

1

**Title:**

Sensitivity to Relational Similarity and Object Similarity in Apes and Children

**Authors:**

Stella Christie<sup>1</sup>, Dedre Gentner<sup>2</sup>, Josep Call<sup>3,4</sup>, and Daniel Haun<sup>4,5</sup>

**Authors/Affiliations:**

<sup>1</sup> Department of Psychology, Swarthmore College, Swarthmore, PA 19081, USA

<sup>2</sup> Department of Psychology, Northwestern University, Evanston, IL 60208, USA

<sup>3</sup> School of Psychology and Neuroscience, University of St Andrews, St Andrews KY16 9JP, UK

<sup>4</sup> Department of Developmental and Comparative Psychology, Max Planck Institute for Evolutionary Anthropology, 04103 Leipzig, Germany

<sup>5</sup> Department of Early Child Development and Culture & Leipzig Research Center for Early Child Development, University of Leipzig, 04109 Leipzig, Germany

**Contact:** Stella Christie, [christie@swarthmore.edu](mailto:christie@swarthmore.edu)

### *Summary*

Relational reasoning is a hallmark of sophisticated cognition in humans [1,2]. Does it exist in other primates? Despite some affirmative answers [3-11], there appears to be a wide gap in relational ability between humans and other primates—even other apes [1,2]. Here we test one possible explanation for this gap, motivated by developmental research showing that young humans often fail at relational reasoning tasks because they focus on objects instead of relations [12-14]. When asked, *duck:duckling* is like *tiger:?*, preschool children choose another *duckling* (object match) rather than a *cube*. If other apes share this focus on concrete objects, it could undermine their relational reasoning in similar ways. To test this, we compared great apes and 3-year-old humans' relational reasoning on the same spatial mapping task, with and without competing object matches. Without competing object matches, both children and *Pan* species (chimpanzees and bonobos) spontaneously used relational similarity, albeit children more so. But when object matches were present, only children responded strongly to them. We conclude that the relational gap is not due to great apes' preference for concrete objects. In fact, young humans show greater object-focus than nonhuman apes.

### *Results and Discussion*

We compared the performance of children and three species of nonhuman great apes—bonobos (*Pan paniscus*), chimpanzees (*Pan troglodytes*) and orangutans (*Pongo abelii*)—on two tasks: (1) a relational task alone, (2) a relational task pitted against competing object matches. Few

prior studies have compared humans and apes on an identical relational task [6,7; also 4-5 with baboons]; none have done so where relational matches compete with object matches.

Subjects saw two identical three-tiered boxes placed side-by-side (Figure 1). They watched as the experimenter placed the bait—a toy for children, food for nonhuman apes—in a container at one of the locations (top, middle, or bottom tier) in the Hiding Box (Box 1). Their task was to find the corresponding bait in the Search Box (Box 2) [14]. They were rewarded if they searched correctly. After each search trial, there was a memory trial in which subjects tried to retrieve the original bait in the Hiding Box.

In Phase 1 (relational task alone), we tested whether subjects were sensitive to relational matches—whether they would use relational alignment in their search. To do this, we created two between-subject conditions: Aligned and Shifted, differing in the rule that linked the hiding location with the search location. In the Aligned condition, there was a spatial *relational* mapping from one box to the other: top→top, middle→middle, and bottom→bottom. In the Shifted condition, the rule was top→middle, middle→bottom, bottom→top—a deterministic rule, but without alignment of parallel spatial relations.

Both rules are perfectly regular, so the task can be passed without attending to the parallel relational structure. However, if subjects readily notice and use the analogous spatial relational structures between the two boxes, then performance in the Aligned condition should be better. Important differences distinguish the current task from [7] where locations of the boxes were connected by lines/tubes and arranged in vertical arrays, potentially permitting gravity-driven cues regarding the correspondence (see also [8]). As in previous studies with children [13-15], subjects received no prior relational training.

The results showed that both *Pan* species and children reaped the relational benefit; *Pongo* did not. Children in the Aligned group searched correctly 68% of the time, versus 21% in the Shifted group ( $F(1, 22) = 39.22, p < .001$ ). Likewise, *Pan*'s search performance was significantly better in the Aligned (45%) than in the Shifted condition (24%),  $F(1, 10) = 21.29, p = .001$ . *Pongo* showed no advantage for Aligned (39%) over Shifted (33%),  $F(1, 4) = .64, p = .47$ , see Figure 3.

Children performed significantly better (68%) in the relationally aligned condition than *Pan* (45%),  $F(1, 16) = 6.5, p < .05$ , consistent with claims of human relational superiority (1, 2). The human advantage was specific to relational reasoning; performance in the Shifted condition was equally poor in children (21%) and *Pan* (24%).) However, these findings also demonstrate sensitivity to parallel relational structure in *Pan*, contrary to claims that relational ability is lacking in nonhuman apes (2).

We next analyzed the patterns of retrieval: whether subjects remembered the bait's location in the Hiding Box. This analysis is important because failure to remember the initial bait location could account for differences in search performance. Children (Aligned = 80% correct; Shifted = 64%) and *Pan* (Aligned = 66%, Shifted = 68%) showed good memory for the original bait location (all above chance (33%), minimum  $t(5) = 3.87, p < .05$ ), with no significant differences between Children and *Pan*. Thus, the superior performance of children and *Pan* species in the Aligned versus Shifted condition was due to relational ability, not memory.

Comparison of the first and last three trials showed no evidence of learning for any species (minimum  $F(1, 4) = 4, p = .116$ ). The advantage of relational alignment emerged even

within the first three trials: Children Aligned = 75% versus Shifted = 11%; *Pan* Aligned = 50% vs. Shifted = 33%.

In sum, a search task involving a relational mapping rule was easier for children and *Pan* than one involving an equally deterministic but relationally arbitrary rule. This evidence of relational ability in our closest living relatives (*Pan*) does not extend to orangutans, who performed similarly under both conditions. But unlike children and *Pan*, orangutans also performed poorly in retrieval (Aligned = 46%, Shifted = 37%, minimum  $t(2) = .601$ ,  $p = .609$ ), so they may have generally failed to grasp the task. This accords with [7] who reported that four-year-old children and *Pan* (chimpanzees and bonobos) succeeded at a different spatial mapping task but gorillas and orangutans did not.

The greater sensitivity to relational similarity in humans surely contributes to the analogical gap between humans and other apes, but it may not be the sole cause. Phase 2 tested another possible cause: that great apes fail to employ relational reasoning because they focus on objects instead of relations. Such is the case for human children: when relational similarity is pitted against object similarity, they robustly prefer the object over the relational match [12-16]. Prior evidence that nonhuman apes tend to be concrete in their reasoning [17] raises the possibility that the effect of competing object matches may be especially strong for great apes.

To test this, in Phase 2, conducted after a delay, we introduced object matches to the task (Figure 2). All subjects from Phase 1 went on to Phase 2 except for one chimpanzee who dropped out. All subjects remained in the same condition (Aligned or Shifted) in both phases. As in Phase 1, subjects saw a bait hidden in Box 1 and then searched in Box 2. As before, the bait in Box 2 was hidden in either a parallel relational pattern (Aligned condition) or in a shifted pattern

(Shifted). But whereas in Phase 1 all containers were identical, in Phase 2 each box contained three distinctive containers. The same three types of containers were used in each box, but, crucially, the containers were distributed differently in the two boxes: the top-to-bottom pattern was ABC in Box 1 and CAB in Box 2 (Figure 2). Thus, object matches *competed* with the relationally aligned rule in the Aligned condition and *reinforced* the arbitrary rule in the Shifted condition. If subjects focus on object matches, they should do well in the Shifted condition, but poorly in the Aligned condition.

As expected, children focused strongly on object matches: they excelled in the Shifted condition but performed at chance in the Aligned condition (Shifted = 70%, Aligned = 28%,  $F(1, 22) = 19.78, p < .001$ ). This is the opposite pattern from Phase 1, where children performed better in Aligned than in Shifted (Figure 3). When object matches were present, children's reasoning was highly concrete.

Surprisingly, this was not the case for the nonhuman apes (Figure 4). Neither *Pan* nor *Pongo* took advantage of object matches to improve their performance in the Shifted condition. Unlike children, *Pan* performed equally in the Shifted (33%) and Aligned (31%),  $F(1, 9) = .08, p = .78$ . The same is true for *Pongo*: Shifted = 26% vs. Aligned = 41% ( $F(1, 4) = 3.29, p = .14$ ). All groups of *Pan* and *Pongo* searched at chance level (minimum  $t(5) = -1.03, p = .35$ ). As before, there was no learning across trials: performance in the first and last three trials did not differ in any species (minimum  $F(1, 4) = .143, p = .725$ ).

Because all subjects stayed within the same condition throughout, they could have simply carried the Phase 1 rule over to Phase 2. To test this, we conducted a repeated-measures ANOVA with *Phase* as a within-subject factor, and *Species* and *Condition* as between-subject factors.

There was no main effect of *Phase*, but there was a significant interaction of *Phase* x *Species* x *Condition*,  $F(2, 35) = 14.91, p < .001$ . Children's performance changed significantly from Phase 1 to Phase 2, declining in Aligned ( $F(1, 11) = 27.9, p < .001$ ) but improving in Shifted ( $F(1, 11) = 37.3, p < .001$ ). When object matches conflicted with relational matches, children responded strongly to object matches, virtually ignoring the relational alignment regardless of prior training.

The two *Pan* species did not show such an object focus; those in the Shifted condition performed at chance (33%,  $t(5) = .058, p = .96$ ). However, *Pan*'s decline in performance from Phase 1 (45%) to Phase 2 (31%) suggests some sensitivity to the competing object matches ( $F(1, 4) = 11.14, p = .029$ ).

The dampened performance of *Pan* in Phase 2 was not due to poor memory for the initial bait location—their memory was excellent (Shifted = 84%, Aligned = 86%, *minimum*  $t(4) = 23.97, p < .001$ ), comparable to children's (Shifted = 81%, Aligned = 72%, *minimum*  $t(11) = 6.04, p < .001$ ).

The orangutans (*Pongo*) showed no change from Phase 1 to 2 in either condition (Aligned ( $F(1, 2) = 1.0, p = .42$ ; Shifted ( $F(1, 2) = 1.34, p = .37$ ), performing at chance in both phases. Retrieval was also at chance in both conditions (Shifted = 43%, Aligned = 52%, *minimum*  $t(2) = 1.57, p = .26$ ), suggesting they may not have understood the task.

### *Conclusions*

There are two main findings. First, our closest relatives (*Pan*) spontaneously attend to relational similarity. These results counter the claim (2) that nonhuman apes lack relational ability, and extend prior findings on relational tasks [6,7,10]. Second, our findings are the first to document greater attention to object similarity among human children than among nonhuman

apes. When object matches were pitted against relational matches, children focused strongly on the objects while *Pan* and *Pongo* did not.

We are not suggesting that great apes cannot make object matches. In fact, apes (and many other species) succeed at object-matching tasks such as the Match-to-Sample (MTS) Task: given A, choose A not B [2,9]—albeit typically with numerous training trials. The great apes were given only 18 trials in Phase 2. Had they been given more trials, we expect that they would have taken advantage of object matches.

What is important here is the overall pattern of attention to relational vs. object similarity. Both human children and the two *Pan* species benefitted from a relational alignment (Phase 1) (though children benefitted more). However, only children benefitted from the presence of object matches (Phase 2). These results show a different profile of attention to object versus relational similarity between humans and other great apes.

There is some precedent for non-attention to object matches in a different primate species, baboons (*Papio papio*) [3]. Given a challenging relational-match-to-sample (RMTS) task (given sample AA, choose BB, not CD) 6 of 29 baboons initially trained on MTS passed this task with a minimum of 15,000 trials. When five of the successful animals were then given a further RMTS task with conflicting object matches, they showed no propensity to match objects. Likewise, two hooded crows (*Corvus corone*) initially trained on MTS succeeded in the RMTS task, and did no better on physical identity trials than on purely relational trials [18].

While young children's object focus can interfere with their relational reasoning, it can also have the opposite effect. For example, 4-year-olds who were shown a bicycle (or a tricycle) with two round wheels labeled "a dax" extended the novel label to similar-looking round glasses



but not to another vehicle (a skateboard). Children missed the shared category *vehicle* because they were focused on object commonalities. But in the same study, when children were shown a bicycle and a tricycle, they extended the novel label to the skateboard [19]. This is when attention to object similarity is useful: the similarity between the bicycle and tricycle invited children to compare the exemplars, allowing them to perceive the shared relational commonality (the vehicle category). Our finding that great apes lack a strong proclivity for object matching suggests that this initial invitation to compare may not be available to them. Over time, the accumulated effects of object comparisons may contribute to the human advantage in analogical reasoning.

*Language, objects and relations.* Our comparison of humans and great apes' relational reasoning cannot avoid discussing the seemingly biggest difference of all—language. Indeed, evidence from both humans and apes attests that relational symbols can support relational reasoning [1,14,20-23]. The present findings rule out the possibility that language—or even prior experience with relational symbols—is essential for the emergence of relational reasoning. The bonobos and chimpanzees in the current study were symbolically naïve, but nonetheless were sensitive to matching spatial relations (see also [7,8]). However, given the evidence that relational language can facilitate relational reasoning, it is possible that children's superior relational insight in our study was enhanced by language. Thus, children may have possessed both a species-level biological advantage in relational ability and a further advantage due to cultural-linguistic learning.

Language learning may also contribute to children's sensitivity to object matches. There is evidence that children's propensity to focus on objects is not inborn, but develops over the first

2-3 years [24-26]—a period during which children acquire their beginning vocabularies, which in many cultures consist largely of concrete and animate nouns [27-30]. By 9-10 months, infants pay more attention to labeled than to unlabeled objects [31,32]. This early focus on learning object names may heighten attention to objects among children.

The largest difference between children and the two *Pan* species was that children focused strongly on object matches, but *Pan* did not. This is the opposite of what would be expected if great apes were more concrete in their cognition than humans. We speculate that the differential attention to objects and relations contributes to the analogical gap between humans and other primates.

### *Experimental Procedures*

*Subjects:* twenty-four three-year-old children (mean age = 41 months, range = 36–48 months), five bonobos (*Pan paniscus*), seven chimpanzees (*Pan troglodytes*), and six orangutans (*Pongo abelii*) (mean age = 14.5 years, range = 6-34 years). All parents/guardians gave informed consent for their children's participation; approved by the Institutional Review Board of Northwestern University. The great apes' study was approved by the joint ethics committee of the Max Planck Institute for Evolutionary Anthropology and the Zoo Leipzig.

Subjects were randomly assigned to Aligned (12 children, 6 *Pan* (2 bonobos and 4 chimpanzees), 3 *Pongo*) or Shifted condition (12 children, 6 *Pan* (3 bonobos and 3 chimpanzees), 3 *Pongo*). Participants stayed within the same condition (Aligned or Shifted) across Phases 1 and 2.

*Material and Procedure.* In Phase 1, six identical wooden round containers with lids

were used—three in each box. In Phase 2, each box had three containers: a red and black lacquer bowl-like object with lid, a green oblong metal container with a pedestal and conical-shaped lid, and a yellow rectangular tin with lid. Children and apes performed search and retrieval as described in the Results and Discussion. Each child had 9 trials (9 searches and retrievals) and each ape had 18 trials in each phase. Further details are described in the Supplemental Experimental Procedure.

#### *Author Contributions*

All authors developed the study concept and design. Testing and data collection were performed by SC and JC. SC and JC performed the data analysis. SC and DG drafted the manuscript, and JC and DH provided critical revisions. All authors approved the final version of the manuscript for submission.

#### *Acknowledgements*

This research was supported by NSF SLC Grant SBE-0541957 awarded to the Spatial Intelligence and Learning Center (SILC), the Max Planck Society, and Swarthmore Lang Sabbatical Fellowship. We thank Ed Wasserman and anonymous reviewers for comments; SC thanks Bartłomiej Czech.

*References*

1. Gentner, D. (2003). Why we're so smart. In *Language in mind: Advances in the study of language and cognition.*, D. Gentner and S. Goldin-Meadow, eds. (Cambridge, MA: MIT Press), pp. 195-235.
2. Penn, D.C., Holyoak, K.J., and Povinelli, D.J. (2008). Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. *Behav. Brain Sci.* 31, 109-130.
3. Fagot, J., and Thompson, R.K.R. (2011). Generalized relational matching by guinea baboons (*Papio papio*) in two-by-two-item analogy problems. *Psych. Sci.* 22, 1304-1309.
4. Fagot, J., Wasserman, E.A., and Young, M.E. (2001). Discriminating the relation between relations: the role of entropy in abstract conceptualization by baboons (*Papio papio*) and humans (*Homo sapiens*). *J. Exp. Psychol. Anim. Behav. Process* 27, 316-328.
5. Flemming, T.M., Thompson, R.K.R., and Fagot, J. (2013). Baboons, like humans, solve analogy by categorical abstraction of relations. *Anim. Cogn.* 16, 519-524.
6. Flemming T.M., Beran M.J., Thompson R.K.R., Kleider H.M., and Washburn, D.A. (2008). What meaning means for same and different: analogical reasoning in humans (*Homo sapiens*), chimpanzees (*Pan troglodytes*), and rhesus monkeys (*Macaca mulatta*). *J. Comp. Psychol.* 122:176–185
7. Haun, D.B.M., and Call, J. (2009). Great apes' capacities to recognize relational similarity, *Cognition* 110, 147-159

8. Hribar, A., Haun, D., and Call, J. (2011). Great apes' strategies to map spatial relations. *Anim. Cogn.* *14*, 511-523.
9. Premack, D. (1983). *The Codes of Man and Beasts, Volume 6*, (United Kingdom: Cambridge University Press).
10. Thompson, R.K., Oden, D.L., and Boysen, S.T. (1997). Language-naive chimpanzees (*Pan troglodytes*) judge relations between relations in a conceptual matching-to-sample task. *J. Exp. Psychol. Anim. Behav. Process* *23*, 31-43.
11. Vonk, J. (2003). Gorilla (*Gorilla gorilla gorilla*) and orangutan (*Pongo abelii*) understanding of first- and second-order relations. *Anim. Cogn.* *6*, 77-86.
12. Gentner, D., and Toupin, C. (1986). Systematicity and surface similarity in the development of analogy. *Cogn. Sci.* *10*, 277-300.
13. Gentner, D., and Rattermann, M.J. (1991). Language and the career of similarity. In *Perspectives on language and thought: Interrelations in development.*, S.A. Gelman and J.P. Byrnes, eds. (New York, NY: Cambridge University Press), pp. 225-277.
14. Loewenstein, J., and Gentner, D. (2005). Relational language and the development of relational mapping. *Cogn. Psych.* *50*, 315-353.
15. Richland, L.E., Morrison, R.G., and Holyoak, K.J. (2006). Children's development of analogical reasoning: Insights from scene analogy problems. *J. Exp. Child Psychol.* *94*, 249-273.
16. Thibaut, J.-P., French, R., and Vezneva, M. (2010). The development of analogy making in children: Cognitive load and executive functions. *J. Exp. Child Psychol.* *106*, 1-19.

17. Povinelli, D.J. (2000). *Folk physics for apes : the chimpanzee's theory of how the world works*, (Oxford ; New York: Oxford University Press).
18. Smirnova, A., Zorina, Z., Obozova, T., and Wasserman, E. (2015). Crows spontaneously exhibit analogical reasoning. *Curr. Biol.* *25*, 256-260.
19. Gentner, D., and Namy, L.L. (1999). Comparison in the development of categories. *Cogn. Dev.* *14*, 487-513.
20. Gentner, D., Özyürek, A., Gürcanli, Ö., and Goldin-Meadow, S. (2013). Spatial language facilitates spatial cognition: Evidence from children who lack language input. *Cognition* *127*, 318-330.
21. Haun, D.B., Rapold, C.J., Call, J., Janzen, G., and Levinson, S.C. (2006). Cognitive cladistics and cultural override in Hominid spatial cognition. *Proc. Natl. Acad. Sci.* *103*, 17568-17573.
22. Pruden, S.M., Levine, S.C., and Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Dev. Sci.* *14*, 1417-1430.
23. Thompson, R.K.R., and Oden, D.L. (2000). Categorical perception and conceptual judgments by nonhuman primates: The paleological monkey and the analogical ape. *Cogn. Sci.* *24*, 363-396.
24. Haun, D.B.M., Call, J., Janzen, G., and Levinson, S.C. (2006). Evolutionary psychology of spatial representations in the hominidae. *Curr. Biol.* *16*, 1736-1740.
25. Newcombe, N.S., and Huttenlocher, J. (2000). *Making space: The development of spatial representation and reasoning*, (Cambridge, MA: The MIT Press).

26. Smith, L.B., Jones, S.S., Landau, B., Gershkoff-Stowe, L., and Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psych. Sci.* *13*, 13-19.
27. Bornstein, M.H., Cote, L.R., Maital, S., Painter, K., Park, S.-Y., Pascual, L., Pecheux, M.-G., Ruel, J., Venuti, P., and Vyt, A. (2004). Cross-Linguistic Analysis of Vocabulary in Young Children: Spanish, Dutch, French, Hebrew, Italian, Korean, and American English. *Child Dev.* *75*, 1115-1139.
28. Caselli, M.C., Bates, E., Casadio, P., Fenson, J., Fenson, L., Sanderl, L., and Weir, J. (1995). A cross-linguistic study of early lexical development, *Cogn. Dev.* *10*, 159-199.
- 29.. Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In *Language Development, Volume 2*, S.A. Kuczaj, ed. (Hillsdale, NJ: Erlbaum Associates), pp. 301-334.
30. Gentner, D., & Boroditsky, L. (2001). Individuation, relativity and early word learning. In *Language acquisition and conceptual development*, M. Bowerman & S. Levinson, eds. (Cambridge, UK: Cambridge University Press), pp. 215-256.
31. Balaban, M.T., and Waxman, S.R. (1997). Do words facilitate object categorization in 9-month-old infants? *J. Exp. Child. Psychol.* *64*, 3-26.
32. Xu, F., and Carey, S. (1996). Infants' metaphysics: The case of numerical identity. *Cogn. Psych.* *30*, 111-153.

*Figure Legends:*

**Figure 1.** Experimental set-up for Phase 1 – Relational Similarity Only. Subjects saw a bait hidden in one of the three containers on the left box (Hiding Box 1), and they had to search among the containers on the right box (Search Box 2). All containers were identical. In the Aligned condition the correct mapping between Hide and Search is the parallel spatial relations. In the Shifted condition, the correct mapping is non-parallel, as indicated by the connecting lines. If subjects are sensitive to relational similarity, they should perform better in the Aligned than in the Shifted condition.

**Figure 2.** Experimental set-up for Phase 2 – Relational vs. Object Similarity. Subjects maintained the same mapping conditions (Aligned or Shifted) as in Phase 1, but the boxes now had distinctive containers. The containers were arranged such that in the Aligned condition, the visible object matches *competed* with the relationally aligned rule; but in the Shifted condition, the object matches were *consistent* with the (arbitrary) correspondence rule. Greater attention to object matches over relational matches would favor performance in the Shifted over the Aligned condition.

**Figure 3.** Proportion of correct searches during Phase 1. Children and *Pan* searched at the correct location significantly more often in the Aligned than in the Shifted condition. *Pongo* searched at chance level in both conditions,  $*p < .05$  between conditions.



**Figure 4.** Proportion of correct searches during Phase 2. In this phase the relational mapping pattern was in conflict with object similarity. In contrast to Phase 1, children searched incorrectly in the Aligned condition, but excelled in the Shifted condition (in which the correct answer follows object similarity). *Pan* and *Pongo* searched at chance level in both Shifted and Aligned conditions,  $*p < .05$  between conditions.

**Figure 1.**

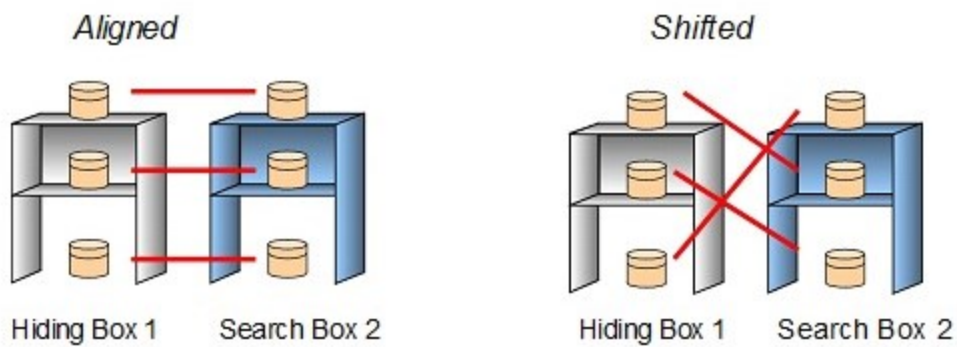


Figure 2.

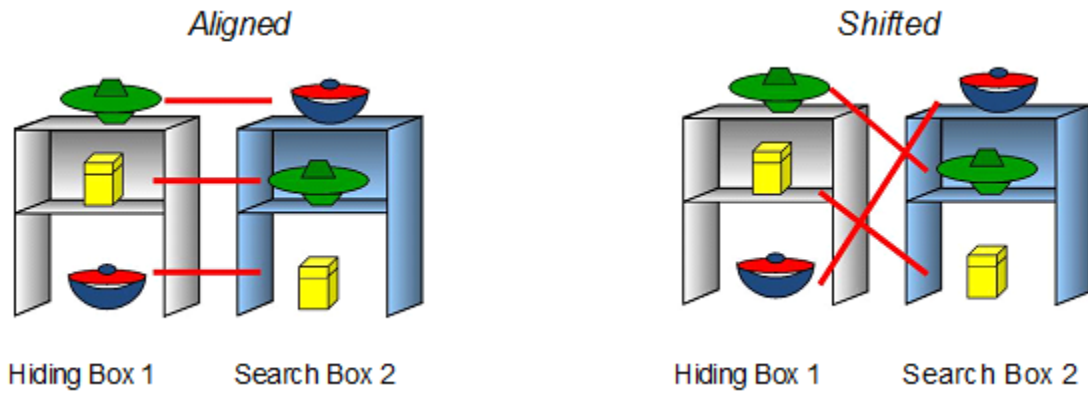


Figure 3.

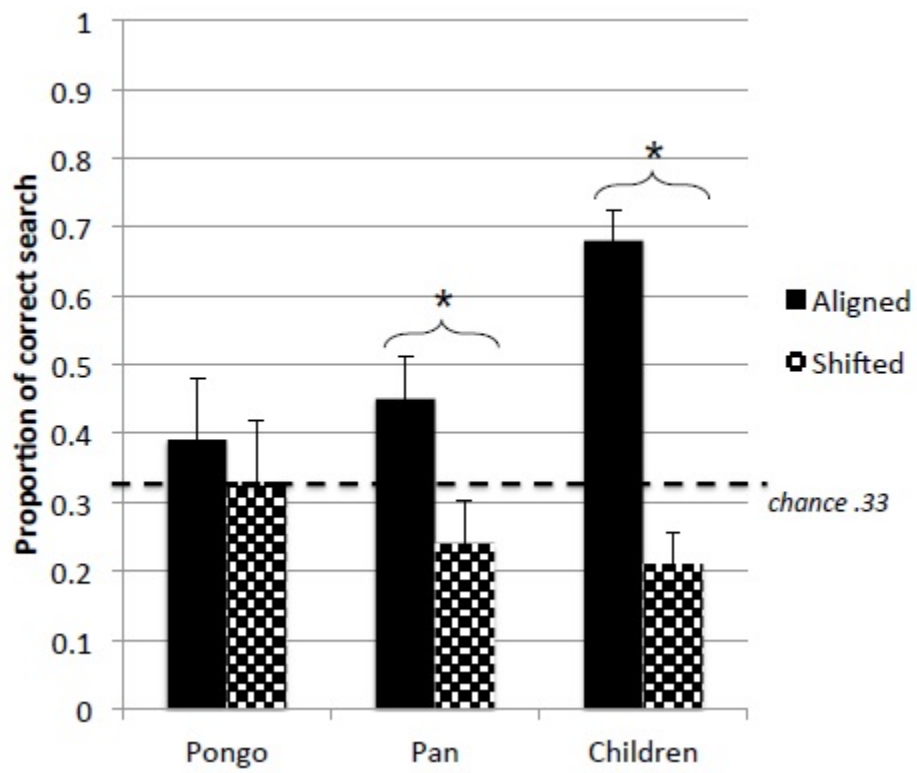


Figure 4.

