Is It Daxing? The Effect of Learning Formats on Preschoolers' Acquisition of Novel Dynamic Relations

Honors Research Thesis

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Abstract

This study investigated whether generic stimuli improve children's ability to acquire and transfer novel dynamic relations. Three-year-olds and four-year-olds learned a novel dynamic relation (an object disappearing), which was arbitrarily termed "daxing." Half of the participants learned with generic stimuli and half learned with concrete stimuli. Then each participant identified novel dynamic relations as either "daxing" or "not daxing." Results revealed both developmental and learning format trends. Four-year-olds in both conditions were more adept than three-year-olds at learning and transferring the relation. Learning formats did not significantly affect three-year-olds' ability to transfer; however, within the four-year-olds, participants who learned with generic formats transferred significantly better than those who learned with concrete formats. Because generic stimuli are perceptually simpler and less distracting than rich stimuli, four-year-olds in the generic condition may have been better able to focus on the relation and, therefore, better able to recognize it in new contexts. These findings add to understanding of the acquisition of novel relations, demonstrating that generic learning formats, as compared to concrete formats, may lend young children an advantage not only for static, perceptual relations, but also for dynamic relations.

The Effect of Learning Formats on Relation Acquisition

Understanding relations is crucial to acquiring knowledge of the world. Many concepts are defined by relations; for example, knowledge of the simple concept “bigger than” depends on noticing the relationship between the sizes of two different items. The transfer of known relations to novel contexts is referred to as analogical reasoning. This process can facilitate understanding of a new situation (Gentner & Holyoak, 1997). For example, when the recent Great Recession began, newscasters began comparing it to the 1930’s Great Depression (hence, the name Great Recession). This analogical link led listeners to make assumptions about the Great Recession based on inferences from the Great Depression. Indeed, government officials seemed to make the same analogical connection, developing economic stimulus plans and public works projects which mirrored President Roosevelt’s Great Depression policies. Noticing the relational similarities between two situations allows one to label both as examples of the same kind of situation.

Understanding relations through analogical reasoning is fundamental to mathematics, science, and higher level thinking in general (Kaminski et al., 2006). In a classroom setting, teachers must present material in such a way that students can grasp underlying relational patterns and transfer them to novel examples in homework assignments or examinations. For example, when elementary teachers teach the concept of fractions using examples of cutting pie or pizza, students must grasp the, perhaps not so apparent, similarities between slices of pie, slices of pizza and the mathematical expression of a fraction: the underlying relation between the numerator and denominator. While these relational similarities may be quite salient to a teacher and to all those who understand fractions, for learners, attending to relational similarities (numerator and denominator) as opposed to surface ones (pies and pizzas are round) may be difficult.

Attention to relational similarities is an ability that develops as children mature (Piaget, Montangero & Billeter, 1977; Sternberg & Downing, 1982; Sternberg & Nigro, 1980). In particular, recognizing relational similarities instead of only surface ones becomes easier as children grow older. This developmental change is often referred to as "the relational shift" (Gentner, Ratterman, Markman, & Kotovsky, 1995). First, children identify superficial, feature similarities (e.g. round ball, round orange). After the shift, they are able to understand relational similarities (e.g. Mom pushing stroller, Dad pushing grocery cart). There are two well-researched mediators of this shift, domain knowledge and relation complexity, and both provide valuable insight into the phenomenon (Richland et al., 2006).

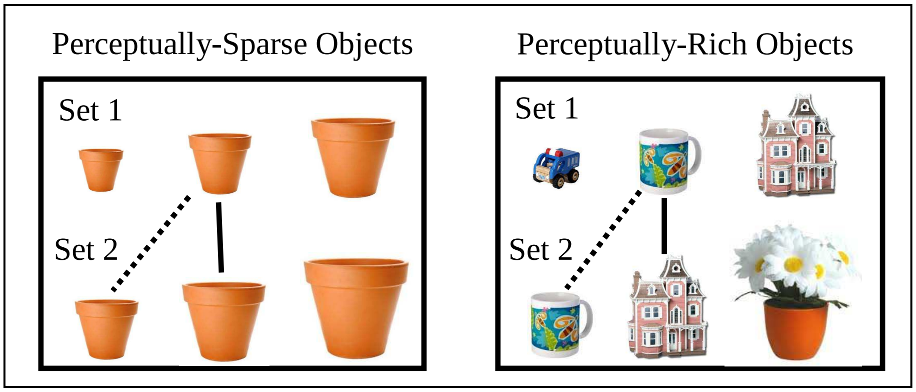
Domain knowledge concerns children's familiarity with the target subject matter. (Gentner & Ratterman, 1998). When children have acquired sufficient knowledge of the relation's subject matter, they can then make the relational shift. Accordingly, children have the potential to reason analogically at very young ages if familiar with the domain (Goswami, 1991; Vosniadou & Ortony, 1983; Brown, 1989, 1990; Brown & Kane, 1988). In a study supporting this theory, experimenters showed four-year-olds a picture of a tree and asked them, "If a tree had a knee where would it be?"(Gentner 1977a, 1977b). Because the posed question dealt with subject matter sufficiently familiar to the children, they were able to respond as accurately as adults. One implication of the domain knowledge account is that children may have shifted to noticing relational similarities in one area while still only recognizing surface similarities in another.

Relation complexity concerns, among other things, the number of elements in a relation (Halford & McCredden, 1998). Children's ability to make the relational shift depends on their mental capacity to attend to the important aspects of the relation. Unary relations relate only one element which corresponds to an attribute or other descriptor (such as "big cookie"). Binary relations such as "brother hugs sister" relate two elements (brother and sister) with one relation (hugs). Ternary relations relate three elements with two relations (brother hugs sister who hugs baby). And quaternary relations relate four elements (the proportion a/b = c/d). Reasoning with these relational structures requires the ability to keep all elements and their relations in mind (Richland, Morrison, & Holyoak, 2006). As children mature, they gradually attain processing capacity for more complex relations. Two-year-olds can process only binary relations, but five-year-olds have the capacity to process ternary relations (Halford, 1993).

Both domain knowledge and relation complexity are important factors in analogical reasoning (Richland et al., 2006). While domain knowledge may enhance children's ability to shift from reasoning with surface similarities to relational similarities, certainly developing mental capacity to handle more complex relations plays a role as well. Our experiment focused on an additional factor that may affect children's ability to notice relational similarities: the perceptual richness of elements involved in the relation.

In one study, experimenters investigated how both differing degrees of elements' perceptual richness and competing surface similarity matches affect children's ability to notice relational similarities between perceptual relations (Ratterman, Gentner & DeLoache, 1990). The experimenter presented each child with two sets of three physical elements arranged by increasing size from left to right (e.g. three clay pots arranged smallest to biggest). Then she asked the child to use the relative location of one of the elements in Set 1 (e.g. the middle clay pot) to find a sticker hidden beneath one of the elements in Set 2 (e.g. the middle clay pot).

Figure 1: Stimuli Used in Relational Matching Study by Ratterman, Gentner & DeLoache, 1990



Both sets were arranged in increasing size, but they were staggered such that Set 1 contained sizes 1, 2, and 3 and the Set 2 contained sizes 2, 3, and 4. So the child could make a surface similarity match and match elements by exact size (Set 1, size 2 and Set 2, size 2) or a relational match and match elements by relative size and location (Set 1, size 2 and Set 2, size 3).

Additionally, the elements in the sets varied in perceptual richness. In one condition, both sets contained perceptually-sparse objects (e.g. three clay pots), and in the other condition both sets contained perceptually-rich objects (e.g. a colorful mug, toy house, and flowerpot). Thus, in the perceptually-rich condition Set 1 contained a car in size 1, a mug in size 2, and a house in size 3, and Set 2 contained a mug in size 2, a house in size 3, and a flowerpot in size 4. Once again, the child could make a surface similarity match and match the Set 1 mug in size 2 to the Set 2 mug in size 2, or a relational match and match the Set 1 mug in size 2 to the Set 2 house in size 3.

Children made more relational matches with the perceptually-sparse elements than with the perceptually-rich ones. Evidently, the distracting surface similarities of the perceptually-rich elements made detecting relational similarities more difficult.

This study primarily investigated children's ability to ignore a competing surface similarity match and make a relational match instead. Perceptually-rich stimuli hindered children's ability to focus on relational similarities and perceptually-sparse material facilitated focus on relational similarities. There is little research that describes the effects of perceptually-rich and sparse stimuli on children's ability to recognize relations without the distraction of a superficial similarity match. However, a few studies have suggested that perceptually-rich stimuli hinder children's ability to notice relational similarities even when a competing superficial match is not present (DeLoache, 2000).

For example, in one study experimenters examined children's ability to transfer relational concepts from models to a life size room (DeLoache, 2000). Models are symbols of the rooms, buildings, or cities, etc. that they represent. Using a model as a symbol requires the ability to observe the relational similarities between it, as a symbol, and that to which it refers. In addition, children must be capable of dual representation, the ability to comprehend the model's concrete and abstract natures (DeLoache, 2000). For example, a model has a concrete nature: it may look like a dollhouse with miniature furniture, people, colors, and textures. However, it also has an abstract nature: the arrangement of the furniture or rooms is a representation of real furniture or rooms in a real house.

A series of experiments with models demonstrated that the salience of a symbol's concrete nature affects children's ability to notice relational similarities between the symbol and what it represents (DeLoache, 2000). Children were less likely to make relational matches when a symbol's concreteness was more salient. Each experiment had a similar set up: a room and a miniature model room were furnished with furniture in the same layout. The experimenter hid a Snoopy doll behind one of the life-size pieces of furniture while the child was not looking. Then the child watched as she hid a miniature Snoopy doll behind the analogous miniature piece of furniture. Next, the experimenter asked the child to use the location of the Snoopy doll in the model as a clue to find the Snoopy doll's location in the room. In three variations of this setup, the child played with the model before the task, simply looked at the model or saw the model behind a glass window. With each variation, the model's concrete nature was less salient and the children were better able to find the big Snoopy doll. Decreasing the model's concreteness may have made it easier for children to attend to its abstract nature and accordingly use relational similarities to find the big Snoopy doll.

These findings have implications on children's ability to shift from noticing surface similarities to relational similarities. When the physical, concrete nature of two objects is salient, relational similarities are less easily recognized. For example, in fraction teaching, the concreteness of pepperoni and sausage may obscure the relational similarities between a pizza and the fraction it represents. Conversely, the perceptual sparseness of a plain circle divided into sections may facilitate recognition of relational similarities between the circle's sections and the fraction they represent.

A few recent studies have demonstrated support for these findings (Kaminski & Sloutsky, 2010; Kaminski & Sloutsky, 2009). One study focused on young children's ability to make relational matches between simple perceptual relations such as monotonic increase, monotonic decrease, and symmetry (Kaminski & Sloutsky, 2010). Experimenters presented children with two side-by-side displays of a perceptual relation on a computer screen. Then experimenters asked the children to point to an item in the right display that was in the same relational role as a target item in the left display. To complicate the task, the left displays varied in perceptual richness. Perceptually-rich displays were termed concrete and perceptually-sparse displays were termed generic. For example, in the generic pairing for one trial, the slide on the left depicted three triangles increasing in size from left to right, while in the concrete pairing the slide on the left depicted three colorful dogs increasing in size from left to right. The slide on the right always depicted concrete items, such as three brightly colored fish, displaying the same relation (increasing in size from left to right).

Experimenters randomly assigned children to see the generic pairings first and the concrete pairings second or vice versa. An experimenter pointed to one of the items in the left display (e.g. the right-most, biggest triangle or dog) and asked the child to point to the item in the right display that played the same relational role (e.g. the right-most, biggest fish). There was no difference in scores on the generic pairings as a function of when they were answered. However, there was a difference in scores on concrete pairings. Children who first saw the generic pairings scored significantly higher on the concrete pairings than children who saw the concrete pairings first. Learning from generic elements gave an advantage on subsequent concrete pairings, while learning from concrete pairings gave no advantage on subsequent generic pairings.

Many studies have demonstrated that perceptually-sparse, generic stimuli have an advantageous effect on adults' ability to learn and transfer relational concepts as well (Goldstone & Sakamoto, 2003; Goldstone & Son, 2005; Kaminski, Sloutsky, & Heckler, 2008**;** Sloutsky, Kaminski, & Heckler, 2005**)**. One study tested undergraduate students' ability to learn a mathematical concept from generic or concrete examples (Kaminski, Sloutsky & Heckler, 2008). Initially, students were able to grasp the concept with relative ease in both conditions. However, students who learned the concept with generic examples were better able to relate or transfer that knowledge to novel examples than those who learned with concrete examples. If distracting, concrete examples hinder adults' ability to pick out and transfer relations, then certainly children, who are less able to control and focus their attention, will learn less effectively with concrete examples.

This experiment further investigated the validity of these implications by examining how perceptual richness affects children's ability to learn and transfer dynamic relations as opposed to the static, perceptual relations in previous studies. By dynamic relations we mean simple actions, including disappearing, going down, rotating, and flying up. We hypothesized that children would be better able to transfer dynamic relations when the elements involved in the relations were generic as opposed to concrete.

Method

Participants

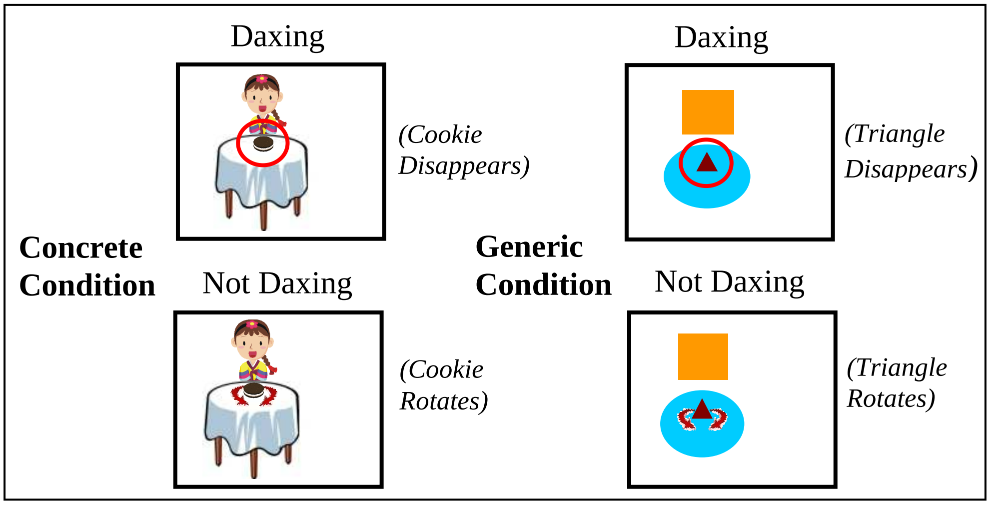
Ninety-six preschool children from middle-class, suburban preschools and child care centers in the Columbus, Ohio area participated in the study (56 girls and 40 boys). Forty-four of the participants were 3.5 - 3.99 years old and fifty-two of the participants were 4.0-4.6 years old (*M* = 3.73, *SD* = .16; *M* = 4.35, *SD* = .15).

Procedure

The experiment was an identification task which included three phases: learning, feedback, and testing. Participants were randomly assigned to one of two groups either the concrete or generic conditions of the task. The experimenter told each participant she would be playing a computer game and learning a new word.

In the learning section, children learned to discriminate between a disappearing relation, which was arbitrarily termed “daxing,” and a non-disappearing relation referred to as “not daxing”. In the non-disappearing relation, rather than disappearing, one of the elements rotated in place. The relations were presented as PowerPoint animations and included three elements. Elements in the concrete condition consisted of perceptually-rich images of a girl, table and cookie. Elements in the generic condition consisted of perceptually-sparse images of a square, oval and triangle. Elements were arranged identically on the screen in both conditions, as shown in Figure 2 below. Children saw the “daxing” animation and the “not daxing” animation three times each. After each animation, the experimenter told the child “that was daxing” or “that was not daxing.”

Figure 2: Learning & Feedback Dynamic Relations



In the feedback section, the experimenter presented the child with the same six animations in a different order and asked the child to identify the relations. The experimenter recorded the child's response on paper and then provided feedback after both correct and incorrect responses (e.g. "Right, that was daxing," *or* "Actually, that was not daxing").

In the testing section, the experimenter presented children in both conditions with the same set of 24 dynamic relations and asked the child to identify them as "daxing" or "not daxing." Within these 24 dynamic relations, the "not daxing" relations were more varied. These included, for example, flying up, falling down, moving to the side, and spinning. This section tested participants' knowledge of the learned relation in the same format they learned it as well as their ability to transfer knowledge of the learned target relation to novel situations. There were four question types. Type 1 questions contained the same relations and elements (e-learned) presented in the learning and feedback sections. They included two "daxing" relations (r-learned) and two "not daxing" relations (r-new). Type 2 questions contained the relations (two r-learned, two r-new) and elements (e-new) presented in the other condition of the learning and feedback sections. In other words, these were concrete format questions for participants in the generic learning condition and generic format questions for participants in the concrete learning condition. Type 3 questions contained five r-learned and seven r-new animations with concrete e-new. And Type 4 questions contained two r-learned and two r-new animations with generic e-new. Each child's score on the identification task had two parts: a learning score and a transfer score. The learning score contained the four Type 1 questions and the transfer score contained the other twenty Type 2, 3 and 4 questions.

During the testing section, the experimenter did not provide any feedback, but merely asked the child if the animation depicted "daxing" or "not daxing" and recorded responses. After the testing section, the experimenter asked a subset of three-year-olds, 10 in the generic condition and 11 in the concrete condition, follow-up questions about the daxing relation they originally learned. The experimenter asked each child what was happening in the relation and why. After completing the experiment, participants chose a sticker and returned to their classroom.

Results

Children who failed the feedback phase (could not identify at least five of six feedback questions correctly) were excluded from data analysis, because they did not demonstrate adequate initial learning. Seven three-year-olds were excluded from both the concrete and generic conditions. Two four-year-olds in the generic condition scored less than five as well and were excluded from data analysis. The two excluded four-year-old scores were two standard deviations below the mean.

On the testing section of the identification task, three-year-olds and four-year-olds in the generic and concrete conditions performed with varying levels of success. Mean test scores are presented in Table 1. All learning and transfer scores except for the three-year-olds' generic learning score were significantly above a chance score of 50%: 2 out of 4 questions for the learning scores and 10 out of 20 questions for the transfer scores, two-tailed, one-sample t-tests (Three-year-olds: concrete learning $t(14) = 6$, $p < .001$, generic learning $t(14) = 2.09$, $p = .055$; concrete transfer $t(14) = 3.13$, $p < .01$, generic transfer $t(14) = 3.44$, $p < .01$) (Four-year-olds: concrete learning $t(24) = 16.83$, $p < .001$, generic learning $t(24) = 19.47$, $p < .001$; concrete transfer $t(24) = 6.23$, $p < .001$, generic transfer $t(24) = 9.62$, $p < .001$).

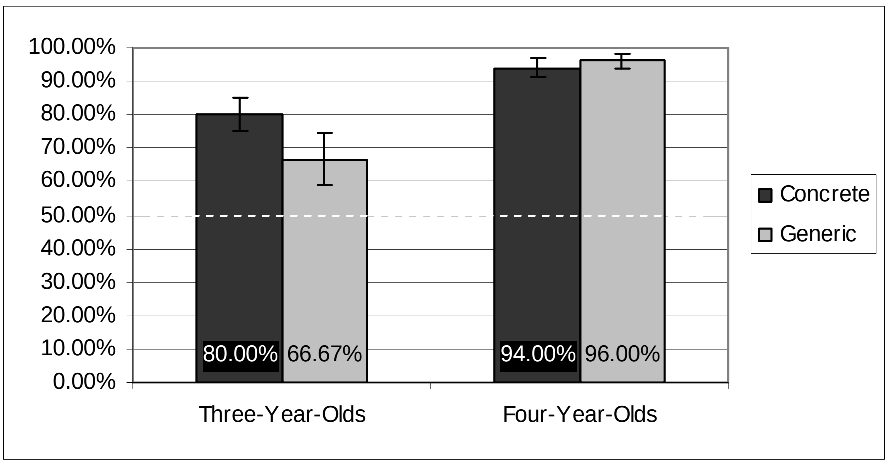
Table 1: Mean Percentages Scored on Identification Task by Question Type. Chance score equals 50%. Standard deviations are shown in parentheses.

	Three-Year-Olds		Four-Year-Olds	
	Concrete ($n = 15$)	Generic ($n = 15$)	Concrete ($n = 25$)	Generic ($n = 25$)
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Learning Score:	***80.0 (19.4)***	***66.7 (30.9)***	***94.0 (13.1)***	***96.0 (11.8)***
Type 1 Questions	80.0 (19.4)	66.7 (30.9)	94.0 (13.1)	96.0 (11.8)
Transfer Score:	***64.7 (18.2)***	***65.3 (17.3)***	***71.0 (16.9)***	***79.0 (15.1)***
Type 2 Questions	75.0 (23.2)	66.7 (27.8)	85.0 (23.9)	93.0 (11.5)
Type 3 Questions	66.1 (23.3)	70.0 (18.9)	68.0 (17.6)	74.7 (18.6)
Type 4 Questions	50.0 (18.9)	50.0 (25.0)	66.0 (23.8)	78.0 (20.8)

Children's learning scores revealed developmental trends. While three-year-olds in the concrete condition did not score significantly better than three-year-olds in the generic condition, there was a trend of better performance in the concrete condition, two-tailed, independent samples t-test, $t(28) = -1.42$, $p = .167$. In the concrete condition, three-year-olds answered 80% of questions correctly; however, in the generic condition they answered only 67% of questions correctly.

As Figure 3 illustrates, four-year-olds demonstrated a different pattern of performance. In both conditions, four-year-olds scored very high on learning questions, two-tailed, independent samples t-test, $t(48) = .568$, $p = .573$. In the concrete condition, four-year-olds answered 94% of questions correctly, and in the generic condition, they answered 96% of questions correctly.

Figure 3: Mean Learning Scores (% correct) by Age and Condition. Error bars represent standard error of mean. Chance score is 50%.



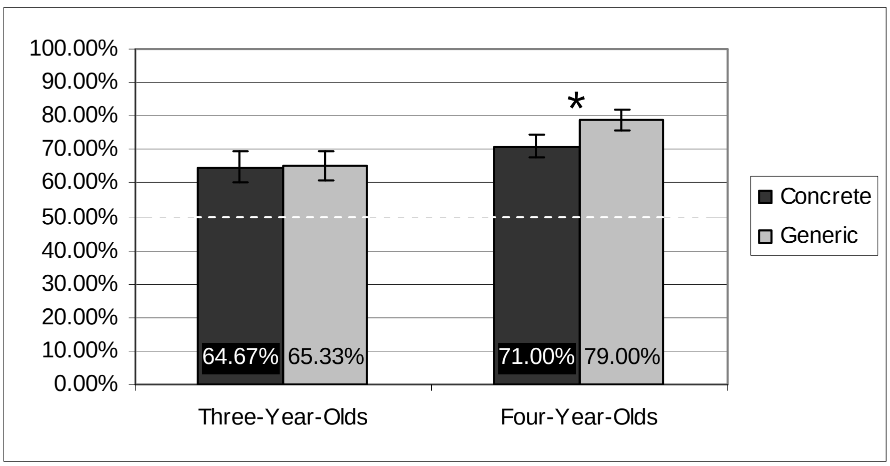
Overall, four-year-olds were better able to learn the relations than three-year-olds. Test scores were submitted to a two-way analysis of variance with age and condition as factors, and results demonstrated a significant effect of age, $F(1,76) = 25.696$, $p < .001$. Additionally, while four-year-olds were equally able to learn relations in both conditions, three-year-olds may have had more difficulty learning generic relations than concrete relations.

In regards to the transfer questions, we originally hypothesized that children in the generic condition would be better at relational transfer. As Figure 4 reveals, four-year-olds performed according to expectations, one-tailed, independent samples t-test, $t(48) =$

1.77, *p* < .05. In the generic condition, they answered 79% of questions correctly, and in the concrete condition, they only answered 71% of questions correctly.

Three-year-olds, however, demonstrated a different trend; they performed similarly across conditions, one-tailed, independent samples t-test, *t*(28) = .103, *p* = 0.459. In both conditions they answered approximately 65% of questions correctly.

Figure 4: Mean Transfer Scores (% correct) by Age and Condition. Error bars represent standard error of mean. Chance score is 50%.



Four-year-olds once again scored better than three-year-olds on transfer questions. Test scores were submitted to a two-way analysis of variance with age and condition as factors. Results demonstrated a significant effect of age, *F*(1,76) = 6.755, *p* < .02. However, condition did not have a significant effect, *F*(1,76) = 1.268, *p* = .264. Additionally, there was not a significant interaction between condition and age, *F*(1,76) = .908, *p* = .344.

Discussion

These findings demonstrate that learning relations, particularly dynamic relations, is difficult for young children. Four-year-olds performed significantly better than three-year-olds on learning questions, confirming developmental trends in previous studies on relational learning. Results suggest that concrete learning material may have been somewhat easier for three-year-olds to learn than generic learning material, however. One reason for this possible advantage might be the familiarity of interaction between the concrete objects that made up the relations learned in the concrete condition. In the study mentioned earlier, where experimenters asked children, “If a tree had a knee where would it be?” children were able to notice relational similarities and reason analogically because the subject matter was sufficiently familiar (Gentner 1977a, 1977b). Because the learned relation in the concrete condition consisted of the familiar situation of a girl sitting at a table with a cookie as opposed to the generic condition’s unfamiliar interaction between a square, triangle and oval, it may have been easier for children to learn in the concrete condition.

Three-year-olds’ responses to follow-up questions about the learned relation provide further insight into why it could have been easier for children to learn in the concrete condition. When asked why the target object in the relation disappeared, 6 out of 11 children in the concrete condition were able to come up with plausible responses, for example, “the girl ate the cookie” or “the cookie went under the table.” However, in the generic condition only 2 out of 10 children were able to come up with a plausible response, for example, “I don’t know, maybe it popped.” These responses suggest that perhaps the relation between the girl, cookie and table was more familiar and thus easier to make sense of. For children in the concrete condition, learning the daxing relation may have only required learning a new word for a known relation. However, for children in the generic condition, the daxing relation was unknown and potentially more difficult to grasp.

This same perceptually-rich familiarity may make concrete relations difficult to transfer. When learning the concrete relation, children may have been distracted from the relevant part of the relation (an object disappearing) and thought that the relation had to do with food or eating. Then, when trying to transfer the learned relation, they might have had difficulty identifying which novel relations matched the learned relation. Though the relation may have been rather easy to learn, because they had mentally tied it to the learning context, children may not have recognized that it applied to novel contexts. This has particular resonance when applied to four-year-olds' transfer scores in the concrete condition. Four-year-olds in both conditions learned the target relation with ease, but four-year-olds in the concrete condition had more difficulty transferring the relation than those in the generic condition. Perhaps the familiarity of the concrete relations made transfer difficult.

Four-year-olds in the generic condition, on the other hand, were old enough to make sense of the unfamiliar, generic, learned relation. Then without distracting concreteness as an impediment, they transferred more effectively than the other four-year-olds. This supports previous work on perceptual relations that has demonstrated the potential liabilities of concrete learning formats and benefits of generic learning formats for young children (Kaminski & Sloutsky, 2010; Kaminski & Sloutsky, 2009). Dynamic relations were more difficult for children to learn and transfer than some of the perceptual relations used in previous studies; however, the generic advantage extends even to these more difficult relations.

Future directions for this research might delve further into reasons for the generic learning format advantage. For example, a study could focus more attention on the follow-up question we posed to children (i.e. “Why did the target object disappear?”). Our results tentatively suggest that children may come to unwarranted conclusions when presented with concrete learning material. In the present study, for instance, a few children attributed the cookie’s disappearance to something the girl had done. This type of causal attribution may contribute to concrete stimuli’s distracting qualities and limited potential for transfer. Instead of confining the “daxing” relation to an object simply disappearing, these children seemed to add an embellished account of what occurred.

Further elucidating the advantages and disadvantages of generic and concrete learning material may shed light on the effective use of analogical teaching methods. Our study suggests that generic learning material may aid transfer of dynamic relations in young children. This may have implications for older children as well and may apply to a variety of academic subjects. Science, for instance, contains many difficult relational concepts, which can be simplified and better understood with analogies. For example, when teaching how electrons orbit an atom’s nucleus, teachers may use the analogy of planets orbiting the sun. Analogies like this can, of course, be very helpful, but teachers should be aware that students may have difficulty deciphering which aspects of the solar system relation are relevant to the atom relation. Our study suggests that, in this case, a perceptually-sparse solar system schematic may convey the desired dynamic relation more effectively than a perceptually rich illustration emphasizing the rings of Uranus and the redness of Mars. More research is needed to determine how this generic learning advantage can best be leveraged in practical teaching applications.

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