Commentary on Steels and Belpaeme

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It takes a(n) (agent-based) village

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Abstract: S&B take technical and conceptual shortcuts which have significant negative consequences on simulation implementation and agent behavior. Justifiably, the model represents a proof of concept for the role of culturalism in category formation; nevertheless, the absence of detailed information concerning embodiment of agents and the superficial implementation of the learning approaches, make S&B's results less relevant than they could be.

One advantage of computational modeling over empirical research is the ability to abstract away layers of the real world in order to focus on aspects considered most relevant for the problem to be solved. However, in S&B's attempt to address the "acquisition problem" in terms of human color perception, categorization, and naming across a population, perhaps they go too far in paring down the object of inquiry. They do not specify, or they eliminate altogether, a number of "details" that they deem unnecessary to the learning process, contrary to empirical data and current theoretical formulations. In all theoretical approaches simulated by S&B, the agent populations reach final states reflecting successful acquisition of color categories and corresponding lexicons for the given environment and ecology which subsequently are shared across a speech community. However, to obtain these results, S&B take technical and conceptual shortcuts which have significant negative consequences on simulation implementation and agent behavior. Justifiably, the model represents a proof of concept for the role of culturalism in category formation; nevertheless, the absence of detailed information concerning embodiment (internal attributes and states) of agents and the superficial implementation of the learning approaches, make S&B's simulation results less relevant than they could be, either for comparison of the different theoretical positions, or for understanding the human phenomena investigated.

Conceptually, the key problem is S&B's drastic simplification of the learning/acquisition approaches explored. Nativism is sketched as "all humans could be born with the same perceptually-grounded categories as part of their 'mentalese.'" By representing innateness (formalized as a genetic algorithm) as a fixed network throughout the agent's lifetime, S&B equate nativism to an adult-like, fully-operational repertoire of categories springing forth at birth, requiring no further experience or maturation/development. Change occurs in each successive generation through genetic mutation. Yet empirical observations indicate that despite our genetic endowment, a child raised without exposure to any human language will not ever come to speak one (Lenneberg 1967). Nativists acknowledge both experience-dependent mechanisms and maturational constraints in the learning/acquisition process (e.g., Chomsky 1980). Furthermore, S&B fail to keep the critical distinction between acquisition and evolution. Phylogeny (how perceptually-grounded categories evolved in the species over time) does not necessarily beget ontogeny (developmental properties of day-to-day learning by the child), and it is too simplistic to suggest the underlying mechanisms for these different domains are identical within a nativist approach. S&B alternatively claim in empiricist accounts (formalized as connectionist models) "all humans share the same learning mechanisms, so given sufficiently similar environmental stimuli and sensory-motor apparatus they arrive at the same perceptually grounded categories." This overgeneralization is not only at odds with attested maturational factors accounting for first (L1) versus second language (L2) learning (Newport 1990, 1991; Sorace 2003), but also with connectionist models of L1 learning in which neural networks function optimally when forced to "start small"---undergoing a developmental change that resembles the incremental increase in working memory occurring over time in children (Elman 1993). While S&B represent empiricist learning as adaptive categorial networks during the agent's lifetime, they stop short at realistically constructing models in which agents within the same population vary developmentally.

Empirical studies pertaining to vision demonstrate similar patterns of emergence. Infants show true color vision when they are able to discriminate between two stimuli of different wavelength, but equal luminance. At 2-4 months of age, infants can discern chromatic differences fundamentally at adult isoluminance (Teller 1998). This said, color vision reaches its adult form only in early adolescent years. Relative sensitivity to varying wavelengths is said to change between infancy and adolescence, with the red-green mechanism appearing to develop before the yellow-blue mechanism (Teller 1998). It is also hypothesized that "appropriate color naming depends on maturation and integration of specific cortical neurological structures" (Bornstein 1985). S&B claim to capture the "prototypical nature of color categorization demonstrated by naming and memory experiments" through the use of neural nets; however it is difficult to know whether they accommodate both adult and child learners.

The second problem is a technical shortcoming of S&B's models, which in fairness falls out somewhat from the conceptual defects. Absent in S&B's simulations is the role of maturational/developmental factors in constraining learning/acquisition. Measures such as, "all agents are assumed to have exactly the same perceptual process," sidestep the point that infant perceptual processes may be sufficiently different from adults. If so, S&B's predictions are potentially invalid for the discrimination game, where the "best" category is found through adult sensory representation (computed CIE L*a*b* values). Success in the discrimination task is crucial, as it is a prerequisite for ongoing communication. Agents are initialized with zero categories acquired, yet all possess relatively powerful capabilities of perception, associative memory and a pre-given repertoire/alphabet of syllables. One speculates that these experiments depict a homogeneous group of agents who are either "wunderkinds," or cognitively-challenged adults (both possibilities represent individuals with mature/adult-like capacities in language and vision, with immature repertoires of color categories). Regardless, either population is anomalous. One benefit of agent-based models is that we are able to design multiple varieties of agents whereby each agent retains its profile of internal characteristics across a designated lifespan (Epstein and Axtell 1996, Ferber 1999). Parameters including age, working memory, attention, lexicon, and perception, etc., can be used in a distributed population of heterogeneous child and adult agents (Satterfield 2001, 2004). These properties are easily integrated as instance variables in the models, and can further constrain agent interaction (culturalism). Lastly, to fully exploit the power of agent-based models in generating complex structures from the "bottom-up", the initial attributes of each agent in the population must be made explicit. S&B are vague about initial states and specific attributes are not ascribed, nor is further elaboration given on the agents' basic architecture for perception, categorization, and naming, beyond "all agents have unique associated information structures, representing its repertoire of categories and its lexicon." Moreover, the logic of learning/acquisition theories dictate that the initial state of the learner be outlined, in order to make informed evaluations with respect to the learner's final state.

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