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Young Children's Analogical Reasoning across Cultures: Similarities and Differences

Brief Report

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Abstract

A cross-cultural comparison between U.S. and Hong Kong preschoolers examined factors responsible for young children's analogical reasoning errors. On a scene analogy task, both groups had adequate prerequisite knowledge of the key relations, were the same age, and showed similar baseline performance, yet Chinese children outperformed U.S. children on more relationally complex problems. Children from both groups were highly susceptible to choosing a perceptual or semantic distractor during reasoning when one was present. Taken together, these similarities and differences suggest that 1) cultural differences can facilitate better knowledge representations allowing for more efficient processing of relationally complex problems, and 2) that inhibitory control is an important factor in explaining the development of children's analogical reasoning.

Young Children's Analogical Reasoning across Cultures: Similarities and Differences

Analogical reasoning is a powerful mechanism in children's cognitive development. In an analogy, successful reasoners construct correspondences between two systems of relations to solve a problem (Gentner, 1983). For example, knowledge of using a stool to reach a toy can be used to figure out that a ladder could help reach a cookie jar. This skill enables children to draw on prior knowledge representations to make sense of new contexts and to build expertise by comparing and contrasting representations (see Goswami, 1992). Infants show analogical thinking and problem solving by a year and a half (Chen, Sanchez & Campbell, 1997); however, they do not approximate adults' levels of competence until adolescence (Halford, 1993; Richland, Morrison & Holyoak, 2006). Errors in young children's analogical reasoning are characterized by difficulty ignoring irrelevant object properties, like the difference in appearance between a ladder and a stool (e.g., Rattermann & Gentner, 1991; Richland et al, 2006). Also, young children have been shown to struggle with reasoning about multiple relationships at once (e.g., Halford, 1993; Richland et al, 2006).

Several explanations have been posed to explain the development of analogy in children. The relational primacy theory holds that adequate knowledge about key relations is the main prerequisite for analogical reasoning (e.g., understanding "reaching" to solve the above example) (Goswami, 1992). Gentner and Rattermann (1991) argue, in addition, that until children have the adequate knowledge, they will not only fail to reason analogically, they will focus their answers on object properties and appearance (Relational Shift Hypothesis). This relational shift is not tied to the age of a child, but rather to knowledge, so that even an adult who is not knowledgeable about an analogy task may tend to make mappings based on object properties, while s/he will shift to more relational mappings once adequate knowledge is acquired.

Two aspects of executive resources have also been suggested as important for the development of analogical reasoning. Halford (1993) has suggested that the inability to process multiple relations in analogies may be due to limits in children’s working memory. Halford and colleagues found that children's developmental differences across a variety of tasks could be calculated as a function of the relational complexity, or the number of relationships that must be held in working memory simultaneously. Based on this model, children should be able to reliably solve tasks with a single level of relational complexity before approximately five years, after which two relations should be attainable.

Likewise, we have previously posited that limits on inhibitory control may explain why young children solving analogy tasks sometimes still map correspondences based on object properties and general appearance correspondences in spite of understanding the relations and the analogy task (Richland, et al., 2006).

The current paper used a cross-cultural approach to explore interactions among these factors and to investigate their explanatory power in a broader sample. Much of the prior research has been conducted with U.S. and Australian children, but adult and developmental research suggest that cultural experiences may impact the development of analogical reasoning.

Relational Reasoning Across Cultures

Cultural experiences may influence relational reasoning in several ways. Knowledge of cultural content may impact prerequisite knowledge of relations, and consequently, influence analogical reasoning on problem-solving tasks that rely on that cultural knowledge (Chen, Mo, & Honomichl, 2004).

In addition, culture may be related to normative patterns of relational reasoning and analogy production (Richland, Zur & Holyoak, 2007). Normative patterns for drawing relational inferences during problem solving can vary across cultures when content knowledge is comparable (see D'Andrade, Nisbett 2003). Chinese and Japanese reasoners may attend relatively more to relational patterns in visual representations and problems, while U.S. reasoners may attend relatively preferentially to object-based information (see Hansen, 1983; Nisbett, 2003). Such cultural variations have been demonstrated in visual scene interpretations, which are often used in analogical reasoning tasks. In one cross-cultural study, Chinese outperformed U.S. undergraduates in assessing covariation in presentations of arbitrary objects (e.g., judging whether schematic drawings of a coin and a lightbulb had been shown on the screen together). The Chinese students also showed greater attention to relations between the figures and background than U.S. participants, who demonstrated more attention to focal objects, or figure independence (Ji, Peng & Nisbett, 2000).

Analyses of children's everyday experiences suggest these reasoning and attention patterns are part of children's socialized experience with relational inputs in schools (Richland, Zur & Holyoak, 2007) and at home with caregivers. Asian caregivers seem particularly interested in directing infants' attention to how entities—human and otherwise—interact and relate to one another, including using action oriented language and referential verbs (e.g., swimming, ate, going to drive) (e.g., **Korean**: Au, Dapretto, & Song, 1994; Gopnik, Choi & Baumberger, 1996; **Japanese**: Fernald & Morikawa, 1993; Ogura, Dale, Yamashita, Murase, 2006; **Chinese**: *(Mandarin)* Tardif, et.al, 1997; Tardif, et.al, 1999; *(Cantonese)* Leung, 1998). The play of English speaking caretakers, who served as a comparison group in many of these studies, is relatively object focused, including using more naming and non-referential verbs (e.g., 'looks like,' 'lookit, 'watch') (e.g., Goldfield, 1993; Gopnik, et al, 1996).

The current paper uses a scene analogy task (Richland, et al., 2006) to explore the hypothesis that Chinese preschool children approach analogies differently than U.S. children based on their relatively greater experiences with relations. We specifically hypothesized that Chinese children might be able to processes analogies more efficiently by constructing higher-level relational representations, thus making better use of comparable working-memory resources. The task used simple, common relations and a counterbalancing design that held necessary content knowledge constant across conditions, so any differences in performance should not be attributable to variations in prerequisite knowledge.

We also sought to test our hypothesis (Richland, et al., 2006) that maturational limitations in inhibitory control explain children's low performance on analogies that include a strong object-similarity distractor. We predicted a common pattern across countries showing relatively lower performance on analogies with a distractor versus no-distractor despite comparable prerequisite knowledge. The relational shift hypothesis (Rattermann & Gentner, 1991), by contrast, would predict that children’s susceptibility to distraction would decrease as their relational knowledge increases. Thus Chinese children should be less susceptible to distraction than U.S. children.

Three and four-year-old Chinese children's task performance was compared to two samples of U.S. children of the same ages: *Sample-1)* previously published data with instructions that were semantically matched to the Cantonese version and used typical grammatical forms in each language (Richland et al, 2006, Experiment 2), and *Sample-2)* new data from a more syntactically similar back-translation of the Cantonese task instructions. We tested cross-cultural variations in ability to handle relational complexity (1-versus vs. 2-Relations) and to avoid distraction from an object-similarity distractor (Distractor vs, No-Distractor).

Method

Participants

Children were sampled from middle to upper income preschools in several locations in the United States and one location in Hong Kong. All children were native speakers in their country of origin. Although demographic data were not collected systematically, participating children in Hong Kong were primarily of Chinese descent, and U.S. children were of diverse ethnic backgrounds, including Caucasian, Asian, Asian American, and Latin American descent. Children were excluded from data analyses for failure to grasp the task as denoted by scoring under two standard deviations from the mean percent correct and correctly answering one or fewer of the simplest problems (1-Relation, No-Distractor).

Hong Kong. Sixty-one preschoolers participated (19 3-year-olds, 41 4-year-olds). Their mean age was 48 months (SD=5.4 mos). One additional 3-year-old was excluded for failing to grasp the task.

U.S. Sample-1. (Richland et al, 2006 Experiment 2). Twenty preschoolers participated (7 3-year olds and 13 4-year olds). Their mean age was 51 months (SD = 9). Three additional 3 year-olds were excluded for failing to grasp the task.

U.S. Sample-2. Thirty-eight preschoolers participated (13 3-year olds and 25 4-years-olds). Their mean age was 46 months (SD = 5 mos). Two additional 3-year-olds and three 4-year-olds were excluded for failure to grasp the task.

Materials

In the scene analogy task (Richland et al., 2006), children saw 20 pairs of scenes with one pair per page (see Figure 1 for examples of one stimuli). The pictures showed the same relation but differed in the objects. For example, in the simplest version of the Figure 1 scene pair, the top picture showed a boy reaching for a cookie. The bottom picture showed a dog reaching for a bone. In the top picture, an arrow pointed to one of the objects (e.g, the boy, who is the "reacher"). The child was asked to point to the corresponding object in the bottom picture (e.g., the dog, who is the "reacher").

Scene analogy pairs varied in a factorial design along two dimensions. First, the level of relational complexity was manipulated by moving objects within the scenes to vary the number of instances of the same relation present within the pictures (e.g., 1-Relation: "boy reaches for cookie"; 2-Relations: "mom reaches for boy who reaches for cookie"). All four versions of each picture set always contained exactly the same number of objects within the picture (either five or six) and all key objects were always present, though in different roles.

Second, the scenes varied in the presence or absence of an object-similarity distractor in the target picture. The distractor was an object in the target scene that was perceptually and semantically similar to the object with the arrow in the source picture, (e.g., a stationary boy in the target picture beside the reaching dog and man). This forced participants to make a choice between a relational and an object-similarity match.

Manipulating relational complexity (1-vs. 2-Relations) and distraction (Distractor vs. No-Distractor) led to four version of each scene pair. There were twenty total picture scene pairs, so packets were constructed such that each packet contained five of each version of the scene pairs (1-Relation/No-Distractor; 1-Relation/Distractor, 2-Relation/No-Distractor, 2-Relation/Distractor). Participants saw each scene pair once.

The packets used in Hong Kong and the U.S. were identical with one small difference between the U.S. Sample-1 and both the Hong Kong and U.S. Sample-2 versions. In the Hong Kong and U.S. Sample-2 stimuli, to ensure children's task understanding during administration, two of the simplest items (1-Relation/No-Distractor) were always administered first, followed by the remaining 18 items in random order. In the original U.S. studies (Sample-1 here), all twenty items were randomized. With the same goal to ensure task understanding, there was also a translational difference in the U.S. Sample-1 versus the Hong Kong and U.S. Sample-2 procedures (described below).

Procedure

The procedure was the same for children tested in Cantonese and English. A trained experimenter tested participants individually beginning with two practice problems, emphasizing that the task was to select the object in the bottom picture that was in the same part of the pattern as the object with the arrow in the top picture. After the child's response to the first practice item, the experimenter gave feedback and a second opportunity to answer. If the child's response was still incorrect, the solution was provided and the cycle repeated for the second practice item.

For each scene pair, the experimenter would verbalize the key relations in the top picture. In the example above, the instruction was: "Look, here is a boy reaching for a cookie. What is like the boy in the bottom picture?" The child would then point to an object in the bottom picture, which was marked by the researcher.[i]

The 2-Relation problems led to a translational challenge. In the original Richland et al, (2006) experiments (U.S. Sample-1 in the current study) the experimenter described the source problem as a series of chained relations: "Look, here is a mom reaching for a boy who is reaching for a cookie." Because there is no Cantonese equivalent to this construction or the relative pronoun "who," the translation for the Hong Kong sample read like two serial phrases: “look, here is a mom reaching for a boy; boy reaching for a cookie." This change should not have altered the relational complexity of the problems because the relations cannot be collapsed in either case (i.e., "mom reaching for a cookie").

Even so, to ensure the phrasing did not make the problem simpler, U.S. Sample-2 was tested on the English back-translation of the 2-Relation problems. The relations were described using two serial phrases as translated above.

Results

Data from the Hong Kong sample and U.S. Sample-2 were first compared to chance to ensure children understood the task as translated into Chinese and back-translated into English. Next, an omnibus ANOVA compared the Hong Kong children's performance to U.S. Samples-1 and 2 to investigate cross-cultural differences or commonalities in reaction to the relational complexity and distraction manipulations. Planned comparisons examined the reliability of the cross-cultural variations across the two U.S. samples.

Comparisons with Chance

Chance was calculated as the likelihood of selecting the target object out of all objects in the target picture, a total of 5.3 across all picture sets, or 19% chance. All means are available in Table 1. Children of ages 3 and 4 in each culture were above chance on all four conditions using t-tests with a Bonferroni corrected alpha at the targeted .05 level (.003), all p's < .001. Results indicated that the children in both groups understood the task, showed adequate prerequisite knowledge, and could reason relationally.

Cross-cultural comparison

A repeated-measures ANOVA compared the Hong Kong and U.S. children's performance. The omnibus ANOVA included relational complexity (1- vs. 2-Relations) and distractor (Distractor vs. No-Distractor) as within-subject factors, and group (Hong Kong vs. U.S. Sample-1 vs. U.S. Sample-2) and age (3 vs. 4 years) as between-subject factors. Means are reported in Table 1.

There was a main effect of age, $F(1, 112) = 9.79$, $p < .01$, $h_p^2 = .08$. Four-year-olds outperformed three-year-olds overall ($M = 42.8$, $SE = 2.39$; $M = 52.0$; $SE = 1.72$), but age did not interact with any other variable (all F's (1 or 2,112) < .92). There was no overall main effect of nationality, $F(2, 112) = 2.7$, $p = .07$. Interactions between nationality and the two other variables are described below.

There was a main effect of relational complexity, $F(1, 112) = 10.2$, $p < .01$, $h_p^2 = .08$ which, as predicted, was modified by an interaction between nationality and relational complexity $F(2, 112) = 3.2$, $p < .05$, $h_p^2 = .053$. Planned comparisons revealed the same interaction when the Hong Kong data were compared separately to each of the U.S. samples ($F(1,78) = 6.6$, $p = .01$, $h_p^2 = .08$; $F(1, 94) = 5.5$, $p < .05$, $h_p^2 = .06$). As shown in Figure 1, on the 1-Relation problems there was no difference in performance between Hong Kong and either sample of the U.S. children ($t(78) = .68$, $p = .5$; $t(96) = .69$, $p = .84$). On the 2-Relation problems, by contrast, the Hong Kong children outperformed both samples of U.S. children ($t(78) = 2.6$, $p = .01$; $t(96) = 3.16$, $p < .002$). This suggests that the Chinese children were better able to handle relational complexity than U.S. children, and that they were using a strategy that allowed them to solve 2-Relation problems without overtaxing their working memory system.

There was an overall main effect of distractor, $F(1, 112) = 35.8$, $p < .001$, $h_p^2 = .24$, such that participants scored higher on No-Distractor problems than on Distractor problems ($M =$

58%, *SE* = 2.34; M = 40%, *SE* = 1.82). There was no interaction between nationality and distractor, $F(2, 112) = .60$, $p = .55$. As shown in Figure 1, planned comparisons showed that accuracy was lower on Distractor problems than No-Distractor problems for all samples, (U.S. sample 1: $t(19) = 5.4$, $p < .0001$, $d = 1.4$; U.S. sample 2: $t(37) = 3.2$, $p < .003$, $d = .63$; Hong Kong: $t(59) = 5.0$, $p < .0001$, $d = .96$).

Discussion and Conclusions

In summary, there were no differences in the simplest problems between the U.S. and Chinese children on the scene analogy task, which ruled out concerns of baseline between-group differences in task comprehension or in prerequisite knowledge. In contrast, there was a cross-cultural difference with respect to relational complexity. As predicted, Chinese children were more skilled at processing complex relations than either group of U.S. children. Though it is possible that the Chinese children had greater working-memory capacity than U.S. children at the same age, the likelihood is low. Young and older adults in the U.S. and China do not show differences in working memory or speed of processing on visuospatial tasks that are unlikely to reflect cultural bias (Hedden et al., 2002). While several studies have shown differences in simple short-term memory (e.g., forward span) between English and Chinese speakers and children, (e.g., C. Chen & Stevenson, 1988; Z.-W. Chen, Cowell, Verley & Wang, 2009), these differences likely reflect differences in language phonology and are not found in measures believed to reflect working-memory capacity (e.g., backward span). Thus it is unlikely the type of working-memory processing required to map scene analogies would differ across our groups. The analogy pattern is more consistent with our initial hypothesis that Chinese children's greater experience with socialized relational inputs would provide them an advantage in complex analogies.

While pinpointing an environmental explanation is beyond this paper's scope, the finding that Chinese children outperformed U.S. children of the same age on relationally complex analogies is informative to theories of analogy development. This pattern suggests that the ability to represent relations is a learnable skill, separable from - though dependent on - the related constructs of prerequisite content knowledge and working memory capacity.

The observed cross-cultural difference supports the view that prior experience is integral to analogical reasoning development, but extends previous descriptions of its role either as prerequisite domain knowledge (Goswami, 1992) or as a mechanism for undergoing the relational shift (Gentner & Rattermann, 1991). With increased relational experience, children may learn greater efficiency in constructing relational representations. In our task, that would mean the Chinese children processed the 2-Relation problems as single three-part relations, while the U.S. children processed them as two two-part relations.

Unlike relational complexity, there were no differences in susceptibility to the distractor object between Chinese and U.S. children. All groups of children were more accurate on No-Distractor problems than on Distractor problems. This result runs counter to the relational shift hypothesis that children will tend to reason relationally, versus based on object similarity, with adequate prerequisite knowledge (Rattermann & Gentner, 1991). Rather, maturation of executive resources may better explain what appear to be age-related changes in object-similarity distractability. This explanation is compatible with developmental studies of executive resources (see Diamond, 2002) and declines in relational reasoning by patients with frontal lobe atrophy (see Morrison et al., 2004; Krawczyk et al, 2008). The explanation also fits developmental trends in children's ability to make decisions about whether to attend to relational versus object similarity based on their determined utility for a given task (Bulloch & Opfer, 2009).

Morrison, Doumas & Richland (2007) used LISA (Hummel & Holyoak, 1997) to simulate these results, providing a framework for how inhibitory control and experience could interact. Assuming that U.S. children represented the 2-Relation problems as two, two-part relations while Hong Kong children chunked these into a single, three-part relation revealed the cross-cultural interaction with relational complexity, while a simple change in inhibition in the model for all children captured the variation between the Distractor/No-Distractor conditions.

Overall, these cross-cultural results suggest that experience plays an under-explored role in relational representation, which can impact processing efficiency, but that maturation in executive resources is also critical for the development of analogical reasoning.

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Table 1. Percentage of correct responses of 3- and 4-year-old Hong Kong and U.S. children in the Scene Analogy task varying in relational complexity and presence/absence of a distractor.

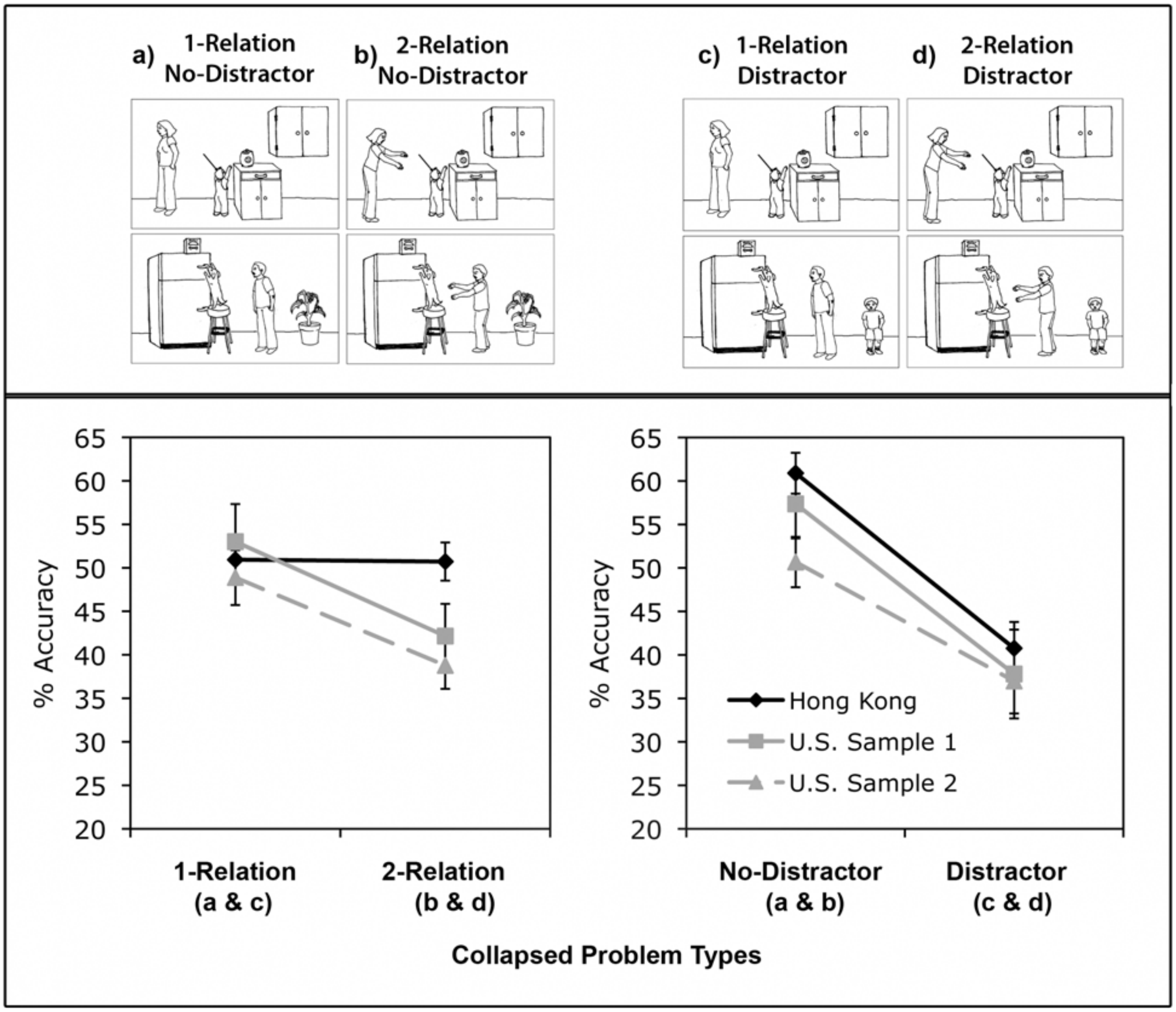
	1-Relation/ No Distractor+	2-Relation/ No Distractor	1-Relation/ Distractor	2-Relation/ Distractor
Hong Kong	62% (22*)	62% (23)	41% (26)	43% (27)
3yr	*59% (27)*	*57% (24)*	*39% (24)*	*36% (20)*
4yr	*63% (20)*	*64% (22)*	*42% (27)*	*46% (29)*
U.S. Sample 1	64% (24)	55% (20)	46% (26)	30% (18)
3yr	*54% (21)*	*49% (25)*	*40% (28)*	*34% (15)*
4yr	*69% (24)*	*58% (17)*	*49% (25)*	*28% (19)*
U.S. Sample 2	62% (23)	44% (25)	40% (30)	39% (25)
3yr	*53% (21)*	*36% (22)*	*32% (30)*	*26% (21)*
4yr	*66% (23)*	*48% (26)*	*45% (30)*	*46% (26)*

* Standard Deviations in parentheses.

+Basic chance levels for all problems were 19%.

Figure Caption Page

Figure 1. Example stimuli showing *Reach* relation (1-Relation: boy reaching for cookie// dog reaching for bone; 2-Relation: mom reaching for boy who is reaching for cookie jar// man reaching for dog who is reaching for bone), with results showing cross-cultural differences in the effects of relational complexity and distraction on 3- and 4-year-olds' analogical reasoning performance.


a) 1-Relation No-Distractor
b) 2-Relation No-Distractor
c) 1-Relation Distractor
d) 2-Relation Distractor
% Accuracy
65
60
55
50
45
40
35
30
25
20
1-Relation (a & c)
2-Relation (b & d)
No-Distractor (a & b)
Distractor (c & d)
Hong Kong
U.S. Sample 1
U.S. Sample 2
Collapsed Problem Types

[i] See Richland et al. (2006) for more detail on instructional controls that ensured children understood they were intended to find the analogical match, versus an object match.