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Oswald Social Sciences Second Place: Do Pigeons Develop Mental Representations when Demonstrating Transitive Inference?

Carter Daniels

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Abstract

Transitive Inference (TI) is shown when after being told that A is better than B and B is better than C, one can answer the question, what is better A or C (in which A, B, and C are arbitrary stimuli). To avoid end-point effects (A is always better and C is never better) and provide a nonverbal task that can be used with young children and animals, the task has been expanded to 5 terms (i.e., A+B-, B+C-, C+D-, D+E- in which + means choice is reinforced and - means not reinforced). TI is found when subjects choose B when given a choice between B and D. Interestingly; TI effects have been shown in many nonhuman animals including pigeons. Several noncognitive, associative theories that have been proposed to explain TI effects have failed to account for the variety of conditions under which TI effects have been found. One cognitive account of TI performance is that organisms are able to form a mental representation of the series (A>B>C>D>E). If so, presentation of the pairs of stimuli in a linear arrangement should facilitate TI performance, whereas presentation of the pairs of stimuli in a circular arrangement should not. We trained pigeons on either a linear or circular arrangement of stimuli. Results indicate that pigeons show TI under both conditions suggesting that mental representations of the linear relation among the stimuli are not responsible for TI in pigeons. We suggest directions for future research.

Transitive inference (TI) in humans involves the manipulation of premises that express a transitive relationship. For example, “Alice is taller than Bob” and “Bob is taller than Carey.” Then, from these two premises we can ask, “Who is taller, Alice or Carey?” If a subject answers, “Alice,” it is typically taken as evidence of TI, whereas if the subject answers “Carey,” it is taken as evidence for lack thereof. TI tasks like the one above have been used as a tool to assess the cognitive development of humans. Piaget (1928) showed that the ability to solve TI tasks emerge in children at about the age of seven. However, Bryant and Trabasso (1971) proposed that this 3-term task could be solved without the ability to think logically because Alice is taller and Bob is taller but Carey is not taller. This is known as an end-anchor effect, where the correct choice is based upon the absolute values of end terms. They presented children with a 5-term task that avoided end-anchor effects (A+B-, B+C-, C+D-, D+E- in which + represented the correct stimulus and – represented the incorrect stimulus) and found that when memory for all premise pairs was intact, children as young as four years old showed good TI performance.

McGonigle and Chalmers (1977) later augmented the 5-term task into a nonverbal task for studying TI in squirrel monkeys. In their procedure subjects were trained with four pairs of overlapping arbitrary stimuli, presented as interrelated simultaneous discriminations. First, they were trained with stimuli A and B, in which choice of A was reinforced and B was nonreinforced (i.e. A+B-). Then, they were trained with stimuli B and C, in which choice of B was reinforced and C was nonreinforced (i.e. B+C-). Pairs C+D- and D+E- were trained in the same manner. It has been suggested that from this training an implied series from A-E develops such that $A > B > C > D > E$ (Trabasso & Riley, 1975). Stimuli A and E serve as the endpoints of the series due to their unique reinforcement history, always reinforced and never reinforced, respectively. The purpose of the five-term series is that the critical test of TI can be derived from nonadjacent,

nonendpoint stimuli B and D, which have had similar reinforcement and nonreinforcement histories. Evidence of TI, then, is choice of B over D, because B is considered to be greater than D in the series. They found that squirrel monkeys, when presented with test pair BD, chose B consistently over D (McGonigle and Chalmers, 1977).

Since McGonigle and Chalmer's seminal study of TI in squirrel monkeys, evidence of TI has been demonstrated in many animals; for example, rats (Roberts and Phelps, 1994), fish (Grosenick, Clement, & Frank, 2007), and pigeons (Fersen, Wynne, Delius, & Stadon, 1991). Furthermore, recent research has suggested that TI may have evolved to serve a functional purpose—TI has been shown to help nonhuman animals in both foraging (Weiß, Kehmeier, & Schloegl, 2010) and social (Bond, Kamil, & Balda, 2003) contexts. The generality of these effects suggests that TI behavior may be governed by processes that are more basic than formal logic.

One account suggests that although the three internal stimuli (B, C, and D) each have been associated with reinforcement and nonreinforcement, the actual reinforcement histories of those central stimuli may not be similar. Thus, it is likely that B has a greater associative value than D, and as such is chosen over D. In a direct test of this hypothesis, Lazareva and Wasserman (2012) trained pigeons on the 5-term task with massed presentations of the D+E-pair such that the associative value of D was greater than the associative value of B. However, they found that B was still chosen over D.

Fersen et al. (1991) suggested an alternative noncognitive theory to account for TI—value transfer theory (VTT). According to VTT, when two stimuli, A and B, are trained in a simultaneous discrimination such that one is always reinforced (S+) and the other is never

reinforced (S-) some of the value accrued to the S+ transfers to the S-. This transfer of value enhances the value of the S-. Thus, in the case of stimuli B and D, although B and D may acquire the same degree of direct value (as the result of B+C- and D+E- training), because responses to A were always reinforced whereas responses to C were reinforced only half of the time (when presented with B+) A should transfer more value to B than C should transfer to D. Weaver, Steirn, and Zentall (1997) tested this hypothesis by training pigeons on a 5-term task in which the values of A, C, and E were all equated. In testing; however, pigeons still reliably chose B over D.

Given that both of the noncognitive theories discussed failed to account for the TI effects found, a more cognitive account may be worth looking into. Some have suggested that mental representations are a fundamental part of cognition in nonhuman animals (Gallistel, 1990). Furthermore, recent research has suggested that the hippocampus, which is involved during acquisition and testing of TI, may also be involved in integration of information and mental representations (DeVito et al., 2009; Wendelken & Bunge, 2009). Thus, it may be the case that pigeons form a mental representation of the series $A > B > C > D > E$ such that all essential information necessary for choice of B over D is retained (Trabasso & Riley, 1975). Roberts and Phelps (1994) suggested that if mental representations are in fact aiding in TI performance, then the arrangement of the stimuli in training should affect the development of TI in the 5-term task. That is, the degree of TI found should depend on whether the stimuli were presented in a linear or a nonlinear arrangement. They trained rats on either a linear or circular arrangement of the 5-term task and found that rats trained on the linear arrangement showed TI whereas those trained on the circle arrangement showed no TI. They suggested that the spatial relationships inherent in

the arrangements facilitated construction of a mental representation that subsequently informed choice during testing.

Although the development of TI in rats, a species that is highly sensitive to spatial cues, appears to be eliminated by the presentation of the stimuli in a circular arrangement, pigeons, that also show strong evidence TI, are much more sensitive to visual cues. Thus, the purpose of the present experiment was to explicitly test the hypothesis that the arrangement of the presentation of the stimuli (linear vs. circular) would affect the mental representation of the series by pigeons. We randomly assigned pigeons to two groups, a linear arrangement group (LA) and a circular arrangement group (CA). Each group experienced a different explicit spatial arrangement of stimuli (see Figure 1) on a touchmonitor that had been fitted to an operant chamber. All pigeons were tested with critical test pair BD in a spatial arrangement different from the one trained so that context cues from the training arrangements could not directly affect their choice. We hypothesized that, if mental representations are involved in the TI effect, then pigeons in the LA group should show evidence of TI whereas pigeons in the CA group should not.

Method

In training, the stimuli (A, B, C, D, and E) were represented by the colors red, (R), yellow (Y), white (W), blue (B), and green (G), respectively, for half the pigeons in each group; and by G, B, W, Y, and R for the remaining pigeons. Training consisted of four phases, one per pair, i.e. A+B-, B+C-, C-D+, D-E+. Within each block, the location of the stimuli in the pair was randomized between two locations (see Figures 2 and 3). Each phase of training continued until a correct choice had been made on 90% of the trials for two consecutive sessions.

The pigeons were then tested on the BD pair. These locations were different from training arrangements, vertically aligned and equidistant (0.635cm) from the center of the screen. Choice of either stimulus was reinforced on a random half of the trials (to prevent differential learning on test trials). After testing, all pigeons were trained with mixed pairs.

Results

Mean percentage choice of B over D for group LA was 70.14% and for group CA was 64.06%. However, the groups did not differ significantly. Thus the data were pooled for further analysis. A one-way analysis of covariance (ANCOVA) using the proportion data compared to a hypothetical mean of 0.5 was conducted with spatial location (counterbalanced) as the covariate. Analysis revealed that the mean proportion choice of B differed significantly from the hypothetical mean, $F(1, 5) = 13.33, p = .015$. Additionally, there was a main effect of the covariate, $F(1, 5) = 9.76, p = .026$. Thus, there was a significant TI effect and there was no evidence that the spatial arrangement in training had a significant effect on the TI effect. The first session of mixed pairs training was taken as a measure of accuracy on training pairs. Accuracy on training pairs was highly correlated with performance on critical test pair BD, $r(5) = .78, p = .037$.

Discussion

Roberts and Phelps (1994) suggested that since spatial relationships influenced TI in rats, it was likely that they constructed a mental representation of the series. However, we found that pigeons trained on a linear arrangement of stimuli and pigeons trained on a circular arrangement of stimuli did not differ significantly in the TI effect found. This suggests that TI in pigeons is not significantly affected by the spatial arrangement of stimuli, which implies that pigeons may

not use mental representations in their choice of B over D. Additionally, we found that memory for training pairs after testing, and subsequently accuracy on training pairs, was highly correlated with TI performance. In other words, pigeons that had greater retention (memory) of values of the training pairs were more likely to choose B over D during TI testing, which is in accordance with data from young children (Bryant & Trabasso, 1971).

With the present results in mind, we believe that associative value theories may yet play an important role in the TI effect in animals. For example, the results of the present experiment suggest that further tests of the effects of value transfer are warranted. In addition, one could test for whether or not the pigeons understand the ordinal relationship of stimuli within the series. For example, one could test whether the pigeons can order the stimuli from largest to smallest. If nonhuman animals can do that, it would suggest that in TI tasks, animals learn both the associative strength and the ordinal relationships of the stimuli. Research along these lines should further clarify the basis for TI in animals.

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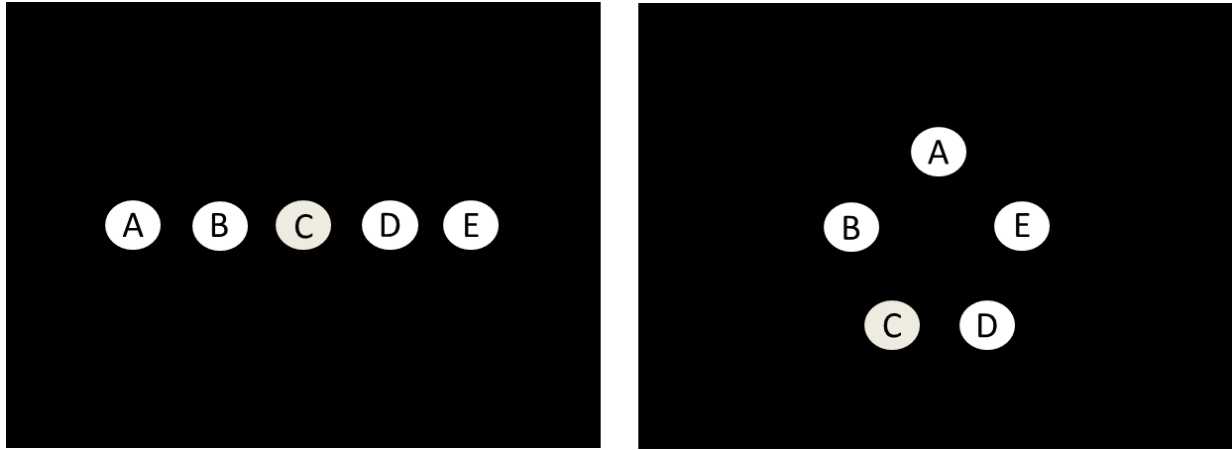


Figure 1. Stimuli locations for groups LA and CA. For the LA group, all birds were trained such that the arrangement was learned both from left to right (A-E) and right to left (A-E). For the CA group, all birds were trained such that the arrangement was learned both counterclockwise (A-E, starting at A's location) and clockwise (A-E, starting at E's location). Thus, both groups learned: $A > B > C > D > E$ and $E < D < C < B < A$.

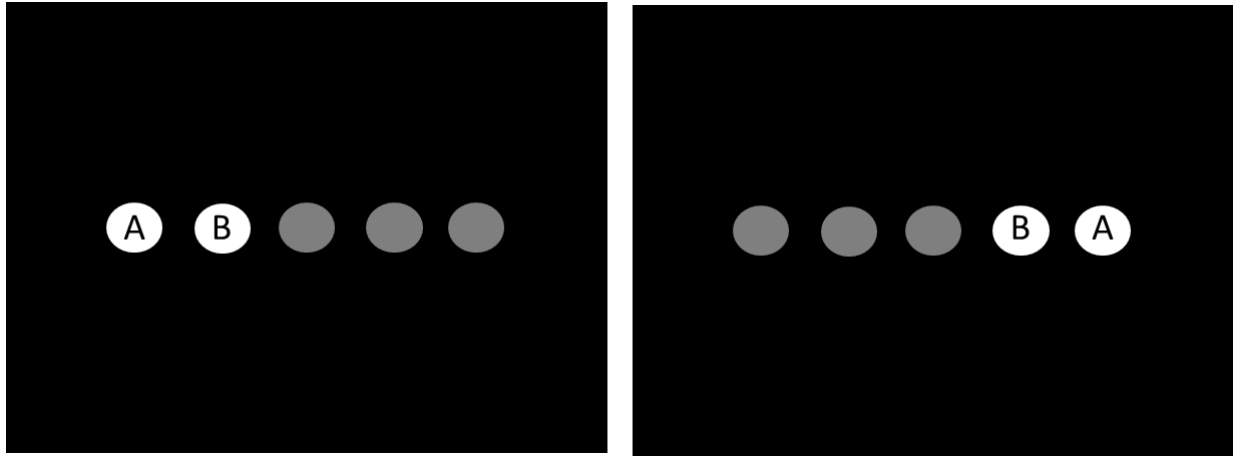


Figure 2. Example of possible locations for pair AB in LA group. During a session, the pair being trained was colored and the stimuli not involved were greyed out. To avoid using location as a cue, each pair could be presented in two possible locations, as seen above.

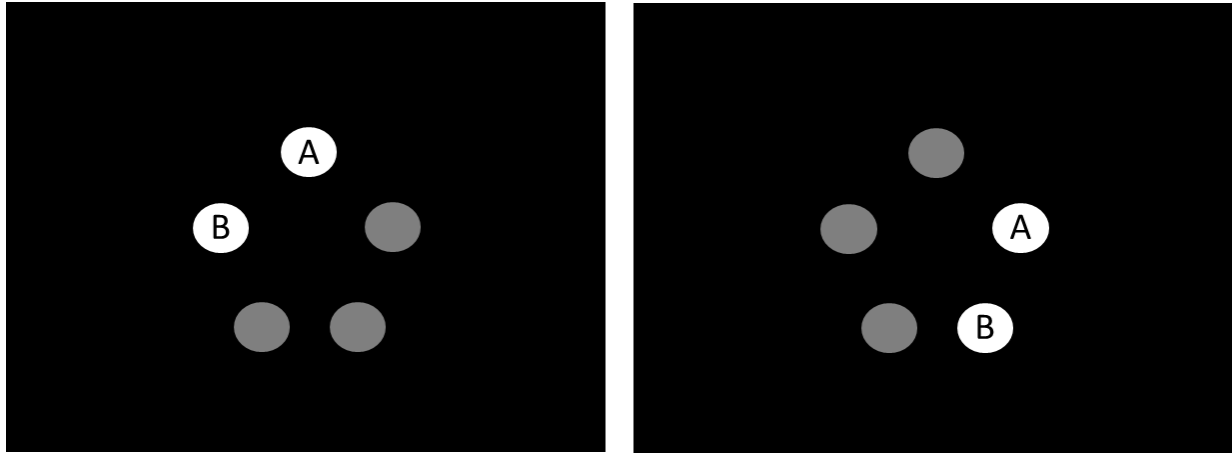


Figure 3. Example of possible locations for pair AB in CA group. During a session, the pair being trained was colored and the stimuli not involved were greyed out. To avoid using location as a cue, each pair could be presented in two possible locations, as seen above.