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PAPER

Developmental changes in children's understanding of the similarity between photographs and their referents

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Abstract

In a series of three experiments, we investigated the development of children's understanding of the similarities between photographs and their referents. Based on prior work on the development of analogical understanding (e.g. Gentner & Rattermann, 1991), we suggest that the appreciation of this relation involves multiple levels. Photographs are similar to their referents both in terms of the constituent objects and in terms of the relations among these objects. We predicted that children would appreciate object similarity *(whether photographs depict the same objects as in the referent scene) before they would appreciate* relational similarity *(whether photographs depict the objects in the same spatial positions as in the referent scene). To test this hypothesis, we presented 3-, 4-, 5-, 6-, and 7-year-old children and adults with several candidate photographs of an arrangement of objects. Participants were asked to choose which of the photographs was 'the same' as the arrangement. We manipulated the types of information the photographs preserved about the referent objects. One set of photographs did not preserve the object properties of the scene. Another set of photographs preserved the object properties of the scene, but not the relational similarity, such that the original objects were depicted but occupied different spatial positions in the arrangement. As predicted, younger children based their choices of the photographs largely on object similarity, whereas older children and adults also took relational similarity into account. Results are discussed in terms of the development of children's appreciation of different levels of similarity.*

Introduction

Developmental psychologists have shown increasing interest in children's understanding of external representations of space, including maps, models, and photographs (Callaghan, 2000; Callanan, Jipson & Soennichsen, 2002; DeLoache, 2000; Lowenstein & Gentner, 2001; Liben, 2003; Uttal, 2000, 2005; Uttal, Fisher & Taylor, 2006). Research on this issue has shed light on several important questions in research on cognitive and perceptual development. For example, studies of the development of children's use of external representations have contributed to our understanding of the development of symbolization, executive control, analogy, and the comprehension of intention (Bloom & Markson, 1998; Carlson, Davis & Leach, 2005; DeLoache & Burns, 1994; Eskritt & Lee, 2002; Lowenstein & Gentner, 2001; Perner, 1991; Robinson, Nye & Thomas, 1994).

Much of the research on children's understanding of external representations has focused on whether children understand the general correspondence between the representation and what it stands for. For example, DeLoache's work (1987, 1989, 2000) has, for the most part, focused on when and how children understand that a scale model represents or stands for a space. Likewise, research on other representations, including video (Troseth, 2003), maps (Dow & Pick, 1992; Marzolf & DeLoache, 1994) and photographs (DeLoache & Burns, 1994) has focused on the development of children's understanding that the various representations can stand for a particular place or thing in the world.

There is, however, another important sense in which children must comprehend external representations in order to use them effectively. In many cases, using an external representation depends upon not only understanding that it stands for a represented space but also upon *mapping* the elements in the representation to the corresponding elements in the represented scene. Prior research has shown that the process of establishing mappings is more complicated than simply perceiving a global correspondence between the representation and its referent (Blades & Cooke, 1994; Loewenstein & Gentner, 2001). For example, Blades and Cooke showed 4-year-old children two models of the same room, each containing, among other things, one wardrobe and two identical chairs. They found that children could reliably find a hidden object in one model after seeing a corresponding object hidden beneath the wardrobe in the other model, but not after seeing a corresponding object hidden beneath one of the chairs. The only way to

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discriminate between the two chairs was to map the spatial relations in one model onto the other. In this case, the children failed to accurately use one model as a representation of the other, not because they failed to see *any* correspondence between the two models, but because, although they could map on the basis of object matches, they could not do so on the basis of corresponding spatial relations.

In this paper, we present a theoretical perspective that can shed light on the process of mapping the relations between objects depicted in external representations and corresponding scenes in the world. We suggest that children and adults often employ different rules for establishing correspondence between representations and reality, and that children's rules change with the acquisition of knowledge. The theoretical basis for this claim stems from research on the cognitive processes involved in understanding analogies and other forms of similarity (Gentner, 1983, 1988; Goldstone, Medin & Gentner, 1991; Markman & Gentner, 1993). Gentner and Rattermann (1991) proposed that, when assessing the similarity of two groups of objects, young children initially attend to similarities between the attributes or features of individual objects in the two groups, but that as children gain knowledge, they increasingly attend to similarities between the relations among objects in each group, undergoing what Gentner and Rattermann term a *relational shift* (see also Halford, 1992). For example, Gentner (1988) found that between 5 years and adulthood participants showed an increased tendency to interpret the metaphor 'plant stems are like drinking straws' relationally (both can be used for drawing water) rather than attributionally (they are both long and straight).

Studies of children's interpretation and production of metaphors provide evidence that children and adults focus on different types of information during comparison. Consistent with Gentner's (1988) finding that children tend to focus on attributional similarities in processing metaphors, Winner (1979) found evidence that younger children primarily produce attributional metaphors. She analyzed the metaphoric productions of a 2-year-old child, and found that most (65%) of his early metaphors were based on common object properties, especially shape, while relational metaphors were rare (12%).

Research using non-linguistic tasks also supports the idea that the way people process similarity undergoes a relational shift (Gentner & Rattermann, 1991; Loewenstein & Gentner, 2001; Rattermann & Gentner, 1998) and that this shift is largely driven by domain learning (Goswami & Brown, 1990; Rattermann & Gentner, 1998). For example, using a causal analogies task (Premack, 1983; Sternberg & Rifkin, 1979), Rattermann and Gentner gave 4- and 5-year-old children A:B::C:? pictorial analogies based on familiar causal relations and asked them to choose the item that correctly completed the analogy from among four alternatives. The results showed a marked shift with age from choosing items solely based on their similarity to the item in the C term of the analogy to choosing items based on the relationship among the A and B terms of the analogy. All children performed better on sets for which they had superior understanding of the causal relations (see also Goswami & Brown, 1990). The relational shift has been found in the spatial domain as well. For example, when children were asked to map between two spatial arrays, 3-year-olds attended strongly to object matches, whereas 5-year-olds were able to ignore object matches and map according to matching spatial relations (Gentner & Rattermann, 1991). This finding is consistent with the hypothesis that the relational shift is driven by gains in knowledge. Further, along with Winner (1979), this study suggests that between 3 and 5 years of age children often acquire knowledge of a variety of relations and may begin to focus on relational similarities in a number of different domains.

People's focus on relational similarities continues to increase into adulthood as they continue to gain expertise about the world around them. Research has shown that although adults are more likely than children to focus on relational rather than object properties in interpreting analogies, adults often first focus on object properties when learning new information, particularly in unfamiliar domains (Chi, Feltovich & Glaser, 1981; Sloutsky & Fisher, 2004).

In the present research, we examined the development of children's understanding of the relation between photographs and their referents in light of the theory that children's assessments undergo a relational shift. Photographs are a relatively untapped medium in which to study children's understanding and use of different types of relations. In addition, almost all research on the development of children's understanding of photographs has focused on whether and when children understand them as representations. For example, research has investigated whether young children understand the basic correspondence between a photograph and a represented space (e.g. DeLoache & Burns, 1994) and whether they understand that a photographic representation remains the same even if the real-world scene that it represented is altered (Zaitchik, 1990).

We suggest that there is a second sense of understanding photographs that extends beyond recognizing that a photograph is a representation of a scene. This understanding involves knowing *how* photographs relate to the objects that they represent. We argue that understanding photographs as representations is not a unidimensional concept; rather, the photographs and their referents are similar on multiple levels. We investigated whether there is a relational shift in the development of children's judgments of the fit between a configuration of objects and a photograph of that configuration. We presented children and adults with a configuration of objects on a tabletop along with three candidate 'photographs' of the configuration shown. Because we were interested in children's relative preference for specific kinds of similarities, in

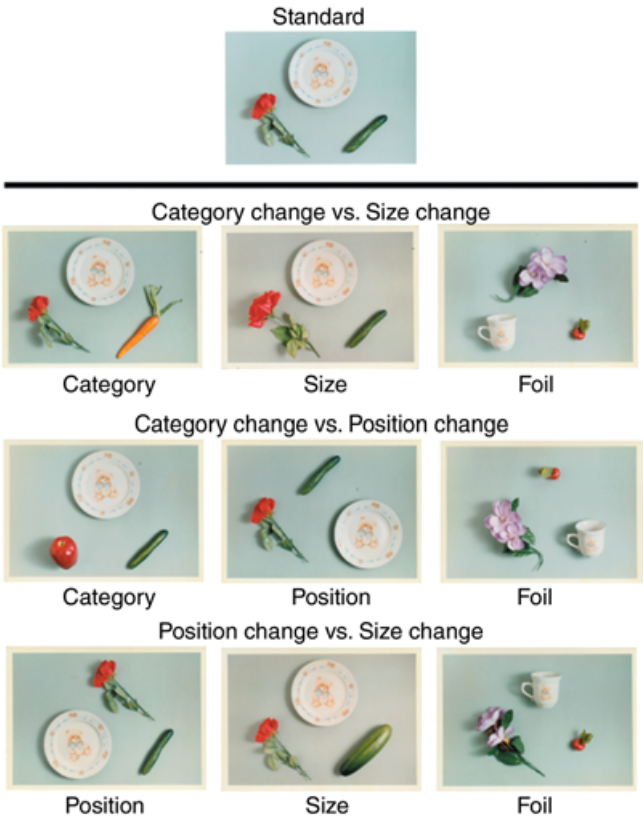

Figure 1 *A diagram of three types of trials testing children's preference for violations of category versus size, category versus position, and position versus size.*

Experiment 1, none of the photographs was a perfect portrayal of the objects but each photograph preserved a few of the objects' properties. All the photographs preserved two of the three following properties: position, category, and size (see Figure 1). We chose violations of position, category, and size because these are salient dimensions on which photographs could be expected to vary that would be familiar to both adults and to children as young as 3 years.

Category-change photographs preserved position and size. Two out of the three objects depicted were the correct objects of the correct size and in the correct position, but the object in the third position was replaced by a different object from the same category. Thus, these photographs depicted a change in the attributional properties of a single object. *Position-change* photographs preserved category and size. They depicted the correct objects in their correct sizes but in a different configuration from the actual objects on the table. Thus, these photographs depicted a change to the spatial relational information in the configuration. *Size-change* photographs preserved category and position. They depicted the correct objects in the correct relative positions, but one of the objects in the photograph was replaced by a larger version of that same object on the table. Size-change photographs largely, but not completely, preserved the attributional features of all objects, changing only a single feature of a single object (i.e. its size). They also largely preserved the spatial relational characteristics of the array, maintaining the relative positions of objects, although the absolute distance between objects changed incidentally as a result of the increase in object size. Thus, the change depicted in these photographs was neither obviously attributional nor obviously relational. Rather, we conceptualized size-change photographs as depicting changes subtle enough to allow participants to focus on different changes in the photographs depending on the context of other photographs with which size-change photographs were presented. For instance, in comparison to a category-change photograph, a size-change photograph depicts less of an attributional change. When compared with position-change photographs, a size-change photograph depicts less of a relational change because the objects all remain in the same relative position in the size-change photograph.

We investigated whether relative preference for photographs depicting changes in size, position, or category would vary as a function of age. We also tested whether participants' preference for the various photographs would vary as a function of the other photographs with which each photograph was paired. If the relational shift hypothesis applies here, then we should expect to find certain patterns of preferences on the three trial types shown in Figure 1.

Both younger and older children, as well as adults, should reject photographs that change the basic nature of the referents. Thus, all ages should reject category-change photographs, in which a live object (e.g. an apple) is replaced by another member of its category (e.g. an orange) in the photograph. We therefore predicted that most participants, regardless of age, would prefer position-change photographs over category-change photographs, because the category-change photographs do not preserve the attributional properties of the referents. Because size-change photographs do preserve most attributional features of the objects, most participants should also choose size-change photographs over category-change photographs. However, if the relational shift hypothesis applies here as we predict, then older individuals (older children and adults) will be more likely than younger children to also consider whether the photographs preserve the relational characteristics of the referents. Thus, we predicted that there would be a developmental difference on trials in which position-change photographs were compared with size-change photographs, because here the major difference lies in whether or not relational information is preserved. In this type of trial, both sets of photographs preserve most of the attributional information about the objects in each configuration – each shows the same objects as are present in the referent scene. But the size-change photographs preserve the relative locations of the objects while position-change photographs do not. Thus, the relational shift hypothesis predicts that young children, who attend mainly to

object identity and not to relational commonalities, should disregard this difference. They should, therefore, show little to no consistent preference in their responding. In contrast, older children and adults should prefer the size-change photographs to the position change photographs, because the size-change photographs largely preserve the spatial relations among the objects.

Experiment 1

Methods

Participants

There were 130 participants, including 109 children (ages 3–7) and 21 adults (ages 14–45). Six age groups were tested: 3-year-olds (3.41, 2.95–3.68); 4-year-olds (4.32, 3.91–4.82); 5-year-olds (5.24, 4.86–5.84); 6-year-olds (6.09, 5.86–6.72); 7-year-olds (6.97, 6.80–7.19); and adults (24.21, 14.74–45.00). There were 21 or 22 participants in each age group, and females comprised approximately half of each age group. The children were recruited from direct mail to their parents. Adult participants consisted of undergraduate students who received course credit for their participation and community-dwelling adults who previously had indicated their interest in participating in research. The adults in the latter group were compensated for their participation.

Materials and procedures

Each participant viewed four triads of objects representing themes familiar to both children and adults: dinner, bath time, school supplies, and fruits and vegetables. (For example, as shown in Figure 1: Standard, the dinner triad contained a plate, a rose, and a cucumber.) For each theme of objects, three trials were conducted to assess participant preference for one type of pictorial inconsistency over another (size change vs. position change, size change vs. category change, and category change vs. position change) in judging the similarity of pictures to the triad configuration.

For a given triad theme, the experimenter placed the objects on the table, one at a time, and asked the participant to name each object as it was placed. The experimenter then brought out a Polaroid camera and asked the participant to count to three while she (the experimenter) photographed the triad. The experimenter then clicked the camera several times, out of view of the participant, and informed the participant that the camera made 'too many pictures'.

Each trial began with the experimenter placing three candidate photographs on the table, and asking which picture was 'the same' as the configuration on the table. The triad of objects remained in view so that children's judgments of what was the same would not be influenced by memory constraints. If the participant responded that either none or more than one of the photographs were correct, they were asked 'Which one looks most the same?' One of the three candidates was always a foil photograph in which none of the objects pictured matched those present in the triad. These foils served as a check on whether participants were on task. Participants who were paying attention and making serious efforts to respond to the question should almost never have chosen the foil photograph. The two remaining candidates each depicted one of the three pictorial violations tested – size, position, and category (see Figure 1 for depictions of the violations in each trial type). Thus, each candidate photograph on each trial preserved different physical attributes of the arrangement of objects on the table (or none of the attributes in the case of the foil photographs). Size-change photographs preserved object identity, and for the most part, spatial position but not object size; position-change photographs preserved object size and object identity but not relational similarity; and category change photographs preserved object size and relational similarity but not object identity. This allowed us to compare participants' preferences for each attribute as it was paired in all possible combinations with each of the other attributes.

The experimenter recorded participants' choices on each trial. At the end of each trial, the photographs were cleared from the table and replaced by the three candidate photographs in the next trial. After the three types of trials were administered for a triad, the experimenter removed the triad of objects from the table and introduced the next theme. All participants were introduced to all four of the themes and completed three trials within each, yielding a total of 12 judgments per participant. The three types of trials were counterbalanced by presenting them to participants in two different orders.

None of the photographs was a perfect representation of the objects on the table. Consequently, each trial required that participants demonstrate a preference for preserving some attributes over others. Furthermore, because the context for these similarity judgments changed from trial to trial, we were able to assess how participants' judgments of 'which picture was the same' changed as a function of the other candidates available in that trial. The trials comparing size-change to position-change photographs were of particular interest because the relational shift hypothesis predicts that, on these trials, we should see the greatest differences in performance between participants of different ages. If the perception of fit between real objects and photographs undergoes a relational shift, then younger children should simply focus on object identity and similarity while older children and adults should also focus on relational similarity. Accordingly, younger children should choose photographs that preserve most of the identifying attributes of individual live objects (position- and size-change photographs) and older participants should choose photographs that also preserve the relations among the objects (only size-change photographs).

Results

We first examined whether participants exhibited clear preferences or whether they simply chose randomly. We checked the rate of choosing the foil photographs, the alternative that failed to preserve any of the attributes of the objects on the table. Because one of the three photographs on each trial was always a foil, foils would have been chosen 33% of the time had responding been random. This was not the case; participants chose the foil on only 1% of the trials, and these choices occurred equally across the three types of trials (1.4% for size vs. position and category vs. position trials; 0.96% for size vs. category trials). Although 3-year-olds chose the foil photograph more frequently than participants of any other age, selecting it on 5.6% of trials, they still selected it far less frequently than would be expected had their responding been random, $\chi^2(1, N = 252) = 87.8$, $p < .001$. Thus, even the youngest children were clearly basing their choices on matching the contents of the photographs to the objects on the table.

Having established that even the youngest children attended to the task and demonstrated reliable preferences, nearly always eschewing the foil photographs, we focused next on the analyses of the types of photographs chosen in each of the three types of comparison trials. Recall that the three types of trials (i.e. size vs. position, size vs. category, and category vs. position) were presented once for each of the four themes. To assess the relative strength of the preferences for the photographs, we analyzed preferences within the three types of trials separately. For each of the three types of trials, we calculated the proportion of times each of the two nonfoil choices was selected. For example, on size versus position trials, we calculated the proportion of times the size photograph was chosen and the proportion of times the position photograph was chosen. Table 1 shows the means and standard deviations for the proportions of each choice on each trial. We also calculated the difference between these proportions. A large difference would indicate a strong preference for one type of photograph over another. These difference scores allowed us to determine whether there were age-related changes in the strength of preference for the different photograph types and whether the pattern of preference strengths varied for the three types of trials.

Size vs. category trials

The analyses of these trials involved the proportion of choices of size-change and category-change photographs. The results are shown in Table 1. To assess preference strength, the proportion of category-change responses was subtracted from the proportion of size-change responses. Consequently, positive difference scores reflect a preference for size-change photographs over category-change photographs, negative scores indicate a preference for category over size, and a zero score indicates no preference. Therefore, testing whether the difference scores were reliably different from zero assesses whether children showed a preference for the size- or category-change photographs.

As predicted, all age groups preferred the size-change photographs to the category-change photographs. One-sample *t*-tests indicated that the difference scores for all age groups reliably exceeded zero, $ts(20–21) > 2.79$, $ps < .05$. However, as shown in Figure 2, the strength of the preference for size-change over category-change photographs increased with age. A one-way ANOVA on the difference scores, with age as the independent variable, revealed a significant effect of age, $F(5, 124) = 10.70$, $p < .001$.

Table 1 *Average proportion of photograph choices by trial type and age*

		Trial type		
Age (years)	Choice	Position vs. category	Size vs. category	Size vs. position
3	Category	.27 (.26)	.27 (.32)	–
	Position	.69 (.26)	–	.43 (.23)
	Size	–	.67 (.34)	.50 (.29)
4	Category	.14 (.21)	.15 (.25)	–
	Position	.82 (.27)	–	.50 (.27)
	Size	–	.85 (.25)	.49 (.27)
5	Category	.06 (.11)	.02 (.07)	–
	Position	.94 (.11)	–	.38 (.24)
	Size	–	.98 (.07)	.63 (.24)
6	Category	.06 (.13)	.02 (.07)	–
	Position	.94 (.13)	–	.41 (.23)
	Size	–	.98 (.07)	.59 (.23)
7	Category	0.0	0.0	–
	Position	1.0	–	.57 (.22)
	Size	–	1.0	.43 (.22)
Adult	Category	.10 (.22)	0.0	–
	Position	.90 (.22)	–	.07 (.14)
	Size	–	1.0	.93 (.14)

Note: The values represent mean measures, with standard deviation in parentheses.

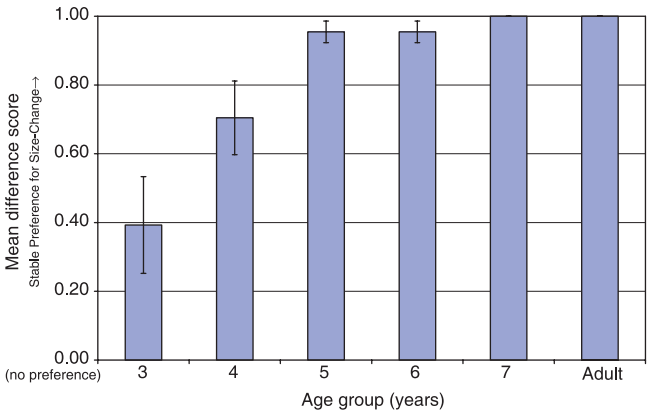

Figure 2 *Average proportion (mean difference score) by which size-change choices were chosen more often than category-change choices on size-change versus category-change trials in Experiment 1.*

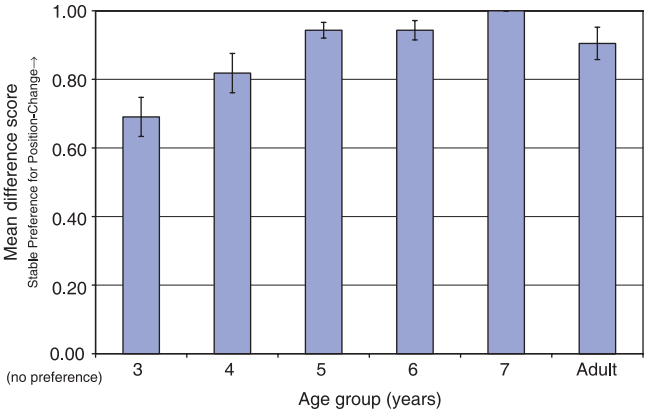

Figure 3 *Average proportion (mean difference score) by which position-change choices were chosen more often than category-change choices on position-change versus category-change trials in Experiment 1.*

To determine which adjacent age groups were significantly different from one another in the magnitude of difference scores, we carried out Bonferroni post-hoc comparisons on the difference scores as a function of age. These contrasts indicated that, on average, difference scores showed a trend of being greater for 4-year-olds (M = 0.70, SD = 0.50) than for 3-year-olds (M = 0.39, SD = 0.65), p = .052, and difference scores for all other age groups were significantly greater than those of 3-year-olds. The five oldest age groups (ages 4, 5, 6, 7, and adult) all exhibited average difference scores close to +1, indicating a consistent preference for size-change photographs over category-change photographs, and difference scores for the four oldest age groups were not significantly different from each other.

Position vs. category trials

On these trials, participants were asked to choose among a position-change photograph, a category-change photograph, and a foil. The proportions of position-change and category-change photographs chosen by each participant on these trials are summarized in Table 1. Again, a difference score was determined by subtracting the second value (category change) from the first (position change). Thus, positive difference scores indicate a preference for position change over category change, and negative scores indicate the reverse preference.

As predicted, both children and adults displayed a clear preference for position-change photographs, which included all of the objects on the table, albeit in the wrong positions, over category-change photographs, which included one non-matching object. Participants chose position-change photographs on 89% of these trials. This preference for position-change photographs was statistically significant among all age groups, ts(20–21) > 3.70, ps < .01. However, as shown in Figure 3, the preference for position-change photographs grew stronger with age. A one-way ANOVA on the difference scores, with age as the independent variable, indicated that this age difference was significant, $F(5, 124) = 7.51$, $p < .0001$. Bonferroni post-hoc comparisons on the difference score as a function of age indicated that difference scores were not significantly different for 3-year-olds (M = 0.69, SD = 0.26) and 4-year-olds (M = 0.82, SD = 0.27), p = .43, *ns*, but that all other age groups expressed significantly stronger preferences than 3-year-olds did. The five oldest age groups (ages 4, 5, 6, 7, and adult) exhibited average difference scores close to +1, consistently choosing position over category. Almost no significant differences were found between the difference scores of these groups, the exception being that 7-year-olds' difference scores were significantly greater than those of 4-year-olds.

Size vs. position trials

On these trials, participants viewed a size-change photograph, a position-change photograph, and a foil. The proportions of each choice are again shown in Table 1. The proportion of position-change choices was subtracted from the proportion of size-change choices to yield a difference score. Positive difference scores here would indicate a stronger preference for size change over position change, and negative scores would indicate the opposite preference. We predicted that, in contrast to the results of the previous comparisons, young children might not show a clear preference on these trials. This is because both choices preserved most of the attributional information about the objects on the table; they differed chiefly in their spatial relational match to the actual configuration, to which we hypothesized young children should be relatively insensitive. Thus, we expected that the youngest children would not exhibit a preference, but that, with age, a preference for photographs that preserved relational information (size-change photographs) would begin to emerge.

Generally, participants' preference for size change over position change increased with age, $F(5, 124) = 12.41$, $p < .0001$ (see Figure 4), and neither 3- nor 4-year-olds showed any reliable preference for size- or position-change photographs. However, Bonferroni post-hoc comparisons showed that although the difference scores of adults were significantly greater than those of all other age groups, the difference scores for all ages of children were not significantly different from each other. One-sample t-tests show that difference scores reliably exceeded zero only for the 5-year-old group and the adults, who showed consistent preferences for size-change photographs, ts(20–21) > 2.42, ps < .05. The difference scores of the 6-year-olds showed a trend exceeding zero, $t(21) = 1.891$, p = .073, but the difference scores of 7-year-olds did not differ from chance and were more similar to those of 4-year-olds than to those of either 5- or 6-year-olds. This finding is unexpected in light of the relational shift hypothesis, which suggests

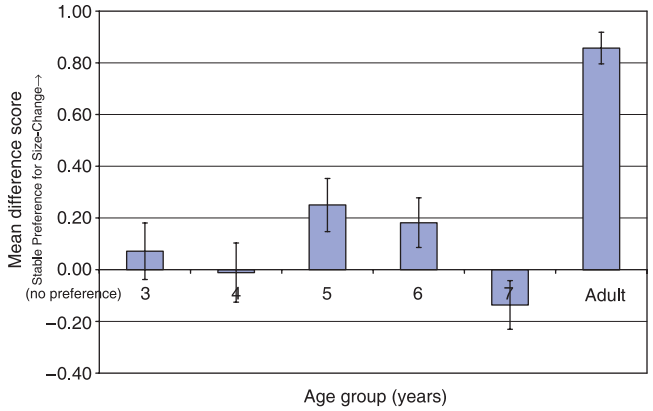

Figure 4 *Average proportion (mean difference score) by which size-change choices were chosen more often than position-change choices on size-change versus position-change trials in Experiment 1.*

that, given the 5-year-olds' performance, the 6- and 7-year-olds' difference scores should have significantly exceeded zero as well. The results show that there is a general age-related increase in tendency to reject position-change photographs when size-change photographs are present and that both 5-year-olds and adults reliably judge size-change photographs as being more similar than position-change photographs to actual configurations. In other words, 5-year-olds and adults preferred representations that preserved the relationships between objects to those that preserved object size. However, as said, 6- and 7-year-olds did not show a significant preference in making these judgments. As we will discuss later, Experiment 2 was conducted to test whether 6- and 7-year-olds' performances were a true contradiction of the relational shift hypothesis.

Discussion

Our results reveal both similarities and differences in how adults and children reason about the relation between a photograph and its referent. Both children and adults rejected candidate photographs that did not share any attributes with the objects on the table; very few participants chose the foil photographs. Candidate photographs that depicted an object that was not present on the table were also rejected (i.e. category change), and this pattern grew stronger with age. Both the preference for size-change photographs over category-change photographs and the preference for position-change over category-change photographs increased with age.

The results of the size versus position trials are particularly interesting because these comparisons provide a test of the relational shift hypothesis (Gentner, 1988; Gentner & Rattermann, 1991). Our results provided some support for this hypothesis, in that the youngest two groups of children showed no clear preference between size-change and position-change photographs, whereas adults did. Adults chose size-change photographs on these trials while younger children (3- and 4-year-olds) chose size and position about equally often. There was also partial evidence – from the 5-year-olds and, to some extent, from the 6-year-olds – that a preference for size-change photographs emerged in school-age children. However, the results from the 7-year-olds were at odds with this idea, as this age group did not demonstrate a reliable preference.

Inspection of the patterns of performance suggested that 7-year-olds' tendency to choose position-change over size-change photographs on some trials stemmed chiefly from a single trial within the school supply theme in which the size photograph depicted a ruler that was much longer than the actual ruler on the table. It appears that the 7-year-old children, as well as some 6-year-olds, may have been particularly attentive to the discrepancy in size between the real ruler and the ruler in the photograph. Given that rulers are, by definition, a certain size, the size change in this photograph may have been particularly attenuated for older children. These children may have seen the longer rulers in the photographs as differing, not just in size but also in identity from the actual ruler. Older children may even have perceived the object in the picture as a yardstick.

The perception of length as a defining feature of a ruler may be particularly salient to 6- and 7-year-olds since the concept of measurement is often introduced in first or second grade. Another intriguing possibility is that the 6- and 7-year-olds, who have more experience in measurement than the younger groups, were actually sensitive to the change in relative size between the ruler and the other objects. This could occur if they viewed the ruler as providing a scale by which the other objects' size could be assessed. Consequently, in Experiment 2, we examined the performance of the 6-year-olds, 7-year-olds, and adults on the same task, but with the school supplies set modified to include a new object in place of the ruler.

Experiment 2

Methods

There were 21 6-year-olds (6.11, 5.77–6.33), 22 7-year-olds (7.23, 6.81–7.71), and 22 adults (19.64, 18.51–22.14), recruited from the same sources as in Experiment 1. None of the participants in Experiment 2 had participated in Experiment 1. We replaced the ruler in the school supply theme with a new object, a pair of scissors. All procedures were identical to those of Experiment 1.

Results and discussion

Figure 5 shows the proportion of choices on the three types of trials. None of the participants chose the foil

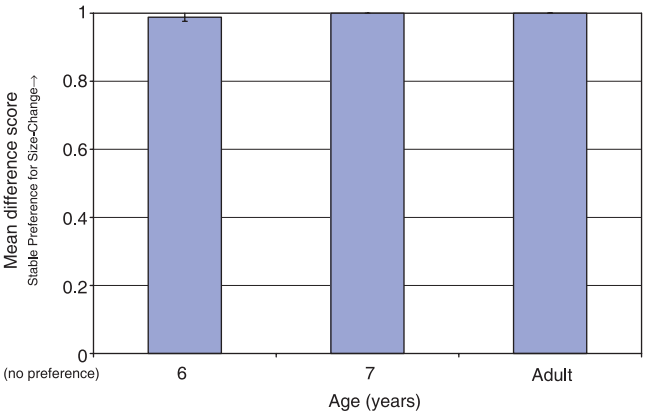

Figure 5 *Average proportion (mean difference score) by which size-change choices were chosen more often than category-change choices on size-change versus category-change trials in Experiment 2.*

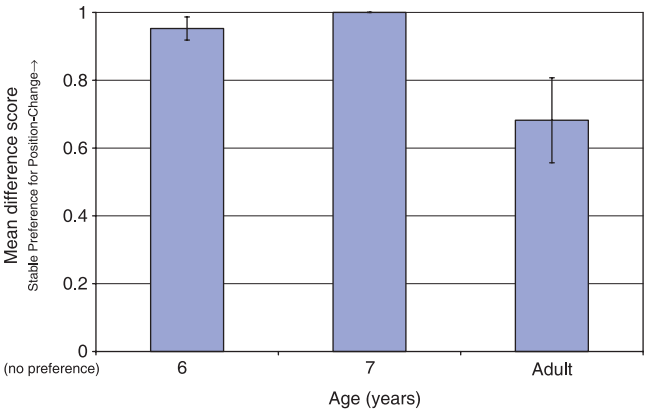

Figure 6 *Average proportion (mean difference score) by which position-change choices were chosen more often than category-change choices on position-change versus category-change trials in Experiment 2.*

photographs on any of the trials. On size versus category trials, both 7-year-olds and adults chose size-change photographs on 100% of the trials, and 6-year-olds also showed a significant preference for size-change photographs, $t(20) = 83.00$, $p < .001$, choosing them on 99% of the trials (see Figure 5). As before, difference scores were calculated by subtracting the proportion of category choices from the proportion of size choices. The mean difference scores of each age group were not significantly different from each other, $F(2, 62) = 1.049$, *ns*, and Bonferroni post-hoc comparisons also failed to reveal any age-related differences.

On position versus category trials, position-change photographs were chosen on 94% of the trials: 98% for 6-year-olds, 100% for the 7-year-olds, and 83% for the adults (see Figure 6). As before, difference scores were calculated by subtracting the proportion of category choices from the proportion of position choices. One-sample *t*-tests on the difference scores showed that they reliably exceeded zero, indicating a reliable preference for position-change photographs over category-change photographs among the 6-year-olds, $t(20) = 27.58$, $p < .001$, 7-year-olds, and adults, $t(21) = 5.43$, $p < .001$. There was a significant difference between the difference scores of the three age groups, $F(2, 62) = 5.01$, $p < .05$. Bonferroni post-hoc comparisons revealed that while the difference scores of 6- ($M = 0.94$, $SD = 0.16$) and 7-year-olds ($M = 1.0$, $SD = 0$) were not significantly different from each other, 7-year-olds' difference scores were significantly higher than those of adults ($M = 0.68$, $SD = 0.58$), $p < .05$. Taken together, the results from Experiments 1 and 2 suggest that among 6-year-olds, 7-year-olds, and adults there is a strong tendency to pick position-change over category-change photographs.

On size versus position trials, 6-year-olds, 7-year-olds, and adults showed a preference for size-change photographs, with 6-year-olds choosing size change on 71% of trials, 7-year-olds choosing it on 69% of trials, and adults choosing it on 77% of trials (see Figure 7). As before, difference scores were calculated by subtracting the proportion of position choices from the proportion of size choices. Thus larger positive difference scores reflect a stronger preference for size-change over position-change photographs. There was a significant preference for size-change photographs over position-change photographs among 6-year-olds, $t(20) = 5.403$, $p < .001$, 7-year-olds, $t(21) = 3.930$, $p < .01$, and adults, $t(21) = 4.805$, $p < .001$. A one-way ANOVA with age as the independent variable did not reveal a significant difference between the age groups in degree of preference for size change over position change, $F(2, 62) = 0.71$, *ns*, nor did Bonferroni post-hoc comparisons. Thus, the low incidence of size-change choices on size versus position trials among the 6- and 7-year-olds in Experiment 1 may have been due to performance on one particular trial.

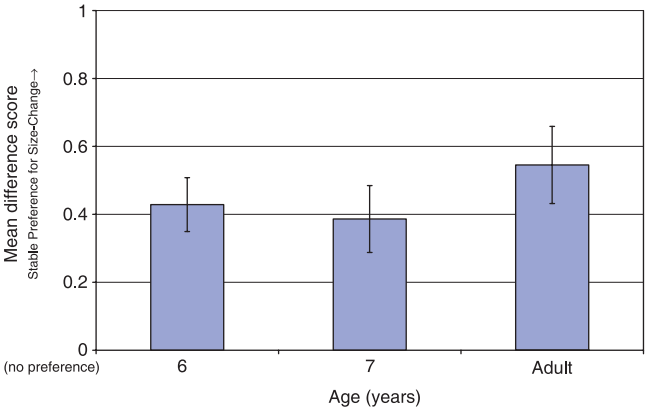

Figure 7 *Average proportion (mean difference score) by which size-change choices were chosen more often than position-change choices on size-change versus position-change trials in Experiment 2.*

The size-change manipulation was selected originally because it depicted a change subtle enough that the extent to which participants saw this change as attributional or relational would be sensitive to the context in which it was present. However, the manner in which size-change was operationalized and presented in one of the photographs, namely by changing the size of an object defined by its length (a ruler), may have led the school-age children to be more attentive to changes in attributional object features than they otherwise would have been. As predicted, once the ruler was replaced, 6- and 7-year-olds chose size-change photographs on this trial as they did on the size versus position trials for the other themes tested.

Experiment 3

The results presented thus far suggest that the younger children's understanding of the relation between photographs and their referents is based primarily on object identity comparisons, whereas older children and adults are more likely to consider spatial relational information as well. However, it is important to note that, in order to encourage participants to focus on the task, we had them verbalize the name of each object as the experimenter placed it on the table in Experiments 1 and 2. It is possible that the labeling itself may have contributed to the younger children's tendency to focus on object properties. That is, the children may have performed as they did in the prior experiments specifically because the labels led them to focus on the objects themselves, rather than the relations among the objects (e.g. Callaghan, 2000). Perhaps the act of labeling affected the young children's performance substantially by teaching them a name, or priming existing knowledge of an object name. To determine whether using labels affected children's performance, we conducted an experiment in which we partially replicated the prior experiments but did not include labels.

In addition, to further probe children's concepts of similarity, all children in Experiment 3 were also tested on a set of trials in which a target photograph, depicting the exact arrangement of objects on the tabletop, was among the three choices on each trial. In Experiments 1 and 2, children were asked to choose which photograph was most similar to the configuration of objects on the table when none of the photographs was a perfect depiction of these objects. This allowed us to determine how children's choices would be affected by the presence of a perfectly accurate depiction of these objects. With the inclusion of the target photograph on half of the trials viewed by each child, one of two things could occur. Children could recognize the target as the *most* similar of all the candidate photographs and overwhelmingly choose the target, or they could see the configuration as also being similar to a second candidate photograph and choose these two photographs equally often.

Methods

Participants

There were 15 3-year-olds (3.11, 2.87–3.94) and 18 5-year-olds (5.03, 4.83–5.25), recruited from the same sources as in Experiments 1 and 2. None of the participants in Experiment 3 had participated in the previous experiments.

Procedures

Because there were no measurable differences in performance across the four themes tested in Experiment 2, we tested only two of the four original themes in order to compensate for the addition of the target-present trials and keep the total number of trials that participants had completed the same as in the previous experiments. We tested the same dinner and bath themes used in the previous experiments, which originally consisted of three trials in which nine photographs were presented: two each in the size-, category-, and position-change categories and two foils.

For Experiment 3, one set of trials was identical to the trials tested in Experiments 1 and 2 except for the omission of labeling (no label trials), and in a second set of trials the target photograph replaced the foil photograph (target-present trials). Thus, six trials were presented for each theme: three no label and three target-present trials. Recall that in Experiments 1 and 2, children were never shown a photograph that accurately depicted the arrangement of objects currently shown on the table. Thus, for the target-present trials, we generated target photographs that were veridical representations of the actual objects displayed on the table for each of the two themes. To generate the six trials, each nontarget photograph in Experiment 3 was presented twice: once as part of its original combination in a replication trial (e.g. size vs. category vs. foil) and then a second time as part of a combination in a target-present trial, in which the target was shown (e.g. size vs. category vs. target). The trios were structured such that every combination of photographs was unique on each of the six trials. For example, a size photograph paired with a category and foil on a replication trial would be paired with a position and target on a target-present trial. The order of photographs was rotated through so that size-, category-, and position-change photographs appeared at least once in the three positions in front of the subject (left, middle, right). Because it was possible that the presence of an accurate representation might prime participants to be more attentive to certain types of discrepancies in representations of the same configuration on subsequent trials, trials were blocked such that all no label trials for each theme preceded all target-present trials for that theme. We devised two different orders that satisfied all of these criteria (one order is shown in Table 2).

Experimental procedures were nearly identical to Experiments 1 and 2. Apart from the inclusion of the

Table 2 *One order of trials used in Experiment 3*

Trial number	Picture order	Trial type
Dinner 1	FSC	Replication
Dinner 2	CPF	Replication
Dinner 3	PSF	Replication
Dinner 4	TSC	Target-present
Dinner 5	CPT	Target-present
Dinner 6	PST	Target-present
Bath 1	FPC	Replication
Bath 2	SFC	Replication
Bath 3	PSF	Replication
Bath 4	TPC	Target-present
Bath 5	STC	Target-present
Bath 6	PST	Target-present

Note: S = Size change; C = Category change; F = Foil; P = Position change; T = Target.

Table 3 *Average proportion of photograph choices by trial type and age in Experiments 1 (E1) and 3(E3)*

			Trial type		
Label	Age (years)	Choice	Position vs. category	Size vs. category	Size vs. position
Yes (E1)	3	Category	.31 (.33)	.21 (.37)	–
		Position	.62 (.38)	–	.21 (.34)
		Size	–	.71 (.41)	.69 (.37)
	5	Category	.02 (.11)	.0 (.0)	–
		Position	.98 (.11)	–	.27 (.34)
		Size	–	1.0 (.0)	.73 (.34)
No (E3)	3	Category	.17 (.24)	.23 (.32)	–
		Position	.77 (.32)	–	.20 (.25)
		Size	–	.73 (.37)	.70 (.37)
	5	Category	.08 (.26)	.03 (.12)	–
		Position	.92 (.26)	–	.11 (.21)
		Size	–	.94 (.24)	.89 (.21)

Note: The values represent mean measures, with standard deviation in parentheses.

target photographs on half of the trials, the only other difference was that we did not include the verbal labels when the dinner and bath objects were placed on the table. At the start of each trial, the experimenter placed the objects on the table but did not ask the child to name the object. As before, the experimenter pretended to photograph the array, informed the participant that the camera made 'too many pictures', and then asked which of the three candidate photographs on the table was the same as the array. Otherwise, all experimental procedures were identical to Experiments 1 and 2.

Results and discussion

As before, the incidence of foil choices was extremely low (1.4% on label trials overall; 1.8% on size vs. position label trials; 1.2% on both category vs. position and size vs. category label trials). Thus, once again, both 3- and 5-year-old children were basing their choices on matching the contents of the photographs to the objects on the table. This result confirms that children understood the task, were paying attention, and were responding systematically, if not always identically to adults. In this section, we report first the results of the label trials followed by the results of the target-present trials.

No label trials

We analyzed the types of photographs chosen in each of the three types of comparison trials. The proportion of times each of the two nonfoil choices was selected is summarized by comparison type in Table 3. One of the goals of Experiment 3 was to test, by omitting the labeling step used in the previous experiments, whether giving verbal labels to objects in Experiments 1 and 2 affected children's performance. To determine whether labeling objects affected performance, we compared the difference scores of children in the current experiment with those of the 3- and 5-year-old children on the dinner and bath trials in Experiment 1. For each of the three types of comparison trials, 2 (Age: 3 vs. 5 years) × 2 (Label: yes vs. no) ANOVAs were preformed on the difference scores and, as in the previous experiment, these difference scores were calculated by subtracting one of the two nonfoil choices in each trial type from the other.

Size vs. category trials. As in Experiment 1, we calculated difference scores for this trial type by subtracting the proportion of the trials where children chose category-change photographs from the proportion of trials where they chose size-change photographs. A 2 (Age: 3 vs. 5 years) × 2 (Label: yes vs. no) ANOVA performed on these difference scores and those of children in Experiment 1 showed that the performance of children who did not label the depicted objects beforehand ($M = 0.73$, $SD = 0.56$) did not differ significantly from the performance of those who did ($M = 0.76$, $SD = 0.58$), $F(1, 72) = 0.12$, $p = .74$. Across both labeling conditions, older children exhibited a stronger preference for size-change versus category-change photographs ($M = 0.96$, $SD = 0.24$) compared with younger children ($M = 0.50$, $SD = 0.72$), $F(1, 72) = 13.96$, $p < .001$, and there was not a significant interaction between age and label, $F(1, 72) = 0.12$, $p = .74$.

Position vs. category trials. We calculated difference scores for this trial type by subtracting the proportion of the trials that children chose category-change photographs from the proportion of the time that they chose position-change photographs. A 2 (Age: 3 vs. 5 years) × 2 (Label: yes vs. no) ANOVA performed on these difference scores and those from Experiment 1 found that the performance of the children who did not label the depicted objects ($M = 0.73$, $SD = 0.53$) did not differ significantly from the performance of those who did ($M = 0.64$, $SD = 0.60$), $F(1, 72) = 0.50$, $p = .48$. Overall, older children exhibited a stronger preference for size-change versus category-change photographs ($M = 0.90$, $SD = 0.38$) compared with younger children ($M = 0.43$, $SD = 0.65$), $F(1, 72) = 13.96$, $p < .001$, and there was not

Table 4 *Average proportion of photograph choices on target-present trials (Experiment 3) compared with the relevant target-absent trials from Experiment 1*

			Trial type		
	Age (years)	Choice	Position vs. category	Size vs. category	Size vs. position
Target present (Experiment 3)	3	Target	.47 (.23)	.50 (.42)	.37 (.35)
		Position	.40 (.34)	–	.33 (.36)
		Size	–	.33 (.31)	.30 (.37)
	5	Target	.67 (.30)	.47 (.44)	.47 (.36)
		Position	.33 (.30)	–	.08 (.19)
		Size	–	.50 (.42)	.44 (.38)
Target absent (Experiment 1)	3	Target	–	–	–
		Position	.62 (.38)	–	.21 (.34)
		Size	–	.71 (.41)	.69 (.37)
	5	Target	–	–	–
		Position	.98 (.11)	–	.27 (.34)
		Size	–	1.0 (.00)	.73 (.34)

Note: The values represent mean measures, with standard deviation in parentheses.

a significant interaction between age and label, $F(1, 72) = 2.94$, $p = .09$.

Size vs. position trials. We calculated difference scores for this trial type by subtracting the proportion of the trials that children chose position-change photographs from the proportion of the time that they chose size-change photographs. A 2 (Age: 3 vs. 5 years) × 2 (Label: yes vs. no) ANOVA performed on the difference scores from both Experiments 1 and 3 showed that the performance of children who did not label the depicted objects ($M = 0.65$, $SD = 0.51$) did not differ significantly from the performance of those who did ($M = 0.47$, $SD = 0.67$), $F(1, 72) = 1.53$, $p = .22$. Although across both conditions, older children's difference scores were higher ($M = 0.60$, $SD = 0.59$) than younger children's ($M = 0.49$, $SD = 0.63$), there was no significant effect of age, $F(1, 72) = 0.83$, $p = .36$, nor was there a significant interaction between age and label, $F(1, 72) = 1.14$, $p = .29$.

Target-present trials

Children in Experiment 3 were also tested on a second block of trials in which the correct photograph of the configuration was included in each trio of choices. The presence of the target photographs permitted a direct assessment of the extent to which children expect photographic representations to be similar to their referents and what kinds of representations children consider to be sufficiently similar to a scene to be classified as a photograph of that scene.

We calculated the proportion of times the target was chosen on each trial and compared it with the most strongly preferred choices reported earlier for the three types of comparison trials (i.e. size in size vs. category trials; position in position vs. category trials; and size in size vs. position trials). Analysis of our data confirmed that the most strongly preferred choice on each type of trial in Experiment 1 was the second most preferred choice after the target on the target-present trials of Experiment 3. The mean proportion of choices is summarized in Table 4. We then calculated difference scores by subtracting from the proportion of target choices the proportion of times the previously preferred choice was chosen instead. Thus, positive difference scores for all three comparison types indicate a stronger preference for the target over the previously preferred choice. Difference scores were analyzed for main effects of age and compared to a reference value of zero to determine if a statistically strong preference for the target existed.

Size vs. category trials. Since size-change photographs were the preferred choice on this trial type in the previous experiments, preferences for size-change photographs and target photographs were compared. When shown both a target photograph and a size-change photograph, neither the 3- nor the 5-year-olds expressed a strong preference for one or the other. A one-sample *t*-test confirmed that the target versus size difference scores did not significantly differ from zero for either the 3-year-olds, $t(14) = 0.96$, $p = .35$, or the 5-year-olds, $t(17) = -.14$, $p = .89$. No main effect of age was found, $F(1, 31) = 0.52$, $p = .48$.

Position vs. category trials. Since position-change photographs were the preferred choice on this trial type in the previous experiments, preferences for position-change photographs and target photographs were compared. One-sample *t*-tests performed for the two age groups revealed that the 3-year-olds' difference scores were not significantly different from zero, $t(14) = 0.49$, $p = .63$. This suggests that 3-year-olds did not reliably prefer an accurate photograph over one containing the correct objects in the wrong positions. This finding is consistent with our hypotheses and with our findings from Experiment 1, in which we suggested that 3-year-olds are object-centered. Additional support is provided by the fact that 5-year-olds' difference scores were significantly greater than zero, $t(17) = 2.38$, $p < .05$, indicating that they strongly preferred the target to position-change pictures. A one-way ANOVA on the proportion of target choices on position versus category trials produced a significant effect of age, $F(1, 31) = 4.54$, $p < .05$, reflecting

the fact that 3-year-olds chose the target photograph on 47% of these trials (SD = 0.23) while 5-year-olds did so on 67% of trials (SD = 0.30).

Size vs. position trials. Since size-change photographs were the preferred choice on this trial type in the previous experiments, preferences for size-change photographs and target photographs were compared. A one-sample t-test revealed that the target versus size difference scores were not significantly different from zero for either the 3-year-olds, $t(14) = 0.41$, $p = .69$, or the 5-year-olds, $t(17) = 0.16$, $p = .87$. No main effect of age was found, $F(1, 31) = 0.03$, $p = .87$.

The results of Experiment 3 rule out some competing explanations for our results. First, children's pattern of preferences could not be explained by the act of labeling the objects depicted in the photographs. Furthermore, the extent to which children did or did not discriminate between target photographs and each type of property-change photographs provides a useful metric for the extent to which these properties are taken into account when computing similarity. When the target pictures were included among the alternatives, the target photographs often became the most strongly preferred choices, with some notable exceptions. Both 3- and 5-year-old children chose size-change photographs and target photographs with equal frequency. However, 5-year-olds reliably chose target photographs over position-change photographs while the 3-year-olds chose position-change photographs and target photographs equally often, suggesting that the younger children considered these two groups to be isomorphic. Thus, our results are consistent with the predictions of the relational shift hypothesis that younger children show a greater tendency to adopt an object-centered approach to this task.

General discussion

Taken together, the results of the three experiments shed light on the development of children's understanding of photographs. We have demonstrated reliable developmental differences in how children weigh the importance of different attributes when they are given the task of selecting the attributes of a referent that should be preserved in a photograph. Our results suggest that the development of children's understanding of the relation between photographs and their referents should not be construed as an all-or-none process. Instead, ideas about similarity develop gradually and depend upon the type of correspondences that must be considered and the context of alternative photographic representations in which photographs are presented.

Overall, our results support our prediction that children's implicit strategies for matching photographs to real-world configurations exhibit a relational shift, changing in a predictable way that is in line with developmental patterns found in other tasks that require comparison and the assessment of similarity (Gentner, 1988; Gentner & Rattermann, 1991; Halford, 1987). As predicted by the relational shift hypothesis, the youngest children in our sample showed a tendency to compute the similarity between photographs and their referents primarily based on local object matches. They did not show a preference for preserving object relations; when representations depicting changes in object locations and representations depicting changes in object size were presented in the same trial they chose these two types of changes equally often. This result cannot be attributed to children's failure to remember the appearance of arrangements of objects, as both the arrangements of real objects and photographs were in full view when the children made their choices. The tendency to choose the photographs that also preserved the relations of the objects emerged with age, such that 5-year-old children and adults displayed a significant preference for preserving position over object size. The second experiment demonstrated that 6- and 7-year-olds also exhibit a strong preference, comparable to that of adults, in choosing photographs that preserve the positions of the referent objects at the expense of preserving their relative size.

Although the younger children did not exhibit all of the preferences of older children and adults, even the youngest children demonstrated some clear and reasonably consistent preferences. Neither children nor adults typically chose photographs that depicted a change in object identity (i.e. the foil photographs) when photographs with the correct identities were present, indicating that both children and adults alike eschewed the photographs that were the least similar to the array of objects. This result also rules out the possibility that the younger children's performance can be attributed to lack of attention to or interest in the task stimuli. Additionally, very few children picked the category-change photographs on any trial type. When paired against a manipulation (category change) that did not preserve object similarity, size-change photographs were clearly preferred by young children. Therefore, young children's lack of an adult-like preference for size-change photographs on size versus position trials cannot be attributed to a general dislike of or objection to size-change photographs.

Thus, the results highlight important aspects of the development of children's understanding of similarities. Our results are consistent with a general view that people's processing of similarities and differences is, in part, a function of what types of relations are presented. Children's preferences were in some sense more flexible than adults' preferences; the younger children were more affected by the context in which different kinds of relations were presented. For example, in one context children preferred the same types of photographs that they rejected in other contexts. Similarity is not simply a matter of calculating how many attributes two things share. Rather, it is a process of constructing and comparing different types of relations (Medin, Goldstone & Gentner, 1993). Our results confirm that, with development, these preferences become more stable, but even adults'

decisions take into account the context in which information is presented.

This explanation of our results can be contrasted with two possible alternative explanations. The first is that the younger children focused on the labels for the objects. In Experiment 1, participants labeled the objects, and hence it was possible that the labels themselves might have been responsible for younger children's focus on object identity in mapping the relations on the photographs to the scenes. However, the results of Experiment 3, in which we did not label the objects, rule out the possibility that labeling *per se* affected participants' performance; the results of Experiment 3 (no labeling) were quite similar to those of Experiment 1, in which we labeled the objects as we placed them on the table.

Of course, these results do not rule out the possibility of a more general influence of language on the development of children's understanding or processing of relational information. Prior research (e.g. Callaghan, 2000; Loewenstein & Gentner, 2001, 2005) has shown that learning relevant relational language can greatly affect children's thinking. For example, in a spatial analogies task, embedding relational information within a systematic linguistic description (e.g. top, middle, bottom) substantially facilitated children's performance in a spatial mapping task that required them to keep track of a location based on its relation to other locations (e.g. Blades & Cooke, 1994). Likewise, Callaghan (2000) showed that learning labels for relevant relations substantially improved children's performance in a symbolic mapping task. Thus, our claim here is simply that the labels *per se* did not affect children's performance. Future research could address how and why other kinds of linguistic information could affect performance or development in these or related tasks.

A second alternative explanation for our results is based on the development of perception or selective attention. In this view, the younger children performed as they did because they did not perceive, or attend to, the scenes well enough to make the relevant distinctions. For example, one view of children's understanding of similarity is that it is based on perceived global similarity between the two scenes (e.g. Garner, 1974; Kemler, 1983; Shepp & Swartz, 1976; Smith, 1989). One might argue that the children did not inspect or think about the photographs or scenes in sufficient detail to notice the relevant similarities and distinctions.

Although it is important to consider perceptual and attentional explanations of our results, several elements of our experimental design and of the data that we obtained lead us to doubt that these explanations can fully account for participants' performance in our studies. Most importantly, the inclusion of the foil picture was designed to check whether participants were paying attention to the task, and the children's responses indicate that indeed they were. Even the 3-year-olds almost never picked the foil photographs, which indicates that they were attending to the stimuli and to aspects that differentiated one object from another. In fact, comparisons of object identity dominated the youngest children's decisions regarding which photographs mapped onto each scene, and this is not easily explained by theories that their judgments are based on the perception of global similarity. Researchers who have characterized the construction of similarity in this way stress that object identity is considered at a relatively late age (Kemler, 1983). In addition, the rate at which participants chose certain types of photographs varied systematically based on the comparisons that they were asked to make. For example, the youngest children reliably chose size-change photographs over category-change photographs, but chose this type of photograph much less frequently when comparing it to position-change photographs. This result also seems difficult to explain if children were generally not perceiving the relevant properties or dimensions. Finally, anecdotal remarks made by a few children indicated that they were aware of inconsistencies in the photographs even as they selected them as 'the same' as the configuration. For example, one 3-year-old boy pointed out that one of the objects depicted was a 'bigger one' when he selected a size-change photograph. Another participant, a 6-year-old girl, frequently qualified her statements, repeatedly explaining to the experimenter that none of the photographs were exactly right. Although these children perceived changes, they chose not to focus on certain ones in making their choices. For these reasons, we conclude that the results largely reflect how children map correspondences in general and hence reflect younger children's tendency to focus on object identity.

More generally, the results provide evidence for the claim that the establishment of children's conceptions of the relation between a photograph and its referent can be construed in part as a form of analogy. The pattern of results helps to highlight the relative importance of object and relational similarity in making judgments about the relation between photographs and their referents. Our results suggest that, at all ages, object similarity plays a particularly important role in people's appreciation of this relation. If participants believed that a photograph did not represent all of the objects, they would reject it as an inaccurate representation. Older, but not younger, participants also showed a preference for the photographs that preserved the spatial relations of the real objects, but only when they were absolutely convinced that the size-change manipulation did indeed preserve object similarity. In sum, our results highlight both similarities and important developmental differences in how children and adults interpret the relations between photographs and their referents.

Our results also raise the important question of whether young children are capable of showing a greater degree of relational focus than we demonstrated in this study. Although we believe the differences between young children and adults are reliable and meaningful, this does not imply that children could not learn to make the necessary choices to show evidence of relational

similarity if given the proper training. In our theoretical account, the critical difference between young children and older children is knowledge. When children are aware of causal relations and how objects can interact, they accurately relate objects to each other more frequently (Rattermann & Gentner, 1998). This perspective thus allows for the possibility that younger children may be able to understand and use the relational information about the objects in maps, models, or photographs if this information is highlighted or otherwise made more tractable (see Loewenstein & Gentner, 2001; Uttal, Gregg, Tan, Chamberline & Sines, 2001). Indeed, prior research has clearly established that children who are given experience with domain relations can learn to assess and make judgments on relational similarity (Brown, Kane & Echols, 1986; Gentner & Rattermann, 1991; Kotovsky & Gentner, 1996; Loewenstein & Gentner, 2001). For example, using language to highlight the spatial relations among objects can improve children's performance substantially in a mapping task that requires relational knowledge (Loewenstein & Gentner, 2001). Therefore, it might be possible to train children to consider relational similarity when evaluating the photographs.

We believe that what we have observed in these experiments reflects the default assumptions of children and a normal developmental progression. Young children tend to focus on object properties, and older children and adults focus on relational information as well. In conclusion, the results highlight that children's understanding of seemingly simple relations, such as those between a photograph and what it represents, undergo complex and often fascinating developments. Certainly some aspects of the relation between photographs and their referents can be directly perceived (Gibson, Kaplan, Reynolds & Wheeler, 1969). But as the present results demonstrate, this is not the end of the developmental story (see also Beilin & Pearlman, 1991; Zaitchik, 1990). Children's conceptions of photographs continue to develop well into the elementary school years.

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