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A One-System Theory Which is Not Propositional

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Abstract

We argue that the propositional and link-based approaches to human contingency learning represent different levels of analysis because propositional reasoning requires a basis, which is plausibly provided by a link-based architecture. Moreover, in their attempt to compare two general classes of models (link-based and propositional), Mitchell et al. have referred to only two generic models and ignore the large variety of different models within each class.

Mitchell et al. depict propositional and associative approaches to human contingency learning as incompatible with each other. Based on a comparison between generic link-based and propositional models, Mitchell et al. conclude that the propositional approach is superior to the link-based approach. We will argue that: (1) propositional and link-based accounts are not incompatible and are concerned with separate levels of analysis and (2) Mitchell et al. complicate their analysis by comparing two broad families of models, which has important implications for evaluating these families.

We assert that the propositional and link-based approaches are concerned with different levels of analysis. Note that our argument is different from Mitchell et al.'s argument that specific link-based models speak to two different levels of analysis. The propositional approach argues that humans and animals use propositional reasoning to guide judgments about outcomes in Pavlovian and human contingency learning situations. This approach is silent concerning the cognitive architecture that supports propositional reasoning. In contrast, the link-based approach is concerned with the extent to which one representation can activate another representation and is relatively silent on the way in which animals and humans use associations. For some of the reasons outlined by Mitchell et al., one might argue that the link-based level of analysis is not useful for understanding behavior. However, we contend that, to the extent that we are able to assess changes in associations through Pavlovian conditioning and human contingency learning, the associative level of analysis is helpful in understanding many aspects of human and animal behavior. Connectionist models have been used to describe phenomena in divergent areas of cognitive psychology. Aside from the obvious examples of Pavlovian conditioning and contingency learning, connectionism has been highly influential throughout cognitive psychology, including perception, categorization, language, memory, attention, social cognition, and cognitive pathology.

Evidence that these approaches are concerned with different levels of analysis comes from the literature concerning connectionist models of language processing. Connectionist models

assume that connections (analogous to links or associations) between processing units provide the foundation for complex information processing. In these systems, weighted connections allow activation to pass between units and learning is presumably driven by changes in the strengths of the weights between processing units. Connectionist models of language are link-based models that can represent and process propositional knowledge. A second notable example of propositional logic being based on link-based knowledge is provided by Wynne (1995) in his associative account of transitive inference. Thus, the existence of several link-based accounts of propositional reasoning suggests that propositional reasoning can be explained at the associative level of analysis by reductionism.

Moreover, associative theories have informed about the way the brain organizes and processes information. According to the Rescorla-Wagner (1972) model, a discrepancy between the strengths of the outcome experienced and the outcome expected based upon all cues present is necessary for changes in the strength of a CS-US association. The results of electrophysiological and neuroimaging studies suggest that the brain generates a signal that encodes the discrepancy between expected and experienced outcomes and that this signal is correlated with learning at a behavioral level (e.g., Corlett et al., 2004; Schultz, 1998). Mitchell et al. aptly noted that in many connectionist-like models of cognition (and in the brain), stimulus representations are distributed, meaning that units in these systems do not carry specific representational value and that information is represented by patterns of activity across arrays of units. This does not necessarily undermine the link-based level of analysis because, in systems of distributed representation, weighted links function to bind together arrays of units that together represent stimuli. Also, the results of modelling studies suggest that individual neurons are highly variable in the extent to which they locally encode information, such that some neurons function like grandmother cells (i.e., a single neuron more directly represents a stimulus) and others are more broadly tuned (Verhagen & Scott, 2004).

Mitchell et al. argued that the link-based approach does not explain behavior as well as the propositional approach. They based this argument on a comparison between a generic associative and a generic propositional model. This strategy has the unfortunate consequence of ignoring the great variety of associative and inferential models available. For example, Mitchell et al. pointed out that the propositional approach is better equipped than associative models to account for data indicating that awareness is related to learning. However, the prediction that awareness will be related to learning is not a necessary prediction from a propositional model. Bayesian models are similar to the propositional approach but do not assert that awareness is necessary for learning. It is also conceivable that an associative model might argue that awareness is necessary for learning. Similarly, data that uniquely support a specific associative model cannot be interpreted as inconsistent with the general propositional approach. The sometimes competing retrieval model (SOCR; Stout & Miller, 2007) uniquely anticipated that when a target stimulus is conditioned in compound with two blocking cues, responding to the target stimulus is greater than when it is conditioned in compound with only one blocking cue (Witnauer, Urcelay, & Miller, 2008). Despite SOCR being an associative model, these data do not allow us to conclude that the link-based approach is superior to the general propositional approach. In fact, Witnauer et al.'s data were problematic for many associative models and might be consistent with revised propositional models (see Miller & Escobar, 2001, for a similar argument concerning ill conceived comparisons between generic acquisition- and performance-focused models). Differentiation between models requires identification of specific models and the results are applicable only to the actual models that are compared.

The predictions of a generic model (like that outlined by Mitchell et al.) or a family of models (like acquisition-focused models of Pavlovian learning) are necessarily less precise

(and less testable) than the predictions of a specific model (e.g., SOCR). This is evident in Mitchell et al.'s application of their generic model to the effect of cognitive load on learning phenomena. On p. 15, Mitchell et al. assert that the studies of the effect of cognitive load on learning agree with the predictions of the propositional approach. Propositional reasoning presumably requires cognitive resources and, consistent with this view, manipulations that diminish the availability of cognitive resources diminish learning. On p. 20, they assert that propositional reasoning can occur in highly complex (demanding) situations. If it is assumed that task complexity is directly related to cognitive load, then the propositional approach (as outlined on p. 15) predicts that learning should not be observed in highly complex situations. This inconsistency (and others) in Mitchell et al.'s propositional approach is the result of comparing generic models of learning rather than fully specified models.

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