

Development of Analogical Reasoning: A Novel Perspective From Cross-Cultural Studies

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ABSTRACT—*Analogical reasoning allows children to generate new abstractions from experience, which drives early learning. But our current understanding of analogical learning is based primarily on evidence from the West, and new data from Asia seem to call into question that information. In this article, we describe our finding that East Asian children do not share their Western peers' strong bias for object similarity—often cited as the major reason for difficulties in relational reasoning. We analyze how this difference affects the ways analogy shapes learning in different cultures, such as what children use as base analogs and their likelihood of using comparison that results in relational abstraction. We also address cross-cultural differences, which are evident in classroom contexts, since teachers from the United States and East Asia use analogy differently. Overall, cross-cultural data are necessary to answer critical questions in theories of analogical learning; in this article, we chart pressing research questions and look ahead at directions for the field.*

KEYWORDS—*analogy; cross-cultural development; learning; cognitive development*

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Learning and development are about making sense of the new: acquiring new words and concepts, and discovering methods to solve novel problems. Analogical reasoning—the ability to perceive similarity of relations across events—is a powerful mechanism that facilitates learning. In reasoning analogically, learners map structures or relations from a familiar situation onto a novel one (Gentner, 1983). For example, if Jen knows that putting larger blocks atop small ones makes her block towers topple, she can put the smaller stool on top of the larger one when reaching for a high-placed cookie jar. The essence of analogical reasoning as a learning tool is that Jen makes a prediction about a novel situation given her knowledge of earlier setups, even if the earlier situation differs from the current task.

The prominence of analogical reasoning in learning theories is paramount. It plays a fundamental role in language learning, problem solving, creativity, scientific discovery, and social cognition (Christie, 2017; see Gentner & Hoyos, 2017, for a review). Some have even suggested that higher-order relational reasoning is what separates the cognition of humans and nonhuman animals (Gentner, 2003, 2010; Penn, Holyoak, & Povinelli, 2008). Analogical reasoning also plays an important role in educational theories and testing (Spearman, 1927). In fact, one of the most widely used intelligence tests—Raven's Progressive Matrices (Raven, 1941)—is essentially an analogical reasoning test.

However, despite the centrality and claimed universality of analogy, almost everything we know about the development of analogical reasoning comes from studies conducted in the West (i.e., the United States, Europe, and Australia). The lack of evidence from other cultures is a critical gap in how we understand analogy and in how much confidence we place in our understanding of the concept. This gap would not be so concerning if preliminary data from other cultural milieus mirrored the results of studies done in the West; however, for the most part, this seems not to be the case. A well-known early example is a study of scene analogy tasks in which preschoolers from Hong Kong outperformed their U.S. peers when complex relations were involved (Richland, Chan, Morrison, & Au, 2010).

In this article, we begin to fill this gap by reviewing emerging works on the development of analogical reasoning in other cultures. Our aim is to establish the importance of the cross-cultural perspective on analogy and chart the most pressing research questions in this field. Because of a lack of studies from other cultures, we refer mostly to cross-cultural evidence gathered in studies of East Asian—primarily Japanese and Chinese—children. We organize the review around three principal questions: (a) How do children’s ability and propensity to reason relationally vary across cultures? (b) Are there cross-cultural differences in how analogy contributes to cognitive development? (c) Is analogy used differently in classrooms around the world?

OBJECT VERSUS RELATIONAL FOCUS

A prominent feature in the development of relational reasoning (as we know it from studies conducted in the West) is that children struggle with relational abstraction because their early judgment of similarity is dominated by attention to object matches. Young children find featural similarity—sameness of perceptual features such as color or shape—to be more salient than relational similarity. For example, when asked, “Dog to dog house is like bird to what?” young children tend to pick another dog rather than completing the analogy with the relational answer “cage.” Over development, children gain knowledge (Rattermann & Gentner, 1998) or abilities (e.g., better inhibitory control; Doumas, Morrison, & Richland, 2018; Richland, Morrison, & Holyoak, 2006) that allow them to perceive similarity of relations. That is, development from object to relation does not happen at one time across all domains, but instead depends on knowledge and domain. Regardless of when it takes place, this *relational shift* (Gentner, 1988) makes two important predictions about learning: First, novice learners will have difficulties arriving at relational abstraction if there are competing object similarities or if the events involve perceptually rich objects. For example, 4-year-olds were more likely to match xXx to oOo (relational match) than to oOO when the symbols were instantiated by simple objects (geometric shapes), but performed at chance when the objects were complex (e.g., gadgets; see Figure 1; Gentner & Rattermann, 1991). Second, attention to object similarity can act as a learning catalyst for analogical abstraction: Learners who spontaneously compare like events such as [dog1-dog house1] and [dog2-dog house2] can learn the structural commonality X-lives-in-Y. Next, we focus on the first prediction and return to the second prediction later.

Studies of Japanese and Chinese children put the universality of prediction of the relational shift into some question. In one study (Kuwabara & Smith, 2012), researchers tested Japanese and American 4-year-olds on a triad task (similar to Gentner & Rattermann, 1991; see Figure 1). Even as the triads featured more complex exemplars and American children failed to find relational matches (consistent with the first prediction), their

Japanese peers continued to succeed. In another study (Carstensen et al., 2019), Chinese and American 3-year-olds learned to activate a novel machine by assembling patterns (a causal Relational Match-to-Sample Task [RMTS], i.e., the machine made a sound only if two identical blocks were put atop it). Chinese children succeeded in identifying the relational pattern that activated the machine; American children did not.

In both studies, researchers reported that Asian children had a greater ability to think relationally. The studies do not tell us directly that Asian children are less attentive to object matches than their American peers (we discuss this later). Pending additional data, these results may be explained in one of two ways: East Asian children either do not undergo the relational shift at all (the stance taken by Carstensen et al., 2019) or they undergo it earlier than their Western peers. The former hypothesis would be a paradigm change in current learning theories, which emphasize the importance of object-based learning early in development. We focus on exploring the second, more conservative hypothesis: that the onset of the relational shift is quicker in East Asian children. Why might this be the case?

Different Allocation of Attention

Adults from so-called collectivist cultures—such as Japan and China—attend more to relations between objects, while Westerners attend preferentially to focal objects (Nisbett, 2004). For example, when asked to describe an aquarium scene, U.S. adults mostly mentioned large fish in the center of the aquarium, while Japanese participants talked about the fish in relation to background items like plants and rocks (Masuda & Nisbett, 2001). This divergence begins in the preschool years: In one study, Chinese 2-year-olds attended to novel actions (relations between an agent and an object) more than their American peers did (Waxman et al., 2016). At the same time, Western children pay more attention to objects: In other studies, American 3-year-olds outperformed their Japanese peers in recognizing and naming objects given their fragments (Kuwabara & Smith, 2016a), and American 4-year-olds outperformed their Japanese peers in an object search task (Kuwabara, & Smith, 2012).

What shapes these differences of attention? One answer is parent–child interactions. In one study, American mothers were more likely to direct their infants’ attention to objects’ (e.g., toys’) attributes, such as color and shape, while Japanese mothers tended to talk about many objects in a scene (Fernald & Morikawa, 1993). In another study, American mothers who talked about a collection of animal toys typically lifted and described the toys individually while Japanese mothers introduced the animals as a group (Kuwabara & Smith, 2016b). A comparative describe-the-vignette study yielded similar results: Japanese parents and 7- to 9-year-olds elaborated more on context while Canadian parents and children concentrated on focal objects (Senzaki, Masuda, Takada, & Okada, 2016). Younger (4- to 6-year-old) children’s descriptions did not differ between

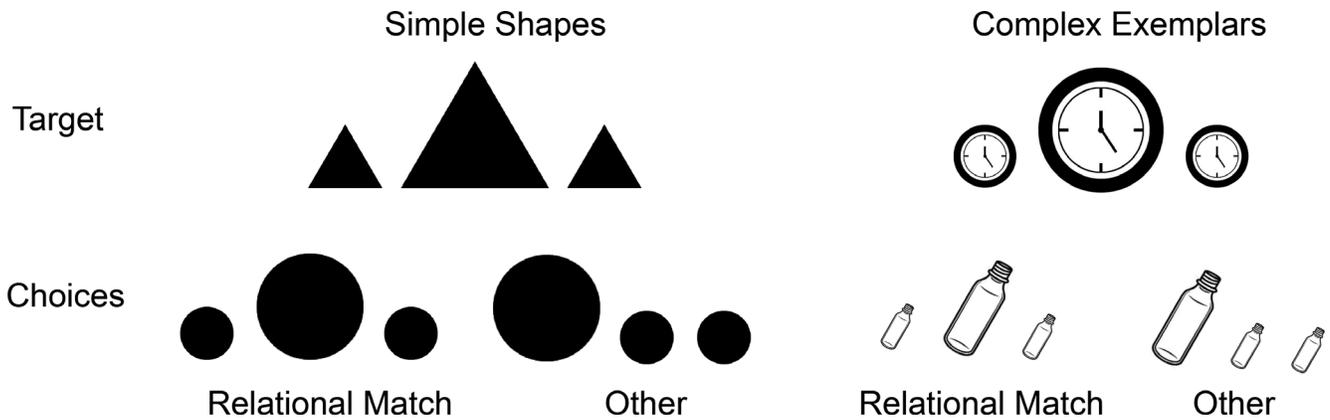


Figure 1. Sample of analogy task with simple and complex objects. Japanese and U.S. children similarly chose the relational match in the simple shapes condition. But with complex objects, U.S. children performed at chance, while Japanese children continued to select the relational matches. Adapted from Kuwabara and Smith (2012).

the two cultural groups, while 7- to 9-year-olds differed only in discussing scenes with their parents and not in individual narrations. Evidently, allotment of attention is shaped by social interactions.

Language Introduces Object Versus Relational Biases

Language affects relational thinking in several ways (Gentner & Christie, 2010), two of which are relevant for our purposes. First, relational language makes relations evident and portable. For example, children selected the relational matches more frequently after hearing the relational terms *daddy-mommy-baby* applied to the pattern *high-middle-low* (Gentner & Rattermann, 1991). Second, learning nouns focuses attention on objects. Four-year-olds who were trained to name pictured objects subsequently failed to choose relational matches in an RMTS task, choosing object matches instead, while children in the control group succeeded at the task (Hoyos, Shao, & Gentner, 2016).

Consequently, we suspect that a language-acquisition pattern with noun dominance may induce learners to direct relatively more attention to objects. The preponderance of nouns is common to typical acquisition patterns of many languages (Gentner, 1982), consistent with the bias for object matches reported in most analogical literature. This dominance is reportedly attenuated among learners of Japanese, Korean, and Chinese. For example, native Mandarin learners may acquire equal numbers of nouns and verbs in their early vocabularies (Tardif, 2015). In several studies on parental language, caregivers who spoke Asian languages used more action-oriented words and verbs than English-speaking parents (Mandarin: Tardif, 2015; Korean: Au, Dapretto, & Song, 1994; Gopnik, Choi & Baumberger, 1996; Japanese: Fernald & Morikawa, 1993; Ogura, Dale, Yamashita, Murase, & Mahieu, 2006). Meanwhile, English-speaking caregivers preferentially used object names or verbs

that highlight objects (e.g., *see this*; Gopnik et al., 1996). Nevertheless, in a cross-linguistic comparison (Bornstein et al., 2004), noun dominance was present in Korean.

In analyzing how language contributes to differences in analogical reasoning, two points must be kept in mind: First, language can promote analogical reasoning in ways that are independent of cross-linguistic differences. For example, the learning mechanism in which language invites comparison and comparison highlights relational commonalities (Gentner & Namy, 2006) activates even when *novel* labels are used (Christie & Gentner, 2014). Second, we are unaware of direct evidence linking linguistic differences to analogical performance. Studies of East Asian children outperforming American peers in analogical tasks (Carstensen et al., 2019; Kuwabara & Smith, 2012) did not examine children's vocabularies. It would be interesting to test this potential link directly.

HOW ANALOGICAL REASONING AFFECTS DEVELOPMENT

Analogical reasoning fosters learning in many areas, including verb acquisition (Childers et al., 2016; Haryu, Imai, & Okada, 2011), spatial cognition (Gentner & Christie, 2006), and number concept (Carey, 2009; Sullivan & Barner, 2014). In learning by analogy, children acquire new concepts in two ways: by mapping structures of familiar events—base analogs—to new ones, and by aligning or comparing two representations, regardless of whether the representations are familiar. To examine how analogy shapes learning across cultures, we should see whether there are differences in base analogs and tendencies to compare.

Cross-Cultural Base Analogs: People

Children of diverse cultures are familiar with humans and relatively unfamiliar with other domains such as animals and plants

(Hatano et al., 1993). This makes *people* a good base analog, which children use to understand other domains (see Hatano & Inagaki, 2013, for a review). For example, when asked, “What will happen with X if we don’t give it water?” Japanese 6-year-olds often answered with an explicit person analogy (e.g., that X will be “thirsty”). Moreover, children’s use of person analogies was constrained: It was used in explanations about animate beings (rabbits or tulips) but not about inanimate entities (stones).

Consistent with this evidence, some suggest that children’s knowledge of roles (relations between people) is a building block to understand complex social structures such as hierarchies and norms (Christie, 2017; Tomasello, 2020). But it is unclear whether the degree of people-based relational abstraction will be the same across cultures. East Asian children pay greater attention to relations in abstract analogy tasks, so their knowledge of relations among people may also be greater. Relational language may also contribute: Languages like Mandarin and Japanese have richer terms for kinship (e.g., different words for older vs. younger brothers and sisters), while Indonesian obligates marking seniority (which Indonesian children are more attuned to; see Anggoro & Gentner, 2003). Therefore, even if the same base analogs are used in different cultures, other factors such as relational knowledge (contributed by attention to specific relations, relational language, or cultural socialization) or inhibitory control may make relational learning unequal (Dumas et al., 2018; Richland et al., 2006).

Do Children Compare the Same Way Across Cultures?

Analogical theories and extensive evidence from the West point to comparison as the key contributor to analogical learning (e.g., Dumas et al., 2018; Gentner & Hoyos, 2017). Therefore, a cross-cultural approach should inspect cultural differences in tendencies or opportunities to compare since this may produce unequal relational abstraction.

To examine this idea, we ask initially what catalyzes comparison in the first place? In explaining how people reason analogically, structure mapping theory (Gentner, 1983) posits that people first align events based on their surface similarities. This alignment results in one-to-one mapping between elements of the compared events, eventually resulting in abstraction of relational commonalities. The key here is that object similarity *invites* comparison—prediction two of the relational shift. For example, preschoolers learned novel verbs if they first saw a pair of similar events depicting the verbs, but children who saw a mix of dissimilar events did not learn the new verbs (Childers et al., 2016; Haryu et al., 2011). In this way, the same object similarity that hampers Western children’s relational reasoning can foster their relational abstraction in the long term. If East Asian children are less attentive to object matches, do they spontaneously compare less?

The only cross-cultural comparison study that directly pits object against relational similarity is one (Richland et al., 2010)

in which children had to map relations between scenes while ignoring object matches (e.g., map boy-the-chaser in the scene [boy chases girl] to cat-the-chaser in the scene [cat chases mouse, boy standing aside]). U.S. and Hongkongese children did *not* perform differently when an object distractor was present—object matches derailed them with equal likelihood. But in the same study, Hongkongese children outperformed their U.S. peers when the scene contained complex relations (e.g., Mom chases boy who chases girl). Consistent with these data, East Asian children might wield superior attention to relations without diminishing their sensitivity to surface similarities.

Several notes are in order. First, routes independent of object similarity may invite comparison. For example, calling two things the same label can invite comparison regardless of the label’s meaning (Christie & Gentner, 2014), although this route to comparison is less relevant to cross-cultural differences since all cultures have language. Second, attention to *relation* (rather than to object) may provide an invitation to compare. This is a valid proposal, but most studies of analogy do not isolate attention to relations from success in analogical reasoning (noticing relational commonalities). When learners succeed in analogy tasks (i.e., choose the correct relational match), implicit in their success is that they attended to the relation in question. Nevertheless, work in our laboratory with East Asian participants suggests that attending to single relations does not actuate attending to relational commonalities.

ANALOGY AS AN INSTRUCTIONAL TOOL IN CLASSROOMS

Analogy is used widely in classrooms around the world (Richland & Simms, 2015). Mirroring its powerful role in cognitive development, analogy allows students to compare representations and use their relational commonalities to understand new problems or concepts. A standard example is the water circuit analogy for understanding electrical circuits—mapping the behavior of a known entity (water) to a new one (electrical current). Unlike cognitive development, classroom use of analogy in different cultures is well documented. Across studies, three points emerge: First, teachers from all cultures view analogies as useful and important instructional tools (Richland, Zur, & Holyoak, 2007). Second, teachers from Japan and Hong Kong are more effective than American teachers in using analogies as instructional tools (Matlen, Richland, Klostermann, & Lyons, 2018). Third, students’ learning outcomes correlate with analogical use: Students from cultures with greater classroom use of analogy perform more optimally than those with less use (Richland et al., 2007). Given space limits, we focus on characterizing Japanese and Hongkongese teachers’ superior *use* of analogy.

Visual Support

The difficulty in using analogy is that students may be unfamiliar with the base scenario presented or unable to map it to the

target. A simple remedy is visual support: an explicit portrayal of the required mapping. For example, in one study, students learned to conduct mathematical comparisons most successfully when they were provided fully visible problems and solutions (i.e., when all problems and solutions were available visually, as opposed to being available partially, as when only the problem and not the solution are visible; Matlen et al., 2018).

Hongkongese and Japanese teachers were more likely than American teachers to present the source analog visually and to keep it visible throughout the comparison (Richland et al., 2007). They were also more likely to invite students to use mental imagery (e.g., “Picture a scale when you balance an equation.”). Providing explicit visualization during the comparison/analogy process may seem simplistic, but is well grounded in the theory of analogical learning: To arrive at relational abstraction, learners must align representations. Simply giving more exemplars without aligning them fails to confer the learning benefits of analogy (Christie & Gentner, 2010).

Gestures

The use of gestures can further facilitate alignment and mapping (Richland, 2015). Japanese and Hongkongese teachers used more linking gestures (e.g., hand and arm motions linking the two representations) and tied their use more effectively to students’ needs, for example, by intensifying gesture use with novice students (Richland, 2015). Another study yielded similar conclusions (i.e., greater use of gestures and visual diagrams by Japanese and Hongkongese teachers) and also confirmed in experimental settings that such supports improve learning outcomes (Matlen et al., 2018).

LOOKING FORWARD

Developmental studies from East Asia, although limited, put to question one of the most fundamental signatures of analogical development: that young children start with a strong bias for object similarity. Compared to their Western peers, children from East Asia seem more attentive to relations. This cultural difference in analogical tasks is consistent with cross-cultural differences from other domains: the differential attention to contexts versus objects among adults (Nisbett, 2004), or Eastern and Western caregivers’ distinct language use and attention guidance in interactions with children (Senzaki et al., 2016). But even if a direct causal relation between attention allocation and relational acumen can be established, we face a more pertinent question: Does the outcome—learning by analogical reasoning—differ across cultures?

Current data do not allow us to answer this question, but we offer several hypotheses. First, in areas where children’s knowledge base is likely to be the same across cultures, we expect similar cross-cultural learning by analogy. One example discussed earlier is familiarity with people, which children use analogically to understand the biological domain (Hatano &

Inagaki, 2013). Whether this assumption is correct for other domains awaits further cross-cultural data. Second, independent of knowledge, children can use comparison to gain relational abstraction (Christie & Gentner, 2010). Since object similarity prompts comparison, the degree to which children from all cultures attend to object matches affects the likelihood of comparison occurring and eventually, the incidence of relational learning. The results of a study mentioned earlier (Kuwabara & Smith, 2012) suggest that Japanese children are less object biased than their U.S. peers, but another study’s findings (Richland et al., 2010) suggest that Hongkongese children are like U.S. children in their preference for object matches. More data are needed to understand the universality and differences of comparison learning. Factors such as inhibitory control may also influence comparison and analogical learning (Domas et al., 2018); if the latter differs across cultures, further differentials in analogical reasoning may result.

Finally, our review of analogy use in instructional settings reveals clear cross-cultural differences. Unlike the developmental context, these differences are amenable to change. Japanese and Hongkongese teachers use analogy more effectively—and their greater effectiveness can be traced to simple tools and techniques: using linking gestures and keeping comparison items visible. Any teacher from any culture can adopt these techniques.

We close with a list of questions to advance the cross-cultural perspective on analogy and development:

- 1 Do children in non-Western cultures pay less attention to object similarities than to relational similarity? Answering this question requires studies that directly pit objects against relations, preferably with East Asian children (currently the most-studied group outside the West).
- 2 If East Asian children are less attentive to object matches, do they spontaneously compare less?
- 3 Is the relational shift universal, possibly happening at different times in different cultures? Answering this question requires a cross-cultural, longitudinal study on children’s spontaneous attention to surface and relational similarities.
- 4 Are East Asian adults more successful analogizers than adults in the West?

We hope this review and the questions we have raised make clear that cross-cultural analogical research should no longer be treated as a mere appendix to work on analogy. Pursuing cross-cultural questions can help reveal which aspects of analogical processing and learning are universal and which are malleable by culture. Answering these questions is a prerequisite to deciding whether analogy truly is what makes us smart (Gentner, 2003).

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