrimination in norm enforcement.

When groups do matter in the Norms game (Figures 10 and 11, left column), defections only hurt agents of the other group, so higher Boldness values (and more defections) successfully replicate and survive over time within each group. The restricted context of acceptable behavior (i.e., group-defined) assures that high Boldness (and defections) will be assured if groups matter in the Norms game. The emergence of vengefulness is problematic, as Vengefulness is costly and must drive the enforcement of both types of norms.

When groups do matter in the Metanorms game (Figure 10 and 11, upper row), groups can only punish their own kind for shirking, but the relative costs incurred by higher Vengeance scores required for both Norm enforcement (punishing agents) and Metanorm enforcement (punishing agents from their own group) can be substantially higher than those incurred through defections. As a consequence, the overall effect of groups in the Metanorms game must be assessed in the context of what is happening in the Norms game. When groups matter in both the Norms and Metanorms games (Figure 10 and 11, upper left), groups repeatedly learn that to “ignore some levels of transgressions of their brethren” is the best strategy, and Vengeance levels decline. When group affiliation matters only in the Metanorms game (Figure 10 and 11, upper right), the relative cost of shirking within a group exceeds the benefit of defection and metanorms quickly dominate group strategies.

When groups do not matter in the Metanorms game (Figure 10 and 11, lower row), evolving a successful norm against defection can also be problematic, but for different reasons. As was noted, under these conditions defection strategies dominate. However, as neither group can single out “the behavior of their brethren” in order to enforce metanorms, the rate of punishing their own agents for shirking increases dramatically. This leads to substantial evolutionary instability and fluctuations in the strategy values emerging over the generations. Without the context of group affiliation in the Metanorms game, Vengeance scores rise as metanorms emerge to address defections spurred on by the larger number of (non-affiliated) agents punishing shirkers. As members from both groups are actively defecting in the Norms game and punishing shirkers (acting as a single group of non-affiliated agents), there is an inherent conflict in the strategies over

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25 With respect to the Metanorms game, the critical element of a metanorm is its control of the non-enforcement behaviors of the group. That is, the existence of a metanorm is defined by the values of its strategy parameters (i.e., high vengefulness, low boldness), but the impact of a metanorm is defined in terms of its ability to reduce defection through the punishment of free-riders.
time that results in instability and turbulence, suggestive of Red Queen types of oscillatory dynamics. This also leads to the highest defection rates in Figure 11.

**Decoupling Metavengeance and Groups.**

Given the prior results, a final question remained of whether the strong effect of alliances in the Norms game could be mitigated by a separate Metanorm structure:

- Would *decoupling vengeance from metavengeance* have an impact on the results obtained when the Groups game is played in the Norms game?

The effect of playing the Metanorms game in conjunction with alliances in the Norms game allowing vengeance and metavengeance to evolve separately were dramatic. In Figure 12 the defection rates for the Strong group dominated under both conditions (left graphs) as there was an emergence of a “norm against others defecting.” Consequently, the Strong group evolved high Boldness scores (and could defect with impunity), moderate Vengefulness scores (to control defection of the Weak group), and low Metavengefulness scores (little value gained for punishing their own shirkers, except when necessary). On the other hand, the Weak group was essentially forced into Docility with lower levels of strategy values on all three dimensions. Decoupling vengeance from metavengeance resolved the difficulties encountered when group affiliation mattered in the Norms game. Once decoupled, the Stronger group could adapt more effectively and efficiently (via a structural mechanism defined by two norms) to exploit its advantage over the Weaker group in order to quash defections.

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Insert Figure 12 about here

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**Discussion**

The results of the present study support, clarify, and extend the findings of the theoretical model and simulation of Axelrod (1986). The basic outcomes of the AMG simulation were replicated. Without metanorms, a norm against defection cannot survive; with a single metanorm structure, a norm against defection can survive. We find this an interesting and counter-intuitive result. When the simulation was extended by increasing the number of *replications*, the variance in strategy values (Boldness, Vengefulness)

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26 As configured, the Groups game could be considered a form of co-evolutionary predator-prey model, where two competing groups could continue “evolving” variations indefinitely – a version of the Red Queen hypothesis (Van Valen, 1973) where species must constantly “run in place” (i.e., adapt) simply to keep up with the changing induced by their environment (predators, competitors, parasites, etc.). That a Red Queen dynamic can be founding such a simple model is theoretical plausible (Marrow, Law & Cannings, 1992), especially considering that mutation inhibits extinction and the bounds on boldness and vengefulness inhibit “unstable runaway escalation” (Dawkins & Krebs, 1979), forming a type of coevolutionary stable community (Abrahms, 1986; Brown & Vincent, 1987).

27 When most people are presented with this model, the initial reaction is that it would require a meta-meta- norm structure ad infinitum, continually defining an enforcement layer of “who watches the watchers.”
and defection rates were reduced in the Norms game, but adding replications did not have the same relative impact on the Metanorms game as the variance was already quite low using only five replications. Furthermore, a detailed analysis of the strategy values across generations revealed that as the number of replications increased, the Norms game did not produce any stable strategy (as defined by the categorization scheme). This was most likely because the model incorporated a mutation scheme that inhibited any strategy from becoming extinct, which led to recurring invasions by (almost extinct) strategies in the time frame (i.e., generations) assessed. In the Norms game, these periodic, oscillating times of stability and turbulence cause multiple quasi-stable (time-dependent) equilibria within the 100-generation time frame.

When the simulation was extended by increasing the number of generations per run, the Norms game did evolve a stable Defection strategy, but the variations in strategy values and defection levels were sensitive to the number of generations, and also demonstrated an interaction between number of generations and replications. With the original number of replications (five), the strategy values at 100 generations significantly underestimated the values achieved when more generations were allowed. Increasing the number of replications caused the average population strategy values to converge quicker to the long-term values, but this convergence still occurred after the 100-generation limit used in the original study.

The examination of the correlated vengefulness hypothesis by decoupling vengeance from metavengeance clarified the suspected correlation between the two kinds of vengefulness. Axelrod proposed that a link between the two was required (and realized by a single vengefulness construct) in order to avoid additional free-rider problems. In fact, this link is not required. Two distinct norms emerge and are maintained by two distinct vengeance levels. The Vengefulness level of the decoupled norm is equivalent to that of the coupled Norm, but the Vengefulness level of the decoupled metanorm is approximately 40% lower. This affords a substantially more efficient adaptation for enforcing norms. Furthermore, the levels of vengefulness for norms were substantially higher than those for metanorms, which seems counter to Axelrod’s (1986) speculations: “The types of defection we are most angry about are likely to be the ones whose toleration also makes us angry” (p. 1103).

The key for why metanorms work (in both coupled and decoupled situations) is found in the nature of how strategies are spread within the group. In essence, the agents are all equivalently docile— the best performing strategies are readily adopted (replicated) by any given agent, as no agent is predisposed (or committed) at any time to any particular strategy. The pay-off structures (of the individual agents) and the dynamics of the group interactions achieve a cultural equilibrium of values defining the metanorm. Thus it is

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28 In fact, this is reminiscent of an observation by Coleman (1990) who suggested that “the sanctioning problem involves a smaller cost to the actors involved than does the original problem” (p. 272).

29 That there are non-zero levels of defection also suggests a structural mechanism that yields tolerated theft types of situations (Bird & Bird, 1997; Wilson, 1998).
the ability of the cultural algorithm to rapidly minimize differences in strategy values between agents that affords the opportunity for metanorms to function and survive as an effective sanctioning mechanism under the given conditions. Once stabilized, all agents adopt the same strategy values to implement metanorms (and norms) in the group.\(^\text{30}\)

Finally, the replication of the Groups game presented interesting results. Recall that norms in these games were defined according to groups, where a norm against defection actually meant a norm against the other group defecting. Whenever alliances among agents occurred in the Norms game, a norm against defection could not emerge in either group, with accordingly high defection rates. However, if alliances were prevented in the Norms game, both groups could develop a norm against defection and overall defection rates were quite low and approached levels found in the condition without groups. Thus, the overall defection rate (across both groups) was minimized and a “population beneficial” solution was reached. The problem, then, centered on situations where alliances are made in the Norms game. The solution to this was the decoupling of the vengeance scores, but the results were not population beneficial. When both groups can evolve separate norms and metanorms, the Stronger group rapidly adopts a stable “norm against defection by the weak” and the Weaker group becomes docile and ceases to defect at significant levels. The Stronger group also developed higher vengeance against the Weaker group defections that it did to its own group defections (shirking).\(^\text{31}\) The dominance of the Weaker group by the Stronger one is complete.

The studies presented in this paper were based on small extensions to the AMG model. We envision five areas of further exploration related to this work that may provide additional insight into the limits and value of this type of metanorm structure.

First, manipulations can be made in the pay-off structures of the agents and the resultant preference ordering among alternatives. Systematically varying the values of the pay-off structures but retaining the inequalities can provide insight into the sensitivities of the results of the parameter space within the general form of the games; varying certain inequalities can determine the impact of the metanorms structure on varies game forms. On the other hand, varying the within-game values implies that games can change dynamically. For example, the current structure assumes that defection and shirking are punished equally (in Figure 1, \(P = P' = -9\)) and incur an equal enforcement cost (\(E = E' = -2\)). Research indicates that as norm enforcement costs rise, sanctioning of defections decrease, but metanorms can become stronger (Horne & Cutlip, 2002).

Second, there are elements of the cultural algorithm that can be explored. For example, the current algorithm assumes that all agents try to “imitate the most successful” performing strategies, but “imitate the

\(^{30}\) This avoids the need to invoke (or explain) what Coleman (1990) calls a heroic sanction which is “a sanction whose total effect occurs through a single agent” (p. 278).

\(^{31}\) For example, Hornsey, Oppes and Svenson (2002) found a sensitivity effect with their group research: criticism from ingroup members were tolerated much better than criticism from outgroup members.
most common” is also a plausible strategy as both can be interpreted as heuristics for social learning (Boyd & Richerson, 1985). Once adopted, the current model assumes that norms can change rapidly and effortlessly, like fads and informational cascades (see Bikhchandani, Hirshleifer & Welch, 1998, 1992). Indeed, norms can change rapidly (Axelrod, 1986), but on the other hand norms can also be quite resistant to change beyond the structural sanctioning support afforded by the model.\footnote{As Brown (1995) notes in his discussion on the emergence of conventions in society, “Once a convention becomes entrenched, it is hard to dislodge” (p. 59). Once the norm becomes entrenched, the switching costs to society can result in a suboptimal norm “trap” (c.f., Posner & Rasmusen, 1999).} If a norm is internalized (Axelrod, 1986), it generally reflects something of a shift from external sanctions to a self-sanctioning structure, thus perhaps reducing the need for (or level of) sanctioning for norms or metanorms.\footnote{This aspect of self-sanctioning (e.g., guilt) has been described as a component of the establishment of moral guidance as a set of adopted social rules (Greenspan, 1995). When considering the type social rules used in the cultural algorithm for this paper (i.e., conformity, sanctions of norms), studies have shown that people are influenced by conformity rules even when there is no possibility of sanctions (e.g., Chekroun & Brauer, in press; Smith & Bell, 1994).} This could be easily modeled by defining a \textit{docility index} for any given agent that reflects an agent’s susceptibility to strategy value adoption (or change) based on, for example, an inverse function of the time a norm is held – the longer a norm is held, the more resistant it is to change.\footnote{In fact, “resistance” itself might be considered a culturally plausible attribute to model.}

Third, such cultural algorithms (or any group-based sanctioning or conformity phenomenon) as defined here can be susceptible to \textit{group size effects} (e.g., Agrawal & Goyal, 2001; Borrett & Patten 2003, Friedrichs & Blasius 2003; Stang, 1976), though the effects are often neither simple nor straight-forward (e.g., Barnir, 1998; Isaac & Walker, 1988; Marwell & Ames, 1979; Rapoport, 1988; Tata & Anthony, 1996). As we have noted, some of the criticisms against this type of metanorm structure have argued that it is plausible only within “small homogenous groups”. Of course, there is not absolute definition of “small” so it necessary to see if there are group size effects and how they are manifested under varying conditions and assumptions. For example, the basic reciprocity explanation for altruism (under standard evolutionary theory) is constrained by the number of individuals who are likely to interact (Boyd & Richerson, 1988). In addition, increasing the size would impact the detection level ($s$ in Figure 1 for monitoring agents) reflecting a common finding that vigilance varies inversely with group size (Dunbar, Cornah, Daly & Bowyer, 2002) as well as the perception of risk in specific cultures (Ho & Leung, 1998; Yamaguchi, 1998) and other interesting hypotheses concerning human networking size in general (e.g., Hill & Dunbar 2003).

Fourth, the cultural algorithm used is based on similar agents; therefore consideration of groups of \textit{heterogeneous agents} is an interesting area of expansion. What we mean by agent heterogeneity is a fundamental different property or set of properties of agents and not simply the difference in particular property values an agent can assume as the game. For example, in the prior discussion one could define that agents differ in their docility index not also as a function the experiences of the group (i.e., number of
generations a strategy value set is held), but also in a discount/acceleration factor that one agent is fundamentally more (or less) docile than another. Similarly, in the cultural algorithm some agents can be more influential than others (De Cremer, 2002). Epstein (2001) proposed an evolutionary model of norms that combined aspects of a cultural algorithm based on proximity with an individual agent property of cognitive effort. Bowles and Gintis (2004) demonstrate how multiple types of reciprocators can emerge and exist in a group that sustains cooperative norms.

Finally, this study provided insight into how the Groups game and cultural algorithm properties interacted to generate norms, metanorms, and dominance of one group over another. This provides an initial thrust into exploring how such a metanorm architecture can fit into (and perhaps help explain) how group norms emerge, prevail, change, or fail in the cultures of competing agents and even how different cultural groups are formed. Anthropology has argued that most of the variation between groups is based on cultural differences (Henrich & Boyd, 1998) and those cultural differences (realized as behaviors at the group level) can be considered units of adaptation in multilevel selection theory (Sober & Wilson, 1998). Based on this theory, analysis (or simulation) of a single group incorporating the cultural architecture defined in this paper (i.e., adaptive components of norms, set of agents with payoff-structures, cultural adoption algorithm, sanctioning mechanism), can yield norm stability in virtually any behavior (Boyd & Richerson, 1992).

Nevertheless, only between-group selection (i.e., competitiveness in adaptation between groups) can favor social norms that realize functionally adapted groups (Sober & Wilson, 1998). Therefore, it would be interesting to incorporate the metanorm architecture in multiple competing groups, but include alternate sets of norms to selectively enforce or ignore. This could be expanded by including what Heckathorn (1990) called collective sanctions, where not only a particular individual would be sanctioned (e.g., for defecting), but the entire group to which the sanctioned individual was a part would also be sanctioned.

May the best group win.

Thus, much can be done to elaborate the original Axelrod theory; however, we should keep in mind a quote by Axelrod (1987) on this specific issue:

…simplicity of theory is always preferable to needless complexity. Nonetheless, society is a stubbornly complex system, and a good model of its dynamics will necessarily be, in some respects, complicated. The norms game, as extended over the generations, is a model of cultural

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35 For example, see the cross cultural norm studies of Jetten, Postmes and McAulliffe (2002), McAuliffe, Jetten, Hornsey and Hogg (in press), and Perlow and Weeks (2002).

36 There are other cultural architectures, which make similarly modest (though not similar) assumptions, that offer explanations for cooperation (normative) behavior, such as those based on external, behavioral-based reputational markers, such as image scoring (Nowak & Sigmund, 1998; Wedekind & Milinski, 2000) or external, affiliation-based social markers, such as dialects (Nettle & Dunbar, 1997) or tags (Riolo, Cohen & Axelrod, 2001).
evolution that can readily accommodate this need, a model that is itself open to endless evolution (p. 51).

May the best theory win.
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Appendix

Norms Game. The basic Norms game was run as described in AMG and is described as follows. The replication algorithm involves reproduction, crossover, and mutation (Goldberg, 1989). Reproduction involves categorizing agents with high payoff scores (at least one standard deviation above the population mean), low payoff scores (less than one standard deviation below the population mean), and mid-scoring agents (between the two extremes) in order to determine what behaviors will be spread (reproduced) in the group. Crossover involves randomly selecting two high scoring agents and randomly duplicating their Boldness and Vengefulness scores (e.g., Boldness of one agent and the Vengefulness of the other), thus spreading their (altered) strategy values to two agents. Mid-scoring agents also cross-over their strategies, but they are passed on to only one agent in a new round. Strategies of low-scoring agents are not replicated. A mutation rate (1%) is applied allowing for random changes in the population strategies as a final step. Note that the incorporation of mutation not only infuses a random component to the algorithm, but also guarantees that no strategy will meet extinction.

1. A population is defined as twenty agents and that population is kept constant. Initial strategy values (boldness, vengefulness) for each agent are selected randomly from integers over the interval [0, 7]. Each agent has a score card that tallies its performance value resulting from subsequent payoff events described below.

2. Each of the twenty agents is randomly selected in turn. An agent $A_i$, upon its turn, is presented with four consecutive situations, or cases, that offer a defection opportunity. For each case, an agent decides to defect if its chance of being seen, $s$, is less than its current boldness level ($B_i$), where $s$ is an exogenous parameter drawn from a uniform distribution between 0 and 1.
   a. If agent $A_i$ decides not to defect, there is no payoff or punishment involved and the case is concluded.
   b. If agent $A_i$ decides to defect, the defector receives a payoff ($T = 3$) and all other agents receive a punishment ($H = -1$). In addition, the defecting agent $A_i$ bears the chance of being seen, also set at $s$, by one or more of the other agents in the group.
   c. If another agent $A_j (j \neq i)$ detects the defection of $A_i$, then $A_j$ decides to punish $A_i$ with a likelihood based on the current level of $A_j$’s vengefulness ($V_j$).
      i. A choice to punish (i.e., enforce a norm against defection) results in an enforcement cost to the punishing agent ($E = -2$) as well as a punishment cost to the offending agent ($P = -9$).
ii. A choice not to punish (shirking) incurs no costs to either agent.

d. Play the Metanorm game (this step is skipped when playing only the Norm game).

3. How the successful strategies are then spread throughout the population agents is then determined by a genetic algorithm, whereby the values of the constructs of the most successful strategies have a higher likelihood of be transmitted to (or adopted by) other agents in the population, than do the less successful strategies.

4. Steps 2 and 3 are repeated for 100 generations, with the final strategy values for each agent being the final (i.e., terminally evolved) strategy.

5. Steps 1 through 4 are repeated five times, defining the five replications of the original AMG simulation.

**Metanorms Game.** The Metanorms game adds a level of norm behavior to the Norms game. Specifically, a metanorm is “a norm that one must punish those who do not punish a defection.” (Axelrod 1986, p. 1101). Expanding the Norms game discussion from above (Step 2d), when an agent \(A_j\) detects an agent \(A_i\) defecting with some probability, \(s\), but decides not to punish \(A_i\) (i.e., shirking), then that lack of enforcement is detected with probability \(s\) by all non-involved agents \((A_k, k \neq i \text{ or } k \neq j)\). This is the same detection probability, \(s\), used in agent defection decisions. In a sense, it could be viewed as the “visibility” of the decisions of other agents (in defection and in enforcement).

There are four additional parameters related to the Metanorms game that are equivalent to those in the Norms game: detection likelihood, choice to enforce metanorm, punishment cost, and enforcement cost. As described, the detection level \(s\) is the same as in the Norms game. The decision to enforce a metanorm is determined by the (level of) vengefulness, \(V_k\), of the observing agent \(A_k\). If an agent decides to enforce a metanorm, then it also incurs an enforcement cost in distributing punishment. In AMG (and in this paper) the enforcement costs and punishment values associated with metanorms are equivalent to those associated with norms. The enforcement and punishment costs for metanorms are equivalent to those of norms. This is a plausible policy assumption for it makes no distinction between the likelihood of enforcing norms or metanorms; that is, the likelihood to enforce norms is dominated by a single policy. Furthermore, all agents abide by this policy reflecting agent homogeneity in this model.

The Metanorm game is played when a defection occurs (see the Norms game section) and is described under the algorithm as Step 2d:

d. **Metanorms game.** If in Step 2c an agent \(A_j\) detects the defection of \(A_i\), and \(A_j\) decides to punish \(A_i\), the Metanorm game is not applied. However, if \(A_j\) decides not to punish \(A_i\), then
i. An agent $A_k$ ($k \neq j$ or $k \neq i$) detects with probability $s$ the lack of norm enforcement by agent $A_j$. $A_k$ then decides to punish (i.e., enforce a metanorm) based on the current vengefulness level of $A_k$ ($V_k$).

ii. A decision to punish results in an *enforcement cost* to the punishing agent $A_k$ ($E' = -2$) as well as a *punishment cost* to the offending agent $A_j$ ($P' = -9$).

iii. A choice not to punish incurs no cost to the agents.
Table 1. Distribution of original and replicated Norms and Metanorms game strategies

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* Results interpreted from original Axelrod (1986)

** Norm against defection
Table 2. Distribution of Norms and Metanorms game strategies across extended replications for 100 generations

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*Average population strategy after 100 generations.
**Results interpreted from original Axelrod (1986) with five replications over 100 generations.
***Entries are percentages of average population strategy values over all generations.
****Norm against defection
Table 3. Distribution of Norms and Metanorms game strategies across extended replications for 1000 generations

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*Average population strategy after 1000 generations.
**Results interpreted from original Axelrod (1986) with five replications after 100 generations.
***Entries are percentages of average population strategy values over all generations.
**** Norm against defection
Figure 1. Structure of basic Norms and Metanorms games
Figure 2. Initial and final average population strategy values for replicated games
Figure 3. Average defections over five runs, Norms and Metanorms games (100 generations)
Figure 4. Population strategy values over generations for differing replication values for Norms and Metanorms games
Figure 5. Percent defection changes over varying replications
Figure 6. Population strategy values over 1000 generations (5, 100, 1000 replications)
Figure 7. Percent defection changes over varying replications (1000 generations)
Figure 8. Average strategy values for coupled (2d) and decoupled (3d) Metanorms games
Figure 9. Groups game results for Norms game
Figure 10. Boldness and Vengefulness strategy values varied by Groups game location
Figure 11. Percent Average Defections varied by Groups game location
Figure 12. Decoupling Vengeance and Metavengeance