
**Title:**
Sensitivity to Relational Similarity and Object Similarity in Apes and Children

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Summary

Analogical reasoning pervades human cognition. While comparative research with apes, monkeys, and corvids [1-7] shows some success in analogical reasoning, there is no satisfactory explanation why other animals’ analogical ability is far below ours. Here we tested one possible explanation, motivated by developmental research showing that even young humans fail to reason analogically if an analogical match competes with an object match [8-11]. When asked, duck:duckling is like tiger:?, young children correctly choose cub (analogical match) unless they are given the option of another duckling (object match) as an alternative. Since both object and analogical matches abound in nature, animals’ strong preference for concrete object matches could undermine their analogical reasoning in similar ways. This explanation has not been tested before. Using an identical spatial analogy task, we compared great apes and three-year-old humans’ analogical reasoning with and without competing object matches. Without competing object matches, three-year-old children, bonobos, and chimpanzees spontaneously used relational similarity, though orangutans did not. But with object matches, only children responded strongly to object matches while great apes did not. We found that our closest relatives—the Pan species (chimpanzees and bonobos)—spontaneously use relational similarity. But contrary to the conventional assumption, great apes are not more object-focused than human children, showing that the gap in analogical reasoning is not due to apes’ greater attention to concrete objects. These results show that human prowess in analogical reasoning requires further explanation. Moreover, they indicate a previously undocumented difference between humans and the other great apes: attention to object matches.
Results and Discussion

We tested great apes and children’s perception of relational similarity—analogue reasoning—between two spatial structures. Our goal was not to add yet another piece of evidence of animals’ analogue ability, but rather to understand the similarities and differences across humans and animals’ analogue reasoning. To do this, we directly compared children and great apes’ (Pan-bonobos and chimpanzees, and Pongo-orangutans) spontaneous performance on two kinds of tasks: (1) a relational task alone, (2) a relational task pitted against competing object matches. Very few studies have compared humans and animals on an identical analogy task [see 12, 13]; none have done so where analogue and object matches compete.

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 the 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].

In Phase 1 (relational task alone), we tested whether subjects were sensitive to relational matches—that is, whether they would make use of 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. This rule follows an analogue mapping of the parallel spatial relational patterns in the two boxes. In the Shifted condition, the rule is also deterministic, but there is no such alignment of spatial relations. Instead, the rule is top→middle, middle→bottom, bottom→top.
Both rules are perfectly regular, but if subjects are sensitive to the analogous spatial relational structures between the two boxes then performance in the Aligned condition should be better than in the Shifted condition. However, if subjects lack sensitivity to relational alignment then performance in the two conditions should not differ. Based on prior evidence with a related task [12], we expected children and both Pan species to show some sensitivity to the relational match—that is, any advantage for a relational mapping (Aligned) over an arbitrary rule (Shifted), while Pongo should show no such advantage. One crucial improvement of the current analogy task compared to [12] is that the locations of the two boxes were not connected by lines or tubes, making spatial relations the only reliable way to connect them [see also 13]. Similar to previous studies with children (see also 12, 13) and unlike most studies testing nonhuman animals [1, 4, 7, 15, 16], we presented the task without any prior training to assess spontaneous analogical reasoning.

As expected, both Pan species and children reaped the relational benefit; the Pongo did not. Children in the relational Aligned group searched correctly 68% of the time while the Shifted group only did so 21% of the time \((F(1, 22) = 39.22, p < 0.001)\). Likewise, Pan’s search performance was better in the Aligned (45%) than in the Shifted (24%), \(F(1, 10) = 21.29, p = .001\). However, the search pattern for Pongo did not differ between the two conditions (Aligned = 39%, Shifted = 33%, \(F(1, 4) = .64, p = .47\)).

We next analyzed the patterns of retrieval: whether subjects remembered the bait’s location at Hiding Box 1. After subjects searched the bait at Finding Box 2, they were asked to go back to Hiding Box 1 and retrieve the original bait. This analysis is important in interpreting the results of the Search task, since failure to notice and remember the location of the bait in Box 1 could account for differences in search performance. We found that children and Pan
remembered well the original locations of the bait. Children in the Aligned (80% correct) and in the Shifted (64%) retrieved the bait at the original location at above-chance rates (minimum $t(11) = 11.1, p < .001$). *Pan* also showed good memory in both the Aligned (66%) and Shifted (68%) groups (compared to chance, minimum $t(5) = 3.87, p < .05$). The fact that children and *Pan* remembered the original locations whether they were in the Aligned or the Shifted conditions showed that the differential Search performance (Aligned better than Shifted) was due to relational ability, not to memory.

In sum, children and the two *Pan* species both found it easier to conduct a search task that followed a relational mapping rule than one that followed an equally deterministic but relationally arbitrary rule. This finding is evidence for relational ability in our closest living relatives, the two *Pan* species. Orangutans did not show differential mapping performance across the two conditions. In contrast to children and *Pan*, orangutans also performed poorly in retrieval (Aligned = 46%, Shifted = 37%, minimum $t(2) = .601, p = .609$), so it is possible that they generally failed to grasp the task. These results accord with [12], who reported that four-year-old children and *Pan* (chimpanzees and bonobos) succeeded at a similar spatial mapping task, but gorillas and orangutans did not.

We cannot, however, conclude that *Pan*’s sensitivity to relational similarity is equal to that of humans. On the contrary, 3-year-old children performed significantly better (68%) in the relationally aligned condition than *Pan* (45%, $F(1, 16) = 6.5, p < .05$). As the performance in the Shifted condition was equally poor in children (21%) and *Pan* (24%), the difference between children and *Pan* was specific to analogical reasoning.

This greater initial proclivity to relations surely contributes to the wide analogical gap between humans and other animals, but is unlikely to be its sole cause. In Phase 2, we tested
another possible origin of the gap: that great apes fail to employ analogical reasoning because they focus on objects instead of relations. Indeed, this is the case for human children: when relational similarity is pitted against object similarity, they robustly prefer the object match over the relational match [8-11]. The existing evidence that nonhuman apes tend to be concrete in their reasoning [17] opens the possibility that the effect of competing object matches may be stronger for great apes than for human children. If so, it could account for the great apes’ poorer analogical reasoning.

In Phase 2, conducted after a delay, we introduced object matches to the Phase 1 arrays, to compare apes and children’s focus on concrete object matches versus relational matches (Figure 2). The same children and apes who participated in Phase 1 took part in Phase 2, except for one chimpanzee who dropped out of Phase 2. As in Phase 1, the experimenter either hid the second bait in a relationally aligned pattern with the first bait (Aligned condition) or in a shifted fashion (Shifted pattern)—and subjects stayed in their respective conditions from Phase 1. 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: in Box 1, the top-to-bottom pattern was A, B, C; in Box 2, it was C, A, B (Figure 2). This meant that in the Aligned condition, the visible object matches competed with the relationally aligned rule; but in the Shifted condition, object matches were consistent with the (arbitrary) correspondence rule. If subjects favored relational alignment over object matches, they should do better in the Aligned condition. However, if they favored object matches, they should perform better in the Shifted condition (in which an object-matching response is correct) than in the Aligned condition (in which the object matches are incorrect and the relational match is correct).
As predicted, and consistent with prior findings, children focused strongly on object matches: they excelled in the Shifted condition (in which object matches led to the correct response), but performed at chance in the Aligned condition (in which object matches were pitted against the correct relational response) (Shifted = 70%, Aligned = 28%, F (1, 22) = 19.78, p < .001). This is the opposite pattern from that of Phase 1, where children performed better in the Aligned condition than in the Shifted condition.

Surprisingly, none of the nonhuman apes showed a focus on object matches. Neither Pan nor Pongo made use of object match cues to improve their performance in the Shifted condition (Pan performed at 33%, Pongo at 26%). We expected that great apes, like children, would do much better in the concrete-Shifted condition than in the Alined one, but instead Pan performed equally in the Shifted (33%) and Alined (31%) conditions (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). Overall, neither Pan nor Pongo showed a gain for the object matches.

Because all subjects stayed within the same condition throughout, they could in principle simply have carried over the rule from Phase 1 to Phase 2. To test whether they did this, we conducted a repeated-measures ANOVA with Phase as a within-subject factor, and Species and Condition as between-subject factors. There is no main effect of Phase but there is a significant interaction of Phase x Species x Condition, F (2, 35) = 14.91, p < .001. Looking within species, we find that children’s performance changed significantly from Phase 1 to Phase 2. In the Aligned condition, their performance declined significantly (F (1, 11) = 27.9, p < .001) and in the Shifted condition it increased significantly (F (1, 11) = 37.3, p < .001). As in prior studies,
when faced with a conflict between objects vs. relations (in Phase 2), young children responded strongly according to object matches, not relational matches.

The two Pan species did not show such an object focus. Their performance did decline from Phase 1 to Phase 2 in the Aligned condition \( F (1, 4) = 11.14, p = .029 \), suggesting that they have been affected by the presence of the competing object matches. However, the fact that Pan performed at chance in the Shifted condition (33%, \( t (5) = .058, p = .96 \)) indicates that unlike the children, they did not readily engage in an object-focused strategy.

The orangutans (Pongo) showed no change from Phase 1 to Phase 2 in either condition (Aligned \( F (1, 2) = 1.0, p = .42 \); Shifted \( F (1, 2) = 1.34, p = .37 \)). They performed at chance in both phases. A concrete, object-match attention would predict high performance in the Phase 2 of Shifted condition, but we did not find such evidence among the orangutans.

It is clear that dampened performance in Phase 2 is not due to lack of memory for the initial bait’s location. The two Pan species showed excellent retrieval performance in both conditions (Shifted = 84%, Aligned = 86%, \( minimum t (4) = 23.97, p < .001 \)), as did the children (Shifted = 81%, Aligned = 72%, \( minimum t (11) = 6.04, p < .001 \)). Hence, it is unlikely that Pan’s failure to make use of either relational alignment or object matches in Phase 2 was due to failure to remember the initial location. For Pongo, as in Phase 1, retrieval performance was at chance in both conditions (Shifted = 43%, Aligned = 52%, \( minimum t (2) = 1.57, p = .26 \)).

Object matching. Non-human animals’ ability to make object matches is not usually a cognitive ability under question. In fact, the standard analogical test widely used in comparative research—the relational match to sample task RMTS (given AA, match BB not CD)—often employs overall-similarity matches that share both object similarity and relational similarity (given AA, match AA not CD) as the initial “warm-up” task \([1, 2, 4-7]\). The general consensus is
that animals can easily pass the overall similarity match task (though not the analogy task). Our current results do not contradict these prior findings, for two reasons. First, in our study object similarities were inconsistent with relational similarities whereas in the warm-up RMTS task the correct choice (AA-AA) is both an object match and a relational match to the standard, making it much easier. Second, animals usually succeed in an overall similarity match task after doing hundreds of trials while in our study great apes were given a total of 36 trials. It is possible that given more trials, great apes would eventually pass the spatial mapping task using object matches. Relatedly, we are not claiming that other animals do not notice object similarities. Instead, it is the comparison with humans that matters: Pan showed far less proclivity to attend to object matches than young humans did. Interestingly, in an RMTS (visual analogy) study with gorillas and orangutans, their performance did not differ based on the presence or absence of feature match [6].

Comparative researchers conducting analogical studies often take direct measures to avoid the presence of object matches in their analogical match stimuli, as a perceptual account could undermine conclusions about animals’ analogical reasoning ability [18]. This approach is well-founded; perceptual object matching should never be a lurking possible confound in an analogical test. Directly contrasting object and relational matches, however, is a critical measure that gives us a fuller picture of a species’ relational cognition.

While young children’s preference for object matches can interfere with their relational reasoning, it can also have an opposite, fostering effect. For example, 4-year-olds who were shown a bicycle with two round wheels labeled “dax” extended the novel label to similar-looking round glasses, but not to another vehicle (skateboard). Children missed the shared category vehicle, because they were so focused on object commonalities. But in the same study, when
children were shown two bicycles, they extended the novel label to the skateboard [19]. This is when the attention to object similarity can be useful: the object similarities between the two bicycles invite children to compare the exemplars, allowing them to perceive the shared relational commonality (vehicle category). Our finding that great apes lack the strong proclivity for object matching suggests that this initial invitation to compare may not be available to them. We speculate that over time the accumulated effect may contribute to the gap in analogical reasoning.

Language and objects. Our comparison of humans and great apes’ relational reasoning cannot avoid discussing the seemingly biggest difference of all: language. Indeed, there is evidence from both humans and apes that relational symbols can invite relational encoding [4, 15, 20-22]. Clearly, 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 able to detect and respond to matching spatial relations despite never having been exposed to any kinds of symbol training. The present results accord with several prior studies [7, 12, 13] claiming that language is not a prerequisite for relational insight. 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. The children may have possessed both a species-level biological advantage and a cultural advantage over the other species.

It is also possible that language understanding contributes to children’s sensitivity to object matches. There is evidence that children’s propensity to focus on objects is not inborn, but rather develops over the first two or three years [23-25]—a period in which children acquire their beginning vocabularies, which in many cultures consist largely of concrete and animate nouns
[26-29]. By nine or ten months of age, infants pay more attention to labeled than to unlabeled objects (30, 31). Perhaps this early focus on learning the names of objects leads to heightened attention to objects among preschool children.

**Summary.** We found that the ability to notice and use relational similarity—a capstone of human cognition—is shared with chimpanzees and bonobos, although it was most pronounced in 3-year-old human children. Surprisingly, the two *Pan* species did not show a propensity to detect and use object matches—a capacity which is less demanding and more available to human children than relational matching. Expectedly, our closest relatives are poorer relational thinkers than us; unexpectedly, their thinking is no more concrete than ours.

**Experimental Procedures**

**Phase 1: Relational Similarity Only**

**Subjects.** The children were 24 three-year-old children (mean age = 41 months, range = 36 – 48 months) who were recruited from local preschools in Evanston, Illinois. All caretakers gave their informed consent. Two additional children were tested, but they were fussy, and did not continue their participation after only a few trials. Since this study required committed involvement from the children participant (the same children had to participate again in Phase 2 after 1 week delay), prior to data collection we decided to attain the minimal number of participants (n = 12 per condition).

The nonhuman great apes were five bonobos (*Pan paniscus*), seven chimpanzees (*Pan troglodytes*), and six orangutans (*Pongo abelii*), ages ranged from 6 to 34 years (mean age = 14.5 years). These were the apes available at the time this study was conducted. They were housed at the Wolfgang Köhler Primate Research Center at Zoo Leipzig, Germany. They lived in social groups with conspecifics and had access to indoor and outdoor areas designed appropriately for
the species. During testing, the apes were fed according to their daily routine four times a day on a diet of fruit, vegetables and monkey chow; water was at their disposal at all times. Subjects were free to choose not to participate at all times (none quit).

Procedure. The procedure was identical in both Aligned and Shifted conditions, except for the placement rule. Subjects first watched the experimenter place a bait (a pom-pom ball for children and a grape for apes) in one of the containers in Hiding Box 1. Then, hidden from the subject’s view, the experimenter hid a second bait in one of the containers in Search Box 2. The subject then searched for the bait at Search Box 2. Only one search was allowed, and a correct search was rewarded (with a sticker for children, and the grape for apes). If subjects searched at the wrong container, they were not shown the correct location. However, because they were rewarded only if they searched correctly, they did have information as to whether they had chosen correctly. After searching at Box 2, subjects were allowed to retrieve the bait from Box 1. This served as a check on their memory for the initial hiding place. Throughout the procedure, children were given minimal verbal instructions, to make the protocol comparable to that of apes. Importantly, none of the species received any training prior to the test. Each child had a total of 9 trials (9 searches and retrievals). Each ape had a total of 18 trials equally distributed into two sessions.

Phase 2: Relational vs. Object Similarity

Subjects. The same subjects (3-year-old children and apes) who participated in Phase 1 participated in Phase 2, approximately one week later in the case of children and several months later in the case of the apes. One chimpanzee who took part in Phase 1 did not participate in Phase 2. All subjects remained in the same condition—Aligned or Shifted—throughout.
Design and procedure. The procedure was identical to that of Phase 1. In Phase 1 all containers were identical, but in Phase 2 each box contained three distinctive containers (see Figure 2). This meant that in the Aligned condition, correct relational matches competed with incorrect object matches. But in the Shifted condition, object matches are consistent with the correct (arbitrary) correspondence rule.

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.

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Figure Legends:

Figure 1. Experimental set-up for Phase 1 – Relational Similarity Only. Participants 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 conditions.

Figure 2. Experimental set-up for Phase 2 – Relational vs. Object Similarity. Same set up and rule as in Phase 1, but the containers are now distinctive. As such, in the Aligned condition, the visible object matches competed with the relationally aligned rule; but in the Shifted condition, object matches were consistent with the (arbitrary) correspondence rule. Greater attention to object 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 better 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 there were 3 different containers such that the aligned 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 (where object similarity and the mapping pattern coincides). *Pan* and *Pongo* did not make use of object similarity, as they searched at chance level in the Shifted condition.

*p < .05 between conditions*
Figure 1

Aligned

Hiding Box 1  Search Box 2

Shifted

Hiding Box 1  Search Box 2
Figure 2

Aligned

Hiding Box 1          Search Box 2

Shifted

Hiding Box 1          Search Box 2
Figure 3

Proportion of correct search

- **Aligned**
- **Shifted**

*chance .33*
Figure 4

Proportion of correct searches

- **Aligned**
- **Shifted**

- *chance .33*