few would perceive it as "water with a little too much oxygen." Instead, the toxic chemical is perceived (or "represented") as something that should be violently expelled from the body. This may lead one to hypothesize that, as with subjective urges (Morsella 2005) and percepts (Sperry 1964), the representation of H_2O_2 is isomorphic with respect to *how one should respond to the stimulus*, but this is not in line with the traditional view (based on the cognitive map) of what a mental representation is (Hommel et al. 2001). Hence, a more precise term is needed for the tokens that furnish the contents of the propositional reasoning system proposed by Mitchell et al. Cognitive science may be far from developing its periodic table, but it can still be rigorous about delineating what is known and what is not yet known.

What is the link between propositions and memories?

doi:10.1017/S0140525X09001083

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Abstract: Mitchell et al. present a lucid and provocative challenge to the claim that links between mental representations are formed automatically. However, the propositional approach they offer requires clearer specification, especially with regard to how propositions and memories interact. A definition of a system would also clarify the debate, as might an alternative technique for assessing task "dissociations."

Propositions, memories, and their interaction. Mitchell et al. use the simple example of learning that a bell signals food to illustrate the differences between the propositional and dual-system approaches. Although useful, the simplicity of the example is potentially deceptive. Focusing on a situation in which the organism learns about a *single* binary cue (bell rings/does not ring) and a *single* binary outcome (food presented/not presented) potentially leaves out some of the devilish details of how organisms learn in *multiple*-cue environments. Learning to form the proposition: "When the bell rings, I expect food" does not appear too arduous (for humans and some other species at least); but is the same kind of propositional statement the *only* form of knowledge learned when situations become more complex?

Imagine an environment where cues and outcomes are continuous and relations are probabilistic. In such an environment, do organisms form propositions of the kind: "When the bell rings for more than 5 seconds (but not over 15 seconds), the green light is at 50% brightness, and the red light is off, I expect food approximately 80% of the time"? Research into multiple-cue-probability learning (Enkvist et al. 2006; Juslin et al. 2003), multi-attribute judgment (Newell & Bröder 2008), and categorization and concept learning (e.g., Allen & Brooks 1991; Nosofsky et al. 1989) has suggested that humans might try to learn such propositional information (i.e., rules) up to a point, but if the environment is too complex (e.g., cue-outcome relations are nonlinear), or feedback is insufficient or inappropriate, other forms of knowledge – principally stored instances – are relied upon.

Mitchell et al. acknowledge that instance memories play a role (sect. 3.1) but state that "recollections of past bell-food pairings alone cannot produce learning" (sect. 3.1, para.6). Such a conclusion implies that experiments demonstrating behaviour accounted for by an exemplar model (which relies exclusively on stored representations of stimuli; e.g., Juslin et al. 2003; Nosofsky et al. 1989) are not demonstrations of learning. This conclusion seems too extreme. Participants in such experiments have learned to classify particular objects as belonging to Category A and others to Category B – they have learned an association between a stimulus (the to-be-classified-object) and a response (the category label). But the content of this learning appears to be instances rather than a proposition (see also Shanks & St. John 1994). The interplay (and relative influence) of instances and propositions is somewhat underspecified in Mitchell et al's approach. However, the implication is that learning can *only* occur when propositions (rules) are formed. This seems a step too far, especially in situations with multiple, non-binary cues.

Systems, processes, and their interaction. Mitchell et al. note that many dual-system models do not specify how systems interact with each other. This is certainly true and, moreover, it appears that there is little consensus across different areas on how such interaction might occur. For example, an influential dual-system model of category learning, COVIS (Ashby et al. 1998), proposes an initial bias towards an explicit hypothesis testing system, which is then usurped by an automatic, procedural system when the explicit system fails to learn. In contrast, popular dual-system theories of reasoning (e.g., Evans 2008) suggest that the initial bias is towards the automatic, intuitive system, which is only corrected by the explicit system when things appear to go awry. Part of the problem in specifying these interactions is that it is often not clear what is meant by a system or a process – and whether these terms are interchangeable (Evans 2008).

Mitchell et al. make a distinction (sect. 3.1), stating that their propositional approach is *not* a dual-*system* approach but that there are two types of *processes* (automatic processes of perception and memory and non-automatic processes of reasoning) in their single *learning* system. Although such specification clearly distinguishes their approach from the link-mechanism theories they wish to challenge, it blurs the distinction with many of the dual-process approaches to "higher-order" cognition. In their footnote, Mitchell et al. contrast their approach to other "dual-process or dual-system" theories of reasoning by stating that such approaches focus on *performance*, not learning – but at the same time Mitchell et al. want to incorporate memory (i.e., performance) processes into their *learning system*. Perhaps some clarification could be achieved by defining exactly what Mitchell et al. mean by a system (cf. Sherry & Schacter 1987).

New techniques for old problems. Much of the evidence for and against the propositional and link approaches reviewed in the target article comes in the form of task dissociations; that is, situations in which a variable (e.g., cognitive load, instruction) is claimed to have an effect on one system but no effect on another. However, dissociations are unable to bear the inferential weight placed upon them for several reasons. One reason is that a simple dissociation requires that a variable have *no* effect on a particular behavioural measure, an assertion that is impossible in principle to verify (Dunn 2003). Hence, although dissociations may be found, they are neither necessary nor sufficient for drawing inferences about the number of processes or systems underlying observed behaviour (Newell & Dunn 2008). An alternative technique which avoids the flaws of dissociation logic is state-trace analysis (Bamber 1979). This technique has already been applied successfully to many areas of cognitive science (see Newell & Dunn 2008), and its application to the areas reviewed in the target article might prove fruitful.

The new enlightenment hypothesis: All learners are rational

doi:10.1017/S0140525X09001095

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