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Honors Thesis Proposal

For

Flocks, Swarms, Crowds, and Societies: On the Scope and Limits of Cognition

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Introduction

Flocks of birds, swarms of insects, and packs of wolves are instances of collective biological systems. Small groups, crowds, and societies are instances of social systems. In these collective biological and social systems, cognition is an emergent property irreducible to the sum of the cognitions of the organisms constituting the system as such. The cognition of a given organism within a collective biological or social system is not entirely amenable to analysis at the level of the individual. New developments in biological modeling and dynamical systems sociology, such as the Vicsek model of self-propelled particles (SPP), allied with the return of systems thinking in the cognitive sciences, have for the first time made possible the study of cognition as a property of collective systems (Baglietto, Albano, & Candia, 2013). To make the case that cognition at the collective level is an emergent property, it is first necessary to describe the functioning of these systems.

First, the orthodox Computational Theory of Mind (CTM) is defined and "collective cognition", an understanding of social cognition consistent with CTM, is presented. Alternate concepts of cognition are then offered as nonreductionist explanations of these same systems, including distributed cognition, swarm intelligence, and the superorganism. Two series of case studies are considered, one animal and one human. In the first series, flocks of birds, swarms of insects, packs of wolves, and schools of fish are studied. In the second series, small groups, crowds, and societies are considered. Conventional empirical fieldwork and newer mathematical models in computational biology and dynamical systems sociology are taken into consideration. The systems are then determined to be a specific type of cognitive system, whether collective, distributed, swarm-intelligent, or superorganismic.

The thesis is divided into four main sections: 1) the introduction, 2) a discussion of what cognitive systems are and how to determine whether a system is cognitive, 3) case studies, and 4) the conclusion. My thesis is not simply considering whether the cases listed under instances of distributed cognition are actually irreducible to the atomic level of agents themselves. Beyond this, it is pushing the outer bounds of what is considered a relevant level of study in the cognitive sciences, perhaps even adding a layer of complexity to the definition of cognition. The ultimate aim of defining these cognitive systems is to expand and delineate the scope of the cognitive sciences.

Once cognitive scientists and philosophers began expanding the bounds of cognition from the nervous system and including—beyond abstract reasoning—lower-order processes like perception and locomotion, cognition itself lost its precision as a concept. Its scope and boundaries are no longer clear or agreed upon, as evidenced by the directions of the multiple noncomputational approaches. A certitude has been lost—the certitude of an autonomous brain cognizing objects for knowledge. Historically, this can be seen as the latest stage of the decentering of the subject that began with Heidegger last century (Varela, Thompson, & Rosch, The embodied mind: Cognitive science and human experience, 1993). Cognition may extend to entities as small as autopoietic bacteria or as large as entire networks of human actors—perhaps beyond. We are in need of a perspicuous and well-defined definition of cognition. Ultimately, this will help us to define the purview of the cognitive sciences, both in its inner and outer bounds. This paper seeks to delineate the *outer* bounds of the concept.

Cognition in Collective Biological and Social Systems

Collective Biological and Social Systems as Cognitive Systems

This section of the thesis introduces and explicates the concept of cognitive systems and introduces the argument that collective biological and social systems are cognitive. It is comparable to a literature review section, although it also contains original arguments. Theiner and O'Connor's "big tent" approach to cognition is first discussed (2010). The big tent approach is an ecumenical approach to the definition of cognition. The motivation for this ecumenicalism is that there are multiple competing and mutually-incompatible concepts of cognition in the cognitive sciences. This discussion aims to show that an ecumenical approach ultimately fails. There is no possible definition of cognition that is acceptable to all schools of thought. Where the big tent breaks down is when it is confronted with nonrepresentational approaches to cognition (Chemero, 2009; Favela, 2014; Hutto & Myin, 2013; Thompson, 2007).

CTM and enactivism are compared with one another to exemplify the mutual incompatibility of representationalist and nonrepresentationalist paradigms. CTM is representationalist, while enactivism is nonrepresentationalist. Representations are, at best, second-order phenomena in the latter approach. In this discussion, minimally cognitive systems and the deep continuity hypothesis of cognition are defined. Minimally cognitive systems are the least complex system to which one could ascribe cognition in accordance with the deep continuity hypothesis. The deep continuity hypothesis of life and mind states that "[m]ind is life-like and life is mind-like" (Thompson, 2007, p. 128). Ticks are an example of a minimally cognitive system (Uexküll, 2010).

The plurality within the nonrepresentationalist paradigms is then discussed. These are known as 4EA (embodied-embedded-extended-enactive-affective) approaches. They share a set of practices rather than a definition of cognition, including dynamical systems theory, the enactive stance, ecological psychology, and phenomenology (Protevi, 2010).

Next, the concepts of self-organization and emergence are discussed. Self-organization is defined (Maturana & Varela, 1980; Heteropoietic, 2004). It is defined in relation to nonlinear dynamical systems and "spontaneous patterning and order" (Depew & Weber, 1999; Riley & Holden, 2012). Raleigh-Bénard convection cells are illustrated as a paradigmatic case of self-organization (Prigogine & Stengers, 1984). Emergence is then defined as epistemological, weakly ontological, or strongly ontological. H_2O is a paradigm case of epistemological emergence (Stengers, 2011). The "emergent" phenomena are only apparent, but the system can be explained reductively. Ontological emergence can be weak or strong (Wilson J. , 2015). Their differences are discussed. The case for strong ontological emergence is made. This is related to the causal incompleteness of physics and the multiple realizability of higher-order phenomena under wildly disjunctive conditions (Sawyer, 2005).

Collective Cognition, Distributed Cognition, Swarm Intelligence, and the Superorganism

Here I give an overview of collective cognition, distributed cognition, swarm intelligence, and the superorganism. The point is to merely present competing hypotheses rather than arbitrate between them, which will be done in the case studies. I will give explicit criteria for each of these these different types of cognition. The criteria formulated in this section will be used to analyze the case studies presented in the next section.

'Distributed cognition' was coined in 1995 by Edwin Hutchins. Here I give an established definition of distributed cognition (Hutchins, 1995b; Kirsh, 2006; Osbeck & Neressian, 2013). Distributed cognition is a form of systems thinking and, as such, is not reductionist. If distributed cognition characterizes groups, then groups have some degree of emergent cognition. It should be noted that the traditional sociological problem of structure-agency is not entirely done away with in distributed cognitive systems. "Distributed cognition remains a challenge precisely because it is so hard to balance the reality of local choice with system constraint" (Kirsh, 2006, p. 250).

The paradigmatic case of a distributed cognitive system is that of ship being navigated by traditional, analog means by a network of sailors and a captain (Hutchins, 1995b). Next, the implications that this model of cognition has for the cognitive sciences is considered. It expands the boundaries of cognition beyond both the ecological and extended approaches. Unlike in ecological psychology, cognition arises beyond the visible or perceptible horizon of phenomenal experience of the organism. The captain may not be anywhere near the sailor taking angular readings of the shore, and they may possibly relay information back and forth through intermediaries. For extended cognition, the tools used by the sailors would constitute a cognitive system with their users. In Hutchins' ethnography, though, it is the sailors themselves who constitute a cognitive system together with the ship they are steering. Finally, other studies in distributed cognition are in turn summarized and considered, such as the Hubble Space Telescope (Giere, 2006).

Collective cognition as an explanation is a reductionist form of explanation (Giere, 2006). It understands the cognitive properties of a group atomically. By summing up the individual cogitations of each agent in the group, the cognitive properties of the whole can be derived. Others' cognitions may affect an agent's cognition, but only tangentially and not essentially. Swarm intelligence is a concept born in computing and is not a concept of cognition. It is a series of algorithms that are abstracted from bees, wasps, and other eusocial creatures. The phenomena described are self-organizing and emergent (Yang & Karamanoglu, 2013).

Superorganisms are not typically associated with cognition. The concept of the superorganism was first created to describe insect swarms (Wenseleers, 2009). This concept has also been used to described the slime mold *Dictyostelium discoideum* (Bonner, A descriptive study of the development of the slime mold dictyostelium discoideum, 1944; Bonner & Raper, A theory of the control of differentiation in the cellular slime molds, 1976). These contexts are biological. Nevertheless, there has been a long tradition of speaking of humans as composing a greater organism (Hobbes, 1996) [find Herbert Spencer reference]. Today, there are few willing to make such a bold claim, although there are some that have argued for it (Kramer & Bressan, 2015). What marks this type of system as cognitive is its autopoietic nature. Maturana and Varela discuss autopoietic systems that are themselves nested within larger autopoietic systems (1980). Find evidence that superorganisms such as swarms actually constitute such a larger autopoietic system. Thus, by definition, they are cognitive systems. Alternatively, discuss cognitive properties of superorganisms in a practical sense—e.g. army ants moving together and devouring an animal on the forest floor (Hölldobler & Wilson, 1990; Hölldobler & Wilson, 2009).

Case Studies of Collective Biological Systems

Cognition in Animal Groups: Flocks, Swarms, Packs, and Schools

This section is the first series of case studies and explores animal groups including flocks, swarms, packs, and schools. This list of animal groups is representative rather than exhaustive. One of the great hurdles of this research is that little data currently exists on the kinematics of organisms within groups (Couzin, 2008, p. 42). Those studied here are some of the few animals for which limited studies of individual, organismic kinematics within the group have been undertaken. The first task is to demonstrate that they are cognitive systems or, at least, that they exhibit cognitive properties. The second task is to analyze each of these group types and determine whether they are best characterized by collective cognition, coupled cognition, distributed cognition, or whether they are superorganisms. They do not all necessarily have to uniformly exhibit the same cognitive structure. For example, there is no contradiction in saying that a flock is an instance of distributed cognition but that slime molds are superorganisms.

Flocks. The first case study is of flocks of birds. The relevant studies include: (Bialek, et al., 2012; Castellana, Bialek, Cavagna, & Giardina, 2016; Couzin, Krause, James, Ruxton, & Franks, 2002). A study by Bialek *et al.* using maximum-entropy models suggests that the global behavior of flocks of starlings (*Sturnus vulgaris*) may result from local interactions of neighboring birds (2012, p. 4787). These local interactions result in an emergence directionality for the flock as a whole (p. 4786). If any given member of a flock interacts with too many neighboring birds, the entropy of the system breaks apart the flock into several smaller groupings. However, if a bird's interactions are less spread out, involving fewer neighbors, the flock persists as a cohesive unity (Castellana, Bialek, Cavagna, & Giardina, 2016, p. 9). While the mathematics of this modeling is highly speculative at this point, the inference is that actual flocks may emerge from the limited interactions of individual birds rather than more widespread, even flock-wide, interactions—unless other strong, cohesive forces exist (p. 10).

The cohesiveness and unified directionality of flocks of birds is maintained through a simple system of alignment (Couzin, 2008, pp. 37-38). Couzin et al. have analyzed the formation of swarms, flocks, and schools in terms of three basic parameters: attraction, repulsion, and alignment or orientation (2002, p. 2). Changes in the values of these parameters creates different aggregate patterns: swarm, torus, dynamic parallel group, and highly parallel group (or polarized) (p. 5). The swarm aggregation type is the least efficient medium for the propagation of information, allowing less cohesive and swift of a response to e.g. an oncoming predator (p. 9).

Flock directionality is an emergent property of local interactions of individual birds. One local group may begin to change direction as the individuals notice a hawk in the distance. As they begin to shift, their neighbors likewise begin to shift, causing a chain reaction that propagates throughout the entire flock as a wave (p. 37). The entire flock then moves away from the hawk, although only a few individuals in one locale may have actually seen it or "know" why they are shifting directions. From this evidence, the case is made that flocks are swarm-intelligent cognitive systems.

Swarms. The second case study is of swarms of ants, termites, wasps, and bees. Swarms are paradigm cases of superorganisms in the sociobiological sense of the term. The relevant studies include: (O'Donnell, et al., 2015; Reeve & Hölldobler, 2007; Beekman, Sword, & Simpson, 2008; Yang & Karamanoglu, 2013; Couzin, 2008; Wilson E. O., 1975; Hölldobler & Wilson, 2009). Ants have a range of degrees of cohesiveness as a collective, from minimal (cf. Couzin, 2008) to the highly eusocial species. They are characterized by a caste structure (sociogenesis). Individuals express up to twelve distinct types of communication (Hölldobler & Wilson, 1990). Ants themselves function according to a series of algorithms (Hölldobler & Wilson, 2009, pp. 53-54). Colonies are self-organized and their order is emergent (p. 58). Examples of striking emergent behavior includes army ants creating shelters out of their bodies and termites building "air-conditioned" nests (p. 59). Ants find food sources and "discern" their relative qualities through the mechanism of positive feedback in pheromone trails (Beekman, Sword, & Simpson, 2008, p. 11). These emergent pheromone trails effectively create dynamic routes to food sources (p. 12).

Bees have a different set of communications and their individual brains are more developed and powerful than those of ants. They engage in the waggle dance in order to communicate sources of food, what in ants would be done by stigmergy (Hölldobler & Wilson, 2009, pp. 63-64). The failed follower mechanism ensures that bees stay on track (Beekman, Sword, & Simpson, 2008, p. 13). They also converge on best nesting site within a local region

(p. 14). Streakers are also discussed in relation to emergent properties of the swarm (pp. 21-22).

The swarming structure is maintained through the same alignment principles, set with different parameters, as flocks (Couzin, 2008, pp. 37-38). Swarming arises when individuals are generally attracted to one another, or move towards one another, in a massive group. Individual movements are not cohesive and may appear random, but the swarm as a whole exhibits remarkable emergent order and directionality.

Ant and bee swarms function much like neural networks (Couzin, 2008, pp. 39-41). Note that Couzin sees swarms, especially ants, as distributed cognitive systems. Keep in mind what might distinguish a superorganism from a distributed system—viz., strong ontological emergence. Negative feedback in stigmergic communication arises from volatility of pheromones, competition between trails, limited foragers, depletion of food source (Moussaid, Garnier, Theraulaz, & Helbing, 2009). Suboptimal solutions of Pharaoh ants are discussed in the absence of stigmergy (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 492). The evidence will prove that swarms are cases of superorganismic cognitive systems.

Wolves. The third case study is of packs of wolves (distributed cognition). The relevant studies include: (Muro, Escobedo, Spector, & Coppinger, 2011; Mech, Smith, & MacNulty, 2015). During the hunt, wolf packs exhibit some level of coordinated behavior. However, there is no consistent evidence that they use any advanced coordinative techniques (Mech, Smith, & MacNulty, 2015). Wolf packs most fit into the category of collective cognition. If they exhibit distributed cognition, it is at a very rudimentary and circumscribed level. Unlike swarms or flocks, pack formation may depend more on direction by a group leader (a "breeder", what was once called an "alpha") rather than emergent, collective directionality (Couzin, 2008, p. 39).

In a simulation of wolf hunting behavior, the only information individual wolves needed to perceive and communicate was others' spatial positions (Muro, Escobedo, Spector, & Coppinger, 2011). In this model, collective behavior is emergent and systemic. While this may appear to contradict Mech, Smith, and MacNulty's empirical studies, it actually might explain why wolves appear to have no organized hunting strategy. Their hunting behavior is emergent rather than directed. Their behavior arises out of a few basic rules. The wolves individually have similar goals, but the behavior of the pack is not telic or intentional. (Muro, Escobedo, Spector, & Coppinger, 2011, p. 195). Even apparent hunting strategies such as encircling, ambushing, and relay hunting are explicable in terms of basic rules creating emergent patterns (p. 196). The evidence will be used to conclude that packs of wolves are distributed cognitive systems.

Schools. The fourth and final case study in the animal series is of schools of fish. The relevant case studies are: (Couzin, Krause, James, Ruxton, & Franks, 2002; Moussaid, Garnier, Theraulaz, & Helbing, 2009). Many exhibit swarming behavior. Some, like barracuda, exhibit toroidal aggregative patterns, intermediate between swarming and polarized patterns (Couzin, Krause, James, Ruxton, & Franks, 2002, p. 5). They can also shift rapidly between these two formations (p. 9).

Two means of interaction are used by fish: vision, and lateral line system, which is an organ giving info about distance to proximal fish (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 280). Three nearest neighbors are sufficient to guide fish movements (less than with flocks of birds). Interaction rules may be adapted according to circumstance. The evidence is used to prove that schools of fish are cases of swarm-intelligent cognitive systems.

Cognition in Human Groups: Small Groups, Crowds, and Societies

This section is the second series of case studies and explores human groups including small groups, crowds, and societies. Some of these might not constitute cognitive systems proper, but may rather simply have cognitive properties by virtue of cognitive systems which partially comprise it. Certain small groups have already been studied in studies in distributed cognition, such as a ship and its sailors or the Hubble Space Telescope (Giere, 2006; Hutchins, 1995b). It is important to note that, in distributed cognition, not only human agents are considered a part of the cognitive system. Rather, it is humans *with* objects and tools (Giere & Moffatt, 2003). The larger groups under consideration, if they are cognitive systems, have the potential to expand the boundaries of what we call cognition. Prior to the case studies, preliminary, foundational conceptual work on social systems as entities in themselves is briefly reviewed. This includes: (Canetti, 1978; Bertalanffy, 1968; Buchanan, 1997; Deleuze & Guattari, 1987; Wiener, 1985).

Small groups. The first case study in the human or social series is of small groups. They are first described. Next, they are analyzed for evidence of cognitive properties. The relevant studies include: (Dyer, et al., 2007; Giere, 2006; Giere & Moffatt, 2003; Harris, Barnier, Sutton, & Keil, 2014; Hutchins, 1995b; Theiner & O'Connor, 2010). Distributed cognition.

Gottman's research is particularly relevant here, although the context is in marital relations. Ephemeral patterns of coordination emerge in communication (Lisiecka, 2013, p. 220). Sudden shifts in conversation, from friendly to negativity, occur during conversations. ABAB communication is discussed. ABAB communication is a manifestation of higher-order disagreement pattern (Lisiecka, 2013, p. 222). The evidence is used to prove that small groups are instances of distributed cognitive systems.

Crowds. The second case study is of crowds. They are first described. Next, they are analyzed for evidence of cognitive properties. The relevant studies include: (DeLanda, 2006; Nowak, Vallacher, Strawińska, & Brée, 2013; Trenchard, 2015; Kheiri, 2016; Dyer, et al., 2007;

Theiner & O'Connor, 2010). Superorganism. Emergent cooperative behavior and competition resulting in peloton; passing, drafting, leading. Superorganism because of dual relations of cooperation and competition. "Driven by basic non-volitional energetic and physiological principles" (Trenchard, 2015, p. 191). Ant colony optimization (ACO) simulations used for modeling pedestrian movement. In this case, applied to pedestrian circulation in Honarmandan Park, Tehran. Predicts routes and route choice behavior as function of propinquity (Kheiri, 2016).

Distributed cognition is used to describe these systems, but this is not the proper concept (Moussaid, Garnier, Theraulaz, & Helbing, 2009). Flows of pedestrian traffic spontaneously organize into two lanes (but, there is a cultural element to this, too) (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 270). The positive feedback loop of the gaze in a crowd is discussed (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 473); negative feedback occurs through losing interest. Stigmergic communication is manifest in e.g. digg.com (cf. Twitter) (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 275). Humans spontaneously create trail systems (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 278). Indirect communication of one's solution are inscribed in trails on the ground.

There is also a direct transfer of information. Synchronized clapping of audiences in Eastern Europe is discussed (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 481). There are three phases: 1) incoherent clapping, 2) synchronized clapping, and 3) repeat. Lane formation with pedestrians is a more universal phenomenon (Moussaid, Garnier, Theraulaz, & Helbing, 2009, p. 485). Also note the reinforcement learning model.

There are information differences in groups: small number know e.g. where resource is, "guide" others (Dyer, et al., 2007, p. 461). Consensus decisions are reachable even if individuals with special knowledge do not know they are in the majority (Dyer, et al., 2007, p. 462). Signaling through head movements and directional gaze occurs (ibid.). Evacuation patterns are constituted by individual (leaders in the know), plus collective herding (follow the leader to safety) (ibid.).

There are sometimes conflicting directional pulls by leaders: Couzin predicts majority will decide on group motion (Dyer, et al., 2007, p. 464). In the study, no difference in times to reach periphery when conflicting pulls present (Dyer, et al., 2007, p. 467). Conflict was resolved early on and dominant leaders take their positions from favorable start positions (Dyer, et al., 2007, p. 468); otherwise, group takes majority position. The evidence is used to prove that crowds are instances of swarm-intelligent cognitive systems.

Societies. The third case in the human series is societies. They are first described. Next, they are analyzed for evidence of cognitive properties. The relevant studies include: (DeLanda, 2000; Rosser, 2011; Sawyer, 2005; Kesebir, 2012). Kesebir sees humans as partially superorganismic (Kesebir, 2012). It is emergence in a nonlocal organism with a hierarchical organization of life (major transitions in evolution) (Kesebir, 2012, p. 235). They are cooperative communities. Superorganismic aspects of human psychology include integration through symbolic communication. The functional integration of parts necessary for individual existence, cf. feral children (Kesebir, 2012, p. 236). Language enables group identity forging, as well.

Integration also occurs through synchronous movement, achieved through mirror neurons (Kesebir, 2012, p. 238). The rhythmic entrainment of dancing is another example. Next, acting as a functional unit is discussed; self-organization in emergence of coordination, order, social patterns (Kesebir, 2012, p. 239). Furthermore, there is a top-down willingness to submit to authority. Shared intentionality is important in human collaboration. For example, human eyes track the gaze signal, and the white sclera help contrast (Kesebir, 2012, p. 240). Collaboration often is coextensive with a division of labor. Play has a significant role in the genesis of shared intentionality. Shared intentionality underlies human division of labor, communicated through language, gaze, body, etc.

Social identification processes are instrumental in the formation of groups (Kesebir, 2012, p. 241). Identification with a group necessary to form a unified front. Individuals incorporate group into their own identity. Emotions are significant in that things affecting group can affect member even if they do not *individually* affect them. Preferential treatment of group members is not simply reducible to self-interest. There is a deference to authority: top-down control in group. Deference is freely given based on status and is not necessarily coerced (cf. Milgram); status hierarchies (Kesebir, 2012, p. 242).

Humans have a large genetic heterogeneity in contrast with bees; but, there is a promotion of phenotypical similarity through social learning (culture). The power of norms in societies cannot be understated; norms affect most behavior (Kesebir, 2012, p. 243). There are even internal consequences to resisting norm, e.g. as manifest in the amygdala. Common fate and the egalitarian imperative are discussed (Kesebir, 2012, p. 244). Income inequality societies less cohesive, less healthy, less safe, less happy, less trusting, less socially engaged (cf. war and common fate). There is a satisfaction in punishing noncooperators (Kesebir, 2012, p. 246). Religion serves to form a community (Kesebir, 2012, p. 247), affirming its normative order. Activation of superorganismic traits only occurs with group identification. Humans are like slime molds (Kesebir, 2012, p. 249). They unify under threat; cf. their willingness to die in martyrdom for a cause. This is the "hivish mind" (Kesebir, 2012, p. 252). While I use this research, I disagree with her analysis of superorganismic traits in humans.

Dynamical social psychology shows that different levels require different approaches (Nowak, Vallacher, Strawińska, & Brée, 2013, p. 2). Complexity science allows meaningful, unified analyses across different levels because it is works bottom-up (but also top-down) (ibid.). There are two levels of organization: within a level and between levels (Nowak, Vallacher, Strawińska, & Brée, 2013, p. 3). There is a marked asymmetry between positive and negative emotions: positive emotions free attention and consciousness, while negative emotions focus attention (Nowak, Vallacher, Strawińska, & Brée, 2013, p. 5). Positive emotions allow for the creation of higher-level order (like contemplation of the meaning of pleasurable activity).

Dynamic social impact theory is next discussed (Nowak, Vallacher, Strawińska, & Brée, 2013, p. 8). There is an emergence of higher level properties from local interactions (8). Strength of source, spatial and temporal propinquity, and number of people are all factors of the distribution of opinions. Note the effects of clustering and polarization of opinions, attitudes, politics, religions, fashion, farming techniques (9). Stronger leaders prevent the decay of minorities and grow stronger because of strength needed to counteract normalization effects of minority. Thus, minority advocates tend to be more influential (10). In opinion change, there is a nonlinear change rule with a bimodal distribution. Linear change would average out and normalize a field into a unified opinion. This requires a threshold to bifurcate and enables survival of minority opinions. Thus, there are different geometries of social interactions.

The society of self is next discussed. Groups are units with nested subgroups down to individual members. That is, they cannot be understood as just a two-level member-group system (Lisiecka, 2013, p. 209). Interactions of individuals lead to group hierarchy, shared goals, roles, responsibilities, group spirit, and ideology (Lisiecka, 2013, p. 210). This in turn affects individuals, habits, social identity, convictions. The group-as-a-whole not static (Lisiecka, 2013,

p. 212).

Groups are emergent. There are multiple coexistent levels: atoms, molecules, individuals, living systems, groups. That is, there is a supervenience of levels (Lisiecka, 2013, p. 215). Ephemeral emergents include group process in psychotherapy (Lisiecka, 2013, pp. 216-7). Stable emergents include group culture, memory, social practices, conversational routines. Lower-level substructures below group-as-a-whole include collective memory, discourse patterns, roles and positions, and communication (Lisiecka, 2013, p. 217). In the late 1990s, computers and multi-agent systems were developed allowing for simulations of societies with individuals (Sawyer, 2005, p. 2). Language shift is an emergent phenomenon (Sawyer, 2005, p. 3). Societies have been analyzed as swarm intelligence (Sawyer, 2005, p. 5). Social systems have *sui generis* levels of order not found in natural complex systems (Sawyer, 2005, pp. 11-12).

The micro-macro link is discussed as the relationship between the individual and the collective (Sawyer, 2005, p. 63). Emergence grounds sociological realism. Ontological individualism is contrary to sociological realism (Sawyer, 2005, p. 66). "Social property is emergent when multiply realized in wildly disjunctive complex systems of individuals" (Sawyer, 2005, p. 72). This is a case of strong ontological emergence (downward causation). Note Bhaskar on society as supervenient upon individuals with downward causal powers (Sawyer, 2005, p. 81). Morphogenesis (Margaret Archer) is emergence over time or diachronic emergence (Sawyer, 2005, p. 83). For example, being a church.

> "Most social properties are nonaggregative, many social systems are not decomposable, most are not functionally localizable, and all depend on symbolic communications that use the full richness of human language" (Sawyer, 2005, p. 99).

On Gaia, or Why the Earth Is Not a Cognitive System

Because the outer bounds of cognition are under consideration, it is pertinent at this time to consider the largest terrestrial system of all—Lovelock's Gaia. The Gaia Hypothesis states "the physical and chemical condition of the surface of the Earth, of the atmosphere, and of the oceans has been and is actively made fit and comfortable by the presence of life itself" (Lovelock, 2000, p. 144). This thesis hinges upon Earth, including its biota, geology, and atmosphere, being a homeostatic, self-regulatory system. Prescinding from the question of the hypothesis' validity, the question here is whether or not it can be characterized as a *cognitive* system. This proves not to be a cognitive system, albeit it is partially characterized by cognition. Societies are thus the limit case of cognitive systems.

Conclusion

Cognition Is a Property of Group and Social Systems

The conclusion begins with a recapitulation of the findings of the case studies. Providing that at least one of these cases is a cognitive system *of whichever type*, the thesis is proven. Not all cognitions of a given organism are amenable to an analysis at the organismic (or organism-environment) level. Some cognitions of an organism must rather be understood as arising within a group or social system and as being properties of that system. The largest cognitive system found in the case studies provides the outer bounds of cognition. Thus, the purview of the cognitive sciences has been defined—in one direction, at least.

Future research will need to study the inner bounds of cognition. There is no commonly accepted inner bound to what constitutes a cognitive system. The smallest *purported* cognitive systems to date are the protists qua autopoietic systems (Maturana & Varela, 1980; Thompson, 2007). This is a consequence of an extreme form of the continuity hypothesis of cognition. A more limited case might be small, limited organisms like the tick (Agamben, 2002; Uexküll, 2010). This entails a critique of enactivism and radical embodied cognitive science insofar as they still remain focused on the individual and ignore its place within collective and social groups.

Towards a Renewed Relevance of Anthropology in the Cognitive Sciences

A corollary consequence of the expansion of the scope of cognition is a renewed relevance for anthropology in the cognitive sciences. In 1978, the six-pronged interdisciplinary wheel of the cognitive sciences was first published (Sloan Foundation). Since then, the relevance of anthropology has tapered off and is only given a passing acknowledgement or a symbolic nod in the cognitive sciences (Thagard, Cognitive science, 2010; Hutchins, 2010). This study shows that anthropology has a renewed relevance insofar as it studies groups and societies. This also implies that sociology should stand with anthropology. The older idea of incorporating anthropology was to get cross-cultural perspectives and not fall into the trap of naively studying the Western individual as if they were the *universal* individual. The new idea is that groups and societies themselves are actually relevant objects of study. This also expands the potential contribution of biology to the cognitive sciences to also include sociobiological work on flocks, swarms, colonies, and other such emergent group entities (Hölldobler & Wilson, 2009).

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