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Border collie comprehends sentences containing a prepositional object, verb, and direct object

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ABSTRACT

This study tested the ability of a Border Collie, Chaser, to learn the syntax and semantics of sentences consisting of three elements of grammar, a *prepositional object*, *verb*, and *direct object*. Understanding of the syntax of the sentences required that Chaser emit responses consistent with three elements of grammar sentences, such as *to ball take Frisbee*. Understanding of the semantics of the sentences required that Chaser respond correctly when the meanings of the sentences were changed by reversing positions of the prepositional object and the direct object in the sentence, such as *to Frisbee take ball*. Chaser's understanding of the sentences was tested in three different scenarios: (a) when multiple and familiar objects were used in the syntax command sentence, (b) when novel objects were used in the syntax command sentence (novel in the sense that objects had not been used during training), and (c) when vision of objects was not possible at the time the syntax command was verbalized. Findings were statistically significant in all three scenarios. Successful findings were attributed to Chaser's intensive training in her first three years of life. Analysis of the data revealed that Chaser's successful understanding of the syntax sentences required the processing and retention of two sound-object mappings (names-objects) into memory, along with simultaneous judgments concerning which object to take to the other – that is, working memory. These two types of cognitive abilities, memory storage and working memory, raise the bar in terms of our expectations of a dog's potential ability to understand verbal communications. We propose that Chaser's understanding of our three elements of grammar sentences represents a giant leap in her referential understanding of language.

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In a previous published paper (Pilley & Reid, 2011), we replicated and extended the findings of Kaminski, Call, and Fischer (2004) who reported that a 9-year-old border collie (Rico) knew the names of more than 200 items. In their first experiment, these researchers demonstrated that Rico's acquisition of the names of toys was genuine – not a “Clever Hans” phenomenon. A second experiment demonstrated Rico's “exclusion learning” – inferring the name of an object based on its novelty in the midst of familiar objects (Carey & Bartlett, 1978). As an example, Carey and Bartlett arranged a scenario during which 3 and 4-year-old children were shown two trays and asked to retrieve the “chromium, not the red tray.” Despite the children's lack of knowledge of the word chromium as a shade of green, the children correctly inferred that the teacher wanted the green tray.

Linguistic researchers Markman and Abelev (2004) were unable to accept Rico's data as compelling evidence for exclusion learning because they identified two potential difficulties with the study: (a) lack of control for baseline novelty preference;

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and (b) reward after the exclusion choice response could have mediated the subsequent exclusion learning test trial. Thus, they questioned the validity of Rico's (Kaminski et al., 2004) demonstration of exclusion learning. Bloom (2004) acknowledged the possibility that Rico's learning of the names of objects may be qualitatively similar to that of a child, differing only in degree. However, he questioned the conclusion that Rico's words actually referred to objects. Did Rico treat the sound "sock" as a sock or did Rico treat the sound as a command to fetch a sock, and nothing more? If Rico treated the sound as a one-word proposition "fetch-the-sock," then his performance may have had little to do with language learning in the human sense. In addition, Bloom argued that words for children become symbols that refer to categories of things in the external world. "They appreciate that a word can refer to a category, and thereby can be used to request a sock, or point out a sock, or comment on the absence of one" (p. 1605).

In our replication and extensions of the Rico study, we conducted four studies with Chaser our border collie (Pilley & Reid, 2011).

Experiment 1 showed that over a 3-year period, Chaser demonstrated impressive abilities to learn the names of proper nouns, and her extensive vocabulary was tested under carefully controlled conditions. She met our rigorous learning criteria repeatedly for 1022 proper nouns. She accumulated and maintained this knowledge of nouns over a lengthy 32-month period. In each month, when we tested Chaser on her entire vocabulary, she was able to respond correctly to more than 95% of the objects. In the last month of teaching the names of proper noun objects (the 32nd month), Chaser again responded correctly to more than 95% of the 1022 proper-noun objects that she had learned. Chaser's ability to learn and remember more than 1022 proper nouns, each mapped to a unique object, revealed clear evidence of several capacities necessary for learning receptive human language: the ability to discriminate between 1022 different sounds representing names of objects, the ability to discriminate many objects visually, a sizable vocabulary, and an extensive memory system that allowed the mapping of many auditory stimuli to many visual stimuli.

Experiment 2 demonstrated that Chaser was able to use inferential reasoning by exclusion to map words upon objects, replicating Rico's performance (Kaminski et al., 2004). Chaser demonstrated strong retention of the name-object mapping when she was tested immediately after the exclusion choice trial. However, retention of the name of the object was reduced at the 10-min delay interval and essentially non-existent at the 24-h delay interval. Rehearsal or play that provides additional name-object pairings is usually necessary for strong long-term memory retention.

Experiment 3 showed that Chaser was successful in learning three common nouns – words that represent categories. Chaser learned the names of two concrete categories, "balls" and "Frisbees." For each of these concrete categories, exemplars of each category displayed physical characteristics that may have helped define the category, such as all "balls" being relatively round. Chaser also successfully learned the abstract concept "toy," which was based on function rather than shared physical characteristics. "Toys" were objects for which she had learned unique proper-noun names and with which she was allowed to play. "Non-toys" were similar objects belonging to family members. The physical characteristics of toys and non-toys were not discriminative features of the category – instead, toys and non-toys differed in functionality. Chaser could play with toys; she could not play with non-toys.

Experiment 4, Chaser demonstrated her syntactic and semantic understanding of the combinations of two word phrases. Chaser was successful in producing appropriate behaviors when three different commands (take, paw, nose) were randomly combined with three different objects (Lips, ABC, Lamb) across 14 independent trials. In this double blind design experiment, three independent confederates judged Chaser's responses to be correct on each of the 14 test trials. The three objects used in the testing were novel objects in that they had never been used in combinations with the three verbs. Chaser did not require special training before producing the appropriate response when the three commands (take, paw, nose) were paired with the three names (Lips, Lamb, ABC). Having learned/knowing the meaning of the three commands and the names of the three objects, she was able to respond correctly when each of the three commands and the three nouns were randomly paired together in verb-noun phrases, demonstrating "combinatorial understanding" of two-word phrases. Thus, Chaser responded as though the commands and the proper-noun names represented independent morphemes. Chaser understood that names refer to particular objects, independent of the activity requested involving that object. Thus, Bloom's (2004) concern that Rico may not have understood the difference between "sock" and "fetch-the-sock" is ruled out in this study. Combined, our four studies provide strong evidence that Chaser satisfied Baldwin's (1993) criteria for referential understanding of nouns – awareness that objects have names and knowledge of the referential cues that enabled her to map the word upon the intended item.

Chaser's learning, as described in the four experiments, caused us to believe that she might be successful when confronted with sentences embodying three elements of grammar. Thus, the purpose of the present studies was to investigate the ability of Chaser to understand the syntax and semantics of sentences consisting of three elements of grammar (a prepositional object, a verb, and a direct object) – such as "to ball take Frisbee" and the inverse "to Frisbee take ball."

Louis Herman and his associates (Herman, Richards, & Wolz, 1984) demonstrated the ability of dolphins to comprehend elements of grammar. Herman has explored the world of the Bottlenosed Dolphin for over 30 years. His research philosophy of long-term intensive education of dolphins has yielded masses of information. Herman and his associates have carried out studies of sensory abilities, cross-modal matching, memory, conceptual processes, vocal and motor mimicry, language understanding, and self-awareness. In a portion of their studies, these researchers demonstrated the abilities of dolphins to understand the syntax and semantics of sentences consisting of 2, 3, 4, and 5 elements of grammar.

Rumbaugh, Rumbaugh, and Fields (2009) revisited the Ape language controversy between linguistic nativist's and non-human animal researchers. These researchers published a comprehensive report of Kanzi's, a pygmy chimpanzee,

understanding of the syntax and semantics of over 660 novel and unusual sentences, such as “put ball in pine needles,” “put the ice water into the potty,” “give light to rose,” “give peas and sweet potatoes to Kelly,” “get rose the snake,” “take the snake outdoors,” “go the refrigerator and get a banana,” “make doggie bite snake,” and “knife the sweet potato.” Kanzi was not given formal symbol training. He learned keyboard symbols by watching his mother on the keyboard – soon passing his mother in language proficiency. He used the keyboard symbols to refer to foods, objects, and places within the lab. These researchers verbally interacted with Kanzi using abbreviated speech and asking him questions. There was a special emphasis in observing Kanzi’s communications with other members of his family. However, linguistic nativists labeled Kanzi’s grammar as ‘proto-grammar,’ something that could not be produced by a grammar module, but only by some other non-defined process (Rumbaugh et al., 2009). In essence, the nativists accounted for Kanzi’s learning on the basis of his abilities to make inferences. As a rebuttal, Rumbaugh et al. asked what assumptions or inferences would Kanzi need to make to respond correctly to a sentence such as “can you make the snake bite the doggie?” These researches identified six difficult inferences needed for Kanzi to respond correctly. Their analysis revealed that the difficulty of all six inferences far outweighed the difficulty of learning the grammar rules. If Kanzi “is capable of such powerful inferential deductive reasoning, why would he not be able to infer the operation of grammatical rules (p. 31)?”

As suggested above, in this present study, we investigated the ability of a dog to learn simple elements of grammar, similar to those learned by dolphins and chimps. Specifically, we sought to replicate that portion of the dolphin research involving the learning of the syntax rules and semantics for sentences consisting of three elements of grammar – prepositional object, verb, and direct object. Because our goals and procedures were highly similar to those of the dolphin studies, we cite essential features of the procedures and findings of the dolphin studies relative to three-word relational sentences.

For sentences consisting of three-word combinations, the dolphin research team (Herman et al., 1984) chose different sequence rules for each of the dolphins. For Phoenix, who had learned to associate the names of actions and nouns by means of acoustical sounds, the sequence order for three-word sentences was *direct object, verb, and indirect object*. For Akeakamai, who had learned the names of verbs and nouns by means of visible signs, the sequence order was *indirect object, direct object, and verb*. For each of the two sequences, changing the positions of the direct and indirect objects altered the semantics of the three-word sequence of events. Both random and non-random procedures guarded against the intrusion of sequence and context constraints, as well as non-linguistic variables that might influence responses. In many instances, novel objects were used during testing. The use of novel objects that had never been used during training enabled the testing of *combinatorial understanding*; that is, an understanding of the sentence even though the items had never been used in three-word sentences during training. Findings for Phoenix’s understanding of syntax and semantics showed that in 43 test trials, Phoenix was correct on 62.3% of the trials. Akeakamai was given 50 test trials for the same combinations and was successful on 56% of the trials.

As stated above, the primary purpose of this study was to test a Border collie’s ability to comprehend the syntax and semantics of sentences consisting of *a prepositional object, a verb, direct object* – for example, ‘to A take B’ and the inverse, ‘to B take A.’ An understanding of the grammatical sequence of events in the sentence required that Chaser carry ‘A to B’ or ‘B to A.’ An understanding of semantics required that Chaser respond correctly when the positions of the prepositional object and the direct object were reversed in the sentence. A secondary purpose of the study was to test Chaser’s *combinatorial understanding* – the ability to respond correctly when the direct objects and the prepositional objects were novel; that is, the objects had never been used in the training of three elements of grammar sentences.

We propose that although our prepositional object, verb, and direct object sentence consists of four words, the semantics of the sentence and the behaviors solicited by the syntax of the sentence are, for practical purposes, identical to the three-word sentences that Herman et al. (1984) used with dolphins. In Herman’s sentence the verb fetch entailed both the taking of an object into the mouth and the taking of the object to another object. In our study, the taking of an object referred solely to the mouthing of an object and the *to* symbol referred to the transportation of the mouthed object to another and different object. In Herman et al.’s sentence the *to* is implicit; in our sentence the *to* is explicit. Thus, our four-word sentences represented three elements of grammar, a prepositional object, a verb, and a direct object. Herman et al.’s three-word sentences also represented three elements of grammar, a direct object, a verb, an indirect object.

In order to test Chaser’s understanding of three elements of grammar, three independent experiments were conducted.

The purpose of the first experiment was to test Chaser’s understanding of the syntax and semantics when the objects used in the sentence were both familiar and multiple. The objects were familiar objects in that they were items for which Chaser had learning a unique proper noun name. The objects were also familiar in that they had been used during local training and testing prior to formal testing of the three elements of grammar sentences. The objects were multiple in that on each test trial there were two prepositional objects and two direct objects available for a choice response by Chaser.

The second experiment sought to test Chaser’s understanding of the syntax and semantic understanding of sentences containing three elements of grammar when the test objects were novel. The test objects were novel in the sense that none of the objects had been used during syntax training. In addition to testing Chaser’s understanding of the syntax and semantics of the sentence, the novelty of objects enabled the testing of Chaser’s *combinatorial understanding*; that is, the ability to understand the syntax sentences, without additional training.

The purpose of the third experiment was to test Chaser’s understanding of the three elements of grammar sentences in a scenario where the prepositional and direct objects were not visible to Chaser when the syntax command sentence was issued, thereby testing her memory storage of the objects in the syntax command sentence.

Method

Subject

Our subject was a registered female Border collie, Chaser, born in May 2004. We acquired Chaser when she was eight weeks old and she lived in our home primarily as a member of the family, as well as a research subject. She displays the usual characteristics of her breed: intense visual focus/concentration, instinct to find, chase, herd, attentiveness to auditory cues even during complex visual stimulation (such as herding sheep), responsiveness to soft levels of praise and verbal correction, and boundless energy.

Materials

Over Chaser's first three years of life, we obtained more than 1000 proper noun objects for Chaser to identify and fetch. Objects were toys for children or dogs obtained mostly from second-hand discount stores and consisting of over 800 cloth animals, 116 balls, 26 Frisbees, and over 100 plastic items. There were no duplicates. Objects differed in term of size, weight, texture, configuration, color, design, and material. Despite some similarities, each object embodied unique features enabling discrimination. We gave every object a distinctive name consisting of 1–2 words (e.g., 'elephant,' 'lion,' 'tennis,' 'Santa Claus') and wrote this name on the object with a permanent marker. This helped ensure that all trainers used the correct name consistently in all training sessions.

Procedures

Local and formal procedures

Language training, ongoing assessment, and formal blind tests of knowledge involve separate procedures that must maintain the subject's interest in participating. Herman et al. (1984) faced similar constraints as they trained and assessed dolphins' acquired language. They introduced terminology to help distinguish between the many informal tests of knowledge carried out in the highly social environment of training and the rigorous formal tests of knowledge carried out under highly controlled conditions. They used the term 'local' to describe the frequent tests of dolphins' learning carried out during the training sessions, which normally lacked the rigorous experimental control necessary to rule out the influence of unintended cues. In contrast, the term 'formal' described the formal assessments of acquired knowledge using the rigorous experimental control necessary to rule out the influence of unintended cues by the experimenter. We adopted these two terms to describe our various tests of word-object mappings.

Definitions of a word, a sentence, and a language

We accept the definitions of a word, sentence, and language that were adopted in the dolphin studies (Herman et al., 1984): "A word is defined as a unique, independent semantic entity; entities were agents, objects, actions, or modifiers of place or direction. A sentence is defined as a sequence of words that expresses a unique semantic proposition. Language refers to the lexical component and the set of syntactic rules that governed the construction and interpretation of sentences (p. 135)." In addition, as in the dolphin studies, we use the terms 'prepositional object' and 'direct objects' to refer both to their referents and to the words in the sentences.

Early training procedures – first three years of life

We initiated simple obedience and socialization training, 4–5 h daily, as soon as Chaser was brought into our home at eight weeks of age. Behaviors were taught by means of associative mechanisms, such as classical and operant conditioning. Gradually, we began to provide training for herding, agility training, and tracking behaviors. In Chaser's fifth month, we began to focus more of our time on word learning. Incentives and rewards used to encourage desired behaviors were petting, attention, and providing opportunities to engage in enjoyable activities (e.g., tugging, ball chasing, toy shaking, Frisbee play, agility play, walks, search by exploration, outdoor tracking, and stalking). For Chaser these types of incentives and rewards were more powerful than the traditional use of food. Furthermore, they were less distracting than food and more resistant to satiation. We used food to shape behavior only when food served as a lure, such as turning around in a circle. Throughout the paper, we use the word *novel* to refer to the objects for which Chaser had not learned a unique name. The word *familiar* denotes objects for which she had learned a unique name.

While we focused primarily upon Chaser's learning of proper and common noun words, we also taught other classes of words, such as verbs, adverbs, adjectives, and prepositions. The meaning of the verb *take* and the meaning of the preposition *to* were taught early in Chaser's first year of life. The "take" command meant for Chaser to take an object into her mouth. The response of taking the object into her mouth was independent from any future action involving the object. Thus, in our training, when she did not have an object in her mouth and was approaching a familiar object with the intent to mouth, we would issue the *take* command. We reinforced the behavior with praise and play. Successive trials were sufficient to bring the act of *taking* under stimulus control. In order to further emphasize this meaning, we interspersed the *take* command

with other learned commands such as “nose, paw, and shake.” Later, when Chaser was taught to take an object to another object, she was praised for dropping the direct object item within two or three feet of the prepositional object and taking the prepositional object into her mouth. Immediately thereafter, we reinforced this response with praise and play, believing that play with the object would enhance its value and her motivation to fulfill our requests.

A verbal command, such as “to Nanny” meant for Chaser to take whatever was in her mouth to a person, a non-transportable object (couch, bed, chair), or a location (kitchen, front porch, living room). Thus, when Chaser already had an object in her mouth, we would issue the *to* command, selecting various humans or stationary objects for which Chaser already knew a unique proper noun name. For humans, Chaser would drop the object at the person's feet or in their hand. For stationary objects, transportable objects, and locations, Chaser would place the object on, in, or within two or three feet of the specified destination. As indicated above, Chaser was rewarded verbally and with a brief period of play with objects.

Local syntax and semantic training and testing procedures

It was not until Chaser's seventh year of life that we attempted to teach her the syntax and semantics in sentences consisting of three elements of grammar. In a personal communication, Clive Wynne suggested that we simplify the command in a way adopted by the dolphin researchers; that is, replace the two words *take* and *to* with the German word ‘*nem*’ which means *take to*. Thus, the command sequence became *direct object, verb, indirect object* (ball, *nem*, Frisbee). However, numerous test trials failed to yield a consistent pattern of successful responding.

The failure to obtain successful results with the ‘*ball, nem, Frisbee*’ sequence and our desire to use word sequences more natural to our every day speech prompted us to change the command sequence of events to a form common in the Spanish language. The Spanish sequence was *prepositional object, verb, direct object*; for example, “to ball take Frisbee.” This sequence enabled us to break down the request into two behaviors ‘*to*’ and ‘*take*’ that Chaser had learned in her first year of life. We chose this sequence primarily because Chaser showed a strong response bias when we informally tested her with the English sequence of *verb, direct object, and prepositional object*. In this English sequence, Chaser's bias favored taking the last object named – that is, the prepositional object. Thus, in order to increase the probability that Chaser would take the direct object into her mouth, we adopted the Spanish sequence of events in which the direct object is close to the end of sentence.

One hundred objects were arbitrarily selected from the 1022 objects for each of which Chaser had learned a unique proper noun name. Selection was guided by the desire to select a variety of different types of objects, such as cloth animals, plastic toys, balls, and Frisbees.

The following statements identify the variety of conditions that existed in our informal training of the three elements of grammar sentences. We focused on one pair of objects at a time; no other objects were on the floor. The sequence command ‘to A take B’ was given with a brief pause of 1–2 s between the ‘to A’ and the ‘take B’ divisions of the command. Initially, visual cues of pointing to a particular object were given at the same time as the auditory request; the pointing was later phased out. Roles of the prepositional and direct object items in the command sentence were frequently randomly altered. All objects were frequently randomly paired with different objects. The reverse sequence of the prepositional and direct objects in the command sentence testing a pair of objects was not always immediate; that is, other objects frequently intervened between the initial trial and the reversal trial of a given pair. Early in training, positions of the prepositional and direct objects were placed from 1.5 m to 3 m apart, such that both objects were visible to Chaser. Later in training, objects were placed in separate rooms, thereby inhibiting Chaser's simultaneous vision of the two objects. There were many spontaneous episodes of training throughout the day and evening. Later in training, multiple prepositional and direct objects were placed upon the floor.

During training, when the three-part sentences were given and Chaser made the error of approaching the prepositional object, she was recalled immediately without correction. The same command was re-issued. Repeating the command and recalling Chaser continued until: (a) Chaser correctly approached and mouthed the direct object, (b) took and dropped the direct object close to the prepositional object, and (c) mouthed the prepositional object. Immediately thereafter, Chaser was verbally praised and a play period with the prepositional object was initiated. As with dolphins, Chaser was sensitive to failure. The above recalls greatly reduced error choices.

Experiment 1 – formal syntax testing when objects were familiar and multiple

The purpose of the study was to test Chaser's understanding of the syntax and semantics of sentences containing three elements of grammar when the objects used in the sentence were both familiar and multiple. The objects were familiar objects in that they were items for which Chaser had learned a unique proper noun name. The objects were also familiar in that they had been used during local training and testing prior to formal testing of the three elements of grammar sentences. The objects were multiple in that on each test trial there were two prepositional objects and two direct objects available for a choice response by Chaser.

Methods and procedures

We incorporated double blind procedures. A Wofford College student, who did not know the names of the objects, served as the testing confederate. In order to enable the testing confederate to issue the syntax command sentence, the confederate

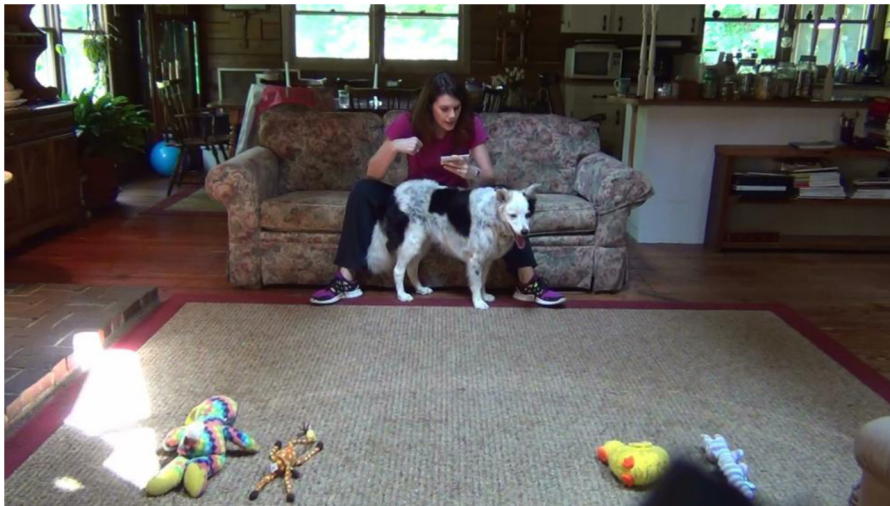


Fig. 1. This photograph displays the scenario for testing multiple and familiar objects. The confederate is on the couch with Chaser close by. Four objects are on the floor.

was provided an instruction sheet describing the names of objects on each trial and the precise command sequence of events for each trial. I, John Pilley, operated the camcorder and identified for the video the names of objects on each trial during the testing trials. The testing confederate was out of the room during the identification of objects. On a later occasion, three Wofford College students viewed the video and independently evaluated the accuracy of Chaser's responses, as well as the possible intrusion of unintended visual cues emitted by myself, John Pilley, video recorder.

Sixteen objects were randomly selected from the 100 objects that had been used during syntax training. Each selected object was arbitrarily assigned a number between 1 and 16. Each number was written upon a small slip of paper and placed in a small basket. Numbers were randomly retrieved from the basket in pairs and each pair was successively assigned a trial number, one through eight. A coin was tossed for each of the eight pairs in order to randomly assign initial direct or prepositional object status in the test sentence. The physical positions of each article were not changed from one trial to another. The "a" trial for each pair of objects represented the first trial of testing for a particular pair of objects. On the "b" trial, the positions of the paired objects were altered in the syntax command sentence, thereby testing Chaser's semantic understanding of the sentence. In order to control for a possible physical position preference (choosing objects on her left side as opposing to choosing objects on her right side), pairs of objects were counter balanced over the 16 trials (Fig. 1).

Testing was carried out in our carpeted living room. For each trial, two prepositional and two direct objects were placed on the floor at a distance of 1.8 m from the camera. The two prepositional and two direct articles were placed 1.2 m apart and were parallel to the couch. Both the two prepositional objects and the two direct object items were placed 2.5 cm from one another. The testing confederate sat on a couch a distance of 3.6 m from the camera. The testing confederate was given an instruction sheet describing the names of objects on each trial and the precise command sequence of events for each trial. Commands were issued when Chaser was facing toward the objects and away from the tester. Immediately after each trial, the camcorder was turned off and Chaser was taken by the tester to a bedroom down the hall for brief play. At the same time, a second confederate rearranged objects or placed new objects upon the floor for the next trial. While the testing confederate was out of the room, the camcorder was turned back on in order to identify the names of the objects for the next trial. The camcorder was turned off until the tester confederate returned with Chaser, at which time the camcorder was turned back on for the next trial. The entire testing session was video taped. On a later occasion, three Wofford College students viewed the film and independently evaluated the accuracy of Chaser's responses, as well as the possible intrusion of unintended visual cues emitted by myself, John Pilley, as operator of the camcorder.

Results – findings when objects were familiar and multiple

Table 1 identifies for each of the 16 trials: (a) the precise sequence of the syntax command, (b) the names and positions of each of the prepositional and direct objects in the syntax command sentence, and (c) the correct or incorrect responses for the direct object and the prepositional object. Note that on each trial, there were always two prepositional and two direct objects available for selection. For each trial, the sequence of the syntax command sentence always began with the preposition "TO". For each trial, the correct response was always taking the correct direct object named in the syntax sentence to the correct prepositional object named in the syntax sentence. Chaser was tested twice for each pair of objects. For example, on trial 1a, sugar was the indirect object and decoy was the direct object. However, on trial 1b, sugar was the direct object and decoy was the indirect object. Thus, the roles of the objects were reversed, thereby testing Chaser's semantic understanding of the sentence. All objects were familiar in that they were used during syntax training.

Table 1

identifies for each of the 16 multiple and familiar trials: the names and positions of each of the prepositional and direct objects in the syntax sentence, the correct and incorrect responses on each of the trials.

Trials	Syntax command sequence		Correct responses	
			Prepositional	Direct
Trial 1a	TO sugar	take decoy	correct	correct
Trial 1b	take sugar	TO decoy	correct	incorrect
Trial 2a	TO Jeffery	take rex	incorrect	correct
Trial 2b	take Jeffery	TO rex	correct	correct
Trial 3a	take hot stuff	TO lipsey	correct	correct
Trial 3b	TO hot stuff	take lipsey	correct	correct
Trial 4a	take spike	TO ears	incorrect	correct
Trial 4b	TO spike	take ears	correct	correct
Trial 5a	TO tobey	take coop	correct	correct
Trial 5b	take tobey	TO coop	correct	correct
Trial 6a	TO snow	take milk	correct	correct
Trial 6b	take snow	TO milk	incorrect	correct
Trial 7a	take andy	TO thingajig	correct	correct
Trial 7b	TO andy	take thingajig	incorrect	incorrect
Trial 8a	take surf	TO rough	correct	correct
Trial 8b	TO surf	take rough	correct	incorrect

Analysis of the testing scenarios revealed that on each trial, there were two response options – the selection of one of the direct objects and the selection of one of the prepositional objects. Chaser could select the first object incorrectly and she also could select the second object incorrectly. In addition, Chaser could make the error of treating a direct object as a prepositional object and treating the prepositional object as a direct object. The random chance of getting a given trial correct was one out of four possibilities. For the 16 trials, Chaser was confronted with 32 response options.

In their viewing of the taped video, the three student confederates, unaware of the purposes of the study, independently, reported that Chaser responded correctly on 25 of the 32 trials. In addition, there was unanimous agreement by the confederates concerning the precise seven trials that were incorrect – four of the errors were prepositional errors and three of the errors were direct object errors. In addition, each of the three confederates, independently, reported that on none of the 32 response test options did Chaser look up and toward my position as I, John Pilley, stood behind the camcorder tripod. The binomial statistical test for Chaser's correct performance on 25 response choices out of 32 yielded a probability of chance performance of $p < .001$. These obtained statistical findings closely match those found in the dolphin studies (Herman et al., 1984) that investigated the abilities of dolphins to comprehend the syntax and semantics of three elements of grammar.

Informal manipulations during informal training suggested that successful performance was enhanced when there was a 1–2 s pause between the *to* and *take* commands. In addition, informal tests suggested that an enthusiastic utterance of the command enhanced Chaser's accuracy of performance.

Experiment 2 - formal syntax testing procedures when objects were novel

This study tested Chaser's understanding of the syntax and semantics of sentences containing three elements of grammar when the test objects were novel. The test objects were novel in the sense that none of the objects had been used during syntax training. In addition to testing Chaser's understanding of the syntax and semantics of the sentence, the novelty of objects enabled testing of Chaser's combinatorial understanding; that is, the ability to understand the syntax sentences, without additional training.

Method and procedures

As in Experiment 1, we incorporated double blind procedures. A Wofford College student, who did not know the names of the objects, served as the testing confederate. In order to enable the testing confederate to issue the syntax command sentence, the confederate was provided an instruction sheet describing the names of objects on each trial and the precise command sequence of events for each trial. I, John Pilley, operated the camcorder and identified for the video the names of objects on each trial during the testing trials. The testing confederate was out of the room during the identification of objects. On a later occasion, three Wofford College students viewed the video and independently evaluated the accuracy of Chaser's responses, as well as the possible intrusion of unintended visual cues emitted by myself, John Pilley, video recorder.

Twenty-four objects were arbitrarily selected from Chaser's collection of over 1000 objects for which she had learned a unique proper noun name. The 100 objects that had been used in the training of the three elements of grammar sentences were excluded from selection. In addition, all objects with a name that matched the physical characteristics of the object



Fig. 2. This photograph displays the scenario for testing novel objects. The confederate is on the couch with Chaser standing in front of her. Two objects are on the floor.

were excluded from selection. Thus, the selection of objects consisted solely of novel objects that had not been used during syntax training and that did not have names that described their physical characteristics. Each selected object was arbitrarily assigned a number between one and 24. Each number was written upon a small slip of paper and placed in a small basket. Numbers were randomly retrieved from the basket in pairs and successively assigned a trial number, one through 12. A coin was tossed for each of the 12 pairs in order to randomly assign initial direct or prepositional object status in the test sentence. In order to control for a possible physical position preference (left or right placement on the floor), object positions were counter balanced over trials; that is, on every other trial, the right and left positions of the direct and prepositional objects in the command sentence were alternated. The reversal test trial of each pair of objects did not immediately follow the initial trial; rather, the reversal test trial testing semantic understanding was delayed by three intervening trials of other pairs of objects. The delay of the reversal test trial sought to control for any possible response bias that might have been initiated by the first pairing of two objects (Fig. 2).

Testing procedures were almost identical as those used in Experiment 1. Testing was carried out in our carpeted living room. For each trial, pairs of prepositional objects and pairs of direct objects were successively placed on the floor at a distance of 1.8 m from the camera. The prepositional and direct articles were placed 1.2 m apart and were parallel to the couch. The testing confederate sat on a couch at a distance of 3.6 m from the camera, with Chaser lying or standing at her feet. The tester issued commands when Chaser was facing toward the objects and away from the tester. Immediately after each trial, the camcorder was turned off and the testing confederate took Chaser to a bedroom down the hall for brief play. At the same time, a second confederate replaced the previous trial objects or placed new objects upon the floor for the next trial. With the testing confederate still out of the room, the camcorder was turned on and the trial number for the next trial and the names of the objects were identified for viewers of the film. The camcorder was turned off and then was turned back on when the testing confederate returned to the couch with Chaser for another trial.

Results: findings for the formal syntax testing when objects were novel

Table 2 identifies for each of the 24 trials the names and positions of each prepositional and direct object in the syntax command sentence, as well as Chaser's responses. The syntax command sentence always began with the preposition "TO". For each trial, the correct response was always the taking of the direct object to the indirect object. Chaser was tested twice for each pair of objects. The second trial always took place after three intervening trials. For example, on trial 1a, leopard was the indirect object and ring neck was the direct object. However on trial 1b, leopard was the direct object and ring neck was the indirect object in the command sentence. Thus, the roles of the objects were reversed in the command sentence, thereby testing Chaser's semantic understanding of the sequence of events. All objects were novel in that they were never used during syntax training.

Three judges, who were unaware of the purposes of the study and who made independent observations of the recorded video, unanimously agreed that Chaser responded correctly on 18 of the 24 trials. There was unanimous agreement on the precise six trials that were incorrect. On three of the trials, Chaser incorrectly responded to the prepositional object as though it was the direct object. On three of the trials, Chaser incorrectly responded to direct object as though it was the prepositional object. Each of the three confederates reported that on only one of the 24 test trials did Chaser look up and toward my position behind the tripod holding the camcorder. On this one trial, Chaser was already approaching the correct object for selection.

Table 2

Identifies for each of the 24 novel trials: The names and positions of each prepositional and direct object in the syntax command sentence as well as Chaser's responses.

Trials	Syntax command sequence	Chaser's responses
Trial 1a	TO Leopard	take ringneck
Trial 2a	take snoopy	TO boston
Trial 3a	TO tinkerbelle	take pucker
Trial 4a	take pancake	TO playmate
Trial 1b	take leopard	TO ringneck
Trial 2b	TO snoopy	take boston
Trial 3b	take tinkerbelle	TO pucker
Trial 4b	TO pancake	take playmate
Trial 5a	TO chuckles	take tongue
Trial 6a	take trouble	TO junior
Trial 7a	TO lulu	take dresser up
Trial 8a	take benji	TO purse
Trial 5b	take chuckles	TO tongue
Trial 6b	TO trouble	take junior
Trial 7b	take lulu	TO dresser up
Trial 8b	TO benji	take purse
Trial 9a	TO hot stuff	take sweet potato
Trial 10a	take lipsey	TO andy
Trial 11a	TO snow	take mouthy
Trial 12a	take awana	TO frosty
Trial 9b	take hot stuff	TO sweet potato
Trial 10b	TO lipsey	take andy
Trial 11b	take snow	TO mouthy
Trial 12b	TO awana	take frosty

Findings showed that Chaser was successful in demonstrating syntax and semantic understanding on 18 of the 24 trials or 75% of the trials, yielding a binomial probability of chance performance of $p < .008$. Again, these statistics closely match those found in the dolphin studies (Herman et al., 1984) when dolphins were tested for their comprehension of sentences containing three elements of grammar.

Experiment 3 – formal testing procedures of the storage of mental images of objects

The purpose of the study was to test Chaser's understanding of the three elements of grammar sentences in a scenario where the prepositional and direct objects were not visible to Chaser when the command sentence was issued. Alliston Reid, my co-author of an earlier paper (Pilley & Reid, 2011), observed in his analysis of the novel syntax video that as the syntax command sentence was verbalized (e.g., to ball take Frisbee) Chaser directed her eyes first toward the 'to' object and then rapidly to the 'take' object. In most cases, immediately after the syntax sentence command was issued, Chaser rapidly approached and took the direct object into her mouth. This observation raised the question as to whether the scenario in the first two studies, during which Chaser observed the objects at the same time that the sentence command was uttered, adequately tested Chaser's processing of a mental image of the direct object. Chaser's focus on the direct object and immediate response may have enabled the correct choice of the direct object without processing a mental image of the direct object. Thus, as stated above, this experiment tested Chaser's ability to store a mental image of the prepositional and direct objects when the prepositional and direct objects were not visible to Chaser when the command sentence was issued.

Methods and procedures

Twelve objects, for each of which Chaser had learned a proper noun name, were arbitrarily selected from the 100 objects that had been used during syntax training. Each selected object was randomly assigned a number between one and 12. Each number was written upon a small slip of paper and placed in a small basket. Numbers were randomly retrieved from the basket in pairs and each pair was successively assigned a number between one and six. A coin was tossed for each of the six pairs in order to randomly assign initial direct or prepositional object status in the syntax command sentence. Thus, on each trial, there were always two prepositional objects and two direct object items. A reversal test trial required that the location of the two objects of that trial be physically reversed – that is, the articles in the living room were moved to the bedroom and the articles in the bedroom were moved to the living room. This reversal enabled all prepositional objects to be placed in the living room and all direct objects to be located in the bedroom.

In testing Chaser's storage of mental images of the direct objects, the intrusion of visual cues by myself, as tester, was controlled experimentally by placing the direct objects on a pillow at the front of a bed where the distance between the



Fig. 3. This photograph displays the scenario for testing of the storage of mental images of objects.

two objects was 2.5 cm. In the testing scenario, I stood at the end of the bed and issued the command sentence with Chaser facing me and away from the direct objects. Immediately, after hearing the command sentence, Chaser turned around, approached, and mouthed one of the direct objects placed upon the pillow at the head of the bed. Thus, Chaser was facing away from me when she chose one of the direct objects. The prepositional objects were placed in the living room, not visible from the bedroom. As with the direct object, the two prepositional objects were placed 2.5 cm apart. No confederate was needed in the living room because no one was present in the living room. As soon as Chaser selected a direct object in the bedroom, she raced to the living room with the direct object, selected one of the prepositional objects and raced back to the bedroom. At the end of each trial, I recorded Chaser's responses and briefly played with Chaser prior to beginning the next trial.

In order to control for a possible left or right side preference choice of objects by Chaser, the correct direct and prepositional objects were placed on left and right sides of one another an equal number of times over the 12 trials. The two direct objects were always placed in the bedroom and the two prepositional objects were always placed in the living room. Prior to this formal testing, Chaser was given several opportunities of observing two objects on the living room floor and two objects at the head of the bed in the bedroom, along with several learning trials concerning the locations of objects (Fig. 3).

Results – formal testing of the storage of mental images of objects

Table 3 identifies for each of the 12 trials: (a) the precise sequence of the syntax command sentence, (b) the names and physical location of each of the prepositional and direct objects, and (c) accuracy of response for the direct objects and prepositional objects. The syntax command sentence always began with the preposition "TO". For each of the trials, 'a' and 'b' represent the different roles of the objects, direct or prepositional in the syntax command sentence. For example, on trial 1a, *honey bee* was the prepositional object and *spot* was the direct object. However, on trial 1b, *spot* was the prepositional object and *honey bee* was the direct object. Thus, the roles of the objects were reversed. Prepositional objects were always placed in the living room and direct objects were always placed in the bedroom. All objects were familiar in that they were used during training. Because prepositional and direct object items were placed in different rooms, we did not video tape the formal testing session – because of our lack of equipment and knowledge necessary for harmonizing two videos.

As in Experiment 1, analysis of the testing scenario revealed that there was more than one way of making a mistake on a given trial. Chaser could select the direct object incorrectly and she also could select the prepositional object incorrectly. In addition, Chaser could make the error of treating a direct object as a prepositional object and treating the prepositional object as a direct object. Thus, the chance probability of Chaser's success on each trial was one out of four. The data showed that Chaser responded correctly on all 24 response options, yielding a binomial statistic of $p < .000001$. These results support the conclusion that in the familiar and multiple study, as well as the novel study, reported above, Chaser did process the direct object items into memory.

Table 3

displays for each of the memory trials: the syntax command sentences, the location of direct and prepositional objects, and the accuracy of the choices of the direct and prepositional objects.

Trials	Syntax common sequence		Accuracy of responses	
	Location <i>Living room</i>	Location <i>Bedroom</i>	Prepositional	Direct
Trial 1a	TO honey	take spot	correct	correct
Trial 1b	bee			
Trial 1b	TO spot	take honey	correct	correct
		bee		
Trial 2a	TO miss	take wheel	correct	correct
	moose			
Trial 2b	TO wheel	take miss	correct	correct
		moose		
Trial 3a	TO pen	take	correct	correct
		hamburger		
Trial 3b	TO	take pen	correct	correct
	hamburger			
Trial 4a	TO foot	take flag	correct	correct
Trial 4b	TO flag	take foot	correct	correct
Trial 5a	TO fuzzy	take kg	correct	correct
Trial 5b	TO kg	take fuzzy	correct	correct
Trial 6a	TO jumpy	take punt	correct	correct
Trial 6b	TO punt	take jumpy	correct	correct

General discussion

Findings for the multiple and familiar objects study, Experiment 1, showed that Chaser was successful in demonstrating syntax and semantic understanding on 25 of the 32 response choices (78%). Findings for the novel objects study, Experiment 2, showed that Chaser was successful in demonstrating syntax and semantic understanding, as well as combinatorial understanding on 18 of the 24 trials or 75% of the test trials. Thus, after learning the name of the objects, she was able, as are children, to understand the meaning of the sentences even though the objects had never been used in the syntax sentence. Findings in the third experiment testing Chaser's understanding of the syntax sentences, when vision of the objects was not possible during the utterance of the syntax sentence, showed that Chaser was 100% correct in her selection of the 12 direct object options and the 12 prepositional options. The combined findings of the three studies support the conclusion that in both the familiar and novel studies Chaser did, indeed, process and retain memories of prepositional and direct objects. Together, the combined findings of the familiar, novel, and memory studies closely match the data obtained in the dolphin studies (Herman et al., 1984, p. 162) involving sentences consisting of three elements of grammar.

Our findings invoke two major questions. First, what mechanisms enabled Chaser to learn the syntax and semantics of the three elements of grammar sentences? Without identifying specific procedures or elements, Herman et al. (1984) attributed the syntax learning of his dolphins to their previous learning experience. They asserted that just as cognitive abilities of humans depend upon previous learning experiences, we should also expect that the cognitive abilities of nonhuman animals depend upon past exposures to challenging training regimes. Often, cognitive abilities depend upon long term, intensive language and non-language learning programs. Intensive training often un-masks cognitive skills. In addition, Herman and Samuels (1996), in their analysis of the successful learning of the two dolphins, asserted that "the syntactic rules of their syntactic language were not explicitly taught to the dolphins. Nevertheless, they acquired an implicit knowledge of those rules through experience with exemplars of proper strings of words (p. 299)." Herman and Samuels proposed that this implicit knowledge enabled successful responding to novel syntactic sentences. Chomsky (1957) asserted that a major linguistic skill humans use to understand the intention or message of others is the use of grammatical features, such as syntactic rules and lexical features. It is this knowledge that enables what Chomsky called the *mysterious ability* of human language users; that is, "having mastered a language, one is able to understand an indefinite number of expressions that are new to one's expression (Chomsky, 1972, p. 100)."

We, too, propose that Chaser's understanding of the three elements of grammar sentences evolved out of her intensive training for learning the metaphorical ABC's of words and grammar; that is, learning the meaning of specific words and different types of words developed greater sensitivity for verbal symbols and referential cues. In some way, whether by cognitive processes, associative processes, by the inherent properties of different types of words themselves, or by the combination of all three mechanisms, Chaser learned, as do children, to respond appropriately to different classes of words. For example, verbs elicited action, nouns were physical entities and were acted upon, adverbs qualified or moderated the action of the verb, adjectives characterized the nouns, and prepositions qualifying the positions of objects. Our findings of Chaser's combinatorial understanding of words reveal that Chaser's comprehension of sentences is not confined to a rote memorized strings of words; rather, in some way, her brain is partially constructed like that of humans; that is, most of the words that she has learned can be used in different contexts and in novel sentences without additional learning.

A second major question evoked by our findings involves cognitive abilities. What cognitive processes allowed Chaser to demonstrate understanding of our three elements of grammar sentences? First, analysis of our findings reveals that Chaser's successful understanding of the syntax sentences required the processing and retention of two sound-object mappings (names-objects) into memory. Second, successful performances required semantic judgments concerning which object to take to the other – that is, working memory. Recognition that a dog possesses these two cognitive abilities, dual memory storage and working memory, raises the bar in terms of our expectations of a dog's language learning.

When humans are asked to complete verbal instructions in a particular order, many people will mentally rehearse the instructions repetitively – maintaining the verbal code in working memory until the task is completed in the correct order. Working memory theorists refer to this rehearsal as the phonological loop. Considering Chaser's successful performance in our three studies, we ask: Is it possible that she has developed a type of phonological loop? If not, might it be possible to teach a dog the phonological loop? Of course, we have no present data to answer these questions; however, these are novel and interesting questions that merit research.

If Herman and Samuels (1996) were right in their conclusion that dolphins acquired an implicit knowledge of their grammar rules, not through explicit teaching, but through experience with exemplars of strings of words, our challenge, as teachers and researchers, is to create challenging word learning experiences. This is how the farmer trains his Border collie to work in harmony with him in herding sheep. Following the learning of a few obedience commands, the dog is literally turned loose upon the sheep. As the dog spontaneously initiates different behaviors, on the basis of positive or negative vocal responses by the farmer, the dog learns to infer correct and incorrect behavior. This learning, however, is nothing more than learning by means of positive and negative reinforcement of responses. But as the farmer alters and labels the goals of the herding, such as herding the sheep toward or away from the farmer or to different locations, the dog infers that the name of the location specifies a given location to which the dog must herd the sheep without the farmer; thereafter, the dog needs only a single verbal command to take the sheep to the designated location.

We propose that Chaser's understanding of the syntax rules and the semantics of sentences consisting of a prepositional object, a verb, and direct object represents a giant leap in her referential understanding of language and opens the door for learning further language skills.

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