Perceptual Supports for Sensemaking: A Case Study Using Multi Agent Based Computational Learning Environments

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Abstract: Many studies have examined how learners make sense of the traditionally difficult ideas of *levels* and *emergence* in complex systems by interacting with visuospatial multi agent based models. In this poster, we review these findings through the lens of human basic perceptual/representational systems. We argue that many of learners' observed strategies and explanations surrounding the ideas of levels and emergence are supported by visualizations that leverage perceptual systems related to objects, motion, and geometry.

Introduction

Recent research has documented the need for integration of complex systems methods and ideas into pre-college curriculum. At the same time, it has documented a number of difficulties in learners' ability to grasp the key concepts of complex systems (Jacobson & Wilensky, 2006). One such difficulty concerns the relationship between micro-level behavior and the associated emergent macro-level behavior that results, even if both levels are recognized as occurring. Visuospatial agent-based modeling (ABM) systems, such as the NetLogo (Wilensky, 1999) modeling environment, have been shown to help learners form these connections. By re-representing difficult or misunderstood phenomena in terms of micro-level interactions, learners are better equipped to accurately describe, explain, and even predict the behavior of traditionally difficult scientific and mathematical phenomena. But what is it about visuospatial ABMs that promote these deep understandings?

In this paper, we discuss several design-based research findings regarding *how learners make sense of emergence* using visuospatial ABMs in light of relevant research in cognitive and developmental psychology that describe *how learners extract and process information* from visual stimuli. We contend that learners make sense of ABMs by leveraging knowledge systems particularly related to object perception, motion tracking, and geometry.

Perceptual Supports for Sensemaking: Evidence from Learners

Research over the past several decades has identified specific "core knowledge systems" (representing objects, agents, number, geometry; Spelke & Kinzler, 2007) that are considered to be particularly important in guiding the ways that humans organize and understand the world around them. While there is certainly controversy regarding the relationship between perception and conception in these systems, it is well established that they play an important role in human information processing, whether those actions are in the world or projected on a computer screen (Johnson & Náñez, 1995). We suggest that several of these systems can provide *perceptual support* for successful reasoning about ideas of levels and emergence. For this poster, we concentrate on the "object" and "geometry" systems in the context of agent-based systems by highlighting *individual micro-level objects* and their interactions, *mid-level collections* of objects as they move through space, and *aggregate-level emergence* of geometric and topological patterns within the agent-based visualization.

The Micro-Level and Object Perception.

The most well studied "core system" is object perception. Specifically, an object is expected to have three basic properties: cohesion, continuous motion (if moving), and interaction only upon contact (for example, objects change direction only if they hit another object; Spelke, 1990). And the object principles – particulate agents, continuous movement, and elastic collisions – are some of the very agent-based phenomena that contribute to important, and often misunderstood, emergent scientific properties.

Several models built within the NetLogo programming environment illustrate macro-level emergent phenomena such as gas behavior (Steiff & Wilensky, 2003; Wilensky, 2003) or electrical current (Sengupta & Wilensky, 2006) by restructuring and describing that phenomena in terms of easily noticed and understood interactions: objects' movement and contact with other objects. Electrical current is illustrated as an emergent property of particulate behavior of electrons and the Maxwell-Boltzmann distribution as emerging from elastic collisions of gas particles. Learners are able to more accurately explain and predict aggregate-level behavior in terms of object-based principles after interacting with such models (Sengupta & Wilensky, 2006).

Mid-Levels and Motion Tracking.

Related to basic object perception is the ability to keep track of multiple moving objects at a time. Humans are limited in the number of independent objects they can visually track at a given time: usually, they can only track about three or four (Spelke & Kinzler, 2007). Findings suggest that this limitation on the number of objects that can be independently tracked at one time provides support for the formation of visual *mid-level* groups, which have been shown to be particularly useful for learners who are working to understand the ways in which micro-level behavior contributes to macro-level emergent phenomena (Levy & Wilensky, 2007).

When interacting with ABMs of electrical current, learners describe visually tracking a small group of moving agents (electrons) in order to understand agent interactions relative one another. These small collections of agents, whose behavior is judged relative to a *locally-anchored landmark*, consist of groups of four to six single entities (Sengupta, Wilkerson & Wilensky, 2007). These groups allow for two separate, but equally important recognitions: that micro-level patterns of electron scattering resulted from increases in wire resistance, and that this scattering in turn affected the macro-level movement of groups of electrons through the wire.

The Aggregate Level and Geometry.

Finally, humans are able to quickly notice the general geometric and topological features of a visual stimulus. This supports learners' propensity to notice emergent or *aggregate* patterns – if and when those patterns are visually represented – in visuospatial models. In NetLogo, these aggregate phenomena can take the form of topological relationships (for example, the difference between one flock of birds or many separate ones, or the shift from several termite mounds to one), near-far relationships (for example, when moths flock toward a light), or concave and convex differences (for example, during the growth of microscopic grains within a given material; Blikstien & Wilensky, 2004).

Moving Forward

Studies that isolate features of the display that leverage perceptual supports such as those described above may inform future designs: for example, while agents with well-defined borders seem to emphasize interactions based on motion and contact (by leveraging the object perception system as a support), agents with fuzzy borders that overlap might emphasize macro-level emergent phenomena such as the formation of groups of certain types of agents (Kornhauser, Rand & Wilensky, 2007). Highlighting groups of four or five agents may or may not explicitly support the creation of mid-levels. Similarly, the addition of "living" agent-related features such as eyes or faces to models of social and behavior phenomena may encourage the use of human "agent" perception systems (Spelke & Kinzler, 2007), for which humans expect behavior to be goal-oriented.

Research on the ways in which dynamic displays leverage these perceptual systems may also provide insight into when dynamic visualization may be most effective. Research suggests that often, animation is not effective as an instructional tool because the depicted events are not "accurately perceived and appropriately conceived" (p. 247, Tversky, Morrison & Betrancourt, 2003). We suggest that a better understanding of the perceptual systems that are most likely to support appropriate interpretations of featured content might outline principles for designing effective visualizations – and encouraging appropriate conceptualizations – of emergent mathematical, social, and scientific phenomena.

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