The Emergence of Collective Structures Through Individual Interactions

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The Emergence of Collective Structures

Cognitive scientists tend to focus on the behavior of single individuals thinking and perceiving on their own. This is natural because our own introspection provides us with unique insight into this level. However, interacting groups of people also create emergent structures that are not intentionally produced by any individual. People participate in collective behavior patterns that they may not even be able to perceive, let alone understand. Social phenomena such as rumors, linguistic conventions, the emergence of a standard currency, transportation systems, the World Wide Web, resource harvesting, crowding, and scientific establishments arise because of individuals' beliefs and goals, but the eventual form that these phenomena take is rarely the goal of any individual.

The purpose of this symposium is to integrate three methods for exploring collective behavior: 1) experiments bridging individual and group levels of behavior analysis, 2) analyses of naturally occurring collective behavior patterns, and 3) formal mathematical and computational models of the emergence of collective patterns. Not all of the speakers will be addressing all three of these methods, but together we hope to form bridges between formal approaches to group behavior and rich data sets.

The study of collective behavior is timely for several reasons. First, as the following contributions attest, there have been recent and important developments in the formal modeling of collective behavior. Models in sociology, economics, psychology, and anthropology have been successful not only in predicting individual and group behavior, but also in organizing theories, highlighting idealized patterns, and determining what data should be collected next. Second, there has been exciting recent progress on empirical tools for measuring and manipulating the collective patterns that people produce. Tools that allow moderate sized groups of people to be connected together via computers, calculators, cell phones, or clicker response systems make it relatively easy for experimenters to collect moment-by-moment data on the decisions of people as they are influenced by the decisions of their peers. Third, a parallel set of technological advances have radically improved the harvesting of data from real-world sources. Archival data available from on-line news groups, blogs, social network services, chat groups, and topical communities can effectively be used to explore naturally occurring coalition formation, idea spread, and group evolution.

The presenters will describe their own research on collective behavior from diverse perspectives including machine learning (Griffiths), psychology (Gureckis). physics (Helbing), and robotics (Steels). Their presentations will also connect with critical issues surrounding collective behavior, including the questions of "Does group behavior always reduce to individual behavior?," "Is 'group cognition' possible?," and "What is the value of formal modeling for understanding group behavior?"

The presenters represent different manifestations of the growing realization across the social sciences that one of the best ways to build useful theories of group phenomena is to create working computational models of individuals and their interactions, and to observe the global structures that these interactions produce. These models benefit from the advanced statistical tools and empirical methods that cognitive scientists have developed for assessing the quality of the fit between computational models and the world. Conversely, modeling methods advance cognitive science by providing a generative, proof-by-construction approach to understanding social behavior. This mutually informing relation between models and data reminds us that organized behavior can be described at multiple levels, and that our thoughts both depend upon and determine the social structures that contain us as elements.

Griffiths: The effects of inductive biases on the creation of communication systems

Accounts of language evolution have tended to focus on two kinds of forces that can change the structure of a language: cultural transmission, and the goal of producing a shared communication system. Both of these forces rely on learning, as people need to infer the structure of a language from the utterances of other people in both cases. However, the effects of inductive biases – those factors that make some languages easier to learn than others – have only been explored in the context of cultural transmission. A mathematical analysis of a simple model of the creation of a communication system by Bayesian agents, and experiments testing the predictions of this model in the laboratory with human learners suggest that inductive biases can have a strong influence on the creation of communication systems.

Gureckis: How you likely picked a name for your child

A key assumption in cognitive science is that the decisions of an individual ultimately reflect subjective utilities, or values, that appraise the relative worth of different options. However, in many cases, the utility of a choice may be influenced by the choices and actions of others. In this talk, we examine the interdependence between individual and group behavior surrounding a somewhat arbitrary, real world decision: selecting a name for one's child. Using a historical database of the baby names registered over the last century, we find that naming choices are strongly influenced by both the frequency of a name in the general population, and by its ``momentum" in the recent past in the sense that names which are growing in popularity are preferentially chosen. We evaluate a number of formal models that detail how individual decision-making strategies, played out in a large population of interacting agents, can explain these empirical observations. We argue that cognitive capacities for change detection, the encoding of frequency in memory, and biases towards novel or incongruous stimuli interact with the behavior of other decision makers to determine the distribution and dynamics of cultural tokens such as names.

Helbing: How Social and Collective Human Behaviors are Born from Simple Individual Interactions

While one often imagines collective action of humans to be highly organized and sophisticated, collective human behavior may also occur spontaneously and even without the individual intention of a specific outcome. Examples are self-organization phenomena in pedestrian crowds, but also the response of people to fire alarms or the crossing of red traffic lights by other people. These behaviors will be illustrated by video recordings. It will then be shown, how the observed phenomena can be understood by means of simple mathematical models of human interactions in space. Such models may also be transferred to collective decision-making. Interestingly, when combining models of selfish behavior with success-driven motion in space, one can find a surprising outbreak of cooperation in situations, where people are normally expected defect, such as the prisoner's dilemma. This may explain the emergence of social behavior and the fact that, in game-theoretical experiments and in reality, people are found to cooperate more frequently than predicted by currently established theories.

Steels: How language communities self-organize and maintain coherence

Over the past decade, a substantial body of work has explored how a group of agents could self-organize communication systems with similar properties as found in human natural languages. The models have been tested both in computer simulation and in experiments with physical robots operating autonomously in a real world environment. This talk discusses the main theoretical principles that have emerged from this work, focusing in particular on the question how coherent collective linguistic behavior may arise. There appear to be four keys: (i) Linguistic interaction is a cooperative problem solving process. The speaker chooses conceptualizations and verbalizations that give the highest possible chance of successful communication. The hearer cooperates fully, filling in missing pieces through inference and shared context. Speaker and hearer usually have a way to establish whether the communication succeeded and to repair it through non-verbal means (like pointing) or additional communication. (ii) The communication must be considered to be an open dynamic system. Speakers are at any time allowed to invent new words or constructions, to stretch the meaning and function of existing materials, or to extrapolate them to new contexts. Hearers pick up these innovations and add them to their own inventories. (iii) Speaker and hearer must be able to take the perspective of the other. This is necessary to conceptualize properly what to say (as speaker) and to guess the meaning of unknown words and constructions (as hearer). Speaker and hearer use their own language system as a model of the other partner and can use re-entrance: The speaker self-monitors and the hearer attempts to interpret from the viewpoint of the speaker. (iv) Speaker and hearer must adapt their own conceptual and linguistic system as part of each interaction. They track the success and failure they have had with particular conceptual and linguistic elements and this influences how they will communicate in the future. It will be shown how the combination of these key elements provably leads a group of agents towards a shared communication system that remains adapted to their communicative needs. The talk is illustrated with data and video-clips from experiments with humanoid robots.