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Brief Report

Young children's analogical reasoning across cultures: Similarities and differences

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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 (a) cultural differences can facilitate better knowledge representations by allowing more efficient processing of relationally complex problems and (b) inhibitory control is an important factor in explaining the development of children's analogical reasoning.

Introduction

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 represen-

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tations 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 1½ years of age (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 in ignoring irrelevant object properties such as the difference in appearance between a ladder and a stool (e.g., Gentner & Rattermann, 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 theories 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) argued, in addition, that until children have the adequate knowledge, they will not only fail to reason analogically but also 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 is tied to knowledge, so that even an adult who is not knowledgeable about an analogy task may tend to make mappings based on object properties, whereas he or she will shift to more relational mappings once adequate knowledge is acquired.

Two aspects of executive resources have also been theorized as important for the development of analogical reasoning. Halford (1993) 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 5 years of age, after which two relations should be attainable.

Likewise, we 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 tasks (Richland et al., 2006).

The current study 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 suggests 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, 1995; Nisbett, 2003). Chinese and Japanese reasoners may attend relatively more to relational patterns in visual representations and problems, whereas 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 that are often used in analogical reasoning tasks. In one cross-cultural study, Chinese undergraduates outperformed U.S. undergraduates in assessing covariation in presentations of arbitrary objects (e.g., judging whether schematic drawings of a coin and a light bulb had been shown on the screen together). The Chinese students also showed greater attention to relations between the figures and background than did the U.S. participants, who demonstrated more attention to focal objects or figure independence (Ji, Peng, & Nisbett, 2000).

Analyses of children's everyday experiences suggest that these reasoning and attention patterns are part of children's socialized experience with relational inputs in schools (Richland et al., 2007) and at home with caregivers. Asian caregivers seem to be 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 such as *swimming, ate,* and *going to drive* (Korean: Au, Dapretto, & Song, 1994, and Gopnik, Choi, & Baumberger, 1996; Japanese: Fernald & Morikawa, 1993, and Ogura, Dale, Yamashita, & Murase, 2006; Chinese [Mandarin]: Tardif, Gelman, & Xu, 1999, and Tardif, Shatz, & Naigles, 1997; Chinese [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 nonreferential verbs such as *looks like, lookit,* and *watch* (e.g., Goldfield, 1993; Gopnik et al., 1996).

The current study used a scene analogy task (Richland et al., 2006) to explore the hypothesis that Chinese preschoolers 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 process analogies more efficiently by constructing higher level relational representations, thereby 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 compared with those with no distractor despite comparable prerequisite knowledge. The relational shift hypothesis (Gentner & Rattermann, 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.

Chinese 3- and 4-year-olds' task performance was compared with that of two samples of U.S. children of the same ages. Sample 1 consisted of 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 consisted of 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 (one relation vs. two 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 failing to grasp the task, as denoted by scoring less than two standard deviations from the mean percentage correct, and for correctly answering only one or none of the simplest problems (one relation, no distractor).

Hong Kong

A total of 60 preschoolers participated (19 3-year-olds and 41 4-year-olds). Their mean age was 48 months (*SD* = 5.4). An additional 3-year-old was excluded for failing to grasp the task.

U.S. Sample 1

A total of 20 preschoolers participated (7 3-year olds and 13 4-year olds) (Richland et al., 2006, Experiment 2). Their mean age was 51 months (*SD* = 9). An additional 3 3-year-olds were excluded for failing to grasp the task.

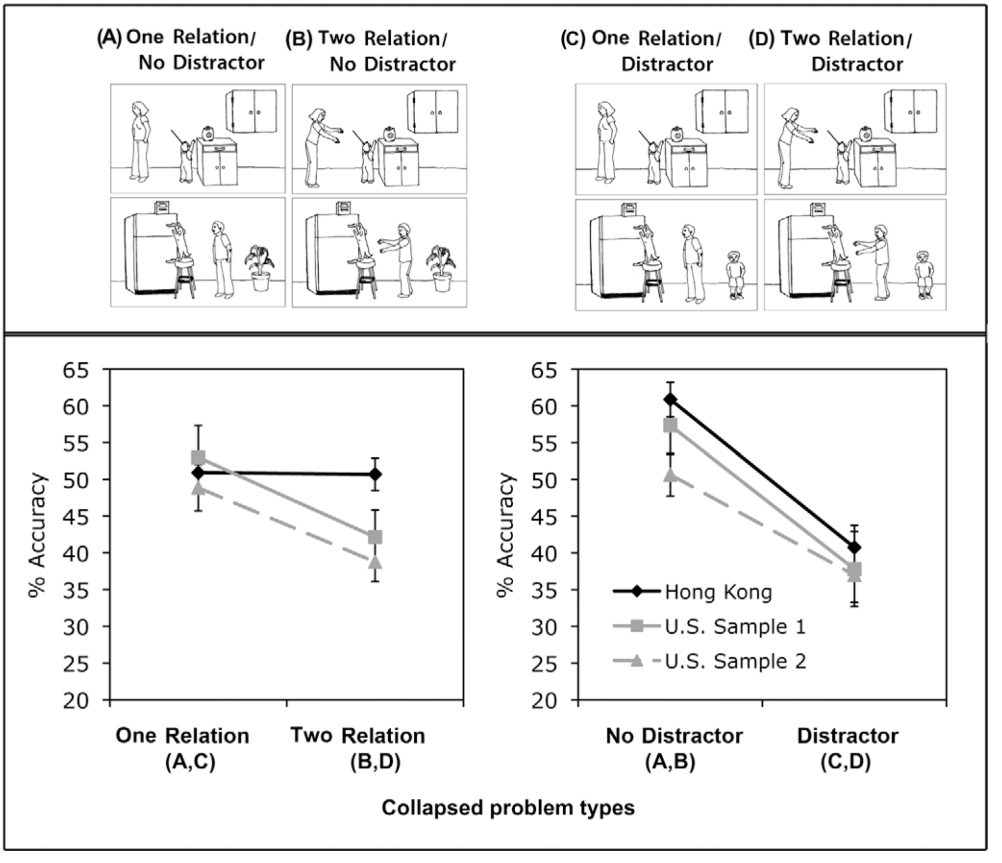

Fig. 1. Example stimuli showing the *reach* relation (one relation: boy reaching for cookie/dog reaching for bone; two relations: mom reaching for boy who is reaching for cookie jar/man reaching for dog who is reaching for bone), with results showing cross-cultural differences in the effects of relational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

U.S. Sample 2

A total of 38 preschoolers participated (13 3-year-olds and 25 4-years-olds). Their mean age was 46 months (*SD* = 5). An additional 2 3-year-olds and 3 4-year-olds were excluded for failing to grasp the task.

Materials

In the scene analogy task (Richland et al., 2006), children saw 20 pairs of scenes with 1 pair per page (see Fig. 1 for examples of one stimulus). The pictures showed the same relation but differed in the objects. For example, in the simplest version of the scene pair in Fig. 1, the top picture showed a boy reaching for a cookie and 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").[1]

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

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

the same relation present within the pictures (e.g., one relation: "boy reaches for cookie"; two 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, albeit 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 match and an object similarity match.

Manipulating relational complexity (one relation vs. two relations) and distraction (distractor vs. no distractor) led to four versions of each scene pair. There were a total of 20 picture scene pairs, so packets were constructed such that each packet contained five of each version of the scene pairs (one relation/no distractor, one relation/distractor, two relations/no distractor, and two relations/distractor). Participants saw each scene pair once.

The packets used in Hong Kong and the United States were identical with one small difference between the U.S. Sample 1 version 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, 2 of the simplest items (one 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 20 items were randomized. With the same goal to ensure task understanding, there was also a translational difference in 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 and 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 was repeated for the second practice item.

For each scene pair, the experimenter verbalized the key relations in the top picture. In the above example, the instruction was as follows: "Look, here is a boy reaching for a cookie. What is like the boy in the bottom picture?" The child then pointed to an object in the bottom picture that was marked by the researcher.

The two-relation problems led to a translational challenge. In Richland and colleagues' (2006) original 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 that the phrasing did not make the problem simpler, U.S. Sample 2 was tested on the English back-translation of the two-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 with chance to ensure that children understood the task as translated into Chinese and back-translated into English. Next, an omnibus analysis of variance (ANOVA) compared the Hong Kong children's performance with that of 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.

Table 1
Percentages of correct responses of Hong Kong and U.S. 3- and 4-year-olds in the scene analogy task varying in relational complexity and presence/absence of a distractor.

	One relation/no distractor	Two relations/no distractor	One relation/ distractor	Two relations/ distractor
Hong Kong	62 (22)	62 (23)	41 (26)	43 (27)
3 years	59 (27)	57 (24)	39 (24)	36 (20)
4 years	63 (20)	64 (22)	42 (27)	46 (29)
U.S. Sample 1	64 (24)	55 (20)	46 (26)	30 (18)
3 years	54 (21)	49 (25)	40 (28)	34 (15)
4 years	69 (24)	58 (17)	49 (25)	28 (19)
U.S. Sample 2	62 (23)	44 (25)	40 (30)	39 (25)
3 years	53 (21)	36 (22)	32 (30)	26 (21)
4 years	66 (23)	48 (26)	45 (30)	46 (26)

Note. Standard deviations are in parentheses. The basic chance level for all problems was 19%.

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 provided in Table 1. In each culture, 3- and 4-year-olds 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 (one relation vs. two relations) and distractor (distractor vs. no distractor) as within-participant factors as well as group (Hong Kong vs. U.S. Sample 1 vs. U.S. Sample 2) and age (3 years vs. 4 years) as between-participant factors. Means are reported in Table 1.

There was a main effect of age, $F(1, 112) = 9.79$, $p < .01$, $h_p^2 = .08$. The 4-year-olds ($M = 52.0$, $SE = 1.72$) outperformed the 3-year-olds ($M = 42.8$, $SE = 2.39$) overall, but age did not interact with any other variable, all Fs(1 or 2, 112) < 0.92). There was no overall main effect of nationality, $F(2, 112) = 2.70$, $p = .07$. Interactions between nationality and the other two variables are described below.

There was a main effect of relational complexity, $F(1, 112) = 10.20$, $p < .01$, $h_p^2 = .08$; as predicted, this was modified by an interaction between nationality and relational complexity, $F(2, 112) = 3.20$, $p < .05$, $h_p^2 = .053$. Planned comparisons revealed the same interaction when the Hong Kong data were compared separately with each of the U.S. samples: Sample 1, $F(1, 78) = 6.60$, $p = .01$, $h_p^2 = .08$; Sample 2, $F(1, 94) = 5.50$, $p < .05$, $h_p^2 = .06$. As shown in Fig. 1, on the one-relation problems, there was no difference in performance between the Hong Kong children and either of the U.S. samples: Sample 1, $t(78) = 0.68$, $p = .50$; Sample 2: $t(96) = 0.69$, $p = .84$. On the two-relation problems, by contrast, the Hong Kong children outperformed both samples of U.S. children: Sample 1, $t(78) = 2.60$, $p = .01$; Sample 2, $t(96) = 3.16$, $p < .002$. This suggests that the Chinese children were better able to handle relational complexity than U.S. children and that the Chinese children were using a strategy that allowed them to solve two-relation problems without overtaxing their working memory system.

There was an overall main effect of distractor, $F(1, 112) = 35.80$, $p < .001$, $h_p^2 = .24$, such that participants scored higher on no-distractor problems ($M = 58\%$, $SE = 2.34$) than on distractor problems ($M = 40\%$, $SE = 1.82$). There was no interaction between nationality and distractor, $F(2, 112) = 0.60$, $p = .55$. As shown in Fig. 1, planned comparisons showed that accuracy was lower on distractor problems than on no-distractor problems for all samples: U.S. Sample 1, $t(19) = 5.40$, $p < .0001$, $d = 1.4$; U.S. Sample 2, $t(37) = 3.20$, $p < .003$, $d = .63$; Hong Kong, $t(59) = 5.00$, $p < .0001$, $d = .96$.

Discussion and conclusions

There were no differences in the simplest problems between the U.S. and Chinese children on the scene analogy task, thereby ruling out concerns of baseline between-group differences in task comprehension or prerequisite knowledge. By 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. Although it is possible that the Chinese children had greater working memory capacity than the U.S. children at the same age, the likelihood of that is low. Young and older adults in the United States 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). Although several studies have shown differences in simple short-term memory (e.g., forward span) between English and Chinese speakers and children (e.g., Chen & Stevenson, 1988; Chen, Cowell, Varley, & 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 that 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 with an advantage in complex analogies.

Although pinpointing an environmental explanation is beyond the scope of this article, 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 that is separable from—but 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 that the Chinese children processed the two-relation problems as single three-part relations, whereas 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, rather than based on object similarity, with adequate prerequisite knowledge (Gentner & Rattermann, 1991). Instead, 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 Krawczyk et al., 2008; Morrison et al., 2004). The explanation also fits developmental trends in children's ability to make decisions about whether to attend to relational or object similarity based on their determined utility for a given task (Bulloch & Opfer, 2009).

Morrison, Doumas, and Richland (2007) used the LISA (learning and inference with schemas and analogies) model (Hummel & Holyoak, 1997) to simulate these results. We assumed 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. Making this assumption, we were then able to capture the complex pattern of relational complexity and distraction results in 3-4 year old U.S. and Hong Kong children by simply reducing adult inhibition levels by a uniform amount. Thus, the observed results are best understood as an interaction of environmentally induced differences in relational representation and reduced inhibitory control in characteristic of young children.

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

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