Evolutionary Tolerance

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Abstract

The mechanisms of emergence and evolution of cooperation — in populations of abstract individuals with diverse behavioral strategies in co-presence — have been undergoing mathematical study via Evolutionary Game Theory, inspired in part on Evolutionary Psychology. Their systematic study resorts as well to implementation and simulation techniques in parallel computers, thus enabling the study of aforesaid mechanisms under a variety of conditions, parameters, and alternative virtual games. The theoretical and experimental results have continually been surprising, rewarding and promising.

Recently, in our own work we have initiated the introduction, in such groups of individuals, of cognitive abilities inspired on techniques and theories of Artificial Intelligence, namely those pertaining to Intention Recognition, encompassing the modeling and implementation of a tolerance/intolerance to errors in others — whether deliberate or not — and tolerance/intolerance to possible communication noise. As a result, both the emergence and stability of cooperation, in said groups of distinct abstract individuals, become reinforced comparatively to the absence of such cognitive abilities.

The present paper aims to sensitize the reader to these Evolutionary Game Theory based studies and issues, which are accruing in importance for the modeling of minds with machines. And to draw attention to our own newly published results, for the first time introducing the use of Intention Recognition in this context, with impact on mutual tolerance.

Keywords: Evolutionary Game Theory; Evolutionary Psychology;
Intention Recognition; Tolerance.

1. Evolution and the Brain

Darwin's hypothesis about the biological evolution through natural selection was one of the most revolutionaries ones in the history of science. Since the publication of the *On the*

Origin of Species in 1859, and until today, a long history of attempts at applying the evolutionary concepts to the understanding of human and social behavior has occurred. Some of these, more polemic, attempts, had disastrous political interpretations and applications (such as, for example, the defense of white supremacy by Nazism), and several intellectual groups developed antibodies against the widening of the scope of evolutionary concepts. Other attempts revealed more fruitful. One such example is the attachment theory developed by Bowlby (1971), extrapolated to the evolutionary processes by Kirkpatrick (2005), with solid empiric evidence and a vast explanatory power. Bowlby considered attachment as an organized set of behaviors, which evolved through the mechanisms of natural selection, to solve a recurrent adaptive problem: the need for protection that immature members have, as much amongst humans as amongst other species.

The *Homo sapiens sapiens* emergence is consensually situated within the Superior Paleolithic, around 45 thousand years ago — by the time when language, sedentary and gregarious behavior had fully developed. One assumes that, in terms of cerebral morphology, we would have been by then essentially the equal of what we are nowadays. From about 40 years ago, the discipline of Evolutionary Psychology has been developed founded on the application of evolutionary concepts to the understanding of the psychological mechanisms that underlie human conduct. It provides a way of thinking about evolution when the advantage of a given behavior depends on some other individual's behavior, or on a group's. According to its followers, there are several human behaviors that are better understood if we rebuild the way how natural selection acted in the past, and lead to the emergence of *Homo sapiens sapiens*.

The first bipedal primates established the separation between the human species and other apes. In order to encompass the capacities of the human brain one needs to understand exactly which problems our primate ancestors were trying to solve, and what lead them to develop such an extraordinarily intricate brain. We cannot look at the modern human brain, and its capacity for creating science, as if the millions of years of evolution that shaped it till its present form had not happened. Amongst the eventual problems there are certainly those of *status*, territoriality, mating, gregarious behavior, altruism versus opportunism, the construction of artifacts, and the mapping of the outside world. The brain of the *Homo sapiens sapiens*, considered anatomically indistinguishable from our current brain, is approximately 100 to 200 thousand years old, with oral language appearing less than 100 thousand years ago. The Superior Paleolithic began around 45 thousand years ago, and lasted until the Neolithic, about 10 thousand years before the current era (C.E.) — during this period language fully matured. However, since the beginning of the Superior Paleolithic, the cultural evolution rhythm has drastically accelerated. According to population genetics theory, the majority of changes happened too quickly to be accompanied by genetic evolution.

The same way a psychiatrist or a psychoanalyst has to look at a patient's history in order to better understand him in the present, it is also important to look at our species's past in order to grasp our modern peculiarities.

Evolutionary Psychology began with sociobiology and the study of insect societies. The quest was to discover the why and how these animals are gregarious. Research was developed in the early 1960's by William D. Hamilton (1926-2000), Robert L. Trivers (b. 1943), and later by Edward O. Wilson (b. 1929). That research was carried out mathematically, first in terms of game theory and computer simulations, and then continued with contributions from other disciplines.

Highly altruistic, the social insects enjoy the so-called haplo-diploidism (instead of our own diploidism), which makes siblings share more genes than usual. In the females of those insects (bees, ants, termites) half the DNA is an exact copy of the father's haploid DNA, and the other half is from the diploid mother — they thus share, on average, 3/4 of their genes. The fact they share more genes endows them with a greater predisposition to sacrifice themselves for their siblings. It is this genetic mechanism that induces a greater social cohesion, and a greater altruism, because it is genes that survive (the «selfish genes») and not the vehicles of the genes, the living beings that transport them like dispensable packaging (Hölldobler & Wilson, 2009).

The problem of selection is particularly important concerning the consideration of individual and group components. Beyond a simple survival of the individual — or family — there is the survival of a larger group which, in a gregarious species like ours, is of extreme importance.

And the problem in explaining cooperation by evolution is this: "By which mechanisms are we the product of gregarious evolution, in that gregarious behavior benefits everyone? How altruistic and socially cooperative are we, or, being altruistic, won't we be fooled by others, the opportunists, focused singly on individual selection?" The evolution of any collective species clashes against this problem of balancing altruism with egotism. It is a strong theme in Evolutionary Psychology, and one to which we can employ computers to perform long and repetitive simulations of joint evolution of behavioral strategies in co-presence, via typical mathematical games' implementation, mixing competition and cooperation situations, and the combinatorics of strategies.

Evolutionary Psychology is not so much a scientific discipline but more of a meta-theoretical reference framework, of assumed presuppositions shared by researchers working in the field. As a starting point it, considers human brains are the product of the evolutionary process and that this fact cannot be ignored when trying to understand the workings of the mind and of behavior.

In this manner, Evolutionary Psychology is becoming a success example under the scope of ongoing scientific unity, resulting from a profound and explanatory combination of Psychology, Anthropology, Biology, Linguistics, Neurosciences, Game Theory, and Artificial Intelligence (Laland & Brown, 2002; Buss 2005; Dunbar & Barrett, 2007; Gangestad & Simpson, 2007; Platek et al., 2007; Skyrms 1996, 2004, 2010). It has been dedicated to the study of the brain and of behavior from an evolutionary perspective, having given rise to extremely relevant contributions. And it has been backed up, and influenced, by Anthropological Archeology in its empirical study of the cultural evolution of mankind (Shennan, 2002). Along this line of development, Evolutionary Psychology has been revealing itself as a paradigm of analysis which is very rich and useful for the understanding of universal sexual differences in the strategies used by men and women when choosing a mate — men tend to seek several young women, whereas women tend to select a unique partner with characteristics associated with power; men tend to be more violent than women; etc. In the study of the workings of the brain through their archeological traces, both theoretical as well as field archeologists (Mithen, 1996), are bringing about historical and pre-historical evidence that our ancestors began with a generic intelligence, such as we find nowadays in apes. There has been intense and wide-scope discussions on the problem of intelligence being of a generic functionality, or being better understood instead through division into components or modules of specific abilities. When Evolutionary Psychology first appeared, it developed a line of work, which Chomsky had started, that insisted in the existence of innate and specialized areas of the brain; it was generally accepted that there is an abundance of specific modules for a diversity of cerebral functions. In the beginning, the opinions of David Buss, Leda Cosmides, Steven Pinker, John Tooby (Buss, 2005), pointed to the scenario where all cerebral functions had their own specific modules — for language, for mating, for religion, etc.

Meanwhile, through historical record, archeologists showed that the human species went from a first stage of generic intelligence to a second stage comprising three big specialized modules: one dedicated to natural history and the rudiments of physics (knowledge of Nature); another for the knowledge and fabrication of instruments; and a third for the cultural artifacts, i.e., the rules of living in society and the politics of coexistence. These three specialized intelligence types were separated. However, at a more recent stage — corresponding to *Homo sapiens*, with the appearance of spoken language — it became necessary to have an umbrella module able to articulate all the other three. And the question arises: How do all these different specialized modules connect, and how do people communicate? The need to find an answer to this problem gave birth to the idea of an encompassing and overlaying module, a more sophisticated form of generic intelligence, the cognitive glue that binds together the specialized modules and allows them to communicate and cooperate.

From our point of view, logic, in a broad sense, provides that encompassing and overarching general conceptual cupola which, as a generic module, allows the fluid articulation of the more specific modules. There is an obvious human ability to understand logic reasoning, and such ability must have developed during the evolution of the brain. The computers we create share the similar counterpart ability to execute any program (Pereira, 2009).

2. Evolutionary Psychology: Genes and Memes

The main notion, with which we must begin, is to understand that there are two Darwinian mechanisms in co-evolution in humans. By Darwinian we mean the great paradigm of emergence that results from mutations, selection and reproduction, that brought life to Earth up till today and, in particular, gave rise to human beings as a species.

Life began on Earth about 3,8 billion years ago with bacteria; only 2 billion years after that, the first unicellular organisms with a nucleus — the eukaryotic cells — appeared. Their components got together thanks to collaboration amongst bacteria and, throughout evolution, ever increasingly complex organisms emerged from simpler ones, with millions of cells binding together to form tissues, different tissues cooperating to build organs, and these intertwining to form systems. Amazing similarities can be found in the way biological complexity increases and the way human societies evolve. The importance of cooperation is evident in both biological and social domains of complexity (Damasio, 2010).

There are two reproductive systems in humans: the sexual reproduction one, in which the replication unit is the gene; and the mental reproduction one. Some authors in the Evolutionary Psychology field defined the notion of «meme», as a mental counterpart of the gene. The meme is the mental replication unit, dual to the gene, and its reproductive system is the brain. Memes get together in groups, patterns or «memeplexes», in a way similar to the union of genes when they form chromosomes and sequences. Memes are characteristic of ideologies, religions and common sense ideas. Certain memes only work well together, mutually reinforcing one another, and others do not, in such a way that certain correction devices must be triggered into action. Mechanisms of tolerance/intolerance, which we further detail in the sequel, can also be triggered, working both at individual and group levels.

The two Darwinian mechanisms in co-evolution are thus the genetic and the memetic (Dennett, 1995). There is a genetic reproductive system and, on top of it, Nature — through evolution — created a second one, which we employ in pedagogy. We reproduce ideas: normally the good ones are propagated and multiply, being selected for, in detriment of worse ones — although nothing and no one guarantees such selection skewing. Genes persist because they reproduce themselves, while memes comprise a parallel reproduction unit associated with the mind — the brain being its reproductive organ. What we do, in schools and universities, is to reproduce knowledge. Educational systems consist in a means to «infect» students with memes, ideas proven capable enough to reproduce and persist, while others that could not survive were discarded in the process. Of course, there are many variants of educational systems, for instance the madrasahs.

When people interact they communicate ideas, and the infectiously good tend to reproduce. As aforementioned, there are groups of ideas, belief sets, that reproduce together. The memes that are part of such clusters — like genes in chromosomes — are in competition/cooperation amongst themselves, and also with the pool of genes. These exist because they are part of a reproductive system necessary for attaining local adaptations more quickly, knowing that genes, concerning the temporal scale of the meme-carrying individuals, take too much time to reproduce. In this way, the meme rich individual phenotype benefits from another chance to improve the conditions to replicate its genotype. This leads directly to meme-gene co-evolution.

However, memes could not spread if it weren't for the valuable biological tendency individuals have to imitate, something the brain is neurologically capable of, namely via mirror-neurons (Rizzolatti & Sinigaglia, 2007). There are very good reasons for imitation to have been favored by conventional natural selection acting on the genes. Individuals genetically more predisposed to imitate can take advantage from a shorter path to learning new skills, that others might have taken longer to build. Consequently, the brain and the mind that goes with it are the result of a profound symbiosis, a genetic product influenced by the memetic reproduction mechanism. With this faster adaptation system we arrived at a point where we can predict our own necessary memetic mutations, as preventive measures needed to prepare ourselves for the future, by anticipating it. As a result, we imagine the future — we create hypothetical scenarios, evaluate possible outcomes — and choose to strive towards some of them, calling it «free will».

As a consequence of the existence of the memetic system, beyond single genetic sexual reproductive success, there arise some important issues regarding social interaction. As communal beings we need to develop a *status* in order to be respected, copied from or obeyed. We have to worry about territorial expansion and its defense if we want to possess the resources necessary to have offspring and, what is more, if we desire our offspring to have offspring of their own. We need to take part in contractual agreements with whomever shares our social and cultural ecology. And there exists also the important requisite of opportunity for personal expression. If we do not express ourselves, no one will copy even our most precious memes, let alone our scientific theories built from memeplexes.

With this perspective, in spite of a spatial and temporal distance, scientific thinking emerges from distributed personal interaction, and never as an isolated act. This interaction has to be built from the ground up from several confluences, or by teams, as is the case in science. Indeed, knowledge is not constructed in an autonomous way; rather, it is weaved by networks of people. In science it is important to work as a team, and science itself comes institutionalized and organized with its own methodologies. It takes place in particular environments, as is the case of educational ones, where memetic proliferation is mechanized.

3. The Logic of Games

Game theory was first develop in the 1940's, and the first work on the subject was *Theory of Games and Economic Behavior* by the mathematician John von Neumann (1903-1957) and the economist Oskar Morgenstern (1902-1977), (Neumann & Morgenstern, 1944). At the time it was directed at the economy, but it was subsequently applied to the Cold War, as the outcome of issues raised by the use of the atomic bomb and the subtle means of bluffing. When some such situation gets complicated, there is need to resort to sophisticated mathematical tools — and computer simulations — to deal with equations that cannot otherwise be solved.

The games theme is as complex as it is interesting and filled with diverse niches. We already addressed genes, memes, their combinations and evolution, questions related to survival and winners. We have already mentioned the combinatorial evolution of strategies, and mutations of those strategies according to diverse conditions, that can both be other game partners or the game board's own circumstances. The notion of game includes uncertainty, and whenever there is uncertainty there has to be some strategy, the moves one makes with given probability. When there is co-presence of evolving strategies from several partners, along with the idea of payoff, we are dealing with the notion of evolutionary game, which can be examined in an abstract and mathematical manner.

The same way we have genetic strategies for reproduction, all of our lives are filled with cultural, or civilizing, strategies. And, in a general way, we can see our species through these lenses still without undervaluing the remaining perspectives, equally important.

There are zero sum games and non-zero sum games. The zero sum ones are those that, by their rules, some players win, some players loose. In Nature's evolution, conditions are those of non-zero sum — all can win or all can loose. Robert Wright (2001) analyses the evolution of culture and civilization with the underlying idea that, in Nature, non-zero sum games are possible, wherefore a general gain may be obtained, leading to illuminated altruism.

Sometimes, co-present strategies tend to achieve a tactical equilibrium. Take the hunter/prey relationship: neither the hunter wants to fully exterminate the prey, nor the latter can multiply indefinitely because that would exhaust the environment's resources. Some of these studies are used by Economics to understand what might be the overall result from the sum of interactions amongst the several game partners.

It is relevant to take into consideration if the game takes place only once with a given partner, or whether the same partner may be encountered on other occasions; how much memory does one have of playing with that partner; and if the possibility of refusing a partner is allowed. Let us take a more detailed look at each of these situations in turn. We begin with the famous prisoner's dilemma, typical of the paradox of altruism. There are two prisoners, A and B, with charges on them. Either of them can denounce the other, confess, or remain silent.

	Prisoner **B** – silence	Prisoner **B** – confession
Prisoner **A** – silence	**6 years in jail for each**	**A = 10 years in jail** **B = 2 years in jail**
Prisoner **A** – confession	**A = 2 years in jail** **B = 10 years in jail**	**8 years in jail for each**

Let the above be a 2x2 payoff matrix where the lines correspond to the behavior of A (remain silent or confess) and the columns correspond to the behavior of B (remain silent of confess). At the intersection of B's «confess» column with A's «confess» row, both receive a jail sentence of 8 years. If A confesses and B does not, A will only get a 2-year sentence, whereas B gets 10 years, and vice-versa. There is an incentive for any of them to confess in order to reduce their own jail sentence. This way, it would eventually be advantageous for them not to remain silent. If one of them defects by confessing, but not the other, he will only stay in jail for 2 years whereas the other will be there for 10 years. But if both confess they will be sentenced to 8 years each. The temptation to confess is great, but so is the inherent risk, because, after all, they would mutually benefit from remaining silent, getting a 6-year sentence each in that case.

The prisoners know the rules of the game, they just do not know how the other player will act. It is advantageous for them to remain silent, but they do not know if the other one will confess. As long as one of them confesses, the silent other will be sentenced to 10 years in jail. A dilemma thus arises: it is good to remain silent, but there is the risk the other one will defect; and the one who does it faster will take the greater gain. In the worst case scenario, both get an 8-year sentence — nobody will take the risk. This is a classic game, one where both players have the tendency to confess — and not benefit from what could be a mutual advantage, but one they cannot assuredly profit from. Firstly, because they do not have the opportunity to talk; secondly, because even if they did, they would still be in risk of being betrayed by the other. They have no joint solution in the sense that A and B could ever choose what is best for both, where there would be an assured increased advantage for the two.

All turns more complicated when one imagines A and B playing this game many times in succession, taking into account their experience of previous mutual behavior in their past. In this case they can go on building mutual trust or distrust. If one betrayed the other once, the betrayed one's reaction will be vengeance, or simply intolerance, in some future opportunity. Let us now visualize a situation with multiple players and ask ourselves which will be, along time, the best of all possible strategies — by running a computer simulation. Of course one thing is to presuppose any one strategy can always match with any other, which is the base assumption, and then to move on to a situation where one wants to match only with certain players. Through these more realistic situations one begins to develop a game theory where social structure is included inside it.

In the early 1980's, Robert Axelrod (1984) launched a worldwide competition taking place in computers, by setting up the following game: Each participant programs, on the computer, the strategy he intends for his player-program in the Prisoner's Dilemma game; thus there is a population of player-programs written by the participants, each with its own specific strategy. At each successive step of the game running on the computer, each player is matched with another player, and each either plays «cooperate» or «defect» according to their respective strategies. If they both cooperate they both win, according to the payoff-matrix settled for the game; if only one defects it will benefit, but the betrayed player will have the chance to reformulate its future behavior. Which will be the best strategy to take when this game is played over and over for thousands of iterations in co-presence with other strategies? The best strategy actually depends on which other strategies are present but it was shown — and the experiment was repeated with a different collection of strategies — that the then best option was the so-called «Tit-For-Tat (TFT)». This strategy consists in beginning by cooperating and, from that point onwards, repeating whatever the adversary did just before — in plain English, "what comes around goes around". If someone betrays me, on principle I will also betray in the next round because I am imitating him. If from the start both cooperate having this strategy, then they will receive back successive cooperation. Amongst all possible choices — cooperate three times, betray twice, etc. — it was shown that the TFT option is, par excellence, a winning strategy which tends to invade a population of strategies. «Invasion» because in presence of someone with a winning strategy, one will imitate it and, if we all play TFT we all win the most. All start by cooperating and keep on doing it, and thus always keep on winning whatever payoff comes out of cooperation. There is only one circumstance where TFT does not invade the population: when all other players are betrayers and only one cooperates — because then there is no one to cooperate with. However, as long as there are two TFT players in the population, they will win whenever they meet and thus start invading the population on being imitated.

Instead of imitating those who win the most, one can alternatively let them reproduce the most, that is, make more copies of them, proportionately, and keep a fixed size for the population, by random elimination. This option can be had because those who lose more easily are eliminated by virtue of their reduced number of copies, and because only those who win more than some threshold are allowed to reproduce. The intent of this interpretation is that, throughout the game, we want to take over resources and occupy vital space for the population. Winning means having more energy to reproduce, while losing means not being able to persist with one's genetic/memetic continuity.

The winning strategies invade the population and, since they self-support, they are labeled "evolutionary stable". Things tend to complicate, naturally. From the moment we introduce more memory, it is possible to remember how much a given individual betrayed us, and who didn't, evaluate them against our own betrayals, and thence exercise tolerance, or not. Our strategy then is not blindly applied to each individual met, but for doing so we need memory, even if limited. If someone plays «Tit-For-Tat» and, every once in a while, betrays, he can accumulate more benefits, in the sense that the other player may exert a tolerant forgetfulness regarding the harm suffered. Till today, with just memory of the last play, the most successful strategy, superior to TFT because resistant to error or noise, is the «Win Stay, Lose Shift (WSLS)» one. That is, if I won in the last play, I repeat my behavior;

if I lost, I change it in my next play; I start by cooperating (Sigmund, 2010).

It is also important for a strategy which aims to be evolutionary stable to be tolerant to the inevitable evolutionary noise or imperfect communication, in such a way as to be able to recover from endless cycles of revenge and counter-revenge. Of course, there will be opportunistic strategies that will try to make an intended betrayal look like noise, and thus gather the benefit of doubt forgiveness. Tolerance needs guardedness. Intention recognition thus becomes important, including how somebody else's intentions are affected by the way others recognize and tolerate our own intentions (Pereira & Han, 2011, 2012, 2012a). In our recently published and submitted work (Han & Pereira & Santos, 2011, 2011a, 2012, 2012a), we have developed an intention recognizer strategy (IR), which wins against WSLS and against all others too, and is evolutionary stable even in the presence of substantial noise. With only about 10% of initial IR players, the strategy invades the population of Prisoner's Dilemma players, or of other classic games — such as the «Stag Hunt» — even in the most disadvantageous conditions of the payoff matrix, that is when the gain of betrayal, and thus the temptation of acting on it, is very large comparative to other payoffs.

Another problem also arises concerning the possibility of reencountering or not the betrayer. If you only encounter that player once, the likelihood of betrayal increases. But if, on the other hand, I know that I will encounter the betrayer several times, the chances of betrayal happening become lower. And I know that kind of memory can be communicated to others — I can tell someone: «you can trust that fellow, take my word», and the other person may believe what I tell him because I have gained some credibility. If I never betrayed anyone, I am a friend — our friends can believe in us — and I can spread that information about the credibility of others, thereby ensuring a certain degree of tolerance towards them.

Whenever there is the choice of playing, or not, with a given partner, the whole game situation changes. One can, for example, explore the evolution of social structure. This means that I begin by clustering players into groups who prefer the same strategies. Scientists like to play with other scientists, lawyers play with lawyers — they have the same psychology, they know what they can expect. It is possible to obtain a larger gain by knowing whom each player can relate with. There is, therefore, the tendency to play with whomever we can establish a trust relationship, and whose thinking strategy type is familiar to us, for our own defense.

This relates both to the memetic game as well as to the genetic game. It is the evolution of the civilization «pool», besides the genetic «pool», that matters. The problem cannot be seen in terms of reproduction of the single individual, but as the reproduction of certain shapes and configurations of genes and memes that make society, as a whole, to benefit from the coexistence of that variety of strategies in co-presence. It is moreover possible to prove that, in certain games, it is the combination of strategies that wins, keeping to an equilibrium amongst them — if one is taken away the whole will be harmed. In general this is the way ecological systems work. It is a combination of strategies of various organisms — some parasitizing others — so that the whole system may live, survive and continue to evolve at the cost of such multiple equilibriums.

The so-called culture of altruism, as long as it is shared by the elements of a group, can be a winning strategy. Under said conditions, as mentioned before, an opportunist can always be born, a parasite, he who says to himself: «I've understood the game and this is what I'll do». The others, meanwhile, find out his scheme and create mechanisms to detect and to not tolerate him. However, each adaptation will make him an ever more sophisticated opportunist — for example, the one who discovers a loophole in a law and takes advantage of it. It is very much necessary to know if one can be detected when preparing a betrayal of the members of the group. To the contrary, if we are about to be detected the guilt feeling grows, and it might eventually reach a point where we confess even before we are caught — another way of getting benefits. The production of a guilt feeling may be seen as a strategy for such a situation.

Wanting to be simply altruistic, even when we expect nothing in return — because exchanges need not be immediate — can be advantageous because, sometimes, it may be good for us to have others just seeing us be kind. If someone sees me being altruistic I will be increasing my credibility. And the best way to gain a good reputation is by being effectively good, or faking to be good. But going down the faking road can lead to a point where we are not aware of being fakes. That is so because I deceive others best if I deceive myself too; otherwise I will be too conscious of my faking and could blow my own cover with a misplaced gesture, and no longer be tolerated in the game. Of course this creates conviviality problems, precisely because he who fakes is convinced that he is not faking, as a result of his consciousness elimination mechanism.

The situation can become more complicated in many ways. There is benefit in being altruistic to the extent that we are betting on the safe side. In a society where altruism is beneficial, showing that you comply with the rules of the game will entitle you to rewards, if the day comes when you need them, as long as there is a measure of intolerance against opportunists. We have social security systems, unemployment benefits, etc., but there will always be that individual who takes undue advantage of them, one way or another; and particularly those who say that such systems are useless, so as to justify not to contribute.

However, there are certain cultures and cultural levels — and I am thinking of two — where the most important is to «give». In New Guinea, every six months, there is a ceremony where people offer pigs, and where whoever offers more pigs becomes, for one season, the overlord. The others feel the obligation to give pigs back, so they raise lots of pigs — which is always very difficult because it is necessary to keep feeding them for six months before offering them — but whoever gives more pigs away obtains greater social recognition. This form of altruism and gift are used as social mechanisms to assess status, to assess who is more important. The same happens with Eskimo, in the potlatch ceremonies — a gift offering and wealth distribution ritual — which is equally a celebration of who gives the most. Yet another example are the scientists — they work to do more research and to publish more results for free, to be more considered and gain social returns. The game consists of giving more, not giving the least to gain the most, because the gain is measured in a different currency.

Another aspect of a player is the notion of honor, most exacerbated in the 19th century, which is the idea of earning a good reputation and knowing how to preserve it, if necessary by means of the courage of strength. When an individual is offended, he takes out a glove and strikes back at his offender slapping him twice — even if the offense is nothing of much importance. What is at stake is to know that the offended always responds. In a sub-organized society — in which altruism is not generalized and in which not everyone pays back — it is necessary to have a signal that defines «I am one of those who pays back, and in the name of my credibility and my honor this is how I behave».

To understand these mechanisms and, opportunistically, profit from these theories, allows whomever knows them to take advantage of the credulity of others.

I have already mentioned that the next step is to have a language system, of commitment by language and, of course, of deceit. One can say «I am all in favor of strategy A» and the other one responds: «I am in favor of strategy B», each one having certain gestures or labels that identify them. Signals are given, which is strategically beneficial because it avoids confusions, betrayals or surprises. Brian Skyrms (Skyrms 1996, 2004, 2010), currently one of the great scholars in this area, shows how systems of signals can arise which, according to him, evolve and are at the origin of languages. Signals correspond to the necessity of determining which kind of player one is, and which secret codes one has access to. If I am with the Freemasons, and the other person says he is too, I will ask him to prove it and he will give me a special handshake. And only those who know it will respond correctly, which allows to identify him as a legitimate member of the group. Of course there are also imitators, and where there are imitators there is also someone that detects and not tolerates them. Bottom line, this "arms race" puts a prize on the evolution of our brains through the games we are involved in. But, I repeat, the strategies are not of one single individual, but of a whole society or group — which can be political, religious, etc. In other words, it is very important to know which partners we are playing with.

This capacity to choose partners raises, a priori, the question of knowing which kind of partner we can rely on. The casting of group identifying signals mentioned above is quite economic, in terms of games; it is more economic than a play, and it can be very rewarding. This way, game theory with signals is born. But when there are signals, there are those who pretend, there are codes that must remain secret.

The choosing of partners thus creates preferential groups, with their unifying and protecting advantages. But the negative side of that is the definition of borders between groups, and the coming into force of group competition for resources, which places and repeats at a new level and scale the problem of altruism/opportunism and that of tolerance/intolerance.

4. Strategic Equilibriums

Game theory focuses on the average expected gain. No one predicts the future and one must simulate all possibilities, with a broad sense of what are the respective probabilities of occurrence. A topic of study is the so-called «Nash Equilibrium». This is about a strategic equilibrium point where we disadvantage ourselves if any of us changes our payoff percentage, increasing or decreasing it. Let us illustrate a few phenomena of evolution towards an equilibrium, experimentally observed in lab and field games specially concocted.

Suppose the following game, where someone with a cake says: «I have a cake to split among us», the whole cake is 100% and each of us must write down the percentage he wants. If someone writes down that he wants 80%, and I myself do the same, the total will surpass 100% and in that case nobody gets any part of the cake. If the sum does not surpass 100% each one gets what he wrote down. If an individual writes down 30% and I write 70% we get the whole cake and share it that way — this is an example of a «Nash Equilibrium». If anyone of us increases his percentage, even if by only 1%, the sum will surpass 100% and we loose all the cake. If we decrease our percentage, we get less that 100% of the cake, which we could have had. This game has an infinite number of solutions, as long as the total adds up to 100% — we achieve the equilibrium and nothing prevents us from playing that way. But if I see somebody eating 70% I will ask for another cake, and the splitting will evolve towards 50/50. Why? The point is that, usually, the strategy occurs within a group. We are many, there are lots of people with cakes and we are all eating them. When I see a couple doing 50/50, and I check that it works, my imitation mechanism will intuitively lead me to copy it. There is an imitation mechanism because those going for 50/50 get the whole cake, get fat and have more offspring with their investment. If they reproduce more, this strategy tends to invade those of others. Those who opt for 30% of the cake, get thinner, will progressively grow weaker, cannot afford the luxury of having offspring — and, in the long run, their strategy will be wiped out. The 50/50 tend to invade the playing field not only by imitation but also by genetic mutation.

In fact, strategies are not fixed. Today I say 30%, tomorrow I will say 35% and, as a living being, I automatically explore around an equilibrium. I try other strategies and the most beneficial persist. The 70/30 split is unstable only if there are others using different strategies, if imitation and crossover are in place. The mutation evolutionary component, the reshuffle and distribute, is essential to attain a «Nash Equilibrium» and to allow evolution towards another solution. Let us return to the cake game, but let us substitute it by a 100 dollar bill that we are splitting in two. Suppose I ask for 30 and the other asks for 70. But let us modify this a bit — there will be a referee deciding who gets the 70 and who gets the 30. If I know the referee and I bribe him I will ask for 99% or even 100%, and he will agree with me. But if, on the contrary, he is fair and I do not know him, it is obvious I will ask for 50%. On the other hand, if the game is not decided by a referee but randomly, say, by a computer generating a random solution, the result would be different. The fact of whether there is or there is not a referee, as well as the kind of referee, will make a big difference — the equality of distribution is now associated with the need for a justice system with judges — and this is how it arises. We will find the 50/50 arise, which our intuition tells us is correct, so much it is branded in our genes. This problem is so general and common that it had to be solved for millions of years, time and again.

There is another game to consider, involving four people. Initially a scientist, in a laboratory experiment, equally distributes a certain amount of money by four people, and these must decide with how much they will contribute to a common fund, which the scientist will then double and use for a new distribution. Suppose I contribute with 10%, the others do the same and the resulting total will be again equally distributed. The problem is evident. The people contribute with equal amounts, the scientist adds a new contribution equal to the sum of the four contributions, thereby duplicating it, and then redistributes it by the four. That is, there is an advantage in contributing to the total because the sum will be double. But I can also get an advantage if I do not contribute to the sum — because others will and, anyway, I will benefit.

These are the explicit rules, and most test subjects tend to risk contributing with half the amount they have received to the sum, which on being doubled, turns to 100%; which is then split in four, resulting in 25% for each and, in the end, you only lose one quarter. If everyone does the same, you actually double what you put in. It is also settled beforehand how many times this game will happen — about 10 or 20. But, towards the end, participants have the tendency to contribute with less money, expecting to gain from what others put in. So, in the beginning, willing to earn the trust of others, they contribute more, but then they progressively contribute less and less, to benefit more before the game ends.

We can make the game even more complicated. I may want to punish someone for not contributing at all or, on average, contributing with less than they should. That, however, will take a personal cost. If I want to punish someone by 70%, I have to chip in with the remaining 30% to sum up the 100% of a total amount which is returned to the scientist. In order to punish I have to pay, and to do that I have to be effectively willing to fulfill my intent. What happens is that people start to punish those who contribute with less, in such a way that it leads the culprit to increase his contributions. The so changed game — it has been verified experimentally — makes the contributions rise up to 100%, both for the duplication of the sum as well as for avoiding punishment. This happens even if there are several groups, and each person keeps changing groups and never re-encounters old game partners — the punishment behavior remains the same. What we conclude is that it is not an educational punishment, because groups are never reconstructed, but that there is in us a tendency to punish the infractor, to make him comply. One can also argue that something makes altruism rules stick in a large group. We do not want to educate a particular individual, but only to keep a general group culture. However, it is also by vengeance, and there exists a retaliation mechanism which is strong up to the point where, even when one changes group, that «trait» still functions. It is in these terms that the origin of the vengeance emotion is explained.

There is yet another game we should mention, said the «ultimatum» game. Someone comes up with 100 dollars and gives them to me. I offer 70 of those 100 dollars to another individual. If he accepts my offer, knowing I get the remaining 30 dollars, that is how the split takes place. If he does not accept we both get nothing. I could have the tendency to offer 1 dollar to the other, which would accept it thinking: «if it weren't for this game I would gain nothing, so I'll take this small offer, it's a gain for me anyway. I'll take it». But the majority of people do not accept such a lowly offer, and accepts only if the offer is between 40 and 50 dollars. Most of the players offering money usually also offer about that amount, keeping a little more than what they offer. If one offers less that 40 others tend to reject the offer, the justification going along these lines: «under such circumstances I don't want anything». They are «irrationally» willing to let go of a pure additional gain because, rationally, there should be no concern about what the offeror gains or not. Due to our innate tendency, we already know that social games are repeated. Even if you tell people that the game is going to be played only once, our genetic — and memetic — programming refuses to accept small amounts, just to make others not be so selfish, to keep the so called altruistic group culture. However, when the percentage is decided by a computer — someone gives me 100 dollars and I just press a button to hear the money distribution instructions given by the computer — the other person usually accepts anything because he considers there was an impersonal decision maker who will not be influenced.

In the Machiguenga tribes of Amazon, and Papua New Guinea, people offer more. In western civilization the common practice is to accept 45%, in the Amazon people stick with only 26% and in Papua New Guinea they offer above 50%, because they are already used to give away the pigs as we have discussed previously, and this is where the concepts of social respect and social debt come into play. The game is being considered in a broader context, not just as an isolated experiment, as in the commercial transactions we are used to.

It is curious that, in these experimental games, certain phenomena are concocted to bring up aspects that change with age. One example is self-esteem, responsible for the rejection of a low offer in such a way that nobody gets tagged as the one who settles for little and to whom we need not offer that much. Self-esteem drives us, even in the absence of consciousness of a clear rejection strategy, like when the waiter at the restaurant rejects a very small tip.

Let us return to the sum game with the punishment possibility. Even when circulating amongst several groups, never re-encountering old game partners, and excluding the notion of education, punishment still persists. From the game theory point of view, vengeance is the feeling that leads to punishment and it is extremely useful, thereby memetically surviving.

Many of our emotions are deceit strategies because, from the moment they exist, and aware of their characteristic of being non dissociable from the human being, we can try to trigger them and move on to the next level: the emotional game. But, first, the game has to be seen from the point of view of survival by the best use of strategy. Those who get resources survive, those who do not go extinct. However, the essence of the game is that both can win or both can lose. The computational simulations, in greatly sophisticated games with a high topological complexity, show what is the best strategy that survives, multiplies and is stable, and they show that altruism and cooperation emerge and spread, under very broad conditions.

We cannot ignore mutations. At any given time a strategy can be altered and the individual may try others. There can be an evolutionary mutation in which people perform differently in their participation tasks. When faced with mutations, we no longer have before us classic games in which there can be infinitely many immutable equilibrium points, those in which each equilibrium point persists because any small change in the payoff of the game move with the ongoing strategy does not bring about new benefits nor additionally avoids harm. By definition, all these are equilibrium points. But it will not be a classic equilibrium if there will occur mutations that give rise to unexpected strategy variants. In such cases, if the equilibrium point still persists anyway, the strategy is said to be evolutionary stable, thus generalizing the concept of Nash Equilibrium. Evolutionary Game Theory studies such circumstances.

Even in simulated situations, where there is neither the education nor the learning factors, and in which individuals know that, in each game, they will not match the same old partners, they still execute certain strategies which are already imprinted in our brains and in the way we behave. It has nothing to do with the consciousness of wanting to influence, but with something already related to feelings and deeper cognitions.

Actually, the structure of games, the structure of repetitions and of encounters — the choosing or not of whom we match with, whose place we go to and whom we welcome in our house — all that game, all those games space possibilities, have been played during the learning of our species. There is a genetic or memetic learning that develops those frames of reference. Evolution itself is a strategy game.

Rationalization itself might be part of a strategy. An individual, if he wants to dispute something, rationalizes. Guilt tends to rise when he begins to feel that he might be caught and, as I have said before, that guilt might ultimately lead him to a pre-empting confession. Laughter itself is a strategy that evolved from a display of aggressiveness into a strategy to appease the other. We can look into the physiological characteristics of laughter and try to understand which were the first motivations that made our body to physically adapt to the production of certain substances and subsequent consequences.

Games can be treated as typifications of social organization, as if they were logical equations subject to theoretical and/or experimental evaluation. Knowledge of them is itself part of a game in which we all can win, because its derived conclusions supply a better knowledge of the reality from which we could move on towards a better game. There are cumulative sets of results that make us move on to the next level, our knowledge grows and we can benefit from that ensemble. This type of game has to be played with a very rigorous tactic.

We began by saying there is a combinatorial game composed by genes, and that certain stable structures can get more complex and give rise to a generating combination, to a nervous system with the capability of reproducing ideas, as well as of modeling external features, of making retrospectives, of aiming for predictions of the future, etc. How did cognition reach this point through evolution? Today science already has the ability to prognosticate and to give some thought-through answers to these questions. But we can see that, at a large scale, the name of the game is to survive and replicate, perhaps only by mere copy — because only by achieving that genetic/memetic reproduction there is a future where the game continues to make sense. Only this way the game can become even more complicated, and it is only by increasing complication that it is possible to aspire to be a better player and to take advantage of the worst players, making them evolve into better ones, in such a way as to attain maximum common benefits, unachievable without generalized cooperation.

We are immersed in games, strategies, coexistence of evolutionary strategies. While psychology and psychoanalysis focus very much on the individual's past, they never truly looked into the species's past. Games create hidden ghosts in terms of certain cognitions, since in the evolutionary game there can be a potential advantage in deceiving the other, even in deceiving oneself. In terms of evolutionary competition there coexist, however, other variants like the games where everyone can win, but involving intra and intergroup altruism problems, always subject to individuals' emotions. The behaviors of human societies, in terms of phenomena, emergent or otherwise, are so deeply underlying that often not even the actors themselves are aware of them, and behaviors express themselves because that corresponds to a cognitive evolution coded in the collective unconscious, which is circumstantially actionable. The very emotions, which are usually seen as opposed to rationality, end up possibly being compiled strategies, that survived as such in a certain type of game. We can then well imagine how emotional and sexual behaviors in general accomplish hidden purposes.

We can easily understand, through computer simulations of competing populations and their respective planning, that the wining strategies change over time. They change in accordance with the probabilities of encountering an opponent with a different tactic, or when we have encountered them before we reorganize ourselves to deal with individuals who share our «tricks» in a manner as to be able to cooperate in order to achieve better results. Here we discover social organization, and it is by these means that exterior signals come about — among them, language reveals itself as one of the most important — which are identifiers of social types, including the facet of the opportunist who pretends to cooperate to take some advantage. Strategies, however, have also progressed to detect so-called opportunists, there being those who maintain that the brain evolved as the result of a complex adaptation to the social system, with its vicissitudes and abusers, since in order to live in this natural world we do not need a very sophisticated brain, as many animals so prove.

It is quite interesting that nowadays all these subjects have began to be studied via mathematical models and algorithms, using the computer to simulate strategies and allowing us to understand the emergent phenomena. In the current state, we begin to instill in the players of these games more flexible cognitive abilities, coming from the Artificial Intelligence domain, like the above mentioned Intention Recognizer, thus allowing the achievement of new levels of sophistication of game models and of the study of cooperative success, encompassing individual and group tolerance.

5. Group Altruism/Opportunism

As aforementioned, whenever there is altruism there is opportunism. Let us imagine, for example, what can happen with the European social model. It has guaranteed pensions, it has a health system for everyone —society has created altruistic mechanisms. Obviously, there are people filing fake diseases, taking advantage of each and every loophole to unduly benefit from that very altruism. We must not only repress the transgressors, but also those who are in charge of repressing them and do not do so: the corrupts. There are individuals who are bribed by the ill-intended because, obviously, the transgressor uses part of his benefit to pay the corrupt fiscal who "closes his eyes". This game between altruism and parasitism is inevitable — as inevitable as the power of gravity. Because there are always mutations that promote altruism, there are mutations that create opportunists who will take advantage of the former. And often they do thrive.

It has been proved, in mathematical models of evolutionary games, that group selection has to do with the memetic pressure for compliance with the rules of the game. But such compliance will only take place if those who do not labor to enforce it, whenever they have the opportunity to do so, are penalized as well. Such is the case since caring and penalizing have a cost that, if we can we will avoid when compliance does not affect us directly, unless we ourselves are penalized for doing nothing.

We have this personal experience in traffic — many times we repress or preventively impede others from doing some maneuver, when faced with a car which we do not know whether it will be trying or not to get forcefully into the queue, thereby violating a traffic law. Playing it safe, we impede this wayward possibility — we are then enforcing the rules of the system, saying to opportunists, manifest or potential, that there are rules and violators are not tolerated.

In terms of human societies, the above means that altruism cannot be for everyone. A person is altruistic towards the group he/she belongs to. It is evident that, when you belong to a group there can be outside groups that will try to take advantage of your own.

Imagine a human group of the Upper Paleolithic or Lower Neolithic that farms, domesticates cattle, has corn already under control, even achieving some genetic improvements — using the mechanisms of natural selection to, in an artificial manner, improve the species of its cattle or grain. This group lives with a certain wealth, it has its society set up, it has a reproductive cycle, their women are able to generate healthy children. It is obvious that another group will always be tempted to attack this group to take the resources it built up. Because resources correspond to an investment, the social organization too corresponds to an investment, and those who have not made that investment will do better if they steal.

There are mechanisms for groups to get along, even on account of their having to exchange genes among themselves. Thus, genes from one group are exported to others and interchange takes place. There are mechanisms of commercial trade that are very important. Commercial trade builds trust relations, and this brings about the problem of credibility: After all, who is the partner I am playing with? After all, which individuals do I prefer to make transactions with? But always there are pirates, and there are still pirates in the seas even today, where there are no law enforcers.

Reciprocal altruism occurs towards a group we know is behaving according to certain rules. We are not going to be altruistic towards strangers, especially if they are with another group whose rules of the game we completely ignore. We ignore if they are deceiving us, if they have second intentions, and what are their behaviors as a group towards others. It is required to build a previous trust, which must undergo the declaration of identities and intentions, and the holding of coherence.

We have previously mentioned individual natural selection, more related to genes. But, when individuals group into units, we can also consider that there is group selection. However, claiming it is not enough, it is necessary to prove it mathematically and with computer simulations. For a long time this notion of group selection has been rejected, except for very specific and rare circumstances. In truth, it can be proven by mathematical simulation that, in fact, individuals of groups had to exchange genes in order to diversify their «pool» for to avoid hereditary diseases. Because, having a double helix, the gene in front of another with a malefic mutation can correct it. However, if both are equal, a hereditary disease manifests itself. That is why there are so many incest prohibiting rules, such rules having appearing spontaneously. Groups who did live by them did not resist the illnesses resulting from «inbreeding». It is necessary to exchange genes. The group must keep its borders open at all times.

Only very recently have we began to look at more sophisticated models and to make memes part of simulations. Indeed, memes code for algorithms, social routines, which afford a behavioral identity and unity to the group, and are interpretable in varied and overlapping relational allegiances with their distinct mechanisms.

The other side of the coin of group unity is, naturally, competition amongst groups. For example, the group can, via its memetic-religious ideology — through a shared divine bonding —, be more fierce, more aggressive, and take all the opportunities to slaughter others. Group behavior, inward and outward, is now determined as well by the memes, a reproductive mechanism which is faster and more flexible than the genetic one — as we said before, genes take a generation to propagate while memes take only the time of a culture sharing act. What survives is the memetic combination of the group, confronted with the other groups and attending strategies. Of course genes are still there. And there stands the global problem of how these two reproductive levels co-inhabit.

We now begin entering *terra incognita*, the issue of the interaction between memes and genes. Because, on the one hand, on some occasions, they are antagonists, but on other occasions they have an interest in cooperating. Memes are relatively recent in evolutionary terms. It was our species who took them to a progressive refinement, only possible because we have language. Language — and it does not necessarily have to be the spoken word, it can be a sign language — is the form *par excellence* of transmitting memes. This memetic reproduction, in the societies we live in today, tends to say that individuals should be treated equally no matter what their genetic combination is (no matter the color of the skin, with or without disabilities, etc.). Our own memetic culture states that genetic difference does not matter — everyone is memetically treated *a priori* in the same way. This is the case in some societies, in others it can be different. We can see that memes themselves already can control genes: by genetic manipulation they can handle them, in a good sense, curing hereditarily transmissible diseases; or also. in a bad sense, given that they could be empowered in eugenics and race improvement programs.

We are still in the beginning of knowing how they work in articulation, these two reproductive mechanisms. From a computational perspective, bottom line, they can be seen in terms of co-present strategies — and it does not matter whether their underlying support is biochemical, or if it is the C++ programming language, or any other. In abstract, what we are studying are certain functionalities in co-presence. But one can say that human evolution is getting ever more memetic (Richerson & Boyd, 2006).

6. Complex Networks of Mindful Entities: a new research domain

With our research on these networks we intend to understand, and explain, how some social collective behaviors emerge from the cognitive capabilities of individual agents, in communities where said individuals are nodes of complex adaptive networks, which self-organize as a result of the referred cognition of individual agents. Consequently, we need to investigate which cognitive abilities have an impact on the emergence of properties of the population and, as a result, which cognitive abilities determine the emergence of which specified social collective behaviors. Hence, the key innovation consists in the articulation of two distinct levels of simulation, individual and social, and in their combined dynamics. This needs to be reified both at the modeling level as well as at the computational implementation one.

Biological evolution is characterized by a set of highly braided processes, which produce a kind of extraordinarily complex combinatorial innovation. A generic term frequently used to describe this vast category of spontaneous, and weakly predictable, order generating processes, is «emergence». This term became a kind of signal to refer the paradigms of research sensitive to systemic factors. Complex dynamic systems can spontaneously assume patterns of ordered behaviors which are not previously imaginable from the properties of their composing elements nor from their interaction patterns. There is unpredictability in self-organizing phenomena — preferably called «evolutionary» —, with considerably diverse and variable levels of complexity.

What does emerge? The answer is not something defined but instead something like a shape, or pattern, or function. The concept of emergence is applicable to phenomena in which the relational properties predominate over the properties of composing elements in the determination of the ensemble's characteristics. Emergence processes appear due to configurations and topologies, not to properties of elements (Deacon, 2003).

As we have remarked before, two hundred years after the birth of Darwin, and 150 after the *On the Origin of Species*, several fundamental questions about evolution still remain unanswered. The problem of evolution of cooperation and of the emergence of collective action — cutting across areas as diverse as Biology, Economy, Artificial Intelligence, Political Science, or Psychology — is one of the greatest interdisciplinary challenges science faces today. To understand the evolutionary mechanisms that promote and keep cooperative behavior is all the more complex as increasingly intricate is the intrinsic complexity of the partaking individuals. «Complexity» refers to the study of the emergence of collective properties in systems with many interdependent components. These components can be atoms or macro molecules in a physical or biological context, and people, machines or organizations in a socioeconomic context.

This complexity has been explored in recent works, where it is shown, amongst several other properties, that the diversity associated with structures of interaction, of learning and reproduction of a population, is determinant for the choices of agents and, in particular, to the establishment of cooperation actions (Santos *et al.*, 2006, 2008). These studies were based on the frame of reference provided by Evolutionary Game Theory (Maynard-Smith, 1982) — alluded to before — and by the theories of Science of Networks (Dorogotsev & Mendes, 2003), combining instruments for modeling multi-agent systems and complex adaptive systems.

«Egotism» concerns the logic behind the unending give-and-take that pervades our societal lives. It does not mean blind greed, but instead an informed individual interest. Thus, «The evolution of cooperation» has been considered one of the most challenging problems of the century. Throughout the ages thinkers have become fascinated by the issue of self-consideration versus "the other"-consideration, but the use of formal models and experimental games is relatively recent. Since Robert Trivers (Trivers, 1971) introduced the evolutionary approach to reciprocity, games have served as models to explore the issue.

The modeling of artificial societies based on the individual has significantly expanded the scope of game theory. Societies are composed by fictitious subjects, each equipped with a strategy specified by a program. Individuals meet in randomized pairs, in a joint iterated game.

The comparison of accumulated rewards is used to update the population: the most successful individuals produce more offspring, which inherit their strategy. Alternatively, instead of inheriting strategies, new individuals may adapt by copying, from known individuals, the strategies that had best results. In both cases, the frequency of each strategy in the population changes over time, and the ensemble may evolve towards a stable situation. There is also the possibility of introducing small mutations in minority, and study how they spread.

Evolutionary Game Theory (EGT) is necessary to understand the why and the how of what it takes for agents with individual interests to cooperate for a common weal. EGT emphasizes the deterministic dynamics and the stochastic processes. Repeated interactions allow the exploration of direct reciprocity between two players (Sigmund, 2010).

In the EGT approach the most successful strategies become more frequent in the population. Kinship, neighborhood relationships, and individual differences, may or may not be considered. In indirect reciprocity (Nowak & Sigmund, 2005), players interact at most once, but they have knowledge of their partners' past behavior. This introduces the concern with reputation, and eventually with moral judgment (Pacheco & Santos & Chalub, 2006; Pereira & Saptawijaya, 2011; Han & Saptawijaya & Pereira, 2012).

The strategies based on the evaluation of interactions between third parties allow the emergence of kinds of cooperation that are immune to exploitation, because then interactions are channeled just to those who cooperate. Questions of justice and trust, with their negative (punishment) and positive (help) incentives, are fundamental in games with large diversified groups of individuals gifted with intention recognition capabilities. In allowing them to choose amongst distinct behaviors based on suggestive information about the intentions of their interaction partners, they are, in turn, influenced by the behavior of the individual himself, and are also influenced by the tolerance to error and to noise in the communication. One hopes understanding these capabilities can be transformed into mechanisms for spontaneous organization and control of swarms of autonomous robotic agents.

With this objective, we have studied the way players' strategies adapt in populations involved in cooperation games. We used the techniques of EGT and considered games such as the «Prisoner's Dilemma» and «Stag Hunt» successively repeated, and showed how the actors participating in repeated iterations with these games can benefit from having the ability to recognize the intentions of other actors, leading to an evolutionary stable increase in cooperation (Han & Pereira & Santos, 2011, 2011a, 2012, 2012a), compared to extant best strategies.

Intention recognition is implemented using «Bayesian Networks» (BN) and taking into account the information of current signals of intent, as well as the trust and tolerance built from previous plays. We experimented with populations with different proportions of diverse strategies in order to calculate, in particular, what is the minimum fraction of individuals with Intention Recognition for cooperation to emerge, invade, prevail, and persist.

7. Directions for the Future

The fact that, in a networked population, individuals can have more cognitive capabilities and dynamically choose their behavior rules — instead of acting from a predetermined set — gives the system a much richer and realistic dynamics, worth exploring. Within the scope of this new paradigm, individuals must be able to hypothesize, to look at possible futures, to probabilistically prefer, to deliberate, to send and respond to signals, to take into account history and trust, to form coalitions, to adopt and fine tune game strategies.

Actually, the study of those properties that emerge from populations in complex networks still needs to further investigate the cognitive core of each of the social atoms. Given the plethora of possibilities in the modeling of cognitive capabilities, we must identify the intrinsic characteristics which, solely by themselves, provide the most prominent individual behavior, and are conducive to an emergent collective behavior which cannot be anticipated, but is cooperative and tolerant. It is required to consider limiting the number of available parameters, in such a way as to render the study treatable, and also to make it implementable in future «robots», in the engineering domain and not just in the simulation domain.

All things considered, one should take into account different types of individual and social cooperation dynamics, whether deterministic or stochastic, and use N-people interactions modeled in terms of evolutionary games that constitute metaphors of the social dilemmas of cooperation. It seems to us that Intention Recognition, and its use in the scope of tolerance, is a foundational cornerstone where we should begin at, naturally followed by the capacity to establish and honor «commitments», as a tool towards the successive construction of collective intentions and social organization (Searl, 2010).

8. Coda

Evolutionary Psychology and Evolutionary Game Theory provide a theoretical and experimental framework for the study of social exchanges, where tolerance towards the inside of a group and discrimination and intolerance towards the outside of the group are the two sides of the same coin. The strategic recipe «love thy neighbor» often paradoxically contains the genesis of hatred and war, because neighbor refers to the «tribe», and the gods are referees on our side.

Recognition of someone's intentions, which may include imagining the recognition others have of our own intentions, and comprise some error tolerance, can lead to evolutionary stable win/win equilibriums within groups of individuals and amongst groups. The manifestation of intentions is a facilitator in that respect. Additionally, by means of joint objectives under commitment, one can promote the inclusion of heretofore separate groups into a more global one. The overcoming of intolerance shall benefit from both these levels of manifest interaction.

We have argued that the study of these issues in minds with machines has come of age and is ripe with research opportunities, and have also communicated some of the published inroads we have achieved with respect to intention recognition and tolerance in the evolutionary game theory context.

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