# Relational Language Helps Children Reason Analogically

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**Abstract**

This paper explores the role of relational language in the development of children's analogical reasoning ability. In two experiments, children were asked to make a relational mapping between two pictures while ignoring a competing object match. Three-and-a-half-year-olds, 5½-year-olds, and 7-year-olds were all more successful at this task when they heard relational language. Experiment 2 further demonstrated that children were as good at finding the relational match with an object match present if they heard relational language as they were when there was no compelling object match present at all. These results suggest that relational language may be important in instilling the ability to reason analogically.

**Keywords:** Analogy; analogical development; relational language; language and thought

## Introduction

Humans are prolific learners, in part because of our ability to learn through analogy. Analogy involves aligning the shared relational structure between a base and target representation (Gentner, 1983). From this mapping, reasoners can draw inferences about a target that are suggested by the base. Analogies also promote the abstraction of relational schemas that can then be applied to new situations or domains (Gick & Holyoak, 1983), and making an analogy often leads to re-representation of either or both aligned structures (Gentner & Colhoun, in press; Gentner & Rattermann, 1991; Loewenstein, Thompson, & Gentner, 1999).

Given analogy's potential to facilitate learning, investigation into children's analogical abilities is crucial to understanding cognitive development. Analogical ability appears to be present even in very young children. For example, Gentner (1977) showed that preschoolers could carry out spatial analogies from the human body to a mountain or a tree, even when the matches were made difficult with surface distractors. Chen & Daehler (1989) found that 6-year-olds were able to transfer relational structure from a story to a real-world situation. Prior to completing a problem-solving task, children heard two stories. Some children heard neutral stories, and others heard stories illustrating abstract schemas for solving the task. Children who heard the abstract schemas were more likely to solve the task using the problem-solving technique from the stories than children who heard neutral stories.

Although young children are able to make and use analogies, their abilities do not match those of adults. One of the most striking differences between adults' and children's performance on analogical tasks is children's focus on objects and object properties over relations (Blades & Cooke, 1994; Gentner & Toupin, 1986; Gentner & Rattermann, 1991). The transition from reliance on objects to relations has been termed the *relational shift* (Gentner, 1988). Although this shift is well-documented, researchers disagree on what drives the change. The various explanations are closely tied to general theories of analogical development, specifically *domain knowledge* accounts and *maturational constraints* accounts.

*Domain knowledge* theories of analogical development suggest that children's ability to reason analogically increases as they accrue knowledge about a particular domain and its relations (Gentner, 1988; Gentner & Rattermann, 1991; Goswami & Brown, 1989; Rattermann & Gentner, 1998; Vosniadou, 1989). Thus, children may successfully reason analogically in a familiar domain (e.g., family relationships), but fail in an unfamiliar domain (e.g., scientific concepts). With limited knowledge of the relations, children depend instead on the information they do have about the objects and their properties. In contrast, *maturational constraints* theories view analogical development as driven primarily by increases in children's basic cognitive capacity, like working memory (Halford, 1993) and inhibitory control (Richland, Morrison, & Holyoak, 2006). In these accounts, children are unable to represent complex relations due to working memory limitations, and they lack the inhibitory control to carry out relational matches when compelling object matches are present.

Of course, it may be the case that maturational gains and knowledge gains interact in the development of analogical reasoning, but it is important to determine the relative contribution of each. Using a paradigm adapted from

Markman and Gentner's (1993) "one-shot mapping task", Richland, Morrison, and Holyoak (2006) investigated the roles of working memory and inhibitory control when knowledge of the relations was held constant. They showed children pairs of pictures depicting familiar relations (e.g., *chasing*) and asked children to find a corresponding object in the second picture that went with an object in the first picture. If children are reasoning analogically, they should select the second object based on its role in the relational structure. Richland et al. varied the complexity of the relations and the presence of a distracting object match[1] and found that 3- to 4-year-olds and 6- to 7-year-olds had difficulty with the task both when the relational structure was more complex and when a distracting object match was present. For the 3- to 4-year-olds, the effect of the distracting object match was such that performance was extremely poor with an object match present, regardless of the complexity of the relation. Richland et al. (2006) argued from these results that knowledge accretion alone is not enough to account for the development of analogical ability. Rather, they suggest that children must also have sufficient inhibitory control to successfully reason analogically.

In this paper, we focus on an additional factor that may be important in children's ability to reason about relations: relational language. In fact, we suggest that relational language can help children overcome the challenge of competing object matches to succeed on analogical tasks.

Relational language is a representational tool that can help children focus on common relations and align two structures (Gentner, 2003; Gentner & Rattermann, 1991). Loewenstein and Gentner (2005) found, for example, that aligning two three-tiered boxes in order to find a hidden object was difficult for young children. The task was even more challenging when distinct objects were placed at each location in the two boxes in such a way that corresponding objects were not in corresponding locations (the objects were *cross-mapped*). However, when the locations of the boxes were described with spatial language (e.g., *on*, *in*, *under* or *top*, *middle*, *bottom*), children were able to successfully align the two boxes and find the hidden toy.

As in Markman and Gentner's and Richland et al.'s studies, the present studies asked children to view pairs of scenes with familiar relations and to select an object from a target picture that corresponded with a particular object from the base picture. However, in our task the key variable was whether children heard relational language to describe the pictures. Given previous research suggesting that relational language enhances children's analogical abilities, we expected that children who heard relational language would outperform children who heard neutral language.

[1] In Richland et al.'s studies, the distracting object was present in the second picture but was not part of the main relational structure. In contrast, Markman and Gentner (and Gentner and Toupin) used *cross-mapped* examples, in which the object participated in the matching relation but in a different role. The impact of different types of object distractors on children's analogical performance was examined directly in Experiment 2.

# Experiment 1

## Method

**Participants** Seventy 5½- and 7-year-olds participated in this experiment. Six children were excluded, due to parental interference ($N = 1$) and answering incorrectly on at least one filler trial ($N = 5$), leaving 32 5½-year-olds (ages 61-71 months, $M = 65.4$ months old) and 32 7-year-olds (ages 78-89 months, $M = 83.3$ months) in the final analyses. Half of the children in each age group participated in the Relational language condition, and half in the Neutral Language condition. All participants were native English speakers.

**Materials and design** Children viewed pairs of scenes depicting familiar relations (e.g., *chasing*) and were asked to select an object from the target picture that corresponded with the actor (the "doer" of the action) in the base picture. Importantly, on experimental trials, the picture pairs were *cross-mapped* (Gentner & Toupin, 1986): that is, the actor in the base picture also appeared in the target picture but played a different role in the relation (see Figure 1). Thus, children could select an object in the target picture by matching objects (e.g., *cat*) or by matching relational roles (e.g., *chaser*).

Children saw a total of 15 pairs (3 practice, 10 experimental, and 2 fillers). The practice pairs served to introduce children to the task. They were literally similar: that is, the relations, the objects and the object roles were highly similar (e.g., a giraffe eating from a tree and a slightly taller giraffe eating from a different tree). We used literally similar practice pairs in order to avoid biasing children towards either relational or object matches.

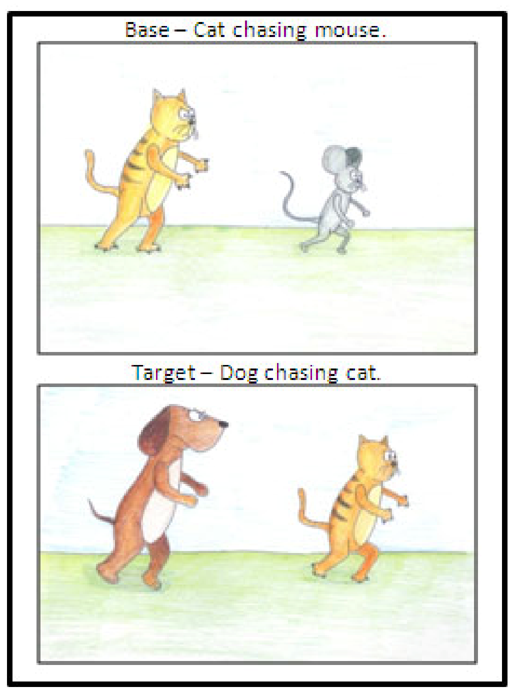


Figure 1: Sample stimuli pictures from Experiment 1.

Two literally similar filler pairs were also interspersed among the ten experimental trials and to check whether children remained engaged throughout the testing session. Children who failed to answer both filler trials correctly were excluded from further analyses.

Children in each age group were assigned to either the Relational Language condition or the Neutral Language condition, resulting in a 2 x 2 between-subjects design.

**Procedure** On all trials, the experimenter began by placing a pair of pictures in front of the child, with the base picture above the target picture. Then, the experimenter pointed to the base picture and asked the child, "What's in this picture?" Regardless of the child's answer, the experimenter agreed and described the picture, mentioning both the relation and the objects (e.g., "That's right, the cat is chasing the mouse."). Following the description, the experimenter pointed to an object in the base and asked the child to find the one that "went with" that object in the target. On experimental trials, children in the Relational Language condition heard, "Do you see this one *that's chasing*? What does this one go with in this [pointing to target] picture?" Children in the Neutral Language condition heard, "Do you see this one? What does this one go with in this [pointing to target] picture?" In both conditions, children heard neutral phrasing for all practice and filler trials.

If children had trouble during the practice trials, the experimenter showed them the correct answer and explained. Once the child understood the format of the task after the three practice trials and was able to respond correctly on his or her own on the last two practice trials, the experimenter moved on to the experimental trials.[2] No feedback was given on the experimental and filler trials.

## Results

Each child's proportion of relational responses was entered into a 2(Age) x 2(Language Type) univariate ANOVA (Figure 2). Seven-year-olds made more relational choices than 5½-year-olds, although this effect was only marginally significant, $F(1,60) = 3.12$, $p = .08$. However, a main effect of Language Type was significant, $F(1,60) = 6.52$, $p < .05$. Children who heard relational language chose the relational match more often than children who heard neutral language. Although the Age x Language interaction was not significant, when the two age groups were analyzed separately, the relational language advantage was found only for the 7-year-olds, $F(1,60) = 7.33$, $p < .01$.

## Discussion

As predicted, hearing relational language helped children make an appropriate relational match, despite a compelling object match. Given how strongly young children are drawn to object matches, this improvement is noteworthy. The degree of improvement is also striking; the 7-year-olds increased relational responding by 40% when they heard relational language.

However, compared to the performance of the 7-year-olds in Richland et al.'s (2006) studies (Richland et al. did not test 5½-year-olds), the performance of the 7-year-olds who heard neutral language in this experiment was fairly low (32% relational responses versus 64% in Richland et al.). This difference may be due to the training procedures used in the two studies. In Experiment 1, children were intentionally given ambiguous training examples that supported either an object or relational matching strategy; children received no feedback about which strategy was the "correct" one. In contrast, Richland et al. used fuller instructions and gave analogical practice pairs with feedback supporting the relational match. To provide children with the best possible chance at selecting the relational match in Experiment 2, we used instructions and practice procedures like those used by Richland et al. In anticipation of improved performance, we replaced the 7-year-old group with a younger group of 3½-year-olds.

One final difference between Experiment 1 and Richland et al. (2006) was the nature of the object distractors. Like Markman and Gentner (1993), Experiment 1 used object distractors that were participants in the target relation but cross-mapped so they filled another role. For instance, if in the base picture a cat was *chasing* a mouse, in the target picture, the cat was *being chased by* a dog. In contrast, Richland et al.'s distractors were extraneous to the main relation. That is, if a cat was chasing a mouse in the base picture, the target picture might show a boy chasing a girl, with the cat in the background (i.e., not chasing or being chased). Therefore, in Experiment 2, we also added a within-subjects factor of Pair Type to investigate any differences that may exist between external and cross-mapped distractors, as well as no distractor.

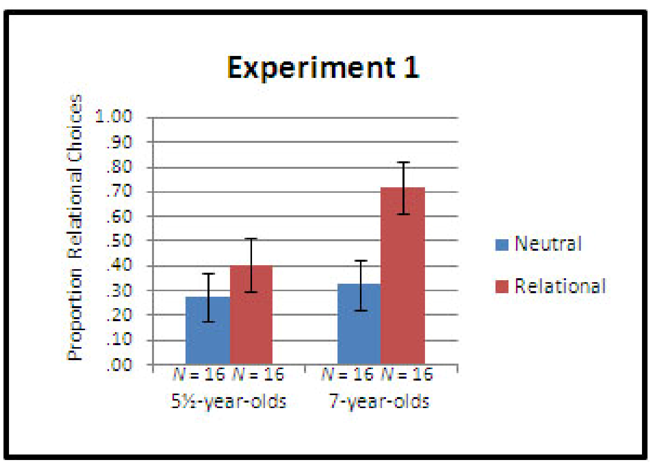


Figure 2: Mean proportion of relational choices in Experiment 1.

[2] These practice procedures differ from those used by Richland et al.'s (2006), which more closely resemble those used in Experiment 2.

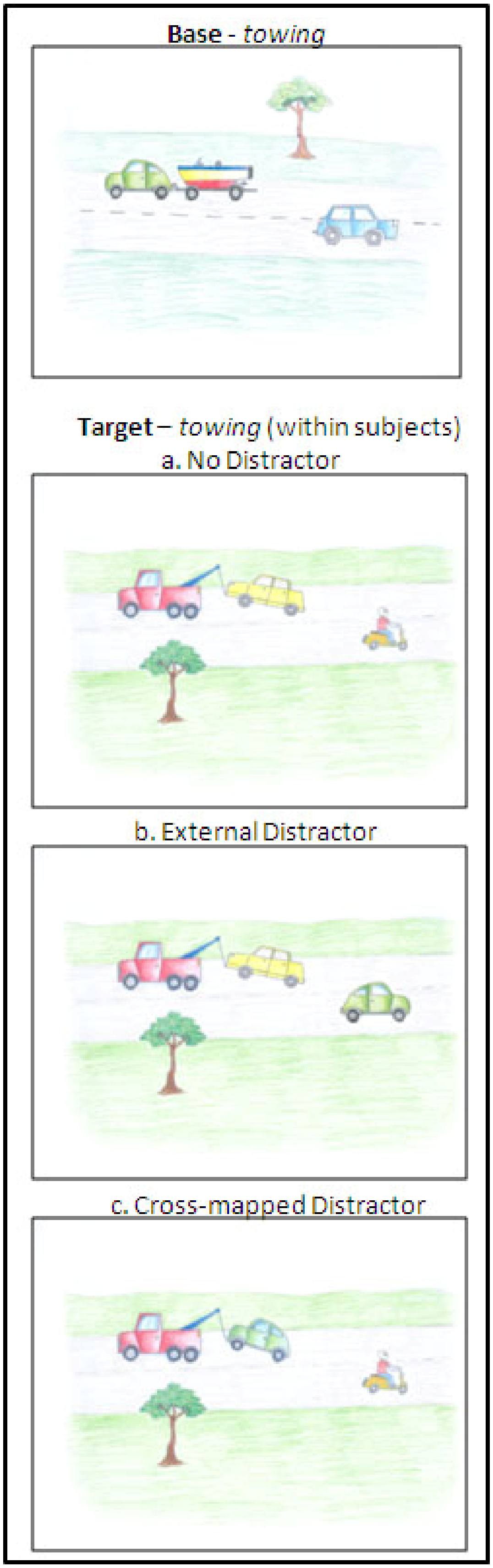


Figure 3: Sample stimuli pictures from Experiment 2.

# Experiment 2

## Methods

**Participants** Twenty-four 3½-year-olds (ages 40-47, *M* = 43.89 months) and 21 5½-year-olds (ages 62-66, *M* = 64.18) participated in this study. Two additional 3½-year-olds refused to participate. All but four children participated in the lab at Northwestern University. The other four children (all 5½-year-olds) were tested individually at a preschool.

**Materials and Design** Like Experiment 1, Experiment 2 employed Age and Language Type as between-subjects factors. Additionally, a within-subjects factor of Pair Type was added to the design, resulting in a 2 x 2 x 3 mixed design. In Experiment 1, the pairs were designed so that the object match, or distractor, was always cross-mapped from the base to the target picture. Experiment 2 also used cross-mapped pairs, in addition to pairs in which the object match was external to the relation and pairs in which there was no distractor (Figure 3). On cross-mapped trials, the object distractor participated in the same relation in the target picture as in the base picture (e.g., *towing*), but in a different role (e.g., *towee* versus *tower*) (Figure 3c). On external distractor trials, the distractor did not participate in the target relation, but was present in the target picture (Figure 3b). On no-distractor trials, no object distractor was present in the target picture (Figure 3a). The direction of the relation (e.g., towing from right to left) was varied within pairs so that spatial location could not be used as a proxy for a relational match.

Children saw a total of nine experimental picture pairs (three of each type), each exemplifying a different relation (e.g., *towing*). The type of pair seen for each relation was counterbalanced across participants. In addition to the nine experimental trials, children also saw three practice trials, one of each pair type, for a total of twelve picture pairs. No fillers were used in Experiment 2.

**Procedure** The general format of Experiment 2 roughly follows that of Experiment 1, but the wording of the instructions and questions were modified to resemble those used by Richland et al. (2006). Specifically, children were instructed that the pictures had a common "pattern" and that they should use this pattern to match the pictures. The experimenter began by laying down the first pair of practice pictures, with the base above the target, and saying:

> "There is a certain pattern in the top picture, and the same pattern happens in the bottom picture, but it looks different. Let me show you what I mean. See, in the top picture, there is a boy holding a dog. Now in the bottom picture, there is an elephant holding a cat. See, the same pattern happens in both, but it looks different. Now, in this game, first you have to figure out what the pattern is that happens in both pictures. Then I am going to point to one thing in the top picture, and your job is to tell me what is in the same part of the pattern in the bottom picture. So, on these pictures, if we have a boy holding a dog, if I point to the boy, which one is like this one

in the bottom picture? Which one is in the same part of the pattern in the bottom picture?"

On practice trials, children were given feedback about the correct (i.e., relational) answer, and incorrect practice trials were repeated. All children first saw the no distractor practice trial, followed by the external distractor practice trial, followed by the cross-mapped distractor practice trial.

Practice trials were followed by the nine experimental trials. On experimental trials, the experimenter did not ask for or give descriptions of the base and target pictures (unlike Experiment 1). Rather, the experimenter only asked what was "like this one" in the target picture. Children in the Relational Language condition heard a relational description of the actor in the base (e.g., "Do you see this one *that's towing*? What is like this one in the bottom picture?"). Children in the Neutral Language condition heard a neutral description of the actor (e.g., "Do you see this one? What is like this one in the bottom picture?"). Children were given no feedback on experimental trials.

### Results

As predicted, children who heard relational language chose the relational match more often than those who did not. This was confirmed by a 2(Age) x 2(Language Type) x 3(Pair Type) mixed measures ANOVA over children's relational responses, where Age and Language Type were between-subjects factors (Figure 4). Main effects of Age, $F(1,43) = 11.79$, $p < .01$, and Language Type, $F(1,43) = 13.06$, $p < .01$, were significant. The 5½-year-olds chose the relational match significantly more often than the 3½-year-olds, and children who heard relational language chose the relational match significantly more often than those who did not. A main effect of Pair Type was also significant, $F(2,86) = 3.92$, $p < .05$. As in prior research, children chose the relational match significantly more often when there was no distracting object match present.

The main effects of Pair Type and Language Type are best understood in light of their interaction, $F(2,86) = 5.22$, $p < .01$. Children who heard relational language chose the relational match as frequently on trials with a distractor (external or cross-mapped) as on those with no distractor. In contrast, children who heard neutral language chose the relational match significantly more frequently when there was no distractor than with either external or cross-mapped distractors (both Bonferronis, $p < .01$). Performance on the external and cross-mapped trials did not differ significantly. The three-way interaction with Age was not significant, suggesting that a similar pattern was found at both ages.

### Discussion

In Experiment 2, as predicted, relational language helped children to select the appropriate relational match and ignore tempting object matches. In fact, children were just as accurate on trials with distractors as on no-distractor trials when they heard relational language, suggesting that relational language helped children focus on the relational matches rather than on the competing object matches. Given how tempting young children find object matches, the fact that hearing relational language boosted their performance to a level equal to the no-competition level is quite remarkable.

It is also interesting that external distractors and cross-mapped distractors were equally disruptive to children's performance in the neutral language condition. The fact that children showed similar performance whether or not the object match participated in the relevant relation suggests that children may not be attending to the relation at all when an object match is present.

## General Discussion

Together, these studies suggest that relational language is a fundamental aspect of children's analogical development. Across two studies, when children were provided with relational descriptions, they were able to overcome their focus on objects to make a correct relational match. The improvements from relational language were large, found across three distinct age groups, and were present despite changes in methodology and stimuli.

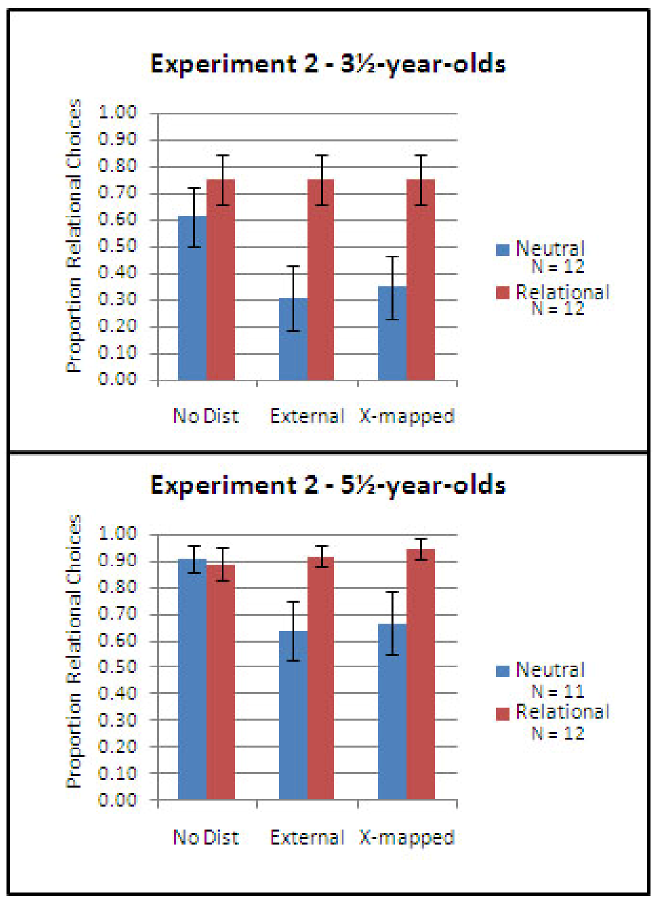


Figure 4: Mean proportion of relational choices in Experiment 2.

Although the results of the two experiments are generally consistent, there are some notable differences. First, performance in Experiment 2 was much better than in Experiment 1. We attribute this improvement to more explicit instruction and feedback in the second experiment. Secondly, 5½-year-olds in Experiment 2 showed significant improvement when they heard relational language compared to neutral language, but this pattern was not significant in Experiment 1. This may be due to the fact that pictures in Experiment 1 were described by the experimenter before asking the child to make a selection (e.g., "In this picture, the cat is *chasing* the mouse, and in this picture the dog is *chasing* the cat."), whereas in Experiment 2 they were not. For 5½-year-olds in Experiment 1, the additional relational role descriptor (e.g., *chaser*) may not have added anything beyond what was already provided by the verb.

In sum, these findings add to evidence that relational language helps children reason analogically (Gentner, 2003; Gentner & Christie, 2008), but more work is needed to determine precisely how language is helping. Relational language could aid the mapping process by selecting among several possible conceptualizations, or by highlighting common relations, so that the child can focus on the common structure (Gentner, 2003; Gentner & Clement, 1988). For example, hearing the relational label *chaser* may invite focusing on the chasing relation and on the role of the cat within that structure, rather than on the cat as an entity. Language might also support executive processes, helping children inhibit attention to objects. Finally, Jacques and Zelazo (2005) suggest that language can increase children's cognitive flexibility.

We suggest that relational language is a powerful tool that helps children represent and map relational structure. The data presented here add to the evidence that symbolic learning is important in human analogical development.

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