An avian parallel to primate mirror neurons and language evolution?

Irene M. Pepperberg

Department of Psychology, Brandeis University, MS062, Waltham, MA 02454. **impepper@media.mit.edu** **http://www.alexfoundation.org**

Abstract: Arbib presents a reasoned explanation for language evolution from nonhuman to human primates, one that I argue can be equally applied to animals trained in forms of interspecies communication. I apply his criteria for language readiness and language (in actuality, protolanguage) to the behavior of a Grey parrot (*Psittacus erithacus*) taught to communicate with humans using rudiments of English speech.

Arbib approaches an old chestnut – language evolution – from the novel standpoint of mirror neurons (MN), building upon his earlier theses. His counterarguments for innatist theories are clearly on target. With little to critique, I focus on possible parallels between Arbib's proposals and Grey parrot behavior – particularly that of my oldest subject, Alex (Pepperberg 1999).

Concerning Arbib's criteria for language-readiness (LR), little is unique to primates. Arbib provides not LR but CCR – "complex communication-ready" – criteria. He suggests this possibility but omits details. LR1 (complex imitation), reproduction of novel behavior that can be approximated by existent actions and their variants, is demonstrated, for example, by Alex's initial immediate utterance of "s(pause)wool" for "spool" (for a wooden bobbin; Pepperberg 2005b, /p/ being particularly difficult to produce without lips and teeth (Patterson & Pepperberg 1998). LR2 (symbolization), LR3 (parity), and LR4 (intention) are demonstrated in detailed studies of Alex's referential communication (Pepperberg 1999). LR5 (temporal versus hierarchical ordering) is more difficult to prove, except possibly in the understanding and use of interactive dialogue (Pepperberg 1999). LR6 (past/future) occurs in any animal that can be operantly conditioned. Although few data exist on Grey parrot behavior in nature, LR7 is likely, given that Greys take several years to reach sexual maturity.

In LA1 through LA4, Arbib also focuses on primates, but Greys seemingly meet most criteria. For LA1, for example, Alex transfers the use of "none" from responding to "What's same/different?" for two objects when nothing is same or different, to responding to, without training, "What color bigger?" for equally sized objects (Pepperberg & Brezinsky 1991), and then, again without training, to designate an absent quantity in an enumeration task (Pepperberg & Gordon 2005). Furthermore, to Alex, "paper," for example, is not merely index card pieces used for initial training, but large sheets of computer output, newspapers, and students' textbooks. For LA2, Alex comprehends recursive, conjunctive queries (e.g., "What object is green and 3-corner?" versus "What color is wood and 4-corner?" versus "What shape is blue and wool?"; Pepperberg 1992). LA3 has not been demonstrated directly in Greys, but birds likely have episodic memory (e.g., work by Clayton et al. 2003). LA4, learnability, exists with respect to semantics and, to a limited extent, for sentence frames (appropriate use of "I want X" versus "Wanna go Y"; Pepperberg 1999). Interestingly, Arbib's criteria closely parallel Hockett's (1959) design features; direct comparison would be instructive.

Given these parallels, do Grey parrots also have MN systems – neurons that, for example, react similarly when birds hear *and* speak human labels? Biologically, existent evidence is sparse but intriguing. For oscine birds' own song, some parallels exist with primates. Songbirds' high vocal center (HVC) sends efferents to both input and output branches of the song system; HVC is necessary for song production and has neurons showing song-specific auditory responses (Williams 1989). Furthermore, playback of birds' own song during sleep causes neural activity comparable to actual singing (Dave & Margoliash 2000).

How these findings relate to parrot brains, which are organized differently from songbird brains (e.g., Jarvis & Mello 2000; Striedter 1994) is unclear. Although studies of ZENK gene[1] ex-

pression show separation of budgerigar (*Melopsittacus undulates*) response regions for hearing and vocalizing warble song (Jarvis & Mello 2000), electrophysiological studies in the frontal neostriatum of awake budgerigars show activity both in production of and response to calls (Plumer & Striedter 1997; 2000); evidence also exists for additional budgerigar auditory-vocal pathways (e.g., Brauth et al. 2001). Because ZENK response apparently is tuned to specific song features (Ribeiro et al. 1998), the relevance of these data for MNs in talking parrots is unknown.

However, arguments for complex imitation, and by inference, brain structures to support such behavior, exist. Like children described by Arbib, Alex goes beyond simple imitation; he acquires the phonological repertoire, some words, and basic "assembly skills" of his trainers and appears to parse complex behavior patterns (words and phrases) into recombinable pieces and familiar (or semi-familiar) actions. In addition to material described above, Alex (1) recognizes and produces small phonetic differences ("tea" vs. "pea") meaningfully (Patterson & Pepperberg 1994; 1998), (2) produces initial phonemes differently depending upon subsequent ones (/k/ in "key" vs. "cork"; Patterson & Pepperberg 1998), and (3) consistently recombines parts of labels according to their order in existent labels (i.e., combines beginnings of one label with the ends of others – e.g., "banery" [for apples] from banana/cherry. After analyzing more than 22,000 vocalizations, we never observed backwards combinations such as "percup" instead of "cupper/copper"; Pepperberg et al. 1991).

Surprisingly, Arbib doesn't discuss Greenfield's (1991) studies that might also involve co-opting gestural forms for vocal language, although she does not examine MNs and imitation. Apparently, human children – and language-trained chimps, but not monkeys – simultaneously develop hierarchical object and linguistic ordering (e.g., serial cup stacking, phrases like I + want + X) as, Greenfield argues, a consequence of Broca/F5 maturation. MNs in these brain areas are activated by both action and observation of hand or mouth gestures; less advanced MNs exist in monkeys than in apes and humans. Similar behavior is observed in Grey parrots (Pepperberg & Shive 2001), although avian combinations both involve the beak. Greenfield implies that these actions emerge without overt instruction; however, these behavior patterns are likely observed from birth (or hatching). Maybe only after maturation of MN and canonical neuron systems can they be expressed (Pepperberg 2005a).

In sum, the communication system I have taught Grey parrots will never be fully congruent with any current human language, but I am intrigued by the many parallels that can be drawn between their protolanguage and that described by Arbib for early *Homo*: Start with a brain of a certain complexity and give it enough social and ecological support; that brain will develop at least the building blocks of a complex communication system.

NOTE
1. Expression of the ZENK gene, a songbird analog to a human transcription factor, egr-1, is driven by actions of singing and hearing. Hence, it is used to form a functional map of avian brains for behavior related to both auditory processing and vocal production (Jarvis & Mello 2000).