The Generative Power of Signs: The importance of the Autonomous Perception of Tags to the Strong Emergence of Institutions

Deborah V. Duong

OSD/PAE Simulation Analysis Center,
1225 South Clark Street Suite 300,
Arlington, Virginia 22202
Phone Number 571-276-8270
Fax Number 703-604-6400

debbie.duong.ctr@osd.mil

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ABSTRACT. The first intelligent agent social model, in 1991, used tags with emergent meaning to simulate the emergence of institutions based on the principles of interpretive social science. This symbolic interactionist simulation program existed before Holland's Echo, however, Echo and subsequent programs with tags failed to preserve the autonomy of perception of the agents that displayed and read tags. The only exception is Axtell, Epstein, and Young's program on the emergence of social classes, who were influenced by the symbolic interactionist simulation program. Axtell Epstein and Young's program has since been credited for strong emergence. This paper explains that autonomy of perception is the essential difference in the symbolic interactionist implementation of tags that enables this strong emergence.

KEYWORDS: Interpretivism, Social Norms, Ontologies, Agent Technology, Symbolic Interactionism, Interpretive Social Science, Emergent Language, Agent-Based Simulation, Tags, Autonomy

"In the beginning was the Word, and the Word was with God, and the Word was God. The same was in the beginning with God. All things were made by him; and without him was not any thing made that was made. In him was life; and the life was the light of men. And the light shineth in darkness; and the darkness comprehended it not." (John 1:1-5, KJV)

INTRODUCTION

Holland saw the creative power of the word as important in the formation of living systems when he included the tag as one of the three basic mechanisms of complex adaptive systems. A "tag" is simply a sign, such as a name or a physical trait, which is used to classify an agent. In the social world, a tag may be a social marker, such as skin color, or simply the name of a social group. A tag goes hand in hand with the other two mechanisms Holland thought important to complex adaptive systems, an internal model (whether tacit or explicit) to give meaning to tags, and building blocks to accumulate and recombine the structures that result from those meanings into hierarchical aggregates (Holland 1995).

Holland is commonly thought to be the first to use tags to simulate social phenomena. However, there is another variation on tags, the symbolic interactionist simulation technique, that was developed before Holland's complex adaptive system research program, the Echo project (Duong 1991, Holland 1992). Like Echo, symbolic interactionist simulation recognizes the primacy of signs in the formation of living systems, but differs from Echo in that its agents have autonomous perception of the meaning of signs. The difference is understandable, because the principle of autonomy of perception is more prominent from the social sciences standpoint than from the biological standpoint, even if it exists in biology as well (Maturana, Lettvin, Mcculloch and Pitts. 1960). Many of the ideas in microsociology are inherited from phenomenology and hermeneutics, philosophies that contemplate the mysteries of autonomy, such as the paradox that human beings can only interpret meanings through their individual experiences with their senses, and yet they still come to share meaning (Winograd and Flores 1987). This hermeneutic paradox is core issue of micro-macro integration in sociology from the angle of perception: to solve the hermeneutic paradox is to solve the mystery of the "invisible hand" by which autonomous, selfish agents synchronize their actions into institutions for the good of the whole. Since emergence in agent-based social simulation is fundamentally about solving the micro macro link, symbolic interactionist simulation seeks to solve the hermeneutic paradox. It is by virtue of the preservation of autonomy that symbolic interactionist simulations exhibit strong emergence and constitute minimal social engines.

BACKGROUND

In Holland's Echo program and its successors that simulate the emergence of cooperation in iterated prisoner's dilemma (IPD) programs, tags are implemented with replicator dynamics. Referring to the work of Riolo, Cohen, and Axlerod as well as the work of Hales and Edmonds, Hales discusses the tag implementation: "the models implement evolutionary systems with assumptions along the lines of replicator dynamics (i.e. reproduction into the next generation proportional to utility in the current generation and no 'genetic style' crossover operations but low probability mutations on tags and strategies)." (Hales, 2004). Replicator dynamics do not keep the principle of autonomy of perception: one agent interprets a sign the same way as another agent because they have a common ancestor, not because they both induced the sign separately based on their individual experiences. Simulations of the emergence of common meaning of tags using replicator dynamics exhibit high amounts of genetic linkage (biological or mimetic), so that the relation between the sign and the behavior is an artifact of the method, rather than emergent from the simulation. Any simulation of contagion that explains macro level institututions with micro-level imitation does not exhibit strong emergence: since institutions are behaviors held in common, institutions would be an aggregate of copying behavior rather than emergent phenomena. Micro macro sociologist James Coleman believed that to explain institutions, we must explain the arise of a network of relations in a social system, and not just an aggregate (Coleman, 1994).

Autonomy of perception has been proposed as a necessary requirement for strong emergence in social systems. Bedau (2002) and other philosophers of emergence agree that "emergent properties have irreducible causal power on underlying entities." Downward causation, or "immergence" as Gilbert (1995) called it, is necessary for emergence in the strong sense. Desalles, Galam and Phan (2007) give more details, saying that for strong emergence to occur, agents must be equipped to identify emergent phenomena, and Muller adds that this must be through the physical world, rather than by direct copying of other agent's perceptions (Muller 2004). According to Desalles et al, agents must describe the emergent phenomena they observe in a language other than the language of the lower level process itself, and agents must have a change of behavior that feeds back to the level of observation of the process. This insightful definition of strong emergence acknowledges the importance of autonomy of perception, that is, of not allowing agents to copy each other's internal states, in developing a new emergent language (with tags) to describe emergent phenomena. Immergence, or the ability of the lower level agent to change its behavior based on the emergent social phenomena, opens the door for generative feedback between micro and macro social levels. Such a generative engine, which some social scientists would call a dialectic, characterizes strong emergence.

Luc Steels' research program also addresses the hermeneutic paradox: his agent's signs come to have shared meaning, even though they have autonomous perception. However, his agent's signs were not tags related to social structure as in symbolic interactionist simulation. In Steel's work, arbitrary signs come to have meaning as agents use them to differentiate objects by their features. As individuals make distinctions based on their own perceptions and associations, they come to have shared words to refer to features and shared ontologies of what distinctions to make are important, in an emergence with upper lower feedback (Steels 1996). Ironically, even though these agents may be embodied as robots, they are not truly situated, as they are describing their environment but not applying this description to their utility, or in anyway changing their world with their language. The ontologies these agents use to cut up the world are arbitrary, whereas the ontologies of human languages cut up the world based on utility. Although language is reproduced, culture and the way that the world is manipulated is not.

SYMBOLIC INTERACTIONIST SIMULATION

In symbolic interactionist simulation, the mechanism of autonomous emergence of the meaning of signs facilitates a strong emergence of practical ontologies that coevolve with practical behaviors in symbolic interactionist simulation. Symbolic interacionist agents interpret signs based on utility, so that an interpretation makes sense given the background of the agent's individual experiences. In symbolic interactionist simulation, a sign is interpreted in a certain way because it makes utilitarian sense, and not because it is copied. Agents communicate solely through signs, inducing the meanings of both displayed and read signs. Inductions are based on economic and practical gain, and as a result of these utilitarian interpretations, symbol system and social institutions coevolve.

The first symbolic interactionist simulation (Duong, 1991, Duong and Reilly 1995) was a simulation of a workforce of employers and employees. In some of the runs, for example, there were 3 employers and 50 employees in a society. Each employee had either a high or low level of talent, which the employer could not see until after the employee was hired. However, the employer would look at the signs that an employee displayed to guess whether that it was talented. The prediction was based on the employer's individual past experiences with employees. The employee displayed a fixed sign (such as skin color or race), a sign that costs money (such as a new suit) and a sign that is free (such as a fad). The fixed sign was made to be uncorrelated with talent.

Employees obtained money through employment, and thus employees that could stay employed longer could make more money than employees that were fired frequently. A certain percentage of the workforce of each employer was laid off every cycle, but employees that were not talented were laid off in greater proportions. Thus, an employee that is talented has more of a capacity to make money, and the potential to differentiate itself from a non-talented employee using that money. The employees would choose a set of signs to display based on their prediction of whether they would be hired after an employer saw them. This prediction was based on their individual past interviews outcomes. Of course, employees could only display the purchasable signs that they could afford. Both the employer and the employee agents had IAC neural networks to induce the meanings of the signs based on their private experiences with the signs. Even though the signs were arbitrary and autonomously perceived (employers did not consult each other on the meanings of signs, nor did employees), they came to have a shared meaning. Agents learned to buy expensive suits as status symbols, and race often became an issue despite the fact that race was uncorrelated with talent, because it sometimes became correlated with the suit. Races could get into a vicious circle where they could not afford a suit because they were not hired and were not hired because they did not wear a suit, at which time social classes based on race would form.

Axtell, Epstein and Young's model of the emergence of social classes subsequently adapted the autonomy of the symbolic interactionist tag methodology (2000). Desalles et al (2007) took note of the strong emergence Axtell et al achieved by use of autonomously interpreted tags. Axtell et al achieved the emergence of social class based on fixed tags (such as skin color or race) in a one shot bargaining model.

SISTER

Another symbolic inteactionist simulation which uses a one shot bargaining model, SISTER (Symbolic Interactionist Simulation of Trade and Emergent Roles) was prior to and influential on Axtell, Epstein and Young's work on the emergence of social classes (The Economist 1997). SISTER also simulates the coevolution of symbol systems and social structure (Duong 1995, Duong 1996, Duong 2005, Duong and Grefrenstette 2005)

SISTER is a study of the "free tags" of the original model on the emergence of social classes (Duong 1991). The free tags were the equivalent of words in a language, but applied to the identification of people. The dynamics involved in the emergence of meaning of tags are the same for the more general emergence of meaning of words. Symbolic interactionist simulation kept the principles of autonomy and hermeneutics in its study of the emergence of language that subsequent more well known works, such as Steels', did. However, it also addressed critical issues that they did not. Steels and subsequent studies of the emergence of language are separated from studies of the emergence of culture. What is missing are models of language as coevolving with culture, models which capture the coevolutionary dialectic in which language and culture create each other and enable each other to grow. The dynamics of the propagation of signs which start out random is studied, but the dynamics of how they come to denote, hold, and spread new concepts needs more exploration. SISTER models the emergence of language as a dynamic creator of culture. If we define culture as the knowledge available to a society, both of the objects and the social structure, then SISTER shows how symbols emerge to hold culture and allow it to complexify, and how they enable culture to continue despite the deaths of individuals.

SISTER offers a solution to the hermeneutic paradox as do Steel's models, of how it is that people can only interpret the meaning of signs from the context of their individual life experiences, and yet still come to share meaning. SISTER agents are autonomous because they are closed with respect to meaning: they each have their own private induction mechanisms, and do not copy one another's signs or interpretations of signs, but induce the meanings of the signs from their own experiences alone. SISTER however, is different from Steels' work in that the feedback is directly connected to the utility of the agent. A sign gets a particular interpretation based on what is good for the agent for it to mean, for its survival, rather than from the grunting approval of another agent. SISTER agents see "as the frog sees green" … just as the frog does not observe reality as it is, but constructs it as is beneficial to its survival (Maturana, Lettvin, Mcculloch and Pitts. 1960), so do SISTER agents interpret signs based on whatever it is that gets them the most food. The combination of a direct relation of interpretation to utility along with perceptual autonomy is what makes SISTER agents both embodied and situated. If we do not model the advantage to utility that an interpretation confers at every step, we lose the ability to model important social processes of what becomes popular.

One example of such a process to model is that of the legend. Legends hold deep cultural meaning, often so deep as to be universal. Legends are told and retold orally over many generations. Each time they are retold, the teller contributes to the creation of the legend in small ways. As all the authors of a legend recreate it to meet their needs, it comes to be very good at meeting needs, settling down on a compromise between all needs. Imitation without such modification does not promote cultural products which contribute to the needs of all, deeply intertwined with the rest of the culture. It is not a deep consensus.

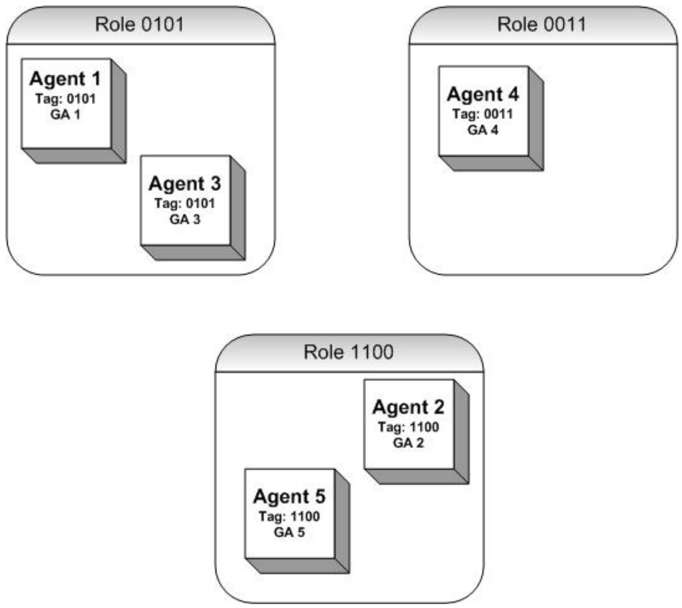
The principles of hermeneutics are important to the study of the emergence of language because we can not separate language learning from concept learning, concept creation, and language creation. If we look at language as a passive thing, it does not matter if we include utility or not. If all a word is, is a random sign, and all we are explaining is how one random sign gets chosen over another random sign, then we need look no further than imitation. However, if we look at a word as a holder of a concept, a concept which serves to meet the needs of people within a web of other concepts, and which can only emerge as a word to denote it emerges, then it is appropriate to model the emergence of words in agents which interpret their meanings solely from their individual perspectives and usefulness to their lives. All the interpretations together create words and concepts which best serve the cultural needs of all the individuals. In the study of the emergence of language, it is not the sequence of phonemes that becomes popular that is important, but rather the capturing of the dynamic in which words make possible the ontologies that we use to construct our world. Studies in the emergence of language should address how words make the most practical ontologies, through the contributions of all utterers of words, rather than address the most practical sounds uttered.

SISTER shows that social systems with an emergent symbol system denoting an ontology of roles can enable cultural knowledge to continue despite the deaths of its individual members. The reason that it can continue is that signs denoting roles create expectations of behavior in agents who interact with a role. These expectations serve to train newcomers to the society into the proper behaviors of the role. Each sign for a role is a focal point of a set of social behaviors in a social network, in that the sign means a different thing to different other roles in a social network, and agents of each role have a certain set of expectation for agents of other roles that they interact with. The signs and the set of relations they denote are emergent, and must be emergent if they are going to denote any arbitrary set of behaviors. The knowledge in the society is held in the expectations that signs bring to the different agent's mind. These meanings are all induced by the private inductive mechanisms of agents, and yet the meanings of the signs come to be shared.

SISTER outputs a division of labor and social structure that increases the utility (that is, "satisfaction") of agents. Agent ontologies of roles emerge that guide agents in complex social relations and behaviors needed for survival. SISTER captures the fundamental social process by which macro-level roles emerge from micro-level symbolic interaction. SISTER comprises a multi-agent society in which agents evolve trade and communication strategies over time through the use of tags. The knowledge in SISTER is held culturally, suspended in the mutual expectations agents have of each other based on the signs (tags) that they read and display. Language emerges and is maintained robustly, despite the stresses of deaths of individual agents. SISTER shows how a complex endogenous communication system can develop to coordinate a complex division of tasking.

SISTER employs coevolution, in which agents each have their own genetic algorithm (GA), whose fitness is dependant on successful interaction with other agents. These GAs evolve tags that come to indicate a set of behaviors associated with a role. Figure 1 illustrates evolved tags indicating agent roles. Roles are nowhere determined in the simulation and exist in no one place, but rather are suspended in the mutual expectations of the coevolving agents. These mutual expectations emerge endogenously and are expressed through signs with emergent meanings. All institutional knowledge is distributed in these subtle mutual expectations.

Figure 1. Agents that evolve the same tags in their separate GAs and have the same behaviors are in the same roles.

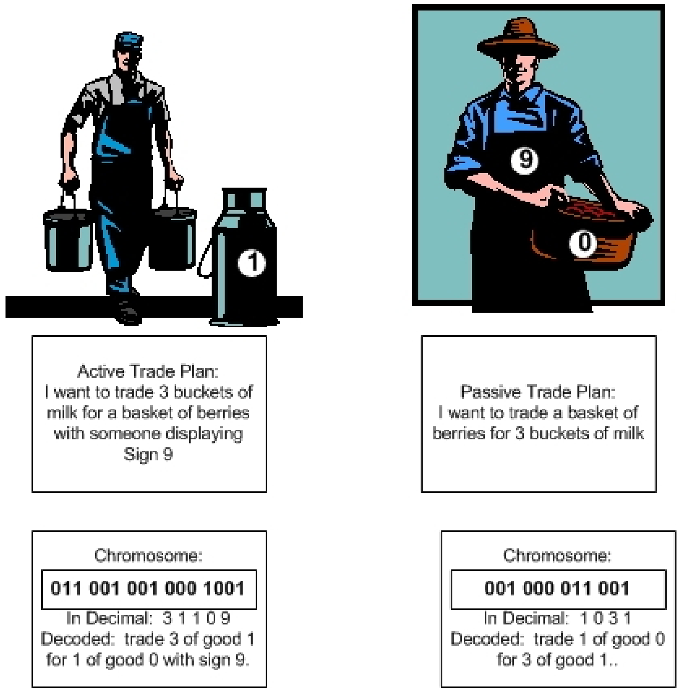


How SISTER Works

SISTER simulates a differentiation into the roles of a division of labor in an economic system (Duong, 1995, 1996, 2005). In SISTER, initially homogenous agents differentiate into the heterogeneous agents reflecting a division of labor. Roles solve the problem of how agents may work together to increase their utility. Every "day" of the model, agents harvest goods in the morning according to their production plans, trade in a market in the afternoon according to their trade plans, and consume their food at night, judging a single chromosome of plans for the day by their satisfaction in consumption (according to a Cobb-Douglass utility function). Agents are free to devote their efforts to harvesting goods or trading them. The simple economic assumption of economy of scale is built in (it is more efficient to produce a single good than to diversify production), as is a utility function that rewards accumulation of multiple goods. These combine to encourage trade among agents.

SISTER focuses on how agents determine who to trade with. Agents seek trading partners based on a displayed sign. Signs are induced both by the wearer, and by the agent seeking trade. See figure 2 for an example of a trade plan. This "double induction" of a sign is a simulation of Parson's "double contingency" (Parsons, 1951), and facilitates the emergence of a shared symbol system. Signs have no meaning in the beginning of the simulation, but come to have a shared meaning. Agents come to agree on what a sign implies about behavior. As they come to a consensus, a system of roles is developed.

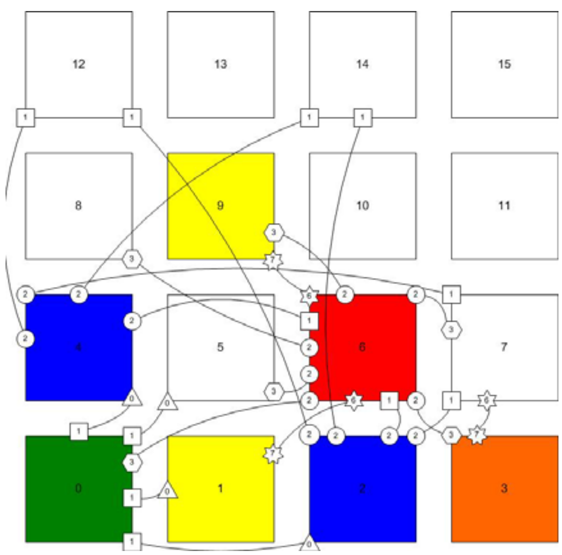
Figure 2. Agents must have a corresponding trade plan encoded in their genetic algorithms for a trace to take place. Each chromosome has all the plans of trade and production for a single day, and the plan to display a sign as well (the Passive trader's chromosome tells him to display sign 9, in a section that is not illustrated).



For example, suppose the goods of a simulation run include *berries* and *milk*. Suppose agents coincidently have the trade plan in figure 2, and each agent benefits from the trade. Both agents are satisfied with the trade and the sign: they remember this sign, and repeat it in future trades. The more the trade is repeated in the presence of the original sign, the more it becomes a stable element in the environment and therefore something that other agents can learn. Since an agent with an active trade plan is looking for any agent who displays a particular sign, any agent can get in on the trade just by displaying the appropriate sign. The agents come to believe that the sign means "milk," in the sense that if an agent displays the sign, then other agents will ask him to sell milk. This puts selective pressure on that agent to make and sell milk. If a random agent displays the sign for a composite good (a good composed of other goods, like "berry-flavored milk"), it learns the recipe for the composite good from marketers trying to sell the ingredients for the composite good. Over time, the society divides into roles, with groups of agents displaying the same sign and having the same behavior.

The signs are Berger and Luckmann's "objectivations" that become coercive: if a new agent is inserted into the simulation, then to participate in trade he must learn the sign system already present (Berger and Luckman, 1966). The signs are a guide to his behavior: When he displays a sign, the other agents pressure him to have the corresponding behavior. Thus a sign creates expectations of behavior, in accordance with Parson's ideas of double contingency and Luhmann's model of mutual expectations (Parsons, 1951; Luhmann, 1984). The mutual expectations that the agents have of the roles allows individuals to take advantage of what other individuals have learned in previous interactions. The knowledge of the society is held in the mutual expectations of the symbol system, as in Parsons' and Luhmann's theories (Parsons, 1951; Luhmann, 1984). The reason that role systems can hold more information about how to make cultural products is that agents can replace one another and can learn from the expectations that other agents have of their replacement class. This is how they become trained to do their role. However, this training is not inflexible: what they do is ultimately connected to their utility. They can reject a trade if it is not to their advantage. Thus SISTER agents have the flexibility needed to complexify. Figure 3 illustrates a role based society that is advanced enough to make composite goods, with a relatively high mutual information.

Figure 3. A scenarios from SISTER representing the trades made in a single day of the simulation. Agents with the same color square have come to have the same role: that is, the same trading behaviors and same sign. The smaller shapes represent goods traded. An arc connecting shapes represents a trade. The stars are composite goods, or goods composed of other goods. Agents have developed complex roles and composite goods.



Experiment

In this experiment, agents which display induced signs are compared to a control in which agents are forced to display a unique ID. The use of an ID prevents the formation of a system of roles denoted by the induced signs. We refer to a society where agents read and display signs freely as a "role recognition treatment" and a society where agents are forced to display a unique ID as an "individual recognition treatment." Whether the sign is arbitrary or an ID, an agent seeking a trade has to induce the sign to seek in trade. However, in the role recognition treatment, the displayer of a sign induces the sign it should display at the same time that the agent seeking a trade induces the sign to read. This double induction allows a system of arbitrary symbols to come to have meaning, but there is no double induction in the control. Duong and Grefenstette (2005) contains an experiment where individual recognition is compared to role recognition in the ability to create complex goods. The experiment of this article has both treatments making complex goods, and compares their ability to make them when there is a complete turnover in their population as a result of death and rebirth of agents. Death and birth is added to test the ability of new agents to acquire the language of the existing agents and achieve cultural continuity that is greater than the individual behaviors of members of the culture. The individual recognition treatment and the role recognition treatment are run twenty times each.

In this experiment, three different death rates are applied to each treatment. The average utility of the agents (the number of goods and the evenness of the spread of the goods, measured with a Cobb-Douglas utility function) is compared in each treatment, as well as the mutual information in the symbol systems that have evolved. The higher the correspondence between behavior and the sign displayed, the higher the information content, or mutual information, in the symbol system. Although the signs of the individual recognition treatment are not modifiable by the displayers of the signs, there is still a symbol system whose information may be measured. The individual recognition treatment can reach high values of mutual information if agents displaying different ID's have different behaviors. If a treatment has a higher utility value, then the agents are more successful in trading with each other. If they have higher mutual information, which is correlated with that utility, then it is likely that they are trading better as a result of the information contained in their symbol systems. Thus language makes knowledge and culture possible. They develop a language that is practical for the purposes of setting up networks of trade. If this language can carry these practical recipes for interaction on even through a complete turnover of the population, then language has reproduced culture, and expectation of the meanings of signs have spread knowledge to new members, so that culture continues despite the deaths of members.

The hypothesis of this experiment is: When birth and death are introduced into agent societies, those with role recognition (arbitrary signs) have greater continuity of knowledge of how to make complex goods than societies with only individual recognition.

While the number of agents remains at 16, agents are periodically killed and replaced by randomizing the chromosomes of the private genetic algorithms in each of their heads. When an agent is replaced, it is given a new unique id. The death rate is tested at several values, a 0.001 chance of death resulting in a complete turnover of agents in about every 1000 cycles, a 0.002 chance of death resulting in a turnover of agents in about every 500 cycles, and a 0.005 chance of death resulting in a turnover of agents in about two hundred cycles. A cycle is defined as a period of 1000 days of trade, after which reproductions in the GAs take place (learning). The tests are all on how well an agent does after one turnover, so the cycle lengths tested are different. Additionally, a 5 bit sign is used to represent the 16 agents rather than a 4 bit sign, in order to give new "names" to the new agents that arise in the system. A 5 bit sign represents 32 different unique names for the individually recognized agents, who must display their unique name in their sign. 32 unique names are needed if all of the agents will die and be replaced about once.

Results

For the parameters of this experiment, 130 is the level of utility where agents have no trade, but have become good at making everything for themselves. Any utility over that level indicates trade, and under that level indicates new agents are having difficulty learning. The average utility is significantly greater in the role recognition treatment, at over the 99% confidence level, than in the individual recognition treatment. Average utilities of the role treatments, for death rates 0.001, 0.002, and 0.005 are 145, 133, and 125. Average utilities of individual treatments are 127, 121, and 115. These show that increasing death rates are harder on both individual and role utilities at above the 99% confidence level. Figure 11 shows these results in tabular format.

Figure 4. Results for the death scenario. Utility is higher in the role treatment than in the individual treatment. Role mutual information actually increases under the stress of death.

Treatment	Death Rate	Avg Utility	Death Treatment Mutual Information(MI)	No Death MI	Correllation MI,Utility
Role	.001	145	0.715	0.665	0.43
	.002	133	0.858	0.794	0.36
	.005	125	0.575	0.65	0.5
Individual	.001	127	0	0.14	N/A
	.002	121	0.04	0.27	N/A
	.005	115	0	0.34	N/A

Death flattens the trade and mutual information in all of the treatments for the individuals. The control run (with no death) for the individual treatment does not have much trade, but has more than zero. This is reflected in the average mutual information scores of the 1000 cycle control, 0.14, as compared to the death rate 0.001 treatment, 0; the 500 cycle control , 0.27, as compared to the death rate 0.002 treatment, 0.04; and the 200 cycle control, 0.34 as opposed to the death 0.005 treatment, 0. These decreases in mutual information from the control are all significant above the 98% confidence level. In contrast, the average mutual information in the role recognition runs actually increased from the control; however this increase is not significant. This is reflected in the average mutual information scores of the 1000 cycle control, 0.665, as compared to the death rate 0.001 treatment, 0.715; the 500 cycle control 0.794, as compared to the death rate 0.002 treatment, 0.858; and the 200 cycle control, 0.65 as opposed to the death 0.005 treatment, 0.575. The increase in the average mutual information of the role recognition treatment over the individual recognition treatment is significant above the 99% level.

In the role treatment, average utility is correlated with average mutual information in death rates 0.001, 0.002 and 0.005 at values 0.43, 0.36 and 0.50. These results are significant above the 95% level except for the 0.36 value, which is significant above the 90% level. Individual recognition values are too low to have correlations.

CONCLUSION

This experiment supports the hypothesis that the use of arbitrary symbols helps to preserve the knowledge in society even though individual knowers die. When an agent dies in an individual based recognition society, all the social coordination associated with its place in society is lost. If an agent dies in a role recognition society, even if there is only one agent in that role at a time, other agents in the society or new agents may adjust their sign and receive the selective pressures to adjust their behaviors to the dead agent's niche. The role system exists because of an emergent symbol system to denote it, and is reproduced through the expectations that these symbols bring to mind in the agents. Language acquisition occurs along with concept acquisition, as a result of the pressures of these expectations.

This finding contributes to artificial intelligence, because it shows a way to keep a coevolving society of agents learning new things. When new agents are brought into a society, they can bring change to the society more readily than old agents that have already-converged genetic algorithms directing them. Thus, death is a type of macro level mutation for coevolving systems. Death enables roles in the society to readjust to each other, change as the need arises, and complexify. If role recognition makes agents robust in the face of death, then it can help keep the diversity up in a coevolving system when used in concert with death. This finding further contributes to artificial intelligence in that robot agents in the real world will die by accident, and role based recognition is a way to keep the knowledge that they have accumulated alive socially despite their accidental death.

Role recognition is superior to individual recognition of agents in preserving knowledge because the agents serve as replacements for each other. Roles form robust replacement classes of agents, which enable the preservation of the knowledge of society, even when individual members of a class die. Role classes also promote the creation of knowledge, not only because agents within a role class may learn from each other's experiences. This experiment has shown that role recognition, in conjunction with death, facilitates the creation of knowledge through the diversity that death and birth bring to a society. Roles coordinate knowledge across generations. These roles are indicated by an ontology in a symbol system, that coevolves with them, and that regenerates them by bringing to mind expectations of behavior, which pressure agents to behave accordingly. Thus, language is generative of culture, and can regenerate it to recover from the deaths of individual members.

FUTURE RESEARCH DIRECTIONS

When Desalles et al praised Axtell et al's strong (symbolic interactionist-style) emergence, Desalles et al noted an immergence, a downward irreducible causation that changed the behavior of the races by means of a tacit, rather than an explicit, understanding of the signs. The signs did not point to something outside of the agent, they point to utility alone as in Maturana et al's frog that sees green. Desalles et al noted that the (symbolic interactionist-style) agent's internal models were not reflexive, that they did not map to the agent's world. However, Desalles along with many other current theorists of "immergence" fail to realize that it is the tacit nature of the model that allows an entire social engine to form, an invisible hand that makes need-filling institutions out of individual selfish actions. Desalle et al proposed an improvement to Axtell et al in which agents can categorize their knowledge into a previously developed ontology. Rather than an improving upon the strong emergence this change would disable the autonomous social engine, because the previously developed ontology is an exogenous and static input. What is needed for true objectivity, the move from tacit as-the-frog-sees-green to explicit, more objective models of the environment that is entirely endogenous is a breakthrough in cognitive science. Since endogenous objectivation is beyond our technical knowledge, tacit knowledge is the only simulatable phenomena that can form an entire need filling engine at this time.

Of course, people cognate detailed models of the environment for their utility just as Maturana et al's frog did, and even though no one person has a complete explicit map of the entire world of thought, these models are more shared than the tacit knowledge of Maturana et al's frog. This objective knowledge is useful in society and to the symbolic interactionist practice of "taking the shoes of another." The technology that could put an agent in the shoes of another would be a technology that could take in correlations that it an agent discovered through induction, and put out a model of cause. Until cognitive science is at the point where it can derive an objective causal simulation from subjective correlative data, programs which purport to simulate immergence must use tacit models. The alternative, considering the state of the science now, is to hard code a representation of the "emergent" property, losing the endogeny necessary for the simulation's fidelity. In the mean time, it is best to, as Holland did, recognize that a tacit model is just as much an internal model as an explicit model.

Endogenously created cognitive maps would go a step farther in simulating the symbolic interactionist paradigm, as reflexivity at the level of getting into the other's shoes is required, and thus the ability to find an objective representation is needed. Further, symbolic interactionist simulations to this point have only covered the first two mechanisms in Holland's recipe for complex adaptive systems: tags and internal models. They have no building blocks, no dynamically recombinable signs that can mean new things to be interpreted during the interaction, as in Garfinkel's ethnomethodology in symbolic interactionism requires (Garfinkel 1967). Endogenous internal causal models from correlated relations and recombinable symbols that are in language are ambitious next steps for not only the symbolic interactionist paradigm, but for cognitive science in general. Maybe the techniques of cognitive science can benefit from the techniques of symbolic interactionism in these next steps for modeling emergent meanings.

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