

as the apes (Marino et al. 2007), giving pause to Penn et al.'s statement that "the substantive difference between human and nonhuman brains will be found in the prefrontal cortices" (sect. 11.1, para. 3). That structure (though not its functions) is lacking in the dolphin brain, but as a whole, the highly encephalized brain allows for levels of cognitive skills convergent with many of those demonstrated among apes (Herman 1980; 2006; Marino 2002). Refuting Penn et al.'s claims for functional discontinuity, the following examples illustrate dolphin relational competencies, as exhibited through laboratory studies of four dolphins, Akeakamai ("Ake"), Phoenix, Hiapo, and Elele.

Example 1. Herman et al. (1984) showed that Ake could learn to understand instructions conveyed gesturally within an artificial language system. A sequence of three gestures framed grammatically as *locative* (*L*) + *object* (*O*) + *action* (*A*) required Ake to take the signified action to the signified object that was at the signified location. A second three-gesture frame specified as *object1* (*O1*) + *object2* (*O2*) + *relational term* (*R*) required her to construct the signified role-specific relation between the two objects (e.g., by transporting *O2* to *O1*). Without further training, she immediately understood (on the first trial), all of the following four- and five-gesture frames: $O1 + L + O2 + R$; $L + O1 + O2 + R$; and $L_i + O1 + L_j + O2 + R$, where L_i and L_j may be the same or different locations (Herman 1986; Herman et al. 1984). Thus, she understood spontaneously the concatenation of these strings of symbols into a single instruction, and in so doing inferred the higher-order relation resulting from conjoined first-order relations. Additionally, when we substituted sequences of two deictic gestures for the symbolic gestural references to those objects, by pointing (*P*) briefly at one distal object and then at a second distal object, followed by a relational term, that is, $P1 + P2 + R$, Ake spontaneously incorporated the inverse grammar used with symbolic gestures, $O1 + O2 + R$, into her interpretation of the deictic gestural sequence, by taking the object pointed to *second* to the object pointed to *first* (Herman et al. 1999). The abstract grammatical rule was transferred not merely to other object exemplars, or to extensions of the existing grammatical rules within a closed symbolic communication system, but to a completely different indexical communication system, in a manner refuting "particular specificity."

Furthermore, Ake, when presented with long anomalous strings of symbols that violated the familiar syntactic structure of the artificial language, spontaneously extracted subsets of items that comprised a legitimate grammatical rule, even combining nonadjacent items when necessary, and she carried out the instruction contained within that embedded subset (Herman et al. 1993a; Holder et al. 1993). Additionally, when given proper syntactic strings that violated a semantic rule, such as a request to transport an immovable object, she rejected the string, either offering no response at all or occasionally carrying out a substitution response by transporting a movable object. These responses to anomalous sequences show a profound understanding of implicit relations within the grammar of the imposed language, and an ability for reinterpretation as necessary of the relations between symbols and the real world.

Example 2. Ake could report accurately whether a symbolically referenced object was present or not in her tank, by pressing a *Yes* or *No* paddle, respectively (Herman & Forestell 1985). Later, on the first occasion that she was given an $O1 + O2 + R$ instruction in that context, with *O1*, the destination object, absent, she spontaneously (and thereafter) carried *O2* to the *No* paddle (Herman et al. 1993b). This, in effect, was a reinterpretation of the perceptual world and a conditional reassignment of the function of the *No* paddle as a destination object.

Example 3. Our work with all four dolphins shows that dolphins are generalized mimics, capable of faithfully imitating on command arbitrary artificial sounds (Richards et al. 1984), as well as copying the behaviors of others (humans, other

dolphins, or themselves), either viewed live or on a television screen (Herman 2002b; Mercado et al. 1998; 1999). Behavioral imitation is a form of "sameness" comprehension in that it requires relating one's body image (see Herman et al. 2001) to the perceived image of another, and may require inferring analogies where imitation crosses species boundaries, such as the dolphin representing the human leg by the dolphin's tail.

Example 4. As described in Herman (2002b) the four dolphins were taught a gestural sign, *tandem*. When each of a pair of dolphins was given the tandem sign followed by a sign for a particular behavior, such as *back dive*, they joined together and carried out that behavior in exquisitely close synchrony. Each dolphin was also taught a sign *create*, which required it to perform any behavior of its own choice. Then, when a pair was given the two-item sequence *tandem* + *create*, they joined together and in close synchrony performed the same self-selected behavior. On a later formal test of Elele and Hiapo's responses to *tandem* + *create*, 79 different highly synchronized behaviors were recorded with 23 of them novel (i.e., they were not under control of established gestures). The tandem responses were very closely timed, and although careful video analysis could detect some slight asynchrony in timing in some cases, there was no consistent "leadership" by one dolphin or the other. These results reveal close collaboration, as well as the marrying of two abstract concepts, *tandem*, a social collaboration, and *create*, a self-determined behavioral innovation, into a higher-order abstract relationship. This collaborative capability likely finds expression in the wild, for example, in the fluid first-and second-order alliances formed in collaborative efforts by male dolphins to secure female consorts (Connor et al. 2000); interestingly, Penn et al. deny that nonhumans can participate in collaborative activities.

Penn et al. make a top-down claim for genetic pre-specification in humans alone of a module for higher-order cognition. However, bottom-up theories may offer better paths to understanding nonhuman animal cognitive potential – for example, the non-generativist image schemas (Clausner & Croft 1999; Lakoff & Turner 1989) that are claimed to create conceptual representations through cumulative sensorimotor experiences. The relational capabilities of the dolphins illustrated (as well as others described in Herman 2006) we believe derive in part from the cumulative cognitively challenging experiences provided within their long-term immersion in a varied and stimulus-rich educational environment (in contrast to many of the animal studies cited by Penn et al.). These experiences allow for the emergence of intellectual competencies that might not be realized otherwise (Herman 2002a).

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Taking symbols for granted? Is the discontinuity between human and nonhuman minds the product of external symbol systems?

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Abstract: The target article provides a convincing argument that nonhuman animals cannot process role-governed rules, relational schemas, and so on, in a human-like fashion. However, actual human performance is often more similar to that of nonhuman animals than Penn et al. admit. The kind of rule-governed performance the authors take for granted may rely to a substantial degree on language on external symbol systems such as those provided by language and culture.

Nonhuman and human brains are made of the same stuff. Yet, as Penn et al. point out, there appear to be deep discontinuities between them. Owing to nonlinear interactions between genotypes, environment, and the resulting phenotypes, functional discontinuities are a common product of continuous evolutionary tinkering. At issue is whether apparent discontinuities in human mental function result directly from biological adaptations such as the "supermodule" hypothesized by the relational reinterpretation (RR) hypothesis or whether human mental abilities – differing quantitatively from those of nonhuman animals – are made qualitatively different by external symbol systems made possible by language, culture, and education.

At the same time as Penn et al. present the evidence against symbolic thinking in nonhuman animals, they tacitly assume that human cognition is innately symbolic and propositional. For instance, they claim that the "propensity to evaluate [similarity] ... based on causal-logical and structural characteristics ... rather than on [...] shared perceptual features appears quite early and spontaneously in all normal humans" (sect. 2.1, para. 1). Yet, one of the authors has himself argued that generating spontaneous analogies poses substantial challenges even for adults who can be easily misled by perceptual similarities (Gick & Holyoak 1980). Although subsequent work went on to provide numerous demonstrations of children's and adults' sensitivity to structural relations (e.g., Holyoak et al. 1984), it is not obvious that this type of reasoning arises spontaneously. For instance, Gentner and colleagues (Kotovsky & Gentner 1996; Rattermann & Gentner 1998b) have argued for the role of relational labels aligning object representations: Hearing three differently sized objects referred to as "daddy, mommy, and baby" seemed to highlight the size relationship among the objects, enabling the 4- to 5-year-old children to transfer the relation to new objects. Without the relational labels, the relationship among the objects remained opaque. Namy and Gentner (2002) further argued that hearing common labels for objects facilitates taxonomic choices, leading children to group objects in more abstract ways (although Penn et al. mention some of this evidence, their dismissal of it is perhaps premature). Importantly, there is evidence that language is not only used as a "training tool," but may continue to play an online role in relational thinking, as suggested by studies using patients with linguistic impairments. For instance, the patient LEW (Druks & Shallice 1996), whose primary impairment is severe anomia showed a similar pattern of performance to that of 4- and 5-year-old children on tasks requiring relational reasoning. The addition of meaningful labels for stimuli induced a similar increment in performance to that found in children (Davidoff & Roberson 2004). It seems that when external aids (here, words) are unavailable, performance becomes more concrete and, to a greater degree, driven by perceptual similarities.

Humans can certainly reason analogically and perform relational judgments. The critical question is where these abilities come from. Are they the natural outcomes of the human genome? Or are they made possible by external aids such as the use of relational language? Penn et al. correctly point out that "normal human cognition clearly depends on normal linguistic capabilities" (sect. 9.3.1, para. 1). It remains possible that human performance that is

qualitatively different from nonhuman performance may depend on an immersion in human culture and language. The evidence discussed in the target article fails to rule out this possibility.

The authors' assumption of innate symbolic reasoning by humans is also apparent in the section on language in which Penn et al. claim that it is "widely recognized [...] that the ability to freely generalize relational operations over role-based variables is a necessary condition for using human languages" (sect. 3, para. 1). Although many researchers do hold this view, there is substantial evidence to the contrary. Some of this evidence is reviewed in the very article used by the authors to support their contention: Gomez and Gerken (2000). For instance, both infant and adult learners become more sensitive to the invariant structure (long-distance dependencies) in an artificial-grammar learning task when the variability of the intervening elements is increased (Gomez 2002) – the kind of token-based performance Penn et al. argue is characteristic of the performance of nonhuman animals (e.g., sect. 2.2., para. 2). Penn et al.'s discussion of language acquisition also omits the work on construction grammars (Goldberg 2006) and item-based learning (Tomasello 2003), which have offered ample demonstrations that children's language learning is intensely shaped by specific examples both at the lexical and syntactic levels. Computational modeling provides sufficiency proofs that item-based learning can produce the appearance of abstract role-based categories (Elman 2004). Evidence also indicates that adult language comprehension, rather than demonstrating knowledge of abstract role fillers (e.g., noun and verb phrases) instead demonstrates fluid interactions between word-specific knowledge and syntactic frames (Hare et al. 2003; 2004). Thus, although it remains to be explained how humans formulate explicit theories about language, actual human language use may rely less on abstract rules than the authors admit.

The human ability to reason about unobservable causes, to draw inferences based on hierarchical and logical relations, and to formulate highly abstract rules is not in dispute. Much of this thinking is compatible on an intuitive level with Penn et al.'s RR hypothesis. But although it is indeed "highly unlikely that the human ability to reason about higher-order relations evolved de novo and independently with each distinctively human cognitive capability" (sect. 11, para. 7), it is not unlikely that such uniquely human abilities depend on the use of external symbol systems. The ability to invent such systems and benefit from them in turn may depend on quantitative improvements in a range of domains: memory, imitation, shared attention, sequence learning, and so on (Elman 2005). The hypothetical child magically kept alive by itself on a desert island will inherit these quantitatively superior abilities in a range of cognitive domains. But would this child have all the abilities Penn et al. list as being uniquely human in the absence of the scaffolding afforded by external symbol systems offered by language and culture more broadly? The evidence that Penn et al. offer is insufficient to dismiss the conclusion that such a child would "not differ very much" from other great apes (Tomasello & Rakoczy 2003). Although the authors provide a compelling demonstration for an insensitivity to structural relations and the use of symbols by nonhuman animals, in taking for granted the biological basis for these abilities in human animals, the very premise of a biologically based fundamental discontinuity between human and nonhuman minds remains unfulfilled.

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