

## S35-2 Simultaneous development of vocal and physical object combinations in the gray parrot (*Psittacus erithacus*): parallels with primates

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**Abstract** Some cognitive abilities of gray parrots (*Psittacus erithacus*) — birds with walnut-sized brains organized differently from those of primates, mammals, and even songbirds — match those of marine mammals, nonhuman primates, and 4–6 year old humans (Pepperberg, 1999); but little attention has been paid to their development. I review a study of co-emergence of communicative and physical object combinatorial skills in parrots (Pepperberg and Shive, 2001) and discuss neurobiological implications.

**Key words** Avian cognition, Comparative cognition

### 1 Introduction

After the “cognitive revolution”, researchers began to accept that nonhuman and human intelligence formed a continuum, to study a wide range of behavior using many techniques in various species, and to overturn negative beliefs about avian cognition (Pepperberg, 2001). Evolutionary theories of intelligence were, however, still built upon analyses of present-day social and cognitive skills in non-human primates that could be ancestral to unique human abilities. But similar abilities may evolve in different ways. Skills comparable to those of primates exist in birds and cetaceans, creatures with different evolutionary histories and differently wired brains (Pepperberg, 2004). Focus on primates will miss insights into the evolution and development of complex cognitive processes, on how development relates to brain function, and how such issues impact on search for analogous/homologous neural bases of behavior. The development of combinatory behavior provides one such caution (Pepperberg and Shive, 2001).

### 2 Co-emergence of object and label combinations

Young children almost simultaneously begin combining objects, behavior supposedly controlled initially by one neural structure (roughly Broca’s area) that, as a child matures, differentiates into specialized areas for language and physical combinations (Greenfield, 1991). After finding that co-emergent spontaneous physical and communicative combinatorial acts of “language”-trained apes (*Pan paniscus*, *P. troglodytes*) were similar to those of young children, Greenfield (1991) proposed that such behavior derives from a homologous structure predating ape and

hominid divergence (Deacon, 1992).

Greenfield (1991) also proposed uniquely primate cognitive connections in seriation (hierarchical) tasks, rule-governed behavior, and early language. Simple seriation, that of putting smaller items into bigger ones, demonstrates elementary ordinality and may relate to grammatical constructs. More complex forms, such as putting C into B, then placing the unit into A, which shows knowledge that B is smaller than A and larger than C, involve multiple, two-way relationships underlying advanced abilities. These include phoneme/word combinations, rudimentary language and syntax (Greenfield, 1991). Such arguments support ideas that spoken language is derived from gesture without major neural restructuring (Hewes, 1973). Co-development of communicative/physical combinations purportedly controlled by one neural center might thus be viewed as unique to primates. But what if Aves exhibited such combinatory behavior?

Study of gray parrot vocal and physical hierarchical combinations began after we observed spontaneous two-object combinations by a bird that had already combined two human vocal labels (Pepperberg and Shive, 2001). Two-item physical and vocal combinations thus are not limited to primate brains. In June 1999, I began examining the nature, extent, and time lines for advanced hierarchical combinations in gray parrots (*Psittacus erithacus*).

### 3 Parrot combinatory behavior

The following summary is drawn from Pepperberg and Shive (2001). The subject gray parrot, Griffin, had never seen humans stacking the items used in the study nor been trained to combine labels or objects. It was being taught single labels (for objects, colors). It heard “want X” and

“wanna go Y” (X and Y, respectively, were items or locations) from another gray parrot (Pepperberg, 1999) and as untrained queries from students. It routinely uttered, “want X” and “wanna go-back” (go back sounded like “g-back”) and untrained color-object phrases.

For object combinations, we used colored plastic or metal bottle caps and lids that Griffin had manipulated previously. Trials initially involved three items; and seven later trials, one per session, involved four. We randomly placed items simultaneously on the counter where it sat, then manually recorded spontaneous behavior. Its actions were never rewarded. A trial ended when Griffin tossed items off the counter. We replaced items and recorded until it began another activity (e.g., eating, preening). Sessions ended when the substitution of new items failed to reengage the bird. Thus its interest dictated the number of trials per session, and trial and session length; it received 50 sessions. A proportion of trials was videotaped, testing transcriptions for inter-observer reliability.

Following Johnson-Pynn et al. (1999), we noted whether and how often Griffin (a) paired two items (pair); (b) put two items successively into a third or placed a third on to a pair (potting); (c) put two-object units into a third (subassembly); (d) combined units out-of-order; (e) picked up new objects versus further manipulation of old; (f) performed other multiple object manipulations; and (g), like apes and *Cebus* but unlike children in Greenfield’s (1991) study, dismantled units. All combinatory efforts were classed as “Attempts”. Successful assemblies stayed together; failures did not fit or fell apart.

In July 1999, a month after the parrot’s first, and for some time only, successful three-item combination, we began training with shape labels, such as “x-corner y”, where  $x=2.5$  and  $y=\text{wood or paper}$ ; a pine pentagon was “5-corner wood”. We recorded vocal combinations outside of training, calculating percentages of two- and three- label combinations. Griffin mostly combined objects in silence;

thus notation of utterances occurred outside those sessions.

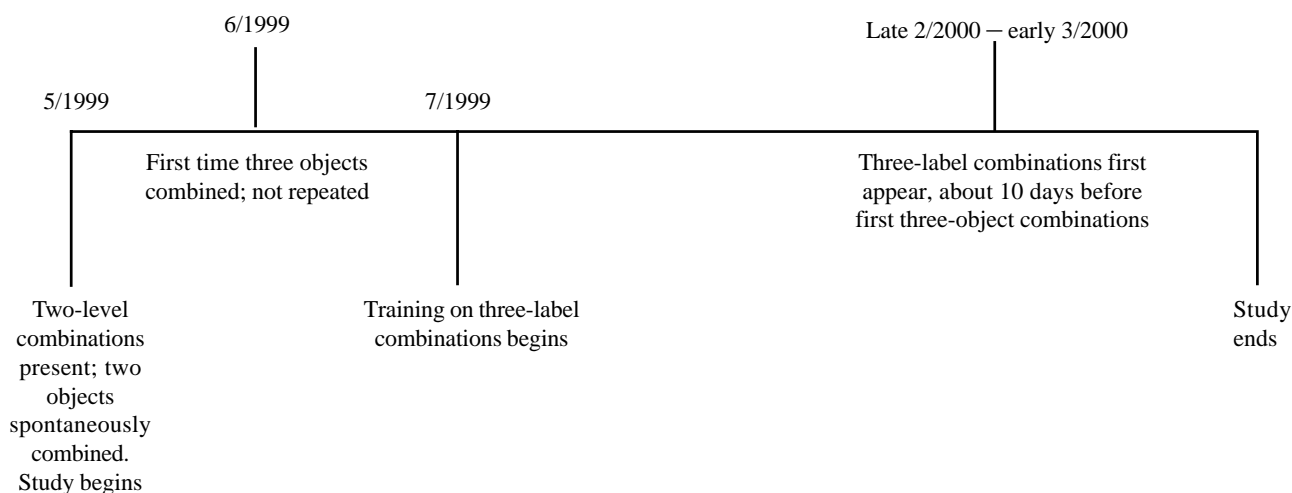
## 4 Results

Using its beak, Griffin consistently combined two of three objects, rarely three (Pepperberg and Shive, 2001). Of 233 attempts, 217 pairings succeeded (93%; binomial test,  $P \ll 0.001$ ). On 65% of trials (141 trials, binomial,  $P < 0.05$ ), he picked units up in his beak, carried them around, threw them off the counter, or, with his beak, flipped the internal object over. Only 38% of successes were not serial ( $P=0.08$ ). Successful potting was rare (7 times; 3% of total attempts, 58% of potting attempts,  $P=0.06$ ), but his first success was in the first month. Subassemblies failed (Pepperberg and Shive, 2001) but co-emerged with spontaneous three-label utterances in early 2000 (Fig. 1).

On 7 trials with four items, Griffin always combined two. Four times it tried but failed at further combinations: it picked up and threw each unit or took it apart to recombine successively. Further attempts were correct but unsuccessful, seemingly because of a lack of dexterity rather than an understanding of seriation.

Other object manipulations (Pepperberg and Shive, 2001) replicated those of children and apes (Greenfield, 1991). Many primate acts, such as the simultaneous lifting of two objects independently, are either prohibited or made difficult by parrot anatomy; but Griffin often simultaneously picked up two objects with sides touching. It also often performed acts of older children (Langer, 1986): transformations (e.g., placing a cap into a ring makes the ring a receptacle) and combinations (e.g., fitting a ring inside a cap), both related to serial actions.

Griffin’s frequency of spontaneous label combinations paralleled physical ones (list in Pepperberg and Shive, 2001). Two-label combinations occurred more often (61%–93% of the time) than single labels. Most two-label combinations (~92%) were hierarchical (e.g., “want+X”, “wanna+X”); others (e.g., “green+X”) might be termed so.



**Fig. 1** Timeline for vocal and object combinations  
From Pepperberg and Shive (2001).

In late February 2000, after eight months exposure, three-label combinations arose (6%–10% of totals), but were rarely those trained. Inter-observer reliability was ~85%; disagreements involved phonetically similar single labels.

Greenfield (1991) also considered phonemic combinations relevant to seriation and syntactical development. Griffin's common phonemic recombinations (e.g., cork/corn) predated this study, but others (e.g., beeper from paper, green, and /b/) developed in early 2000 (list in Pepperberg and Shive, 2001). Notably, Greenfield would consider "Want corn", "Want cork" as three-element serial combinations.

## 5 Discussion

Co-emergence of physical and label combinations is not limited to primates. Griffin simultaneously initiated three-item and -label combinations. Note that (a) percentages of physical and vocal combinations roughly match; (b) despite months of training on x-corner wood/paper, three-label utterances emerged only as Griffin began combining three objects; (c) vocal combinations were rarely those trained; and (d) it executed physical combinations with beak and tongue, not feet. Thus a mammalian brain is not necessary for such behavior, and physical combinations need not be manual.

### 5.1 Manipulative and vocal combinations

Griffin predominantly paired; potting was limited compared to primates. Pottings, successful slightly more than half the time, probably failed because the bird lacked physical dexterity. Subassembly failures did involve impossible combinations.

Humans introduced only a framework for vocal combinations. Of Griffin's spontaneous three-label combinations, only 2-corner wood was trained (1/14); no other trained combinations appeared. Phrases were generally novel, or reproduced what was heard from trainers, not taught by them. Some novel utterances lacked clear syntactic, hierarchical form and were unlikely to have come from trainers.

Might both types of combinations continue developing? Behavior in other gray parrots, as interpreted by Greenfield (1991), suggests that this is likely (Pepperberg and Shive, 2001).

### 5.2 Neural Issues

Mirror neurons might explain co-emergence of primate object and grammatical combinations; avian data are preliminary (see below). Monkey F5 Manes (MNs) are activated by both action and observation of hand and mouth gestures, supporting theories of gesture origins for speech because similar human MNs occur in Boca's area of the brain, including gesture function (Parsons et al., 1995). For monkeys, in which complex hierarchical behavior must be trained (Johnson-Pynn et al., 1999), the observed action is already fixed in the repertoire and is

goal-oriented (e.g., Chaminade et al., 2002; Rizzolatti et al., 2001); great ape MNs have not been studied. Human MNs, however, probably evolved to analyze and developmentally recreate actions to which they are exposed, including speech, where neurons react to activate unobserved muscles.

What might act like MNs in a parrot, an animal that cannot recreate human vocalizations or primate actions in exactly the same manner as humans, even if it achieves the same results? Does exposure to human speech and behavior initiate patterns in the parrot brain analogous or homologous to those of humans? Interestingly, electrophysiological studies in frontal neostriata of awake budgerigars show activity in production of and response to calls (Plumer and Striedter, 2000); evidence also exists for additional auditory-vocal pathways.

Further research must determine what, if any, avian neural substrates mediate co-emergent vocal and physical combinations and if there are differences between bird groups. Neural vocal control pathways differ in oscines and psittacids and, although their vocal learning supposedly arose independently (Jarvis and Mello, 2000), the structures responsible may have been derived from a common ancestor and then lost in some descendants. Interestingly, physical and vocal combinations in both wrens and parrots involve beak and tongue, closer vocal and physical ties than in primates. Such data, and arguments concerning gestural origins for speech without major neural restructuring, support a motor control theory for the origin of song (Nottebohm, 1991) which involves neural substrates similar to those proposed for primates. Arguably, emphasis in future research is best placed on coordinated neuronal activity linking brain areas (Deacon, 1997), and on how alternative neurological means can achieve the same end (Jarvis and Mello, 2000).

## 6 Implications

Co-emergent vocal and physical combinations so far documented in the gray parrot resemble those of primates. Clearly, the behavior of gray parrots is not isomorphic with the language of children or complex combinatory behavior. Nevertheless, (a) combinatory behavior in the gray parrot resembles that of nonhuman primates, (b) parallel communicatory and physical development is not limited to primates, and (c) involved neural structures are unlikely to be unique to primates. How avian neuroanatomy evolved is not yet well enough understood to determine parallels among oscines, psittacines, and primates. The search for such parallels should thus be of high priority.

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