© 2004 Universities Federation for Animal Welfare
The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK

Animal Welfare 2004, 13: S203-208
ISSN 0962-7286

Cognitive and communicative capacities of Grey parrots — implications for the enrichment of many species

IM Pepperberg

Massachusetts Institute of Technology, School of Architecture and Planning, Building 7–231, 77 Massachusetts Avenue, Cambridge, MA 02139, USA; Brandeis University, Department of Psychology, Waltham, MA 02454, USA; impepper@media.mit.edu

Abstract

*Much of my research has been devoted to determining the cognitive and communicative abilities of Grey parrots (*Psittacus erithacus*), but other companion animals and those in captivity in zoos also have considerable capacities that are often under-utilised in such settings. Many such animals are left to their own devices for large parts of the day; their boredom may translate into unsuitable behaviour patterns. In order to address this problem, my colleagues and I began to devise various computer-based 'toys' that would not only provide enrichment in the sense of relieving boredom and reproducing situations somewhat like the challenges faced by animals in the wild on a daily basis, but also would help us determine the extent of these animals' cognitive capacities. Some of these systems allow remote interactions between owners and their pets and others might be adapted for animal–animal interactions. In this paper I will describe these projects, their aims, and our limited progress.*

Keywords: *animal–human communication, animal welfare, avian intelligence, companion animals, computer-based enrichment, Grey parrot*

Introduction

For over 25 years I have taught Grey parrots (*Psittacus erithacus*) meaningful use of English speech (eg to label objects, colours, shapes, categories, quantities, absence). Using this code, my oldest subject, Alex, exhibits cognitive capacities comparable to those of marine mammals, apes, and, depending on the task, those of children around five years of age (Pepperberg 1999). Thus, his abilities are inferred not from operant tasks, common in animal research, but from *vocal* responses to *vocal* questions; that is, he demonstrates intriguing communicative parallels with young humans despite his phylogenetic distance. Related data (eg Reiss & McCowan 1993; Savage-Rumbaugh *et al* 1993; Shumaker *et al* 2001; West & Young 2002; Kilian *et al* 2003) suggest that other companion animals and zoo inhabitants may also have such cognitive, if not communicative, abilities, but that their environments generally do not enable them to exhibit such behaviour patterns, or even patterns like those observed in nature. Many such intelligent animals are left to their own devices for large parts of the day; their boredom may translate into unsuitable behaviour patterns. During my stay at the Massachusetts Institute of Technology (MIT) Media Lab, colleagues and I began to develop computer systems that might alleviate boredom, enable animals to demonstrate their innate cognitive capacities, and enhance animal–human interactions. Many of these systems were based on what we had already determined about how birds, and possibly other animals, learn.

Training Grey parrots to communicate with humans

I was not the first researcher to attempt to establish two-way communication with avian subjects (for details see Pepperberg 1999, 2001). In the 1940s and 1950s, Mowrer (1952, 1954, 1980), using standard conditioning techniques and food rewards unrelated to the labels or concepts being trained, failed to teach English speech to several psittacids (parrots). Some researchers, possibly believing that the social setting of Mowrer's birds was responsible for this failure, attempted to train mimetic birds under more rigorous operant conditions using sound isolation boxes and tapes of human voices — but with little success (Ginsburg 1960, 1963; Grosslight *et al* 1964; Grosslight & Zaynor 1967; RL Gossette 1969, personal communication to OH Mowrer [see Mowrer 1980, pp 105–106]; Gramza 1970). In contrast, Grey parrots that observed two humans interactively model specific vocal dialogues acquired targeted speech patterns (Todt 1975). Todt developed the model/rival (M/R) technique in which humans assume roles played by psittacine peers in the wild. Humans thus demonstrate to the parrots the types of interactive vocalisations to be learned. In Todt's procedure, one human is exclusively the principal trainer of each parrot, asking questions and providing increased visual and vocal attention for appropriate responses. Another human is exclusively the *model* for the parrot's behaviour and simultaneously the parrot's *rival* for the attention of the principal trainer. So, for example, the trainer says "What's your name?" and the human model/rival responds "My name is Lora." Such human interchanges are similar to the duets observed between parrots in large aviaries (Mebes 1978). Todt's parrots learned the model/rival's response often in less than one day, in striking contrast to the slow and sparse acquisition of responses in operant paradigms. The rapidity with which Todt's birds acquired human speech was impressive, but the phrases used did not allow him to determine whether the birds understood their meanings. That is, words and phrases did not refer to specific objects or actions, such as "tickle", to which an experimenter could respond by scratching the bird's head. Thus, Todt's birds may have learned a human-imposed form of antiphonal duetting (ie an elaborate form of contact calling for interacting with social peers [Thorpe & North 1965; Thorpe 1974]) or a simple conditioned response (eg Lenneberg 1971, 1973). Furthermore, Todt's parrots vocally interacted solely with their particular trainer and learned only the phrase or sentence spoken by the model/rival, never that of the principal trainer. Todt's intent, however, had not been to train birds to communicate meaningfully with humans, but only to determine optimal learning conditions.

My students and I adapted Todt's procedure: adding semantic *reference* so that words and phrases referred to specific objects and actions; including *functionality* so that the bird observed that the purpose of learning the odd humans sounds was to obtain desired interactions or objects; and *exchanging roles* of model/rival and trainer, so that the bird saw that the process was interactive, ie that one individual was not always the questioner and the other always the respondent. The extensive *social interaction* between trainers, and among the trainers and the bird, also involved different forms of affect: positive (praise) for correct responses, negative (chiding) for errors. The results of our work are described below (see also Pepperberg 1999). Interestingly, the ape that appears most proficient in symbolic communication, Kanzi (*Pan paniscus*), initially learned to use computer keys to label and request objects by watching his mother's training sessions (Savage-Rumbaugh *et al* 1993); that is, via a form of M/R training. Quite possibly, the M/R technique can be adapted for exhibits in zoo settings as a means of both enhancing the environment and demonstrating the extent of various species' intelligence, much as the orangutan (*Pongo pygmaeus*) 'Think Tank' exhibit has done in the Smithsonian's National Zoo (eg Shumaker *et al* 2001).

Cognitive and communicative abilities of Grey parrots

Using the M/R technique, our oldest subject, Alex, has learned to label more than 50 representative types of objects or materials, seven colours, five shapes, quantities from 1–6, three categories (material, colour, shape), and to use "no", "come here", "wanna go X" and "want Y" (where X and Y are appropriate location or item labels). Alex combines labels to identify, classify, request, or refuse approximately 100 items, and to alter his environment. He processes queries involving concepts of category, relative size, quantity, and the presence or absence of similarity/difference in attributes; he shows label comprehension and he semantically separates labelling from requesting. Alex processes conjunctive, recursive queries to tell us, for example, the material of one object among seven that has a particular colour *and* shape, or the number of green blocks in a collection of green and blue blocks and balls. He understands hierarchical categories; that is, that specific attributes that are labelled "blue", "green" etc are subsumed under a category labelled "colour", whereas the attributes of "3-corner", "4-corner" etc are subsumed under a category labelled "shape". If shown a novel item and told that its "colour" is "taupe", he understands how a second novel object of that hue is to be categorised. He also forms new categories readily. He transferred his knowledge of absence of similarity and difference to respond correctly, without training, the first time he was given two objects of equal size and asked to label the one that was bigger (Pepperberg & Brezinsky 1991). He thus exhibits capacities once presumed to be limited to humans or apes (Premack 1978, 1983). He is not unique: other Grey parrots replicate some of his results (Pepperberg 1999). The questions thus are: a) how does a creature with a walnut-sized brain that is organised differently from that of mammals and even of other birds (Striedter 1994; but see Jarvis & Mello 2000; Jarvis 2002) learn these elements of human language? and b) how do Alex and the other parrots solve complex cognitive tasks that require generalisation and concept formation?

The specific answer as to 'how' their brains function to accomplish these feats of intelligence remains to be discovered, and I can only suggest hypotheses and propose parallels with children. What is clear, however, is that a particular type of input is needed in order for Alex and the other parrots to learn these elements of human language and cognition; that is, to make the transition from simple associations to advanced forms of learning. Specifically, what was it about our M/R modelling technique that made it so successful? Could it be the basis for a new learning paradigm, not only for parrots but also maybe for other species? We embarked upon a series of experiments to answer these questions.

How aspects of training affect/effect learning

We asked what would happen if we began to remove various aspects of input from M/R training: reference (the connections between words or phrases and specific objects or actions), functionality (ie the purposefulness of the labels learned), interaction (amongst trainers and birds), and modelling (the presence of a human model/rival). Table 1 depicts the seven different methods that we used to train our birds, and which aspects of input were lacking in each case. In each experiment, at least two labels were trained via the M/R technique and two different labels were trained with another method. The number of birds involved in each experiment ranged from one to three, but all were birds other than Alex, that is, birds who had no pre-exposure to

Table 1 The effects of different training methods on the ease with which Grey parrots (n = 1–3, depending on the experiment) learned object or material labels (from Pepperberg 2001). See text for details of training methods.

Training method	Features of training method				Evidence of learning?
	Reference?	Functionality?	Interaction?	Modelling?	
M/R	Y	Y	Y	Y	Y
~~Jt~~-Atten	Y	N	Partial	N	N
HAG-dual	Y	Y	Y	Y	Y
HAG-solo	Y	Y	Partial	Y	Y (slow)
HG-solo	Y	Partial	Y	N	Latent
Video	Y	Partial	N/some	Not live	N
Audio	N	N	N	N	N

Y = Yes; N = No

the M/R system. The column 'Evidence of Learning' contains a Y (yes) only if birds demonstrated full, referential use of the label during testing conditions. If birds did not learn after 50 sessions, training ended; birds usually begin to attempt labels at or before 20–25 M/R sessions have occurred. In the experiment labelled '~~Jt~~-Atten' we tested the effects of a lack of joint attention (ie not having the trainer and the bird jointly focusing on the object that the trainer was labelling, such that interaction was considered 'partial'). Here, a student sat with her back to the bird and talked about an object that was within the bird's reach (Pepperberg & McLaughlin 1996). She did not attend to the object nor interact directly with the bird. When children were placed in such a situation, they failed to acquire the object label (Baldwin 1995). The 'HAG-dual' study (HAG = 'Human-Alex-Griffin') tested the effects of using our already-talking parrot, Alex, as an additional trainer (ie a conspecific tutor) of a younger bird, Griffin; the M/R procedure was thus expanded to include a third trainer, although not one with full competence. In the 'HAG-solo' study, Alex was paired with only one of the human trainers in the M/R procedure; because he did not question Griffin directly, some of the normal interaction was missing, and thus was considered 'partial' (Pepperberg *et al* 2000). In the 'HG-solo' study (HG = 'Human-Griffin'), a single student conversed with the bird about the object in question, maintaining joint attention, but eliminating modelling and thus some functionality (Pepperberg *et al* 2000). In the video training, the parrots watched a video of Alex's sessions on a particular label, with various levels of interaction with a single human: from no human present ('none') to a human who would label the object that Alex was receiving in the video ('some') (Pepperberg *et al* 1998; Pepperberg *et al* 1999). In audio sessions, the birds simply heard the audio portion of the same or different videotapes, to ensure that labels were appropriately balanced across conditions (Pepperberg 1994). The final column of Table 1 shows that when any aspect of the modelling was missing, the birds failed to learn the targeted labels, with the intriguing exception of latent learning, which occurred in the HG-solo situation. In this study, after 50 sessions of solo training, Griffin had not uttered the targeted labels even once. When we immediately began to re-train these labels via the M/R technique, however, Griffin began producing them after only two or so sessions, unlike the 20 or so M/R sessions that are usually needed when we switch from, for example, video presentations. Thus, when functionality was not demonstrated via modelling, the bird apparently learned the label, but did not learn what to *do* with it.

These results showed that M/R training gave the birds the tools to learn new labels and concepts, but actually this was not the entire story. First, we found that, like children (eg Hollich *et al* 2000), our parrots' initial learning of labels was slow and difficult, although they could transfer what they learned to novel, related items (eg to pieces of paper other than the various bits of index cards used as initial exemplars), and, like children, later label acquisition was much faster and involved interesting types of transfer and concept formation. Second, we found that considerable learning was occurring outside the training sessions, and that some of this learning was initiated by the birds, much like children playing the 'naming game' (Brown 1973). Detailed discussion of these additional learning strategies can be found in Pepperberg (2001, in press a,b). The main issue however is that, given our knowledge of these abilities and of animals' various approaches to learning, we can use this information to design equipment to further examine their abilities and at the same time to enrich their lives.

Plans for enrichment

When I first arrived at the MIT Media Lab, I was amazed at the variety and number of different ways in which computers and computer–human interfaces were being used to enrich human lives — but only *human* lives. As an ethologist, however, with some knowledge of the intelligence of animals, their natural ecologies, and the ways in which they learn from and interact with their environments, I recognised how this technology could be adapted to non-humans. Such was the origin of the short-lived 'Pet Projects' group.

It was not difficult to obtain data to convince the Media Lab of the importance of animals in the lives of humans, and the concomitant need for animal enrichment. Through an internet search of various sites concerning pet-ownership (eg www. apapets.org; www.avma.org), zoos (eg www.aza.org), and public information (eg www.consumer-reports.org; www.americanbirding.org), my colleagues and

I quickly found that, at least in America: 60% of households have a dog or a cat and that there are over 13 million pet birds; over 50% of pets receive holiday gifts; 94% of people ask about their dog when they are away from home and 26% talk to their dog when phoning home; 25% of dogs share their owners' beds; 30% of dog owners like their dog better than their best friend; and 10% of dog owners like their dog better than their spouse. Furthermore, in America: 'pet owners' are now often legally classified as 'pet guardians', with all of the implications of legal guardianship (eg Landmark Rhode Island 2nd Generation Guardian Bill, HB 5817[http://www.rilin.state.ri.us/Billtext/BillText03/HouseText03/H5817.pdf]; San Francisco File Number 021645 — Pet Guardian Ordinance); humans who own pets are less vulnerable to the adverse health effects of stressful life events (eg Siegel 1990); attendance at zoos, aquariums, wildlife parks, etc, is above that at sporting events; over six million people belong to conservation-related societies; and over 50 million people engage in bird-watching activities. From these sites, we also inferred that zoos are becoming increasingly concerned with enrichment, and that they desire not only to improve the lives of their animals, but also to explain the importance of these improvements to the public.

Thus, not only should we view animals as an inspiration, or as models, for intelligent learning systems, as do many computer scientists (eg see Pepperberg 2001), but also we should begin to use technology to aid research into the cognitive capacities of intelligent non-humans and to improve their lives. One way of doing this is by designing appropriate animal–human–computer interfaces or interactive systems to understand more about the capacities of animals. In the Media Lab, students and I have designed or proposed the following projects, based on the technology available at the lab and current interests of the lab sponsors:

- **Twitcherz** (in collaboration with Jacky Mallet) — an automatic bird-song recogniser that could be used to analyse/classify the songs of different bird species and possibly of individuals, to census birds for conservation, to reproduce vocalisations and to design better interactive playback systems for research. The system could be used to (a) identify other bird species in the target animal's native habitat so that representative songs might be played when the bird is exhibited in captivity, and (b) initiate and maintain appropriate counter-singing bouts with captive birds, both to demonstrate their behaviour to zoo visitors and to make their environments more naturalistic.

- **Bird Sitter** — a system to train companion birds to keep their vocalisations within a specified sound threshold using a reward (a number of different, favoured video clips, which would be updated based on their effectiveness) if vocalisations are below a preset auditory range and no reward (a blank video screen) if vocalisations are too loud. (NB one reason that owners give for putting their pet birds up for adoption is the volume and amount of noise that the birds make [personal observation]; this system therefore has the potential to improve the animal–human bond.)

- **Serial Tr-Hacking for Birds** — a system designed to test whether birds can understand the concept of serial learning; that is, a system that could change the order of serial tasks that a bird must perform in order to receive a reward. This system could also be used for interactive 'turn-taking', so that two individuals (bird–bird or bird–human) must act in turn to earn rewards.

- **PollyGlot Computer** — a system to entertain and to teach labels to parrots, and possibly also to autistic children, using radio-frequency identification (RFID) tagged items and video: as items are picked up by the subject, the RFID tags trigger the computer to show a video about the relevant item. Dropping the item shuts off the video, thereby giving the subject control of the interaction.

- **InterPet Explorer** — a system that allows limited 'web-browsing' for parrots as a form of stimulation. A two-switch controller respectively allows the bird to choose the type of content (video, games, audio, photos) and to make a selection within the content (eg one of four video clips). Content material can be updated as desired.

- **Smart Nest** (in collaboration with Spencer Lynn) — a system designed to record, via Global Positioning System (GPS) tags, infra-red cameras, and RFID tags, the location and interactions of birds in the wild. Information obtained from this system could be used to improve zoological exhibits, for example, to suggest the optimal size of an exhibit based on a species' range in the wild, and thus to determine how many birds of a given species might reasonably co-exist in an exhibit.

- **Cat Bat 'Bot** — an interactive 'mouse' robot that would not only be chased by a cat, but also would tease and chase the cat after a specified period of immobility. This system could be adapted as a means of allowing captive large cats to exhibit predatory behaviour.

- **Congo Conundrum** (in collaboration with Cynthia Breazeal) — a system whereby the actions of an ape on an 'artificial fruit' (Whiten 1998) could be tracked remotely to determine imitative behaviour. Researchers could determine whether an ape exactly imitates the actions and order of actions performed by a human or ape demonstrator, or to what extent the animal responds in an innovative manner. The 'artificial fruit' itself is a puzzle box, designed to necessitate some of the manipulations inherent in foraging in the wild in order to obtain food, and therefore acts to enrich the captive animal's environment; tracking an animal's behaviour could lead to improved design of the artificial fruit and, as a consequence, the animal's environment.

- **Rover@home** (in collaboration with Benjamin Resner and Bruce Blumberg) — a system whereby dog owners could interact with their pets via remote connections over the internet: a home computer tracks the dog's actions and rewards the dog via a clicker-training system, and an office computer allows the owner to view the dog's behaviour, give commands, and reward the dog for correct responses.

Conclusions and animal welfare implications

Although none of these systems could be developed beyond 'proof of concept' before the project ended (ie we had prototypes for all or parts of these projects, which could be demonstrated to lab sponsors, but nothing that was functional for an extended period), I believe that these systems demonstrate a possible future of technology to improve animal welfare. We can use knowledge of how animals learn and how appropriate training methods can 'unlock their potential' (M/R training being one such demonstration), together with technology, to expand interest in toy development from children to pets, to learn more about wild animals and the abilities of zoo inhabitants, and possibly even to enable remote interactions among pets, wild animals, zoo inhabitants, and humans. Furthermore, some of these systems could be adapted for use with differently-abled humans; they can also teach us about designing novel interfaces (ie new ways to facilitate interactions with computers), can enhance the animal–human bond and the lives of captive animals, can improve the quality of field and captive research, and, possibly, can be used in conservation programs to monitor animals' environments — information which can also be used to assist in the design of exhibits for their captive counterparts.

Acknowledgements

I thank the Media Lab for the support of all the computer-based work, and my colleagues there for the wonderful environment they provided. Research on parrot cognition was supported by grants from the United States National Science Foundation, the American Foundation, the Kenneth A Scott Charitable Trust, The Pet Care Trust, the University of Arizona Undergraduate Biology Research Program, and donors to The Alex Foundation (particularly the Pearl Family Foundation).

References

Baldwin D A 1995 Understanding the link between joint attention and language. In: Moore C and Dunham P J (eds) *Joint Attention: its Origin and Role in Development* pp 131-158. Erlbaum: Hillsdale, New Jersey, USA

Brown R 1973 *A First Language: The Early Stages*. Harvard: Cambridge, Massachusetts, USA

Ginsburg N 1960 Conditioned vocalization in the budgerigar. *Journal of Comparative and Physiological Psychology 53*: 183-186

Ginsburg N 1963 Conditioned vocalization in the mynah bird. *Journal of Comparative and Physiological Psychology 56*: 1061-1063

Gramza A F 1970 Vocal mimicry in captive budgerigars (*Melopsittacus undulatus*). *Zeitschrift für Tierpsychologie 27*: 971-983

Grosslight J H and Zaynor W C 1967 Vocal behavior of the mynah bird. In: Salzinger K and Salzinger S (eds) *Research in Verbal Behavior and Some Neuro-Physiological Implications* pp 5-9. Academic Press: New York, USA

Grosslight J H, Zaynor W C and Lively B L 1964 Speech as a stimulus for differential vocal behavior in the mynah bird (*Gracula religiosa*). *Psychonomic Science 11*: 78

Hollich G J, Hirsh-Pasek K and Golinkoff R M 2000 Breaking the language barrier: an emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development 262*: 1-138

Jarvis E D 2002 Evolution of vocal learning and associated brain structures in birds. *Unpublished Proceedings of the 23rd International Ornithological Congress, 11–17 August 2002, Beijing, China*

Jarvis E D and Mello C V 2000 Molecular mapping of brain areas involved in parrot vocal communication. *Journal of Comparative Neurology 419*: 1-31

Kilian A, Yaman S, von Fersen L and Güntürkün O 2003 A bottlenosed dolphin discriminates visual stimuli differing in numerosity. *Learning and Behavior 31*: 133-142

Lenneberg E H 1971 Of language, knowledge, apes, and brains. *Journal of Psycholinguistic Research 1*: 129

Lenneberg E H 1973 Biological aspects of language. In: Miller G A (ed) *Communication, Language, and Meaning* pp 49-60. Basic Books: New York, USA

Mebes H D 1978 Pair-specific duetting in the Peach-faced Lovebird. *Naturwissenschaften 65*: 66-67

Mowrer O H 1952 The autism theory of speech development and some clinical applications. *Journal of Speech and Hearing Disorders 17*: 263-268

Mowrer O H 1954 A psychologist looks at language. *American Psychologist 9*: 660-694

Mowrer O H 1980 *Psychology of Language and Learning*. Plenum Press: New York, USA

Pepperberg I M 1994 Vocal learning in African Grey parrots: effects of social interaction. *Auk 111*: 300-313

Pepperberg I M 1999 *The Alex Studies*. Harvard University Press: Cambridge, Massachusetts, USA

Pepperberg I M 2001 Lessons from cognitive ethology: animal models for ethological computing. In: Balkenius C, Zlatev J, Kozima H, Dautenhahn K and Breazeal C (eds) *Proceedings of the First International Workshop on Epigenetic Robots, September 17–18 2001, Lund, Sweden*. Lund University Cognitive Science Series Number 85. Available at: http://www.lucs.lu.se/Abstracts/LUCS_Studies/LUCS85.html

Pepperberg I M Evolution of communication from an avian perspective. In: Oller K and Grieble U (eds) *Evolution of Communication*. MIT Press: Cambridge, Massachusetts, USA (in press a)

Pepperberg I M Insights into vocal imitation in Grey parrots (*Psittacus erithacus*). In: Hurley S L and Chater N (eds) *Perspectives on Imitation*. MIT Press: Cambridge, Massachusetts, USA (in press b)

Pepperberg I M and Brezinsky M V 1991 Relational learning by an African Grey parrot (*Psittacus erithacus*): discriminations based on relative size. *Journal of Comparative Psychology 105*: 286-294

Pepperberg I M and McLaughlin M A 1996 Effect of avian–human joint attention on vocal learning by Grey parrots (*Psittacus erithacus*). *Journal of Comparative Psychology 110*: 286-297

Pepperberg I M, Gardiner L I and Luttrell L J 1999 Limited contextual vocal learning in the Grey parrot (*Psittacus erithacus*): the effect of co-viewers on videotaped instruction. *Journal of Comparative Psychology 113*: 158-172

Pepperberg I M, Naughton J R and Banta P A 1998 Allospecific vocal learning by Grey parrots (*Psittacus erithacus*): a failure of videotaped instruction under certain conditions. *Behavioural Processes 42*: 139-158

Pepperberg I M, Sandefer R M, Noel D and Ellsworth C P 2000 Vocal learning in the Grey parrot (*Psittacus erithacus*): effect of species identity and number of trainers. *Journal of Comparative Psychology 114*: 371-380

Premack D 1978 On the abstractness of human concepts: why it would be difficult to talk to a pigeon. In: Hulse S H, Fowler H F and Honig W K (eds) *Cognitive Processes in Animal Behavior* pp 421-451. Erlbaum: Hillsdale, New Jersey, USA

Premack D 1983 The codes of man and beasts. *Behavioral and Brain Sciences 6*: 125-167

Reiss D and McCowan B 1993 Spontaneous vocal mimicry and production by bottlenose dolphins (*Tursiops truncatus*): evidence for vocal learning. *Journal of Comparative Psychology 107*: 301-312

Savage-Rumbaugh S, Murphy J, Sevcik R A, Brakke K E, Williams S L and Rumbaugh D M 1993 Language comprehension in ape and child. *Monographs of the Society for Research in Child Development 233*: 1-258

Shumaker W, Palkovich A M, Beck B B, Guagnano G A and Morowitz H 2001 Spontaneous use of magnitude discrimination and ordination by the orangutan (*Pongo pygmaeus*). *Journal of Comparative Psychology 115*: 385-391

Siegel 1990 Stressful life events and use of physician services among the elderly: the moderating role of pet ownership. *Journal of Personality and Social Psychology 58*: 1081-1086

Striedter G 1994 The vocal control pathways in budgerigars differ from those in songbirds. *Journal of Comparative Neurology 10*: 1541-1556

Thorpe W H 1974 *Animal and Human Nature*. Doubleday: New York, USA

Thorpe W H and North M E W 1965 Origin and significance of the power of vocal imitation: with special reference to the antiphonal singing of birds. *Nature 208*: 219-222

Todt D 1975 Social learning of vocal patterns and modes of their applications in Grey parrots. *Zeitschrift für Tierpsychologie 39*: 178-188

West R E and Young R J 2002 Do domestic dogs show any evidence of being able to count? *Animal Cognition 5*: 183-186

Whiten A 1998 Imitation of the sequential structure of actions by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology 112*: 270-281