Pattern Recognition and Prepositions: Testing African Grey Parrots on the Concept of "In"

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Abstract

Prepositional phrases make up a key component of human language; understanding prepositional phrases helps humans communicate spatial information. The comprehension of spatial relationships between objects is not restricted to *Homo sapiens*; for most animals, a measure of spatial understanding would be beneficial for survival. We demonstrated the different age-based abilities of Congo African Grey Parrots (*Psittacus erithacus*) to not only understand the basic concept of "In" but also their abilities to comprehend increasingly complex visual patterns. We presented colored cups stacked in different orders to the parrots, and asked them to distinguish between the different patterns (pick blue IN yellow vs yellow IN blue). The study demonstrated that a 23-year old parrot answered experimental trials correctly 75% of the time without retrials compared with only 58% in a 4-year-old parrot. The older parrot was also more successful when transferring the concept tested to other colors. The data suggest that both birds developed an understanding of the concept of "In" in cup-stacking selection tasks. This study could be used as a precursor for other studies testing other prepositions or patterns, or as a precursor for recursion (a linguistic property in which limitless grammatical insertions or extensions can logically exist).

Introduction

Animal Cognition

Animal cognition is the field of study that focuses on the mental capabilities of non-human animals. Studies centered on animal cognition seek to explain and define animal behavior through mental processes and cognitive states, as opposed to assuming all behaviors arise from genetically pre-programmed responses to external stimuli. A key feature of the cognitive approach is a focus on the individual animal and its specific internal processes; without a focus on the individual, scientists may incorrectly attribute externally similar behaviors to similar cognitive processes and mental states. The major assumptions of cognition-based studies are that animals have internal cognitive networks that are developed and modified throughout the lifetime of an individual organism (Roitblat et al. 2016). Experiments in the field of animal cognition have been conducted in a variety of organisms from many different taxonomic groups, from scrub jays (*Aphelcoma coerulescens*) to bottlenose dolphins (*Tursiops truncatus*) to rodents (Bekoff 2010, Shuttleworth 2001). This paper involves the subset of cognition studies known as communicative avian cognition. Avian cognition studies have encompassed a wide variety of behaviors, especially language development and object permanence.

Interspecies Communication

Historically, interspecies communication, or communication between two species (especially between humans and other animals), was difficult to study accurately and objectively; nowadays, however, there are improved ways of understanding interspecific communication (Pepperberg 2016). What is communicated from the perspective of the human has been clear, but it was often significantly more difficult to understand what was being communicated from the animal's perspective (Pepperberg 2016). The development of a bi-directional code, however, can mitigate this uncertainty. Bi-directional codes are communication strategies that are understood by both the researcher and the study subject, and consist of a wide range of systems, from language-based codes such as ASL (American Sign Language) or English phrases to token-based systems. As long as each phrase or unit in the code represents a distinct concept or idea (i. e., is symbolic), information can be conveyed successfully between scientist and subject. Once a two-way communication method is established (and both scientist and subject can understand what information is being conveyed), researchers can ask increasingly complex questions (Pepperberg 2002). A variety of studies have shown that Grey Parrots are not only able to learn labels for objects, concepts, and categories (including colors, numerals, materials, and locations), but are able to combine these labels in meaningful ways to interact and communicate with human researchers (Pepperberg 1981, 1987, 1996).

Language Development

In humans, many cognitive abilities are expressed through language use; it thus makes sense that many researchers turn to species-specific language or communication development to test and understand cognitive processes in these species (Pepperberg 1991). By studying animal communication, researchers can hope to understand not only the information being communicated but also the cognitive processes underlying the communicative behaviors and the cognitive abilities these behaviors may express. Grey Parrots (*Psittacus erithacus*), for example, are very good at mimicking human speech, and have been extensively studied by a number of labs (Todt 1975, Peron et. al. 2010, 2011, Cruickshank et al. 2008, Pepperberg 1981, 1987, 1991). Studies have shown that not only do these parrots develop language in similar ways to humans, but also that Grey Parrots will combine already learned phonetic units and vocalizations to create new labels (Pepperberg 2007).

Prepositions

The development of prepositional understanding has been studied extensively in children (Meints et al. 2002, Geert 1986, Tomasello 2009). Research has shown that the first sets of prepositions learned and understood by human children are the opposing pairs “in-out” and “on-off/under” (Meints et al. 2002, Geert 1986, Tomasello 2009). Thus, if animals (especially Grey Parrots) are also able to develop understandings of prepositions, it is likely that these pairs are also the first relations acquired; thus, my study focused on “In”. Kako (1999) explored the language abilities of three language-trained animals (Alex the Grey Parrot, Ake and Phoenix the bottlenose dolphins (*Tursiops truncatus*), and Kanzi the bonobo (*Pan paniscus*)). Kako concluded that further testing is required to tease apart whether these species can understand prepositions as modifiers as opposed to commands (prepositions being considered closed-class elements in his study), although he noted that these species can understand spatial relations between objects and themselves (with definitive proof from Kanzi and the dolphins). More recent papers have discussed the abilities of Grey Parrots to understand prepositions and the spatial relations between objects, and it can be assumed from certain behaviors that Grey Parrots may understand prepositions (Pepperberg, 1999). No study, however, has definitively proven that animals understand prepositions as individual words as opposed to modifiers.

Model-Rival Technique

The model/rival (M/R) technique is an interactive form of training, and relies upon social interactions and role-play to teach the subject concepts (Todt 1975, Pepperberg 1994). The subject, a parrot, watches two humans interacting with certain objects or participating in a task, and views a question-answer session conducted between the humans. The roles in this training technique are trainer (who asks the questions), the model/rival (who acts as both the model for the parrot and the rival for the trainer's attention), and the observer (most frequently the parrot watching the interaction). The "trainer" human asks the "model/rival" human a question about an item or a procedure, and rewards the model with praise and the object in question when the model answers correctly (see Figure 1). The model also makes incorrect responses, to copy what the parrot may do, and is consequently scolded by the trainer, and has the object in question temporarily removed from view. The presentation or removal of the object represents a referential reward or punishment for the model and, by association, the parrot. The parrot is then treated as the model/rival for the original model human, and the trainer asks the parrot questions similar to what was asked of the human model. The parrot is rewarded or scolded in the same manner as described earlier when it answers, leading to referential learning based on social interactions.

Other laboratories that use the M/R technique often do not interchange the roles of model and trainer; that is, one human always plays the role of model and one human always plays the role of trainer (Todt 1975). In our lab, the roles of model, trainer, and observer are constantly being shifted, helping the parrot understand that specific roles are not tied to specific humans (Pepperberg 1994). This allows any human to ask the parrots questions without worrying about the parrot only associating questions with one specific person.

Pepperberg Lab

In the Pepperberg lab, Grey Parrots have been taught basic English labels using the model-rival technique (discussed above) for a variety of concepts and categories including color, shape, number, relative size, and material. These labels make up the basis for the two-way communication system employed in the lab; by using simple, condensed phrases (e.g. "What matter" instead of "What is this made of"), researchers can garner an understanding of the birds' cognitive capabilities. The importance of a flexible, language-like communication system shows itself when considering representational tasks. When using a communicative (as opposed to operant) approach to label acquisition, subjects learn labels for specific attributes of objects, as well as overarching categories into which these attributes fit (such as orange, blue, and yellow being in the category of "color"). When approached with a question such as "What's different," among a set of objects, the birds must first recognize the question, assess all of the attributes of the objects presented, and then choose a word to correctly answer the question (see Figure 2). In this case, a category is being queried (such as color, shape, or matter). Attribute-specific questions can also be posed, such as "What color bigger" or "How many green blocks" (Pepperberg, 2002).

Hypothesis

If African Grey parrots (Psittacus erithacus) of two ages (23yrs and 3yrs) are exposed to different arrangements of stacked cups, they will both be able to identify the correct pair of cups requested by the researcher. Thus, African Grey parrots will be able to understand the meaning of the preposition "In" as a modifier in relation to this experiment. Furthermore, once the initial trial set is complete, both parrots will be able to transfer the concept over to different colors and arrangements of cups, and the older parrot will understand the concept faster than the younger parrot.

Materials and Methods

Materials Required

- 2.5 foot tall stool
- Work perch (2.5 feet tall)
- 12in X 8in X 1.5in tray
- Colored cups (Red, Blue, Green, Yellow, Orange)
    - Two "size 5" cups of each
    - Two "size 7" cups of each
- Cashews
- Zo's (cheerios)

Methods: Subjects

The subjects of the study were two Congo African Grey Parrots. Griffin was a 23-year old male, and had been used in a variety of other studies in the lab, including object permanence, vocal tasks, and numerical competence tasks. Athena was a 4-year old female, who had been used on a few other studies in the lab, such as conservation and object permanence.

Methods: Griffin

All trials were conducted in the lab, some by myself and others by Dr. Pepperberg and an RA I trained in the correct protocol. The setup consisted of a project perch (approximately .75m tall) placed directly behind a wooden stool of the same height. There was a 7.5cm gap between the edge of the stool and the perch. A thick (3.8cm) tray was placed on top of the stool, with two X markings (9cm apart) on the tray indicating where to put stacked cups. The two X's were drawn in pencil on top of the tray, equidistant from the center of the work perch. For Griffin, the X's were drawn to take into account Griffin's arthritis and reluctance to lean to one side. Red, blue, yellow, and green plastic cups were required. Two cups of each size were needed: two "size 5" plastic cups and two "size 7" plastic cups. The reward for a correct answer was ¼ of a cashew. The locations at the front of the tray were referred to as Left or Right from the researcher's perspective (behind the stool) (see Figure 3).

For the Yellow/Blue protocol (the first experiment), the setup was as outlined above. Data sheets were randomized for the position of the cups and the side that was being asked for. Once all of the data sheets were ready, the first trial began. The procedures were as follows. Griffin was placed in the center of the work perch and was told to "wait". Griffin was asked if he was ready to get a nut, and if he responded positively (showed interest), setup of the cups began. Two size 7 cups (one blue and one yellow) were placed on the white tray on top of the marked X's. The smaller cup of the reverse color was then placed inside the larger cup, leading to two sets of stacked cups. Starting with the right stack, the researcher picked up the inner cup of the stack with his or her right hand and showed it to Griffin, saying "Look Griff! We have **Color 1** (blue or yellow) **IN Color 2** (yellow or blue)" while placing the smaller cup into the larger cup, showing stacking. Using the same hand, the researcher then repeated this process with the stack on his or her left side. Then, the researcher lifted up the stacked set of cups on the right side, tilting them forward slightly to let Griffin see into the cups. The same process was repeated with the left stack. After the process was completed, the researcher touched the tops of both stacks of cups (to avoid any sort of cueing) and said "Alright Griff, you ready? Pick Color 1 **IN** Color 2. Color 1 **IN** Color 2." While maintaining eye contact with Griffin's head, again to avoid cueing, the researcher pushed the tray forward. Griffin then chose a stack of cups by grabbing it with his beak (see Figure 4).

If he answered correctly, he was rewarded with the nut piece and praise in the form of "Yes Griff! That's right! Color 1 **IN** Color 2!". If he answered incorrectly, the researcher said "No, that's wrong" and conducted a quick retrial. A word-by-word protocol is described at the bottom of the methods section. Griffin quickly mastered the Yellow/Blue trials and was able to move on to other color combinations (Yellow/Red and Blue/Red). The protocols for these trials were identical to the ones outlined above; they were simply done using the new colors.

Methods: Athena

The protocol for Athena's trials was very similar to Griffin's trials. For Athena's trials, her reward was ¼ of a Zo (cheerio). When testing Athena, it was exceedingly important to pay attention to her behavior when asking her if she was ready to work. If she was not focused on the reward or did not give an audible cue referencing a desire to work (saying "Zo" or "yes"), she would not pay attention to the task. Athena would then refuse to answer, either by ignoring the cups or stepping onto the tray and rolling over on the cups. She would also answer randomly or incorrectly, by simply throwing the cups at the researchers or tapping both stacks in a short period of time (less than 1sec). Athena was not offered retrials, as she would immediately distract herself after answering her initial trials. Thus, retrials were unable to be performed due to her lack of focus.

Methods: Step-by-Step Protocol: Griffin

1. Place Griffin in the center of the perch, make sure he is alert and focused. Say "Alright Griff, are you ready to get a nut?"
    a. If positive response, move on to step 2
2. Starting with the researcher's right side, use one hand to pick up the inner cup and show it to Griffin

   a. Hold the cup first by his eye and lower it down into the larger cup, showing the stacking
   b. While lowering the cup into the larger cup, say "Ready Griff? Look! We have Color 1 (Yellow or blue) **IN** Color 2. You see Griff? Color 1 **IN** Color 2"
   c. Should take approximately 6-8 seconds to complete this step
3. Use the same hand to pick up the inner cup on the left side and show it to Griffin
   a. While stacking the cup, look at Griffin and say "and we have Color 1 **IN** Color 2. Color 1 **IN** Color 2"
4. Hold up the right side stack of cups, tilting them forward slightly
   a. Show them to Griffin by holding it first to his right side, then to his left, and once more to his right (see attached Image 1A for clarification)
      i. Hold arm steady in front of Griffin's face and swing wrist from right side to left side to show the cups
   b. Say "You see, Griff? Color 1 **IN** Color 2"
5. Repeat step 4 using the left side cup stack
6. Say "Alright Griff, you ready? Pick Color 1 **IN** Color 2. Color 1 **IN** Color 2." Push tray forward while maintaining eye contact with Griffin's head (to avoid signaling)
   a. If correct, reward with nut while saying "Yes Griff! That's right! Color 1 **IN** Color 2!" and pulling back the incorrect cup stack
   b. If incorrect, say "No, that's wrong" and conduct a quick retrial
      i. For the retrial: If correct, reward as per step 6a
      ii. For the retrial: If incorrect, say "No, that's wrong"

Methods: Statistical Analysis

One-tailed binomial tests were conducted to quantify the significance of both Athena and Griffin's results, with $p<.05$ being the cutoff for statistical significance. One-tailed binomial tests were chosen because the data obtained fell into two categories: correct and incorrect. Since the data could be divided evenly between these two answer choices, one-tailed binomial tests are appropriate. The null hypothesis assumes that there is a 50% chance of each answer being chosen (thus random). The one-tailed binomial test calculates the probability that the number of correct answers chosen by Griffin or Athena is not due to chance, as predicted by our hypothesis (and thus due to understanding the experiment).

Results

Griffin

Yellow/Blue: The data were analyzed both with and without taking into account retrials. When looking at all of the Yellow/Blue trials, Griffin initially got the first few trials wrong, but quickly began to understand the concept. Counting all retrials as incorrect answers (e.g. only looking at his first responses), Griffin answered 15/24 correctly, or about 63% correctly. In the first 10 trials, Griffin answered correctly on 4/10 trials. When including correctly answered retrials with correct answers, Griffin answered 21/24 correctly, or 88% correctly (see Table 1 and Figure 5).

When considering all retrials as incorrect answers, Griffin's responses were not statistically significant for the Yellow/Blue trials; 15/24 = 63%, $p=.15$ with a chance value of 1/2. When considering correct retrials as correct answers, Griffin's responses were statistically significant; 21/24 = 88%, $p=.0003$ with a chance value of 1/2.

Red/Yellow: When it appeared that Griffin understood the question (pick color 1 in color 2), we switched to another set of colors (Red/Yellow). Griffin immediately began answering correctly in the transfer trials, showing he understood how to transfer the concept he was tested on in Yellow/Blue to different colors. When looking at all of the Red/Yellow trials, and counting all retrials as incorrect answers (looking only at his initial responses), Griffin answered 13/16 trials correctly, or 81%. When counting correct retrials as correct answers, Griffin answered all 16 trials correctly, or 100% (see Table 1 and Figure 5).

When considering all retrials as incorrect answers, Griffin's responses were statistically significant for the Red/Yellow trials; 13/16 = 81%, $p=.01$ with a chance of 1/2. When considering correct retrials as correct answers, Griffin's responses were statistically significant;16/16=100%, $p<.0001$ with a chance value of 1/2.

Red/Blue: Griffin was able to transfer to another set of colors while I was at the lab (Red/Blue), and when looking only at initial responses, answered 14/16 correctly (88%). When looking at correct retrials, Griffin answered 100% correctly (see Table 1 and Figure 5).

When considering all retrials as incorrect answers, Griffin's responses were statistically significant for the Red/Blue trials; 14/16 = 88%, $p=.003$ with a chance value of 1/2. When considering correct retrials as correct answers, Griffin's responses were statistically significant;16/16=100%, $p<.0001$ with a chance value of 1/2.

Griffin Overall: When looking at all of the data together, counting all retrials as incorrect answers, Griffin answered 42/56 correctly, which is statistically significant; 42/56 = 75%, $p=.0002$. When counting correct retrials as correct answers, Griffin answered 53/56 correctly, which is statistically significant; 53/56 = 95%, $p<.0001$. All results are outlined and summarized in Figure 5 and Table 1.

Athena

Yellow/Blue: Athena in general was less willing to work on the study, but we were able to collect some data from her. She had some trouble at first with the task, answering the first 4 trials in a row incorrectly. After that, however, she answered 7 of the next 8 trials correctly. Overall, Athena answered 7/12 trials correctly (58%). Fewer trials were conducted with Athena because she is currently a subject in two other studies and she has a hard time focusing on multiple experiments at once (see Table 2).

Overall Athena: When considering all of the trials, Athena's responses were not statistically significant, with significance being determined by $p<.05$. When looking at the last 8 trials, however, she scored 7/8 correctly (88%), which is statistically significant ($p=.04$) given a chance value of 1/2. All results are summarized in Table 2.

Discussion

The data obtained in this study support our hypothesis that at least one of the subjects (Griffin), if not both, developed a basic understanding of the preposition “In”. Previously, the birds had been exposed to the word “In” in the lab simply as a byproduct of normal conversation; they had not, however, been exposed to the word in an experimental setting before. As both Griffin and Athena answered incorrectly on the first three trials, it is assumed that both birds were initially unsure of the meaning of “Pick ___ IN ____.” The later shift to answering correctly indicated that the birds learned the meaning of the preposition “In” as a modifier for the cups. Rigid procedures were followed to ensure a lack of bias and cueing, as outlined in the methods above.

Griffin: As the trials progressed, there was a clear point at which Griffin seemed to understand what was being asked of him; after approximately the 10th trial, Griffin began to answer correctly on almost all of his trials, and transferred the concept to the other color combinations successfully. Griffin was significantly older than Athena, and was able to concentrate well on tasks if there was a desired reward (a nut). The difference in age and maturity between Griffin and Athena is one possible explanation for Griffin’s better performance on the task. Griffin can spontaneously develop a lack of interest or “boredom” for new studies relatively quickly. Because of this, we limited trial sets to five trials per day, as to avoid overexposing Griffin to the study.

Athena: Athena was more difficult to work with than Griffin. Perhaps because she is still a young bird, she was easily distracted and often refused to pay attention to researchers or to the experimental apparatus. When Athena actively paid attention, it was clear that she was able to understand our questions and pick an answer choice. Often times, however, when we would present her with the cup experiment, she would refuse to answer and begin preening, start yawning and falling asleep, or throw cups off the experimental tray. As in human children, age (through adolescence) is correlated with mental development and the ability to concentrate for longer periods of time; as Athena ages, her focus may improve. Only during the trials where Athena paid attention and watched the researcher closely did we receive usable data from her.

The results from this study thus provide evidence for some prepositional understanding by Grey Parrots. By having the birds choose from different arrangements of the same colors, the birds could not simply choose whichever colors were familiar. They needed to pay attention to the way we asked the question and the order of colors before and after the preposition (e.g., pick Blue IN Yellow vs pick Yellow IN Blue). As Griffin was both statistically significant and highly accurate in his trials, there is solid evidence that he understood the query and the use of the word "In" in our trials. Athena was also at a level above random in her trials, and we thus suspect that she also understood the meaning of the word "In" as used in our experiment.

There are a variety of ways we hope to expand upon this study with both Griffin and Athena. First, increasingly difficult patterns should be presented. By adding more cups to the stacking sequence (3 or 4 layers of cups, for example), we will be able to see whether Griffin and Athena are able to understand complicated layering, and distinguish between different orders of stacked cups (Pick B in Y in G vs G in Y in B, etc.). If the birds are able to understand the complex rearrangements in later portions of this study, we can move on to pattern completion. Another follow-up would be to introduce colors of cups to the study that Griffin or Athena have no name for yet; for example, Griffin does not have a label for the color Black. We could then see whether the birds need labels for all the colors they see to be able to comprehend "In."

Further studies could test whether the birds could develop understanding of other concepts (namely prepositions). It has already been proven that Grey Parrots can understand the concepts of same/different (Pepperberg 1987) bigger/smaller (Pepperberg & Brezinsky 1991), and can even categorize objects (Pepperberg 1987). These concepts all are considered relations between objects based on physical properties. It would be interesting to explore whether Grey Parrots are similarly capable of understanding a wide variety of spatial relations between objects, using prepositions such as under, over, out, etc.

Finally, a later study should test whether the birds could complete visual patterns based on cup stacking. For example, a stack of cups could be layered as so: B/Y/B ____. The birds could then be asked to select "What's Next," and presented with a variety of cups in different colors to choose from. If Griffin or Athena were able to understand the question and select the color that comes next in the pattern, the study could move on to expanding these patterns in both directions. After "What's Next" would be "What's Before," and if the birds are shown to understand that patterns can continue endlessly in both directions, this could be a direct precursor to recursion. Previous studies have shown that animal vocalizations, including complex birdsong, can be viewed as precursors for the recursive patterns needed to communicate in human languages (Berwick et al. 2011, Cate 2016). Recursion is the phenomenon in which a sentence or a pattern can have no limit in length; infinite grammatical or pattern units can be added to the inside or either end of the sentence or pattern (while still making grammatical or logical sense). (Corballis 2007). Recursion can be broken down into two types: center-embedded recursion and tail-recursion (which covers both left and right recursion). In center-embedded recursion, a phrase can be inserted and re-inserted into the center of a grammatical unit or pattern and still have logical meaning. In tail-recursion, phrases are added to the beginning or end of a grammatical unit or pattern. Recursion studies involving stacked cups would be a precursor to tail-recursion, as the birds would answer questions about what comes before or next in a pattern.

References

Bekoff, Marc, et al. *The Cognitive Animal: Empirical and Theoretical Perspectives on Animal Cognition*. MIT Press, 2010

Berwick, R. C., Okanoya, K., Beckers, G. J. L., & Bolhuis, J. J. (2011). Songs to syntax: The linguistics of birdsong. Trends in Cognitive Sciences, 15, 113–121.

Cate, Carel Ten (2016). Assessing the Uniqueness of Language: Animal Grammatical Abilities Take Center Stage. *Psychonomic Bulletin & Review*, vol. 24, no. 1, pp. 91–96.

Corballis, Michael C. (2007). Recursion, Language, and Starlings. *Cognitive Science*, vol. 31, no. 4, pp. 697–704., Cruickshank, Alick J., et al. (2008). Vocal Mimicry in Wild African Grey Parrots Psittacus Erithacus. *Ibis*, vol. 135, no. 3, pp. 293–299.

Kako, Edward. (1999). Elements of Syntax in the Systems of Three Language-Trained Animals. *Animal Learning & Behavior*, vol. 27, no. 1, pp. 1–14.

Pepperberg, Irene M. (1981). Functional Vocalizations by an African Grey Parrot (Psittacus Erithacus). *Ethology*, vol. 55, no. 2, pp. 139–160.

Pepperberg, Irene M. (1987). Evidence for Conceptual Quantitative Abilities in the African Grey Parrot: Labeling of Cardinal Sets. *Ethology*, vol. 75, no. 1, 12 Jan, pp. 37–61.

Pepperberg, Irene M. (1987) Acquisition of the Same/Different Concept by an African Grey Parrot (Psittacus Erithacus): Learning with Respect to Categories of Color, Shape, and Material. *Animal Learning & Behavior*, vol. 15, no. 4, pp. 423–432.

Pepperberg, Irene M. (1991). A Communicative Approach to Animal Cognition: A Study of Conceptual Abilities of an African Grey Parrot. In *COGNITIVE ETHOLOGY: essays in honor of donald r. griffin* (pp. 153-186). Hillsdale, NJ: Lawrence Erlbaum Associates.

Pepperberg, I. M., & Brezinsky, M. V. (1991). Acquisition of a relative class concept by an

African gray parrot (Psittacus erithacus): Discriminations based on relative size. *Journal of Comparative Psychology,* vol. 104, no.3, pp. 286-294.

Pepperberg, Irene M. (1994). Vocal Learning in Grey Parrots (Psittacus Erithacus): Effects of Social Interaction, Reference, and Context. *The Auk*, vol. 111, no. 2, pp. 300–313.

Pepperberg, Irene M. (1996). 5 Categorical Class Formation by an African Grey Parrot (Psittacus Erithacus). *Advances in Psychology Stimulus Class Formation in Humans and Animals*, pp. 71–90.

Pepperberg, Irene M. (1999). Rethinking Syntax: A Commentary on Kako's Elements of Syntax in the Systems of Three Language-Trained Animals. *Animal Learning & Behavior*, vol. 27, no. 1, pp. 15-17.

Pepperberg, Irene M. (2002). *The Alex Studies: Cognitive and Communicative Abilities of Grey Parrots*. Cambridge, MA: Harvard University Press.

Pepperberg, Irene M. (2007). Grey Parrots Do Not Always Parrot: the Roles of Imitation and Phonological Awareness in the Creation of New Labels from Existing Vocalizations. *Language Sciences*, vol. 29, no. 1, pp. 1–13.

Pepperberg, Irene M. (2016). Animal Language Studies: What Happened? *Psychonomic Bulletin & Review*, vol. 24, no. 1, pp. 181–185.

Peron, Franck, et al. (2010). 'Unwilling' versus 'Unable': Do Grey Parrots Understand Human Intentional Actions? *Interaction Studies. Social Behaviour and Communication in Biological and Artificial Systems*, vol. 11, no. 3, pp. 428–441.

Peron, Franck, et al. (2011). Cooperative Problem Solving in African Grey Parrots (Psittacus Erithacus). *Animal Cognition*, vol. 14, no. 4, pp. 545–553.

Roitblat, H. L., Bever, T. G., & Terrace, H. S. (1985). *Animal cognition*. Hillsdale, NJ: L.

Erlbaum Associates.

Shettleworth, Sara J. (2001). Animal Cognition and Animal Behaviour. *Animal Behaviour*, vol. 61, no. 2, pp. 277-286

Todt, Dietmar. (1975). Social Learning of Vocal Patterns and Modes of Their Application in Grey Parrots (Psittacus Erithacus) 1,2,3." *Ethology*, vol. 39, no. 1-5, pp. 178-188.

Figures, Tables, and Charts

Figure 1: Two humans and a Grey Parrot in Model/Rival conformation; the trainer is asking a question ("what's this") to the model, who responds correctly while the parrot is observing. The trainer then praises the model while the parrot watches. This praise makes the model act as a rival to the parrot for the trainer's attention, influencing the parrot to want to answer questions and receive praise/attention as well. "African Grey Jonathan - Training Using Model Rival Technique - With Subtitle." *YouTube*, YouTube, 30 Nov. 2016

Figure 2: Alex the Parrot viewing two keys of different colors, sizes, and “matters.” Because of M/R training and the communicative approach the lab uses, when asked “What’s different,” Alex could choose to say color, size, or matter, and understood the meaning of all three words in the context of the lab.

Figure 3: Griffin sitting at the experiment perch, with the stool, tray, and cups set up in front of him. This was the exact setup for the experiment before the tray was pushed forward. Once the tray was pushed forward, Griffin would select a stack with his beak.

Figure 4: Griffin selecting a set of stacked cups by leaning over and grabbing them with his beak. This occurred after the researcher told Griffin to “pick Yellow IN Blue”. He chose correctly, so he was rewarded with a piece of nut and praise.

Table 1: Summary of Griffin's Results On All Trial Sets

Number of Trials Conducted & Percentages Correct

Trial Set	Number of Trials	Number Correct (With Retrials)	Percent Correct (With Retrials)	Number Correct (Without Retrials)	Percent Correct (Without Retrials)
Yellow/Blue	24	21	**88**%	15	63%
Red/Yellow	16	16	**100%**	13	**81%**
Red/Blue	16	16	**100%**	14	**88%**
Overall	56	53	**95%**	42	**75%**

Table 1: Summary of Griffin's results on all trial sets. **BOLD NUMBERS** indicate statistical significance on a one-tailed binomial test. Griffin improved from set to set and performed best in the Red/Blue trial set; this supports that Griffin developed a better understanding of our question (using "In") as he completed more trials.

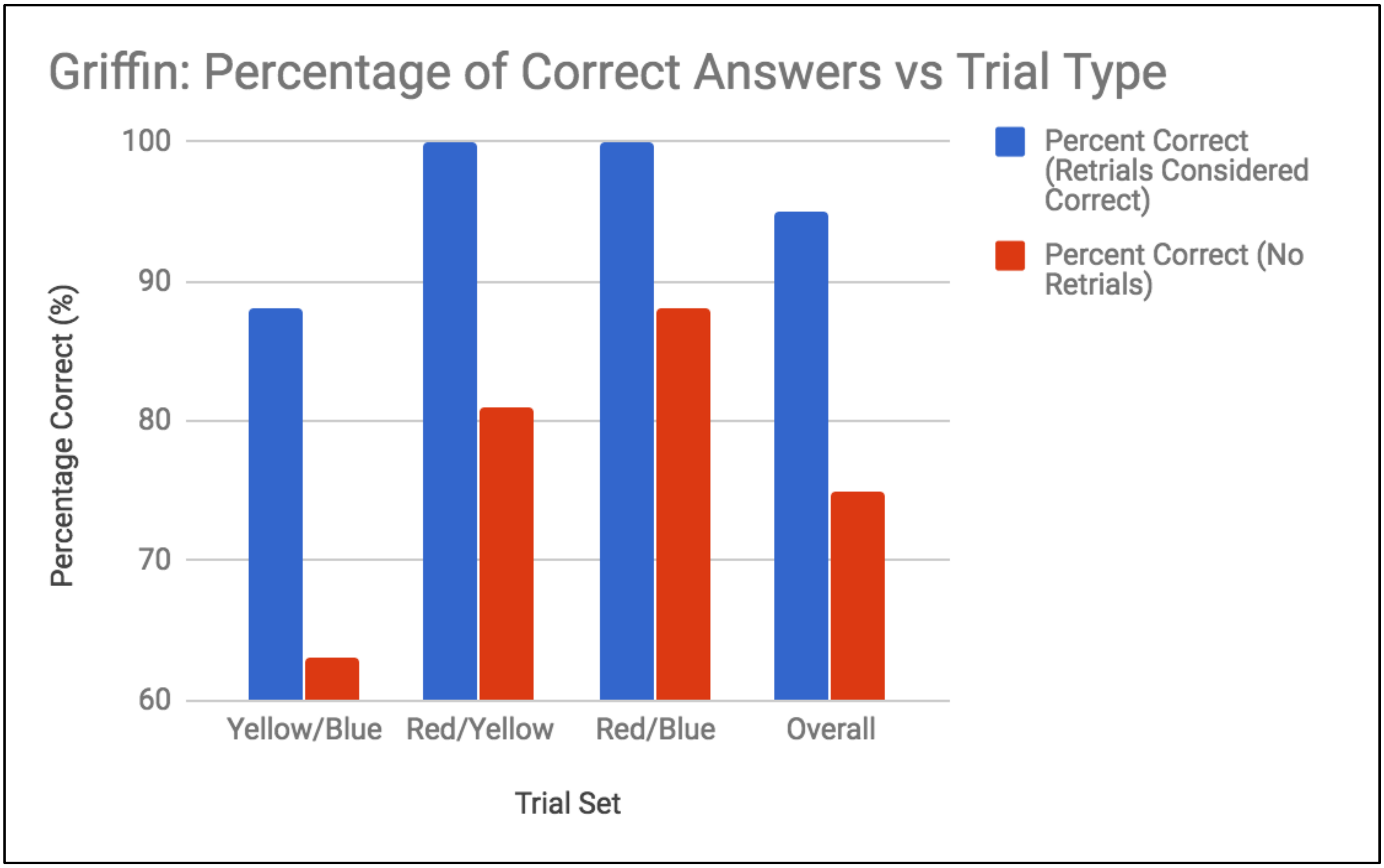

Figure 5: Graphical summary of Griffin's performance on all sets of trials. Blue indicates the percent correct when considering all of Griffin's correct answers (retrials included). Red indicates the percent correct when considering all retrials as incorrect answers. Note all trials are above 60% (above random), and all trials aside from Yellow/Blue (no retrials) are statistically significant.

Table 2: Summary of Athena's Results On All Trial Sets				
	Number of Trials Conducted & Percentage Correct			
Trial Set		Number of Trials	Number Correct	Percent Correct
	Yellow/Blue: Overall	12	7	58%
	Yellow/Blue: Last 8	8	7	**88%**

Table 2: Summary of Athena's results on all trial sets. **BOLD NUMBERS** indicate statistical significance on a one-tailed binomial test. Athena improved drastically over the course of her trials, and answered 7 of the last 8 trials correctly. This implies she learned or was starting to understand our question (using the word "In").