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The paradox of relational development: Could language learning be (temporarily) harmful?

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Abstract

Recent studies report a striking decline in children's ability to notice *same-different* relations around age 3 (Walker et al., 2015). We propose that such a decline results from an object focus related to children's avid noun-learning. To test this, we examine children's performance on a classic relational task – the relational match-to-sample task (RMTS). Prior work has shown that 4-year-olds can pass this task (Christie & Gentner, 2014). However, if nominal language induces an object focus, their performance should be disrupted by a noun-labeling pretask. In two experiments, 4-year-olds either labeled objects or actions in a naming pretask. Then they completed the RMTS task. Consistent with the noun-focus explanation, the object-naming group failed the RMTS task, whereas the action-naming group and a control group both succeeded. This suggests that nominal language can lead to an object focus, and that this could explain the temporary decline in children's relational processing.

Keywords: cognitive development, relational processing, learning, language

Introduction

Relational processing is the capstone of human reasoning. Some have proposed that humans' remarkable capacity for relational processing may be the key difference between humans and non-human primates (Gentner, 2003, 2010; Penn, Holyoak, & Povinelli, 2008). The focus of the current work is to examine how language influences changes in relational processing over development.

How well do children engage in relational processing? Gentner's (1988) relational shift account posits that early in learning, children (and other novices) tend to focus on objects and surface-level attributes, and that with learning, they become able to focus on relational similarity (Gentner & Rattermann, 1991; Honomichl & Chen, 2006; Paik & Mix, 2006; Rattermann & Gentner, 1998). For instance, Gentner (1988) found that 5-6 year olds interpreted the metaphor "A tire is a shoe" based on their shared attributes ("both are black"), whereas 9-10 year olds produced more relational interpretations ("you can go places on both").

Gentner and Rattermann (1991) provided further support for the relational shift using a different paradigm. In their relational matching task, the experimenter and child each had their own set of three distinct objects. The experimenter hid a sticker under an object in their set, and the child had to find a sticker in the corresponding location in their set (i.e., if the sticker was in the center of the experimenter's set, then the child would find sticker in the center object of their set). In one condition, the objects were cross-mapped—for example, the center object in the experimenter's set was identical to the rightmost object in the child's set. Under these conditions, it was difficult for 3-year-olds to resist matching by object identity. Instead of searching in the corresponding relational location (center), they searched under the identical object. In contrast, 5-year-olds were able to resist the object matches and make relational matches.

Christie and Gentner (2014) measured children's performance on a different relational matching task used widely with other species – the relational match-to-sample task (RMTS; Premack, 1983). In this task, subjects are given a standard (AA) and must select a match between two options (BB or CD). The BB pair should be matched to the AA pair on the basis of the common *same* relation between them. Christie and Gentner (2014) found that 4-year-olds were able to make relational matches at above chance levels in the RMTS task, but 3- and 2½-year-olds were not. Together, these studies reveal that younger children tend to focus on individual objects rather than on relations. (These studies compare younger versus older children because age generally correlates with greater knowledge and thus better relational processing. However, a relational shift occurs at different times for different tasks. For example, college students show a novice-expert shift from focusing on concrete domain matches to focusing on common causal systems [Rottman et al., 2012].)

What factors improve children's relational processing? Gentner and colleagues have proposed that the acquisition of relational knowledge, via a combination of structure-mapping processes and relational language, allows learners to shift their focus towards relations (Christie & Gentner, 2014; Gentner, 2010; Gentner & Christie, 2008; Rattermann & Gentner, 1998). Other accounts emphasize the maturation of domain-general cognitive abilities. For instance, some have argued that the development of working memory (e.g.,, Halford, Wilson, & Phillips, 1998) and inhibitory control (e.g., Richland, Morrison, & Holyoak, 2006; Thibaut, French, & Vezneva, 2010) allow children to consider multiple relations and resist object matches. Nonetheless, there is widespread agreement that children's relational processing generally improves over time. This consensus has been challenged by recent findings.

Developmental Decline in Relational Processing

While Christie and Gentner (2014) found that 2½- and 3-year-olds failed to make relational matches in the RMTS task, the ability to generalize *same-different* relations has been found to be present much earlier in development. Ferry, Hespos and Gentner (2015) habituated 7- and 9-month-old infants to either *same* or *different* pairs of objects. At test, they were shown novel *same* and *different* pairs. Infants looked longer at the novel relation (i.e., infants in the *same* condition looked longer at the *different* pair, and vice versa). Thus, infants appear capable of analogical generalization across multiple examples (see also Marcus, Vijayan, Bandi Rao & Vishton, 1999; Saffran, Pollak, Seibel, & Shkolnik, 2007).

Toddlers have also been found to generalize *same-different* relations. Walker and Gopnik (2014; Walker, Bridgers, & Gopnik, 2015) modified the classic blicket detector paradigm and showed 18- to 30-month-olds a machine that played music only when certain pairs of objects were placed on it. During training, four unique pairs of objects were placed on the machine (twice each). In the *same* condition, the machine played music only when the experimenter placed *same* pairs on the machine, and not when *different* pairs were used. The reverse pattern held for the *different* condition. After this training, the toddlers successfully chose between a *same* and a *different* pair to make the machine play music. Thus, very young humans can generalize these relations from multiple examples.

In themselves these results may not be totally surprising. Perhaps toddlers do well on the blicket-detector task because it is an especially engaging task or because it affords opportunities for comparison. But if so, then performance should continue to improve with age and experience. Surprisingly, Walker et al. (2015) found that older children performed worse than younger children. When older children (30 to 36 months) were tested in the same task, they could select the correct pair only in the *same* condition, and not the *different* condition. An older group (36 to 47 months), failed in both the *same* or *different* conditions. These results suggest that between the ages of 18 and 47 months, there is a decline in children's ability to notice these relations *in the same task*.

The overall picture that emerges is a puzzling one. Taken together, the evidence suggests that the developmental trajectory of relational processing is a U-shaped curve. At an early age, at least some relations are available to children (with the right scaffolding). Over time, relations become temporarily less available.

What could account for this decline in relational ability? As discussed above, failure to make relational matches can result from a focus on objects. Thus if children focused strongly on individual objects in the relational blicket detector task, this could account for their failure to notice that the objects form an abstract relation. But this line of reasoning would call for an explanation of *why* the object focus should become stronger during early childhood.

Language and Relational Processing

What could explain the apparent decline in relational ability roughly between 2.5 and 3 years of age? One proposal, advanced by Walker et al. (2015), is that children's early hypothesis space gives equal priority to objects and relations, but with learning, children form "a different overhypothesis namely, that individual kinds of objects, rather than relations between them, have causal powers" (p. 2560). As children learn that individual objects are likely to be causally potent, they prioritize object-focused hypotheses over relational hypotheses. Thus, the older group fails to attend to relations in the task.

Here we consider a different hypothesis—that patterns of language learning are to blame for the object focus. Specifically, we hypothesize that young children are focused on learning names for objects and that this focus on objects temporarily impedes their ability to notice relations.

We note that this proposal runs contrary to the abundant evidence that language aids relational processing (Gentner & Christie, 2008; Gentner & Rattermann, 1991; Loewenstein & Gentner, 2005; Pruden, Levine, & Huttenlocher, 2011; Pyers & Senghas, 2009). For example, learning spatial relational terms such as *left-right* (Hermer-Vazquez, Moffet, & Munkholm, 2001) and *on* (Casasola, 2005) have been shown to help children in relational and categorization tasks. Even in *same-different* tasks like the RMTS, 3-year-olds given training in the meanings of *same* and *different* succeed in making relational matches (Christie & Gentner, 2014). However, these studies all concern the benefits of *relational* language. Our hypothesis concerns a different aspect of language. We propose that the early acquisition of nouns can have a temporarily negative influence on relational reasoning.

The Nominal Explosion There is overwhelming evidence that nouns are among the first words that children learn, and they dominate over other word classes in early vocabulary (Bates et al., 1994; Bornstein et al., 2004; Gentner, 1982; Gentner & Boroditsky, 2001; Gleitman et al., 2005; MacNamara, 1972). Bates and colleagues' (1994) used the MacArthur-Bates Communicative Development Inventory (MCDI) with a large sample of parents and showed that children's early vocabulary was dominated by nouns. The proportion of nouns relative to other words was found to peak at a vocabulary size of 100 to 200 words (55.2% of these words were found to be nouns). Peak "nouniness" occurs roughly between 1 ½ to 2 ½ years of age. As children's vocabularies grow, the proportion of verbs and other predicates increases, while the proportion of nouns decreases. This pattern of early noun dominance appears across languages, as evidenced by MCDI data collected from thousands of children across 13 languages (Braginsky, Yurovsky, Marchman, & Frank, 2015). We propose that the dominance of nouns early in language learning can make objects particularly salient.

According to the natural partitions hypothesis (Gentner, 1982), early noun dominance results from the fact that many

nouns refer to concrete, perceptually individuated entities in the environment (unlike verbs and prepositions, whose meanings vary cross-linguistically). Nouns are thus a natural entry point for referential language. Children are eager to learn language, and acquiring names for objects is a highly successful strategy for young children. This strategy can lead young children to focus strongly on objects. Of course, in the long run, a repertoire of noun meanings will aid children in learning relational terms (Gentner 1982; Gleitman, 1990). But in the short run, it may result in an object focus that renders relations temporarily less available.

We tested this idea in a pilot study. We asked whether 2-year-olds' performance on the RMTS task was related to their language development, as assessed by the MCDI. We found that 2-year-olds who performed better than chance on the RMTS (5/8 trials or more) had fewer words checked off on the MCDI (M = 441.38, SD = 153.51) than children who performed at or below chance (M = 562.23, SD = 124.82, $t(28) = 2.21$, $p = .04$, $d = 0.86$). This provides some encouragement for the idea that knowing more words could in fact impede relational processing. Our goal for the current research was to manipulate children's noun focus and examine its influence on relational processing.

Experiment 1

In the current work, we test the hypothesis that nominal language induces an object focus and disrupts children's ability to make relational matches. We used Christie & Gentner's (2014) *same*-only RMTS task, and tested children at an age at which they already pass the RMTS task – 4 years. We developed a naming task in which children are asked to provide noun labels for common objects presented on cards. By having children activate many noun labels, we hypothesized it would lead to an object focus. The goal was to bring children back into a "younger" mindset – to an earlier age at which they were captivated by objects. If nominal language induces an object focus, then children in this condition should show impaired performance on a subsequent RMTS task. We compared this group of children to a separate group who also engaged in a naming task. However, we asked this second group to produce verb labels for images of scenes. Because the verb naming group was a control, we chose transitive action verbs that could be easily depicted. We did not predict that priming transitive verbs would improve children's performance on the RMTS task relative to the baseline group. Instead, we predicted that the noun labeling group would perform poorly because of the induced object focus.

Methods

Participants Fifty-nine 4-year-olds were recruited from the Evanston/Chicago area (29 females, M_{age} = 53 months). The racial and economic composition of the sample reflected those of the local population. Children received a small gift for their participation.

Materials & Procedure The RMTS task was presented on cards. There were 8 trials. Each trial was made up of a triad of three cards: the standard card, and two possible matches. Each card depicted two shapes – either a *same* pair or *different* pair. The standard always showed a *same* pair, and children had to select between a *same* pair and a *different* pair to match the standard (see Figure 1 for a sample triad). Within each triad, each pair was made up of unique shapes and colors. At the end of the 8 target trials, there were two catch trials meant to determine whether the child understood the task. These catch trials were literal similarity matches that did not require the child to judge relational similarity. Children who failed any of the catch trials were not included in the analysis (n = 8).

For each trial of the RMTS task, the experimenter placed the standard in front of the child and asked "Do you see this one?" Then the experimenter placed the two possible matches below the standard (as in Figure 1) and asked "Which one of these two goes with this one?" No feedback was given on the child's response. The next trial was presented until the task was complete.

Children were placed in one of three between-subjects conditions: *Object Naming*, *Action Naming*, or *Baseline*. Children in the Object Naming condition first completed the object naming pretask. A set of 39 cards was created depicting everyday objects (e.g., pencil, ball, turtle). The experimenter presented each card in the object naming set one at a time and asked the child "What is this called?" If the child did not know one of the words, they were told the label and were asked to repeat it. After the child named all the objects, they completed the RMTS task.

A similar procedure was used in the Action Naming condition. Children first completed the action naming pretask. A set of 35 cards was created depicting scenes involving actions that were familiar to children (e.g., kicking, throwing, jumping). For each card, children were asked "What is (s)he doing?" They generally provided verb phrases ("he's throwing it"), or single word utterances ("jumping"). If the child could not produce a label, it was provided for them and they were asked to repeat it. After naming the action cards, children completed the RMTS task.

In the Baseline condition, children simply completed the RMTS task. This condition was created in order to test children's relational ability with no prior manipulations. We expected to replicate the performance of 4-year-olds in Christie and Gentner (2014).

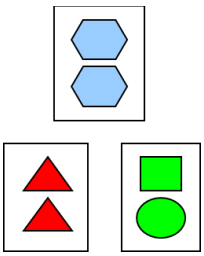

Figure 1. A sample triad from the RMTS task.

Results & Discussion

We measured the mean proportion of relational matches in the RMTS task. Two different analyses assessed performance. First, we used a one-way ANOVA to calculate differences between the conditions. We found a significant effect of condition, $F(2,48) = 4.43$, $p = .02$, $\eta^2 = 0.15$. Bonferroni post-hoc tests revealed that the Baseline group ($M = 0.76$, $SD = 0.22$) made significantly more relational matches than the Object Naming group ($M = 0.51$, $SD = 0.28$), $p = .03$. The Action Naming group ($M = 0.73$, $SD = 0.30$) was no different from the Baseline group, $p = 1.00$. The difference between the Action Naming and Object Naming groups approached significance, $p = .06$.

In the second analysis, we compared the means of each group to chance (50%). We found that the Baseline group selected relational matches significantly more than chance, $t(16) = 4.76$, $p < .001$, $d = 1.18$, replicating the findings from Christie and Gentner (2014). The Action Naming group also performed above chance, $t(16) = 3.16$, $p = .006$, $d = 0.77$. However, the Object Naming group performed no differently from chance, $t(16) = 0.11$, $p = .91$, $d = 0.04$.

As we predicted, the children who labeled objects prior to the RMTS task performed worse than those who did not (the Baseline condition). Further, those who labeled actions did not display impaired performance on the RMTS task, suggesting that the impairment was specific to noun labels and not due to fatigue. This pattern is consistent with the idea that nominal language can impair relational matching.

Experiment 2

Experiment 1 provided evidence that noun-naming can (at least temporarily) impair relational reasoning. However, before drawing conclusions we wanted to generalize the findings and address some possible concerns. In Experiment 1, we used a mix of hand-drawn and printed images, and different numbers of cards between conditions. For Experiment 2, we developed new sets of cards, using words that weren't used in Experiment 1, and we used a more uniform style across the images. The number of cards shown in each condition was also equalized (a total of 40 cards each). We also changed the instructions given in the RMTS task. In Experiment 1, the target question was "Which one of these two goes with this one?" The meaning of "goes with" may not be immediately clear to children, so in order to make sure this did not influence the results, we asked children "Which one of these two is more like this one?" (following Christie & Gentner, 2014).

Methods

Participants Twenty-nine 4-year-olds were recruited from the Evanston/Chicago area (14 females, $M_{age} = 53$ months). The demographics were the same as in Experiment 1.

Materials and Procedure Two new sets of cards were developed. Forty new objects and forty new actions were depicted on cards for the Object Naming and Action Naming conditions. The RMTS task was identical to Experiment 1, with the exception that an additional catch trial was added for a total of three literal similarity catch trials. Children that failed any of these catch trials were excluded from analysis (n = 4).

The overall procedure was the same as in Experiment 1. Children were placed in either the *Object Naming* or *Action Naming* condition. In the Object Naming condition, children were shown a card with an image of an object and were asked, "What is this called?" In the Action Naming condition, children were shown a card with an image of a scene and were asked: "What is (s)he doing?"

Following the naming pretask, children completed the same 8 trials of the RMTS task as in Experiment 1. However, the instructions were slightly different. After the two possible matches were placed underneath the standard, the target question was "Which one of these two is more like this one?" No feedback was provided.

Results & Discussion

As in Experiment 1, we measured the proportion of relational matches in the RMTS task. Although the Object Naming group ($M = 0.55$, $SD = 0.32$) appeared to perform worse than the Action Naming group ($M = 0.69$, $SD = 0.21$), the difference did not reach significance, $t(23) = -1.23$, $p = .23$, $d = 0.54$. However, whereas the Action Naming group performed above-chance on the RMTS task, $t(8) = 2.80$, $p = .02$, $d = 0.90$, the Object Naming group did not, $t(15) = 0.58$, $p = .57$, $d = 0.16$.

These results largely replicated Experiment 1. We found that with a new set of stimuli, providing noun labels for objects hindered children's ability to make relational matches in the RMTS task. This effect was not seen when children were asked to provide verb labels for actions.

General Discussion

Research on relational processing in the first few years of life has revealed a puzzling pattern. Infants and young toddlers can generalize *same-different* relations when presented with multiple examples (Ferry et al., 2015; Walker et al., 2015). In contrast, slightly older toddlers, from around 2.5 years of age, show a steadily decreasing ability to notice these relations. Here we tested the possibility that this decline results from an object focus that is a side effect of children's early focus on acquiring nouns. We hypothesize that children's interest in noun-learning can make objects more salient, and interfere with children's ability to judge relational similarity across instances.

We tested this possibility by simulating these conditions in preschoolers. We first verified that four-year-olds could easily make relational matches in the RMTS task in the absence of any manipulation via the Baseline condition. We found that this was the case, replicating Christie and Gentner (2014). We asked children in the Object Naming condition to generate noun labels for familiar objects. We predicted that this experience would lead them to focus on objects and thus perform poorly on a subsequent RMTS

task. Across two experiments, we showed that the use of noun labels had a negative influence on children's relational matching. In both studies, children in the Object Naming condition went on to perform at chance in the RMTS task—far lower than the Baseline group. In contrast, children asked to generate verbs in the Action Naming condition saw no such impairments. This finding supports our hypothesis that the relational decline is related to children's early tendency to focus on objects in the service of noun learning.

An interesting aspect of our findings is that we successfully induced a general focus on objects, rather than a focus on specific objects shown in the pretask. To illustrate this difference, let us consider one of the studies conducted by Ferry et al. (2015). Infants were exposed to specific objects in the waiting room before the experiment began. When these same objects appeared within a relational pair in one of the test trials, this impaired infants' ability to notice that the object was part of an abstract relation. They focused on the individual object they had seen earlier, and this impaired their ability to notice relational similarity. However, the current experiments differ; the objects that children labeled in the pretask never appeared in the subsequent RMTS task. Thus, activating multiple noun labels led to a general focus on objects that influenced how the children processed unrelated objects in the RMTS task. This supports our claim that language can lead to a generalized object focus.

The current work shows that focusing on nouns can direct attention to objects at the expense of relations. These findings dovetail with other results showing that noun labels lead both infants and children to focus on objects (Balaban & Waxman, 1997; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002; Xu & Carey, 1996). For instance, Xu and Carey (1996) found that 10-month-olds who knew the names of particular objects could keep track of the objects' identities in an object individuation task better than the infants who did not know the words.

Comparative work also provides some support for the notion that language is related to the object focus. Christie, Gentner, Call, and Haun (2016) compared the performance of nonhuman apes and 3-year-old children on the same relational mapping task. Children displayed greater relational matching ability than chimpanzees and bonobos. But when given a cross-mapping task, children were far more distracted by object matches than were the apes. Thus it does not appear that children's early noun focus results from a general phylogenetic bias. As none of the apes in this study had been taught symbol systems, language learning is at least a plausible candidate for the greater object focus seen in children.

We note that there is a slight difference between the generally assumed age of the nominal explosion and the age at which Walker et al. (2015) found a relational decline. The nominal explosion occurs between 18 and 30 months, whereas the decline in relational reasoning occurs slightly later, starting around 36 months. However, effects of language often take time to become entrenched. Noun-dominance in language learning may appear early, and affect relational attention at a somewhat later time.

The current work has focused on a temporary decline. But in the larger picture, children improve dramatically in their relational ability over the preschool and early school years (Gentner & Rattermann, 1991; Paik & Mix, 2006; Rattermann & Gentner, 1998). Although general experience (Rattermann & Gentner, 1998) and increases in executive ability (Richland et al., 2006; Thibaut et al., 2010) and processing capacity (Halford et al., 1998) may all contribute to this development, we suggest that a major factor is relational language learning (Gentner, 2010; Gentner & Rattermann, 1991). Children are acquiring relational terms—including spatial terms and mathematical terms—that support relational representation and reasoning (Casasola, 2005; Christie & Gentner, 2014; Gentner & Christie, 2008; Hermer-Vasquez et al., 2001; Loewenstein & Gentner, 2005; Pruden et al., 2011; Pyers & Senghas, 2009). Over learning, language becomes a fine-tuned instrument that can support selective attention to either objects or relations.

Our goal here was to induce an object focus via our object naming task as a microcosm of what occurs on a macro scale with the noun explosion. In ongoing studies, we aim to trace these effects at younger ages.

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