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Distinguishing Logic From Association in the Solution of an Invisible Displacement Task by Children (Homo *sapiens)* and Dogs *(Canis familiaris):* Using Negation of Disjunction

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Prior research on the ability to solve the Piagetian invisible displacement task has focused on prerequisite representational capacity. This study examines the additional prerequisite of deduction. As in other tasks (e.g., conservation and transitivity), it is difficult to distinguish between behavior that reflects logical inference from behavior that reflects associative generalization. Using the role of negation in logic whereby negative feedback about one belief increases the certainty of another (e.g., a disjunctive syllogism), task-naive dogs *(Canis fantiliaris; n* = 19) and 4- to 6-year-pld children (Homo *sapiens; n* = 24) were given a task wherein a desirable object was shown to have disappeared from a container after it had passed behind 3 separate screens. As predicted, children (as per logic of negated disjunction) tended to increase their speed of checking the 3rd screen after failing to find the object behind the first 2 screens, whereas dogs (as per associative extinction) tended to significantly decrease their speed of checking the 3rd screen after failing to find the object behind the first 2 screens.

In his classic investigations of children's development of the conceptual understanding of object permanence, Piaget (1937/1954) used a progressive series of tasks to establish the level of a child's understanding of how objects exist in the physical world. Piaget proposed two capacities as central to normal progress in this development. One was the capacity to mentally represent the object during times when there was no direct sensory evidence of its existence, such as when the object is occluded by another object or container, and the other was the capacity for sensing logical implication. Thus an 8-month-old child's successful recovery of an object hidden under a cloth was seen as supporting the claim that the child was guided by some representation of the object's existence. However, when the child searched the same place immediately after watching the object be hidden elsewhere, Piaget argued that this (A-not-B) error disclosed the incapacity of the child to place the object concept in logical relation to its defining spatio-temporal context. Later, in what he termed *Stage VI,* which children would reach at about 18 to 20 months, the child's success at finding an object by systematically searching the places to which it might have been moved while it was occluded was taken as evidence of the child's object concept being properly integrated logically with the concept of space. The criterial task was termed *invisible displacement* wherein an object is occluded within a container (or behind a barrier) and the container passes within or behind other occluders and then is shown to no longer hold the object. The child with a logically organized concept of the object would be expected to search the places that the container had visited between the time it held the object and the time it no longer held the object. At this stage, objects are conceived of in terms of being particular identities such that when an object reappears after being absent, it is viewed as the object that disappeared versus an object of equivalent form. In Piaget's (1937/1954) words

> The representation and deduction characteristic of the sixth stage result in extending the process of solidification to regions of that universe which are dissociated from action and perception; displacements, even invisible ones, are henceforth envisaged as subservient to laws, and objects in motion become real objects independent of the self and persisting in their substantial identity. (p. 86)

Animal Research on the Stage VI Invisible Displacement Task

Dore and Goulet (1998) have recently reviewed the existing investigations of the capacity of nonhumans to solve the invisible displacement of objects. Dore and Goulet's focal interest in doing

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so was to introduce a classical theoretical distinction between two kinds of representational capacity: recognition and recall. Consistent with Piaget (1937/1954) Dore and Goulet have argued that true Stage VI solution of invisible displacement involves the subject being guided by recall of the object versus by mere recognition of some cue that was associated with the time and place of the object's disappearance (see Piaget, 1937/1954, pp. 84-87). They concluded that the evidence to date supports attributing Stage VI capacity to only a few primates and possibly a species of bird (a parrot). Of particular interest to this study is their conclusion that dogs as well as cats are limited to Stage V capacity (which is the ability to solve visible but not invisible displacement). Of special relevance is Dore and Goulet's summary review of the extensive series of studies with dogs conducted by Dore and his colleagues (Dore, Fiset, Goulet, Dumas, & Gagnon, 1996; Gagnon & Dore, 1992, 1993, 1994). Although Gagnon and Dore's 1992, 1993, 1994) early research appeared to support the dogs' capacity to perform at Stage VI, the eventual pattern of results with sophisticated controls for the animals' reliance on recognition of place cues led these researchers to conclude that the dogs were not guided by recall of the object per se.

The apparent failure of dogs to reach Stage VI level of representational capacity raises the question of whether they are likewise limited in terms of deductive capacity. Piaget (1937/1954) attributed primitive deduction to children as they solved Stage IV and Stage V of the object permanence task series. However, only at Stage VI did Piaget view deduction as being applied to the logical integration of time, space, and identity of substance.

Animal Research on Logical Capacity

Behavioral guidance by logical implication (inferential or deductive) is difficult to verify in young children and animals. It is often the case that the same behavior might be expected on the basis of past associative learning (McGonigle & Chalmers, 1977, 1992; Russell, McCormack, Robinson, & Lillis, 1996; Watson, 1968). This difficulty has been a challenge for cognitive psychologists, particularly Piagetian constructivists, as they offered alternative explanations of associative learning theories during the second half of the past century. Yet even after the ascendance of cognitive psychology and the theoretical acceptance of logical reasoning as separable from associative generalization (Pascual-Leone, 1996; Sloman, 1996), there remains a basic problem of finding situations in which the two modes of behavioral guidance predict different behavior.

One of the earliest attempts to separate logical behavior from associative behavior was done by Smedslund (1961), who assessed children's behavior in the classic Piagetian task of substance conservation. Children were asked whether an amount of plasticine was the same or different after a transformation of shape. In three successive displays and questioning trials, the experimenter surreptitiously removed some of the plasticine while transforming its shape. The conserving response of saying the transformed substance was still the same amount was thus exposed to three extinction trials. Children who, by virtue of a training routine, gave the conserving response showed significant extinction. By contrast, children who were already conservers before the training did not stop claiming that the substance was still the same after transformation despite the negative feedback for this response. Smedslund interpreted their resistance to be evidence that they possessed a mediating logical structure.

Watson (1968) raised some doubt about the validity of resistance to extinction of saying same as a basis for distinguishing between logical behavior and associative behavior in Smedslund's (1961) subjects. Watson argued that one might simply propose that subjects who gave the conserving response prior to the training were exhibiting the effects of prior associative experience that, added to the training, provided them with a greater resistance to extinction.

In a separate context, Bryant and Trabasso (1971) developed a task of transitive reasoning that appeared to show that children might display deductive inference long before they reach Piaget's stage of concrete operations. However, in its simplest form, Piaget's three-step transitive problem maps onto a ready solution by association. A is greater than *B* and B is greater than C sets up A is greater than C by the associative history of A and C for the slots in - is greater than - To avoid this problem, Bryant and Trabasso introduced a five-step transitive problem and inverse wording during testing. After learning four relational pairings (i.e., $A > B$, $B > C$, $C > D$, and D > E), subjects were asked if $D < B$ as well as all other possible pairings. The results from their sample of 4-year-old children provided Bryant and Trabasso with evidence that was consistent with what logical coordination of the relations would predict.

However, McGonigle and Chalmers (1977) presented a version of this procedure to a sample of adult squirrel monkeys and found their test performance to be remarkably similar to that of Bryant and Trabasso's (1971) sample of 4-year-old children. McGonigle and Chalmers went on to test the monkeys with triadic subsets (*ABC, BDE* etc.) in addition to the standard binary subsets (AB, *DE,* etc.) and found that their monkeys' performance could be accounted for by a binary sampling model, which predicted a reduced transitive effect under the triadic presentations. In short, the monkeys' behavior implied some level of inference but not necessarily full deductive coordination of transitive relations.

In a later series of studies, McGonigle and Chalmers (1992) provided evidence that squirrel monkeys may be capable of true transitive reasoning and perhaps even a form of protoseriation of transitively related items. Introducing an extended period of experience with binary subsets, they found that their monkeys performed the triadic test items in a manner that was no longer explicable by binary sampling and thus appeared to display a true solution by transitive inference. Thus, McGonigle and Chalmers (1992) were moved to make a stronger claim than in their earlier (McGonigle & Chalmers, 1977) study about the potential logical prowess of their subjects. This change is reflected in the titles of McGonigle and Chalmers's two studies: "Are Monkeys Logical?" and "Monkeys Are Rational!" However, the shift of terms from logical to rational appears to represent a cautionary stance with regard to excluding an associative explanation of nonverbal test results.

Russell et al. (1996) proposed that the tasks used by McGonigle and Chalmers (1977, 1992) did not really afford a true logical solution because they did not manipulate a dimension of preference but rather a set of discriminative choices among stimulus pairs (a criticism seemingly anticipated and countered by McGonigle & Chalmers, 1992, pp. 224-225). Russell et al. proceeded to compare children's performance on McGonigle and

Chalmers's (1992) test and another test (modeled on Bryant & Trabasso's, 1971, task), which involved a preference dimension. Russell et al. found that children performed significantly better on the latter and concluded that their finding "leaves open the possibility that, although children are not restricted to associative strategies when completing 5-term series tasks, animals may be thus restricted" (p. 231). However, even if a person accepts their requirement of testing with an explicit dimension, the absence of data on how monkeys would perform on the dimensional task obscures Russell et al.'s comparative claim. The authors, aware of this, defend their claim on the grounds of parsimony. However, the idea that children may use either logical strategies or associative strategies in contrast to the monkeys' possible limitation to use only associative strategies, is consistent with Sloman's (1996) review of evidence for the existence, in humans at least, of two systems of reasoning: rule-based and associative.

A Nonverbal Test of Deduction in the Invisible Displacement Task

The prior work on nonverbal indexes of logic in other task contexts encouraged our effort to examine deduction in the invisible displacement task. When considering the potential impact of negative feedback during an exhaustive search, a distinction between associative guidance versus deductive guidance would seem rather clear. The effect of failing to find the hidden object under one of multiple possible places should have quite the opposite effect on the anticipation of subsequent success for the two modes of behavioral guidance.

Under the guidance of only an associatively based commitment to search (i.e., acquired disposition, habit, reinforced response tendency, or even an associative rule), each failure to find the object behind a selected screen amounts to an extinction trial for the association. Adding to this the assumption that the sequence in which places are searched represents an implicit order of the relative attractiveness of those places, one should expect declining response strength with each failure to find the object and thus a slowing of the rate of search over time.

Under the guidance of only a logically based commitment to search (i.e., a belief that the object must be in one of the hiding places), each failure to find the object in a selected place amounts to an increase in the implied likelihood of the object being at a place not yet searched. Just as with consideration of associative guidance, the order chcsen for searching potential hiding places carries an implicit designation of relative attractiveness. However, in the case of expectancy being affected by logic, one can expect an increase in absolute attractiveness of places searched later, particularly the final place for which deduction (via a disjunctive syllogism: A or B, not A, therefore B) claims certainty.

In the present study, we applied this index of deduction to the search behavior of (a) adult dogs and (b) a comparison group of 4- to 6-year-old children in a test situation involving three potential hiding places.[1] On the assumption that dogs have not reached Stage VI in either deductive or representational capacity, our prediction was that the time taken to move from the first searched place to the second would be shorter than the time taken to move from the second to the third. On the assumption that 4- to 6-year-old children (being midway into the preoperational period according to Piaget, 1937/1954) are fully capable of performance at Stage VI of the sensory motor period test of object permanence, our prediction was that the time taken to move from the first searched place to the second would be longer than the time taken to move from the second to the third.

Method

Subjects

Dogs

It was important to test dogs (*Cams farnitiaris)* that were initially naive to the structure of the task. The dogs were recruited from among pet owners who were attending a dog-obedience training class. None of the dogs had received special training in hunting, retrieval, or rescue. As pets, some may well have played fetch in informal contexts. Dogs were selected on the basis of availability and willingness of their owners to participate. However, because active participation in trials was essential, an initial warm up and screening procedure, lasting about 5 min, was used to establish the basic inclination of the dogs to retrieve objects. In this procedure, the experimenter first familiarized himself with the dog (by greeting and petting it) and then presented it with several different objects (see *Procedure).* When the dog picked up one of the objects, the owner was asked to take it away from the dog and throw it about 1 to 2 m away. While throwing, the owner was to say, "Fetch it here, please" ("Hozd, hozd ide kerlek" in Hungarian). This routine was repeated 10 times. Dogs that made seven or more successful retrievals were presented with the introductory visible displacement trials. Seven dogs were rejected from the sample because they did not pass the warm-up criterion. Four more were rejected because they failed to search for the object in the introductory vials. After these exclusions, the sample consisted of 19 dogs (8 females and I 1 males between 1.5 and 7 years of age: 9 tervuerens, 2 malenois, 3 Labrador retrievers, 4 golden retrievers, and I Doberman pinscher).

Children

The sample of children *(Homo sapiens)* was drawn from those attending a nursery school in Budapest. During a warm-up period prior to the introductory trials, the experimenter greeted the child and the assistant (a familiar adult from the nursery school who accompanied the child to the testing room) and tried to interest the child in selecting a toy (see *Procedure). Two* children appeared too shy to engage in the task at this point. Four other children failed to search during the introductory trials (e.g., signaling a desire to return to the nursery school classroom by going to the door instead of searching the screens). After these exclusions, the sample consisted of 24 children (14 girls and 10 boys between 4 and 6 years of age).

Experimental Setting

The experiment was carried out in Hungary in environments that were moderately familiar to the participants. Children were observed in a room of their nursery school, and dogs were tested in an enclosure at the obedience training school that they attended on weekends together with their owners. The experimental arrangement is shown in Figure 1. Three green plastic screens (frontal side: 40 cm wide *X* 60 cm high) were placed along a semicircle, and a plastic, opaque flowerpot (20 cm deep, 15 cm in diameter) was used as a container. It is important to note that there was a

[1] The data presented here are part of a larger unpublished study involving additional subsequent testing. The larger study was concerned with acquisition of social rules and involved the testing of adult participants as well.

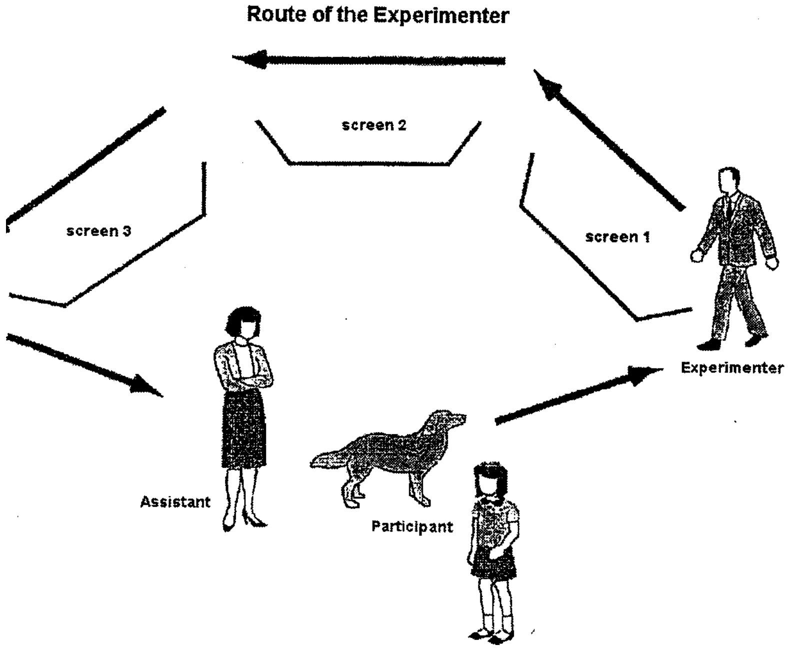

Figure 1. Schematic drawing of test situation showing route of experimenter behind the three screens where object could be hidden.

wall 1.5 m behind the center screen so that while searching, a subject's sight line was always restricted at most to one screen's hiding area. The experimenter, camera person, assistant, and subject were in the room during the trials. For the dogs, the assistant was the dog's owner, and for the children, the assistant was a familiar adult from the nursery school.

Procedure

Dogs

In compliance with current Hungarian laws on animal protection, dog owners accompanied their dogs to a room in the dog training center. The dogs were allowed to explore the room for about 1 min. Depending on which of the potential target objects the dog had selected most frequently during the warm up trials, the target object used was either a small rubber bear, a plastic dog, a plastic baby doll, or a small ball. The owner had the dog sit in the middle of the circle, and if necessary, restrained the dog by its collar. The experimenter then captured the dog's attention with the target object in hand and placed the object in the container. The experiment consisted of two phases: (a) the introductory trials and (b) a test trial.

Introductorv trials of visible displacement. To appropriately orient the dogs to the task, we ran six successive visible displacements trials. For 9 of the dogs, the experimenter visited each screen sequentially in a clockwise direction through the arch of three screens. For the other 10 dogs, the experimenter visited each screen in a counterclockwise direction. In half of the trials (i.e., during the first, third, and fifth trials), the toy was left behind one of the screens in randomized order (once per screen across the three trials). After crouching behind the 60-cm high screen, the experimenter placed the container on the floor. The object was removed from the container (or not) and after 3 s, the experimenter stood up and continued. After visiting a screen, the experimenter either took the retained toy out of the container and held it up for a moment before placing it back in the container or showed that the container was now empty. After returning from visiting all three screens (taking 12-14 s including approximately 3 s crouching down behind each screen), the experimenter placed the empty container in front of the dog for inspection (which usually consisted of the dog looking in, sometimes followed by inserting the muzzle). The owner then prompted the dog to search for the toy using the Hungarian phrase "Hozd, hozd ide kerlek" ("Fetch it here, please"). The owner stayed at the starting position as the dog searched freely on its own. When the object was retrieved, the owner praised the dog. In the other half of the trials (during the second, fourth, and sixth trials), the experimenter visited all the screens and after each visit held up the object momentarily and then returned it to the container. Thus, in these cases, the dogs saw that the object remained in the container throughout. The dogs were prompted to retrieve the object in these trials just as they were prompted in the trials of displacement behind a screen.

Test trial of invisible displacement. The introductory trials were followed by a modified version of the standard successive invisible displacements task. This was similar to the introductory trials in which all three containers were visited (clockwise for 9 dogs and counterclockwise for 10 dogs) except that now the displacements of the target object were invisible (i.e., the content of the container was not revealed in between visiting the screens). In fact, the target object was not left behind any of the screens because the experimenter placed the toy surreptitiously in his pocket while hiding the container behind one of the three screens. Thus, when the experimenter returned, the empty container was shown to the dog. The dog was then prompted with the Hungarian word "mehetsz" ("you may go") but without any additional instructions or gestures to encourage searching. The dog was allowed to search some or all of the containers for l min or to engage in any other type of behavior while its performance was videotaped. During this time, all but 1 dog completed an exhaustive search of *all* three screens, and that dog visited two of the three screens. At the end of the 1-min trial, the hidden toy was presented to the dog by the experimenter. The videotape provided the basis for subsequent data analysis.

Children

In compliance with current Hungarian laws on human participation in research, a familiar adult from the nursery school accompanied the children to the testing room in the nursery school. The children were not given any specific instructions about the nature of the task before the trials of the experiment began. They were allowed to explore the room for about 1 min. The assistant then presented the set of potential target objects (small rubber bear, plastic dog, plastic baby doll, and small ball) to the child trying to arouse interest in the objects. When the child selected a toy, the experimenter held it up and asked, "Would you like to do something interesting with this toy?" If the answer was yes, the experimenter said, "Let's start; you'll see this will be fun." Then the assistant had the child sit in the middle of the circle and stood immediately behind the child. The experimenter captured the child's attention with the target object in hand and then placed the object in the container. As with the dogs, the experiment consisted of two phases: (a) the introductory trials and (b) a test trial.

Introductory trials of visible displacement. To appropriately orient the children to the task, six successive visible displacement trials were run in exactly the same way as described with the dogs. For half of the children, the experimenter visited each screen sequentially in a clockwise direction through the arch of three screens. For the other half, the experimenter visited each screen in a counterclockwise direction. In half of the trials (i.e., during the first, third, and fifth trials), the toy was left behind one of the screens in randomized order. After visiting a screen, the experimenter either took the retained toy out of the container and held it up for a moment to show it to the child before placing it back in the container or showed the child that the container was now empty. When the experimenter returned from visiting all three screens, he placed the empty container in front of the child for inspection (which usually consisted of the child quickly looking in the container) and then the assistant prompted the child to search for the toy using the Hungarian phrase "Hozd, hozd ide kerlek" ("Fetch it here, please"). The assistant remained in her position, which had been directly behind the seated child, as the child went about his or her searching. When the object was retrieved, the assistant praised the child. In the other half of the trials (during the second, fourth, and sixth trials), the experimenter visited all the screens and after each visit held up the object momentarily and then returned it to the container. Thus, in these cases, the child saw that the object remained in the container throughout. The child was prompted to retrieve the object in these trials just as the child was prompted in the trials of displacement behind a screen.

Test trial of invisible displacement. In the same manner as with the dogs, the introductory trials were followed by the successive invisible displacement task. This was similar to the introductory trials in which all three containers were visited (clockwise for 12 children and counterclockwise for 12 children), except that now the displacements of the target object were invisible (i.e., the content of the container was not revealed in between visiting the screens). In fact, the target object was not left behind any of the screens because the experimenter placed the toy surreptitiously in his pocket while he hid the container behind one of the three screens. Thus, when the experimenter returned, the empty container was shown to the child. The child was then prompted with the Hungarian word "Mehetsz" ("you may go") but without any additional instructions or gestures to encourage searching. The child was allowed to search some or all of the containers for 1 min or to engage in any other type of behavior while his or her performance was videotaped. During this time, all children completed an exhaustive search of all three screens. At the end of the 1-min trial, the hidden toy was presented to the child by the experimenter. The videotape provided the basis for subsequent data analysis.

It should be noted that neither the owners of the dogs nor the assistants with the children were informed of the specific objectives of the experiment. They were told only that the task involved searching for hidden objects. They were, of course, given instructions for where to stand and when to give the specific verbal prompts.

Results

Introductor3, Trials of Visible Displacement

The search pattern of subjects was analyzed for the trials on which the object was hidden (first, third, and fifth trials). When shown the empty container, the children typically glanced into it and set out to search the screens. The dogs also made a quick visual inspection of the container, but most dogs also sniffed it as well and then went on to the screens. *No* dogs continued to sniff in the area around the container. All subjects continued searching until they found the object, and all completed this within 15 s. A trial was considered correct if the subject's first choice was the screen containing the object. If the first choice was an empty screen, then an error was recorded. More frequently than expected by chance, dogs (13 of the 19) chose the screen containing the target object on the first trial (68% vs. 33%), $X^2(1, N = 19) = 10.54, p < .01$, as did the children (17 of the 24) on their first trial (71% vs. 33%), $X^2(1, N = 24) = 15.19, p < .01$. The groups did not differ significantly on this trial, $X^2(1, N = 43) < l$, ns. However, as shown in Figure 2, dogs showed a significant decline in performance from the first to the third trial (Sign test; 9 declined, I improved, 9 ties; $p < .02$). Children did not decline significantly, resulting in the fact that dogs performed significantly less well than did children on Trial 3, $X^2(l, N = 43) = 5.39, p < .05$, and marginally so on Trial 5, $X^2(1, N = 43) = 3.40, p < .10$.

On Trials 1, 3, and 5, all subjects searched until they eventually found the target object. Thus, one of the two possible errors that subjects could make on Trials 3 and 5 was the classic A-not-B error of returning to the place in which the object was found on the preceding trial of screen hiding. Errors on Trials 3 and 5 were examined to determine the extent to which subjects were prey to this error form. Of the 12 errors made by children, 5 (42%) were A-not-B errors. Of the 23 errors made by dogs, 16 (70%) were A-not-B errors. In the latter case, the difference from 50% chance expectancy as observed across individuals (11 favoring, 5 not, and 3 ties) approaches significance (Sign test, $p < .11$).

Performance of subjects on Trials 2, 4, and 6 is notable. On these trials, the object was shown to remain in the container. None of the children and only 2 of the dogs ever went on to check behind the screens once shown that the object was still in the container.

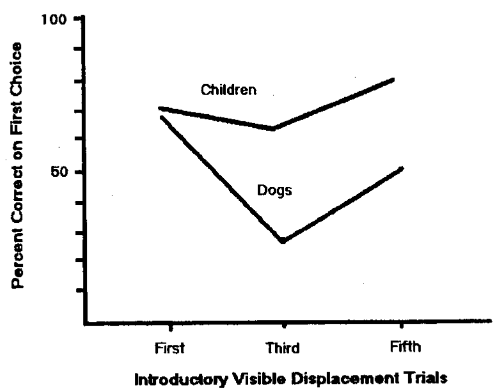

Figure 2. Comparison of success at finding object on first choice for the three visible displacement trials that occurred on the first, third, and fifth introductory training trials.

This was a clear and sensible contrast to the motivated search on Trials 1, 3, and 5 following disclosure of the empty container.

Test Trial of Invisible Displacement

Following the experience with the six introductory trials, one might predict that subjects would conduct an exhaustive search of all three screens during the invisible displacement task on the basis of either associative generalization or logical deduction. Subjects had observed that when the object is no longer in its original container, then it is behind a place that the container has visited. Because the container has visited all three of the screens, the screens should be viewed as equally likely to hold the object unless the subjects were to introduce a search bias to the task. Even with some form of search bias, there should be a decided difference between subjects guided by associative generalization and subjects guided by logic as they receive negative feedback for their search behavior. With a purely associatively based commitment to search, each failure to find the object behind a selected screen amounts to an extinction trial, and we expect declining response strength across search trials. With a purely logically based commitment to search, each failure to find the object behind a selected screen amounts to an increase in the implied likelihood of the object being behind a screen not yet searched, and we would expect increasing response strength across search trials.

All children performed a full search of all three screens. The dogs did so as well with the exception of 1 dog that searched only two of the three screens in the 1-min time allotted. A search sequence was classified as systematic if the subject progressed sequentially through the three screens (i.e., without returning to the first searched screen upon leaving the second). All but 2 children and 6 dogs displayed systematic search. This difference in relative frequency of systematic search between the groups was not statistically reliable, X`(1, N = 43) = 2.40, *ns.* It is worth noting that the dogs appeared to primarily search visually, though occasionally visual inspection was followed by the dogs' lowering the head and sniffing the area.

Because the container was shown to pass behind all three screens, in the absence of a search bias there is no reason to prefer any one of them. However, as Table 1 shows, both dogs and children exhibited clear screen preference as their first choice for inspection. Most of the dogs inspected first the screen that was visited last, as if they followed the local rule of "go to the screen last visited by the experimenter." The children searched systematically either in a backward direction (i.e., similar to the dogs, starting from the last visited screen and proceeding backward) or in a forward direction, starting from the first screen visited by the experimenter, as if they acted according to the local rule of "go to the first screen visited by the experimenter." It seems clear, therefore, that both children and dogs enter the search task with a dispositional bias for setting the relative attractiveness of the otherwise equal options. The preponderance of both groups to begin with an outside (vs. the middle) screen may also reflect the influence of some evaluation of least effort in composing a search path.

The focal test was composed of a comparison between the speed of moving from the first screen to the second screen in contrast to the speed of moving from the second screen to the third screen. The overall time taken to complete inspection of all three screens ranged from 3.4 to 28.6 s for the 24 children and from 4.6 to 31.7 s for the 18 dogs that searched all three. If a subject was in nonoverlapping areas behind each screen (standing or passing through it) and was facing the screen interior (i.e., head oriented toward it), then we counted that as an act of inspecting that screen. We assumed that the time taken to move between screens would be an index of the momentary attractiveness of the screen being approached.

As shown in Figure 3, dogs took longer to move from Screen 2 to Screen 3 ($M = 7.80$ s, SD = 10.46 s) than they had taken to move from Screen 1 to Screen 2 ($M = 3.12$ s, SD = 2.50 s). By contrast, children took less time to move from Screen 2 to Screen 3 (M = 1.58 s, $SD = 0.95$ s) than they had taken to move from Screen 1 to Screen 2 (M = 2.45 s, $SD = 3.45$ s). Performance differences between groups and across trials were subjected to a 2 X 2 analysis of variance (ANOVA) with trials as a repeated measure. As is common with duration measures, the skewed distribution of time scores required conversion to logarithms prior to analysis. The main effect of groups in speed of moving between screens was reliable, $F(1, 41) = 12.37$, $p < .001$. As is evident in Figure 3, children generally moved faster from screen to screen. The main effect of trial was only marginally significant, $F(1, 41) = 3.17$, $p < .09$, with the movement to the third screen being somewhat slower than the movement to the second screen on average. The predicted interaction between trial and group, however, was reliable, $F(1, 41) = 10.66$, $p < .002$. Subsequent tests of the within-group differences from a null hypothesis of no change found that the dogs reliably slowed down, $t(18) = 2.84$, $p < .02$, but the children's tendency to speed up was not reliable, $t(23) = 1.36$, *ns.*

As Table 1 shows, 3 dogs and 1 child visited the middle screen first. This fact could have biased their relative times on account of the greater distance between Screens 1 and 3 versus the distance between Screens 1 and 2 or Screens 2 and 3. To eliminate this potential bias, we repeated the analysis without the data from these 4 subjects. The means for time between screens remained virtually unchanged by this adjustment (for dogs, the mean movement from Screen 2 to Screen 3 was 7.77 s, $SD = 11.12$ s, and for children, the mean movement from Screen 2 to Screen 3 was 1.57 s, $SD = 0.98$; for dogs, the mean movement from Screen 1 to Screen 2 was 3.01 s, $SD = 2.46$, and for children, the mean movement from Screen 1 to Screen 2 was 2.51 s, $SD = 3.61$). The results of ANOVA of the unbiased logarithmic time scores were only slightly different than the results with all scores. The main effect of groups in speed of moving between screens remained reliable, $F(1, 37) = 9.58$, $p < .004$. Children moved faster from

Table 1
Screen Visited First by Subject on the Invisible Displacement Test Trial

Subjects	Screen location: First	Second	Third	Difference from random distribution
Dogs	4	3	12	$\chi^2(2, N = 19) = 7.70$*
Children	10	1	13	$\chi^2(2, N = 24) = 9.75$**

Note. Screen location order as visited by experimenter.
* $p < .05$. ** $p < .01$.

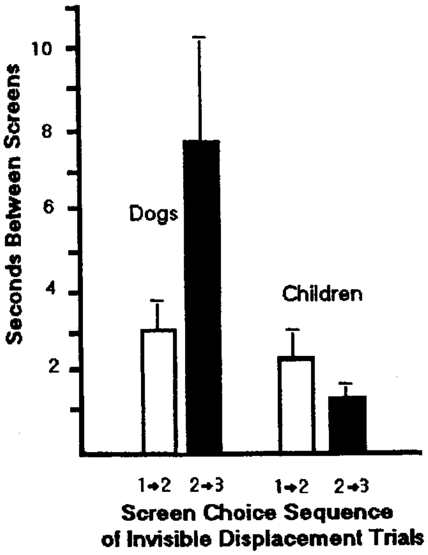

Figure 3. Comparison of mean (and standard error) time taken to move from the first screen chosen to the second screen chosen and from the second screen chosen to the third screen chosen on the test trial of invisible displacement. On this trick trial, the object was neither in the container nor behind any of the screens.

screen to screen. The main effect of trial was reduced in its marginal significance, $F(1, 37) = 1.95$, $p < .17$, with the movement to the third screen being somewhat slower than movement to the second screen on average. The predicted interaction between trial and group remained reliable, $F(1, 37) = 8.89$, $p < .005$. Subsequent tests of the within-group differences from a null hypothesis of no change found that the dogs reliably slowed down, $t(15) = 2.30$, $p < .04$, but that the children's tendency to speed up was not reliable, $t(22) = 1.55$, $p < .14$.

Discussion

The predicted increase in time taken between screens over trials for dogs was observed in 16 of 19 dogs (13 of 16 in the unbiased subsample). By contrast, 15 of 24 children (15 of 23 in the unbiased subsample) decreased their time. The predicted interaction of change in time taken by species was very significant. Although the predicted contrast to chance expectancy was significant for dogs (i.e., they decreased their speed), it was not for children (i.e., they increased their speed but not reliably). There would seem to be two potential explanations for the finding with children. On the one hand, it is conceivable that some children functioned logically whereas others functioned associatively. As Sloman (1996) has proposed, both systems of behavior control may be available to humans, whereas only the associative appears to be available to dogs. However, were that the case, one might expect to observe a bimodal distribution of speed change scores, with some children clearly speeding up and others clearly slowing down. No indication of bimodal distribution was observed. On the other hand, it is also conceivable that the children of this study were all subject to the modulation of behavior by logical implication. In the case of logical control, the intrinsic order of attraction to the three locations has to be countered by the force of implication. Presumably, the third location is lowest in the rank order to start with. Theoretically, logical implication needs to raise the attraction of this location to a level greater than that which had previously existed for the second position following the first position choice. Unlike the case for associative control, where the effect of extinction simply decreases the attractiveness of the later options, the effect of logical implication is adding incentive to the initially lower incentive values. It seems reasonable to suppose that in some cases the initial rank order will not be overcome even with an absolute increase in incentive.

The findings observed here for dogs reinforce Dore and Goulet's (1998) judgment that even though dogs may engage in an exhaustive search pattern in the invisible displacement task setting, they are not really functioning at a Stage VI level. Dore and Goulet's grounds for that conclusion are based on their failure to find evidence of the theoretically prerequisite level of representation in dogs. The performance of dogs in the present study's preliminary trials of visible displacement is consistent with Stage IV representational competence. The significant increase in error from Trial 1 to Trial 3 and the concomitant trend for committing the A-not-B error support that view. The finding that dogs significantly decreased speed of search behavior as they failed to find the hidden object after invisible displacement likewise indicates that dogs are not functioning at the level of Stage VI of object permanence in terms of its deductive prerequisite.

The present study provides support for an additional modest but important conclusion. Negation of disjunction can be added to the short supply of nonverbal tests of logical versus associative guidance of behavior. None of the tests, including this one, are immune to being recast in a manner by which associative learning could, with certain assumptions, account for the data. This was so, as noted earlier, regarding tests of transitive reasoning. In the present case, dogs and children could surely be shaped over a series of discriminative stimulus trials such that they learn in a certain situation that failure predicts success (e.g., p[Bl not A] > p[A] and p[Cl not A, not *B] > p[Bl* not A]). Given that the present study restricted testing to one trial with naive subjects, the observed contrast in response timing between children and dogs would seem most parsimoniously viewed as indicating that dogs rely on associative guidance and children rely, to some degree, on logical guidance when searching for objects that have recently disappeared.

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