Title
Parental use of relational language with 3-year-olds in math and spatial activities: A cross-cultural perspective

Author
Zhang, Yu

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PARENTAL USE OF RELATIONAL LANGUAGE WITH 3-YEAR-OLDS IN MATH AND SPATIAL ACTIVITIES: A CROSS-CULTURAL PERSPECTIVE

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Yu Zhang

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The dissertation of Yu Zhang is approved:

Professor Su-hua Wang, Chair

Professor Barbara Rogoff

Professor Maureen Callanan

Quentin Williams
Acting Vice Provost and Dean of
Graduate Studies

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Abstract

Parental use of relational language with 3-year-olds in math and spatial activities: A cross-cultural perspective

Yu Zhang

Relational reasoning lies at the core of math and spatial learning. Like other cognitive abilities, relational reasoning is intertwined with one's own cultural experiences. Growing evidence has shown cross-cultural differences in attention to relation and object in East Asian and North American participants (Kuwabara & Smith, 2012; Masuda & Nisbett, 2001). However, our understanding of possible mechanisms beyond the cultural variations is limited.

The present study aimed to fill this gap by examining *how* mothers from first-generation Chinese immigrant and European-American cultural backgrounds use relational language with their 3-year-olds in math-related activities in everyday contexts (e.g., home). Specifically, we examined parental use of three types of relational language (e.g., structural relation, object similarity, self-association) in three activities (e.g., 3-D puzzle play, sorting activity, book reading). Additionally, we examined cultural variations in parental language that directs children's attention to labeling objects or events. As a secondary question, we investigated the correlation between parental relational language and children's math performance in four tasks (e.g., modified TOSA, matching dots, counting, give-n-task). Twenty European-American (English-speaking) and 16 first generation Chinese immigrant (Chinese-speaking) families were observed mostly at home.

Results showed that the Chinese immigrant mothers used a significantly higher proportion of structural relation in the puzzle and the sorting activities than European-American mothers. Chinese immigrant mothers also attended more to labeling objects or events than their counterparts. Generally, the mothers cross two groups used more structural relation in the puzzle and the sorting activities whereas they used more self-association in the book reading activity. No significant correlations were found between parental use of relational language and children's math performance in the four tasks. Together, the findings suggest a culturally specific way of engaging young children in relational learning by Chinese immigrant mothers, and offer important insights into how parental language practice may serve as a potential mechanism of early childhood math and spatial learning.

Dedication

For those first-generation immigrants who inspired me with their humbleness, bravery and resilience!

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Parental use of relational language with their 3-year-olds in math and spatial activities: A cross-cultural perspective

Children possess a tremendous cognitive ability to learn. Relational reasoning, the ability to discern meaningful patterns and regularities and make an inference in a new situation, lies at the core of human learning (Hofstadter, 2001). This ability allows us to solve mathematical problems, navigate maps and spatial locations, find differences and similarities across contexts, search for patterns and regularities in various situations, come to new conclusions or discoveries based on what have known, and so on. Relational reasoning can be challenging for young children. However, relational language, which involves making connections or comparisons, and highlighting underlying relational structures of objects or events, has been shown to facilitate children's relational reasoning (e.g., Loewenstein & Gentner, 2005; Valle & Callanan, 2006).

Like other cognitive abilities, relational reasoning is intertwined with one's own cultural experiences. A great body of research has shown cultural variations in attention allocation in children and adults from some East Asian and North American cultural communities (Carstensen et al., 2019; Kuwabara & Smith, 2012; Masuda & Nisbett, 2001, Richland et al. 2010). Participants from some of the East Asian communities (e.g., Hong Kong, Japan) tended to focus on contextual and relational information in various social and cognitive tasks. In contrast, participants from some of the North American communities tended to focus their attention on focal objects and their features (e.g., Ji et al., 2000; Nisbett et al., 2001).

The primary purpose of the present study is to fill the gap in cross-cultural research on children's linguistic experiences pertaining to relational reasoning. Specifically, the present research examined the similarities and differences in how parents from different cultural backgrounds talk with their children in early relational-learning activities in everyday contexts (e.g., home). The investigation focused on the types of relational language that first-generation Chinese immigrant (Chinese-speaking) and European-American (English-speaking) parents use with their 3-year-olds in three activities (e.g., puzzle play, sorting game, and book reading) that captured a range of everyday mathematical concepts.

Mathematical learning provided a useful platform to look into children's everyday experiences with relational learning. From a very early age, children are involved in math-related activities at home (Saxe et al., 1987). To date, much of the research on children's math learning has focused on number experiences (e.g., parental number talk), number knowledge, and the relationship between the two (Chang, Sandhofer, & Brown, 2011; Chang, Sandhofer, et al., 2011; Goodman et al., 2008; Huttenlocher et al., 1991; Levine et al., 2010; Jordan et al., 2007, but see Blevins-Knabe & Musun-Miller, 1996). However, children's everyday experiences with math learning extend beyond numerical activities. Children are provided with everyday opportunities to participate in various activities that involve much broader math-related concepts such as concepts about spatial relations, relative sizes, patterns, and comparisons. This study also aimed to extend the research to these broader areas of math learning. We took a sociocultural perspective (Rogoff, 2003; Rogoff et al. 2018) to examine children's learning experience in everyday contexts (e.g., at home).

Specifically, the study examined parental use of relational language that captures a broader level of mathematical concepts through parent-child interaction in three spatial and math learning activities, as children's cultural ways of learning are usually facilitated or scaffolded by parents or others in the community (Vygotsky, 1978).

Relational language and relational reasoning

Relational reasoning is a symbolic process for thinking about relational patterns and regularities between situations and making an inference in a new situation (Hofstadter, 2001). Relational reasoning is ubiquitous in our everyday learning environment, such as using maps, grouping objects, arranging patterns, learning new words, and interpreting others' social cues. Relational reasoning plays a critical role in math and spatial reasoning (Loewenstein & Gentner, 2005; Mix, 2009, Richland et al., 2007), and it is also an essential part of complex problem-solving (Holyoak, et al., 1984) and scientific reasoning (Dunbar, 1995; Valle & Callanan, 2006). For example, parental use of relational analogies helped children understand the illusion of motion that was produced by zoetrope exhibits in museums (Valle & Callanan, 2006).

Yet, it can be challenging for young children to reason relationally or see relational patterns and regularities in their problem-solving process. For example, research done with children at 3 to 4 years old tended to find it difficult to pick out correct relational correspondence when the situations involved complex relations (Richland et al., 2010). One of the main challenges has to do with the tendency that perceptual salience of object features could interfere with learning of new relations among objects (Ferry et al., 2015; Gentner & Rattermann, 1991, Son et al., 2008, 2011). For example, compared to simple shapes, objects with rich details were more likely to draw children's attention to the details and prevent them from appreciating the relational structure between the objects (Son et al., 2011). Relational reasoning can also be difficult for children due to less developed executive functioning capacity (Richland et al., 2006). Because reasoning about relationships requires learners to hold information in mind, control their attention relevant aspects and filter irrelevant information. It is a demanding process for young children. The lack of relational knowledge in certain domains can further hamper the relational-reasoning process (Cheng & Holyoak 1985; Gentner, 1989; Rattermann & Gentner, 1998a). This leads some researchers to argue that acquiring adequate knowledge of relations would help learners see relational structures and focus their attention on object properties (e.g., Rattermann & Gentner, 1998a).

To mitigate the demands of relational reasoning, Gentner (2016) argued that relational language can be powerful in promoting the acquisition of relational concepts and augmenting the capacity in the relational-reasoning process. The definition of relational language usually involves highlighting underlying relations between objects or events, inviting relational comparisons, and helping learners extract common structures between exemplars, and in turn, facilitating learning and transferring of relational concepts (Gentner, 2016). For example, Loewenstein and Gentner (2005) provided empirical evidence to support the idea that relational language augments children's cognitive ability. The study examined the role of spatial language on 4-year-old children's ability to represent and reason about spatial relations. Children were asked to retrieve an object from a three-tiered box after seeing the same object was placed in another perceptually similar box. The findings showed that children who heard spatial terms (e.g. in, on, under) in the task performed significantly better than the ones in the control condition who did not hear spatial terms but a general reference to location (e.g., "I am putting this here"). Therefore, hearing spatial relational language helped children perceive and conceptualize spatial relations among objects.

Relatedly, Rattermann and Gentner (1998b) examined the effect of using relational labels on children's performance in an analogical mapping task. In this study, researchers introduced 3-year-olds to the use of the relational labels "daddy/mommy/baby" to describe the relationship of monotonic change in size (e.g., large/medium/small), and then the children were asked to map objects based on their relative size. The results showed that by using relational labels to represent the relative size of exemplars, children were more likely to map objects based on their relational match, suggesting that relational terms highlighted the underlying relations between objects and in turn promoted children's performance in analogical mapping.

The role of relational language in promoting children's relational learning has also been examined in more naturalistic settings. An observational study by Valle and Callanan (2006) examined parental use of similarity comparisons in helping their school-aged children learn unfamiliar scientific topics in museum settings. Researchers analyzed parental use of similarity comparisons—statements connecting or comparing the exhibit to real-world objects or events—during the exhibit visit. Results showed that more than one-third of the parents used similarity comparisons during the visit. Among those similarity comparisons, about half of the comparisons were relational analogies—comparisons referred to a common relational structure between the objects or processes. The findings also revealed that parental use of relational analogies was positively associated with children's post-task performance of understanding of the topics.

Taken together, these studies indicate that relational language plays a critical role in children's learning and understanding of spatial and scientific concepts. Specifically, by learning relational labels that represent underlying patterns among exemplars children were more likely to map objects based on their relational structures. By hearing spatial relational terms that highlight spatial relations between objects and events, children were better at detecting spatial locations of hidden objects. In addition, through parental use of similarity comparisons that relate tasks at hand to more familiar real-world objects or events, children were better at learning abstract scientific concepts.

From a sociocultural perspective (e.g., Rogoff, 2003; Vygotsky, 1978), children learn through everyday communications and interactions with more knowledgeable others, and through participation in practices and activities that are available in their cultural communities. Language as an important cultural tool serves critical functions in everyday cultural practices and children's learning and reasoning. In the realm of relational reasoning, relational language facilitates children's understanding of relational concepts and structures, and in turn, promotes children's learning and transfer (Gentner, 2016).

However, most research studies that examine the links between relational language and relational reasoning have been conducted in the laboratories.

Laboratory experiments usually provide participants a controlled environment in which systematic cues or learning phases are provided. But as we may agree, children's learning environment in everyday life is never carefully controlled. Systematic and intentional teaching is not prevalent in parent-child interaction at children's early age in many cultural communities. Children are active participants in the social environment, and their learning happens in different forms and through various ways across cultural communities. What we have learned from the studies in the laboratories is important to understand the mechanism of analogical reasoning, but research that focuses on children's cultural experiences is crucial to deepen our understanding on relational reasoning and relational language use in everyday contexts.

Cultural variations in relational learning

Theorists have argued that people's thinking and reasoning shall not be viewed as a universal process, rather, it is by and large rooted in the cultural ideals and values of that community (Hofstede, 1980; Nisbett, 2003). Embedded in Confucian ideology, Chinese culture values harmonious relationships and tended to emphasize on collective agency in which individuals are understood as a part of a group, rather than separate entities on their own (Fung, 1948; Nisbett et al., 2001). Similarly, in the process of thinking and reasoning, one can not understand the part without understanding the whole (Nisbett, 2003).

One line of well-replicated cross-cultural studies has shown that adults and children from certain East Asian cultural backgrounds tended to employ a holistic cognitive process in relational reasoning compared to their counterparts from certain

North American cultural backgrounds (e.g., Kitayama et al., 2003; Nisbett et al., 2001; Peng & Paletz, 2011). For example, when asked to describe a scene (e.g., an aquarium), adults from the United States described the scene by focusing on the main focal object (e.g., a large fish in the center). In contrast, adults from Japan focused more on contextual components (e.g., water color, plants, small fish) in relation to the central fish. This finding along with many others (Kitayama et al., 2003; Masuda & Nisbett, 2001, 2006; Nisbett & Miyamoto, 2005; Nisbett et al., 2001) suggested that adults from some East Asian communities were more likely to allocate attention to relations within a larger whole while adults from European-American communities tended to focus attention on objects and their features.

Similar findings were obtained from developmental studies with children (Carstensen et al., 2019; Duffy et al., 2009; Kuwabara et al., 2011; Kuwabara & Smith, 2012; Moriguchi et al., 2011; Richland et al., 2010). For example, Carstensen et al. (2019) examined how Chinese and American 3-year-olds performed in a causal relational match-to-sample task. Results showed that Chinese children in China were more likely to identify relational patterns in the tasks and preferred relational matches in ambiguous settings compared to their English-speaking American peers. In another study, Richland and colleagues (2010) examined how relational complexity would affect U.S. and Hong Kong preschoolers' performance on pointing out the correct relational correspondence in pictures of everyday events. Participants were provided with pictures that depicted either one relation (low relational complexity) or two relations (high relational complexity) between the objects and characters. Results showed that Hong Kong children were more likely to pick out the correct relational correspondence across the pictures of everyday events than their U.S. counterparts when the relational complexity was high. Taken together, these findings suggested that adults and children from certain East Asian communities (e.g., China, Japan) were more likely than their counterparts from certain North American communities (e.g., the U.S., Canada) to pay attention to relations between objects and their contexts in their learning process.

Even though a large body of research has well supported the observed cultural pattern on relational learning, the possible mechanisms of the cultural pattern remains unclear. Researchers have argued that parent-child interaction is a contributing force to the cultural variation in children's relational learning (Christie et al., 2020; Kuwabara & Smith, 2016b). Up to date, very limited research has examined parent-child interaction as a possible mechanism beyond the cultural variations observed in the past research (Carstensen et al., 2019; Duffy et al., 2009; Kuwabara & Smith, 2012; Masuda & Nisbett, 2001). One study by Senzaki and colleagues (2016) investigated parental talk with their children (4-6 and 7-9 years old) in responding to different vignettes in a lab setting (Senzaki et al., 2016). The vignettes were similar to those used in Masuda and Nisbett (2001). In the study, parent-child dyads were asked to describe six vignettes jointly, and researchers later coded for parents' verbal description. Results showed that Japanese parents with children of 7 to 9 years of age made more references to context-related elements (e.g., backgrounds), whereas their American counterparts were more likely to focus on the focal objects during the interaction (Senzaki et al., 2016), providing further evidence to support the cultural variation in relational learning through parental talk with their children. The findings supported the view that parent-child interaction can may serve as a mechanism of children's relational learning.

Indeed, these findings provided evidence to help us think about the origins of these cultural variations, and the sociocultural perspective (e.g., Rogoff, 2003; Vygotsky, 1978) leads us to speculate that variations in the reasoning style are rooted in people's cultural beliefs and values which are embedded in their cultural practices and language in everyday contexts. Children's learning happens through their everyday interactions and communications with caregivers and others in the cultural community. Rogoff (2003) discussed the importance of the role parents play in everyday interaction. She posited a view that human development and learning is a cultural process through which children develop to be participants in the cultural communities, and there are different ways of interaction guided by the practices and values of different cultural communities. Thus, from Rogoff's sociocultural perspective, children's learning and cognitive development should be understood through their everyday cultural experiences.

We argue that taking on this perspective to study cross-cultural variations of children's learning is particularly important. Any observed cultural patterns should not be seen as a homogeneous group feature that applies to everyone with the group membership, as it would easily lead to overgeneralization based on only a limited sample population of certain cultural groups. Learning and development happen through everyday participation in cultural practices (Rogoff et al., 2018). In addition, relational learning is a complex process. To understand cultural similarities and differences require even more attentiveness to how children learn in their everyday settings.

Learning as cultural experience

Human as social beings live in different cultural communities, Vygotsky (1978) believes that all types of learning and cognitive reasoning are situated in cultural communities. Things that children learn and how they learn lie heavily in their everyday interactions with others. As Rogoff (2003) also argued, our thinking is rather a culturally specific process, and the cognitive development of a person is situated in his/her everyday cultural practices. Therefore, cultural variations in the performance of cognitive tasks could be explained by the variations of participants' everyday cultural experiences.

Indeed, children's learning experiences are likely shaped by their immediate contexts such as the physical environment and activities at the moment. Parents or other community members might engage in children's learning based on what is available at the moment and adjust their language use when the activity changes. For example, parents might naturally use more spatial language when playing blocks and puzzles with their children (Ferrara et al., 2011; Pruden et al., 2011), and make more personal connections and similarity comparisons when helping children understand abstract contents of a museum exhibit (Valle & Callanan, 2006). Thus, parent-child interaction is not only shaped by the large sociocultural environment but also influenced by the immediate activity at hand.

To understand children's cultural experiences in learning, cultural psychologists proposed a *situated perspective*—that is, instead of seeing culture as a category assigned to individuals, we should see culture as a “dynamic repertories of practices” where our learning happens in different ways which dynamically depend on certain contexts. (Bang, 2015; Rogoff et al., 2007). Relatedly, Hatano (1988) proposed an idea of *adaptive expertise*—the ability to flexibility apply and transfer conceptual knowledge to solve problems in novel situations. He argued that learners gain conceptual and meta-procedural knowledge in a certain domain by interacting with experts or more experienced others in their cultural community where rich artifacts are available for learning. At the same time, the knowledge is learned through the use of a symbol system (e.g., language, number) that’s adapted by that community. Both Bang’s (2015) and Hatano’s (1988) ideas highlight the importance of one’s everyday cultural practices in learning and development.

Therefore, in order to understand the manifestation of certain cultural variations in relational reasoning, researchers should situate children’s learning in their everyday contexts and investigate their cultural ways of learning. From the perspective of relational reasoning, investigations of parental use of relational language through their cultural experiences have significant implications in children’s learning and development.

The present study

Considering the importance of studying children’s cultural ways of learning through their lived experience, the significance of relational language in children’s cognitive development, and the lack of research on examining the possible mechanisms of cultural variations in children’s relational reasoning, the primary purpose of the present study was to explore how mothers from first-generation

Chinese immigrant and European-American backgrounds use relational language in three math and spatial activities (e.g., 3D-puzzle play, sorting game, book reading) with 3-year-olds in everyday settings (e.g., home). Particularly, we examined first-generation Chinese immigrant mothers who spoke Chinese (either Mandarin or Cantonese) and predominantly European-American mothers who spoke English in California, United States. We asked two questions: what kinds of relational language do parents use in each activity? How do parents from these two cultural backgrounds use relational language with their 3-year-olds?

Previous cultural research suggested parents from certain East Asian communities tended to view objects or events in a more holistic view than their North American counterparts. For example, Japanese parents tended to situate individual objects in the contexts (e.g., creating narratives that relate individual animal figures to the group), or direct children's attention to the contextual information (e.g., backgrounds) when describing different vignettes. In contrast, parents in some North American communities tended to focused on the focal objects and its attributes (Kuwabara & Smith, 2016b; Senzaki et al., 2016). Along this line, it seems plausible to predict that Chinese immigrant mothers might use more relational language that highlights relations among objects or events, particularly, they might be more likely to use a type of relational language that situates individual objects in relation to other objects and attend individual objects as a supporting component of a group. On the other hand, European-American mothers might focus more on non-relational aspects such as labeling objects and features.

Therefore, besides relational language, we also examined parental talk that focused on labeling surface level information of objects to see if there were cultural variations in parental use of object labeling. Based on past research that North American participants tended to focus on objects whereas East Asians tended to focus on relations (Masuda & Nisbett, 2001; Senzaki et al., 2016), we predicted that the European-American mothers would use more object labels than the Chinese immigrant mothers.

In addition, parental use of relational language might differ based on the activities at hand. The present study employed three activities that are commonly available to children in the current communities—a commercially available 3D wooden puzzle (see figure 1), a sorting set that contained 9 foam balls of three colors and sizes (see figure 2), and a wordless picture book that depicted a wide range of everyday math-related scenes (see figure 3). These activities were chosen to capture a range of math-related learning contexts that are common to children's everyday environment. Past research has shown that parents were sensitive to the immediate learning contexts and tended to adjust their use of language based on different types of toy manipulation (Ferrara et al., 2011; Verdine et al., 2019). In the present study, the 3D-puzzle and the sorting set involved manipulating and arranging groups of objects based on spatial relations, patterns, size organizations and so on. The picture book reading, on the other hand, usually involved interpreting and verbalizing what is depicted on the book page. Thus, it is plausible to predict that the mothers might use more relational language that highlights spatial relations or patterns in the 3D-puzzle and the sorting activity than the book reading activity.

Past research has shown positive correlations between parental talk (e.g., spatial terms, number talks) and children's later spatial reasoning or mathematical skills (Pruden et al., 2011; Verdine et al., 2017). Therefore, a secondary purpose of this research was to explore the links between parental relational language and children's math task performance. Based on past research on young children's math and spatial reasoning, we measured children's spatial ability with a modified TOSA (Verdine et al., 2014) in which children were asked to re-assemble premade Lego models. We also used additional three tasks to examine children's number sense: a matching dots task (Mix, 1999a; 1999b) in which children were asked to select a corresponding choice card that depicted the same quantity as the target card, a counting task where children were asked to count ten dots, and a give-n-task (Wynn, 1990) in which children were asked to give a certain quantity of toys to the researcher. Based on previous findings (Pruden et al., 2011; Verdine et al., 2017), we hypothesized that mothers' relational language use would positively correlate with children's math performance. However, it is worth noting the present study aimed to examine the parental relational language that captures a broader level of math-related concepts such as language that highlights patterns, spatial relations, size relations and similarity comparisons, whereas the past research (e.g., Pruden et al., 2011) has examined relational language as in specific spatial terms (e.g., deictic words, dimensional adjectives, shape terms). Also, past research has mainly examined the long term effect of parental use of relational terms on children's math-related performance at a later age (e.g., Pruden et al., 2011). Therefore, it is likely that we would not find correlations between parental relational language and children's math performance in the present study.

Method

Participants

The participants were 36 mothers and their 3-year-old children (17 girls, 19 boys; *M* = 38.3 months, *SD* = 5.1 months). There were 16 first-generation Chinese immigrant families (8 girls, 8 boys; *M* = 37.1 months, *SD* = 5.0 months; range: 30.1 months to 47.7 months) and 20 families (9 girls, 11 boys; *M* = 39.2 months, *SD* = 5.1 months; range: 30.5 months to 47.6 months) from predominantly European-American backgrounds.[1] The families were recruited from local libraries, word of mouth, or an existing subject pool from the Infant Development Lab at UCSC. The majority of families come were from middle-class backgrounds (see Table 1 for demographic information). All European-American and 6 of the Chinese immigrant families were recruited from the Bay area in California, and the remaining 10 Chinese immigrant families were recruited from Los Angeles, CA. All but 4 dyads participated at their own home. One European-American family preferred to participate in the lab, and three Chinese families participated in a study room at local libraries because it was part of their everyday activity such as toddler or preschooler story times and social gatherings in the libraries.

Thirteen of the Chinese immigrant families (81%) were originally from Mainland China, and 3 (19%) were from Taiwan. At the time of participation, the

[1] Four mothers were mixed ethnicity (2 Caucasians/Asian Pacific Islander, 1 Caucasian/Hispanic, 1 Caucasian/Native American)

mothers had lived in the United States for an average of 10.9 years (*SD* = 5.7 years, range: 2.5 to 22 years). Eight of the 16 Chinese immigrant families spoke Mandarin; they came from various cities in Mainland China (e.g., Hangzhou) or Taiwan. The other 8 Chinese families spoke Cantonese—a local dialect of the southeast provinces of China; they came from various cities in Guangdong province. Mandarin and Cantonese differ in phonological aspects: Mandarin has 4 tones and Cantonese has as many as nine tones. However, these dialects share the majority of the vocabulary and syntax (Organization for Economic Cooperation and Development, 2016). Given the shared linguistic aspects of the two dialects, we did not differentiate between Mandarin- and Cantonese-speaking families.

All of the European-American families spoke English and all except two[2] (90%) were born in the U.S. and had lived in the U.S. since born (*M* =35.6, *SD* = 7.5 years, range = 12 to 44 years). All children except one[3] were born in the U.S. (see Table 2 and Table 3 for more information about parental language and cultural backgrounds)

Procedure

The study procedure was identical for all families except for the language used (i.e., English, Mandarin, or Cantonese, whichever was their home language). After the mothers provided informed consent, the mother-child dyads were asked to draw a family scene together for 5 minutes as a warm-up activity. Next, the dyads

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[2] One mother was born in South Africa, and has lived in the U.S. for 24 years; another mother was born in Czech Republic and has lived in the U.S. for 12 years. For these two families, they only speak English at home.
[3] A Chinese immigrant child was born in Taiwan

engaged in three main activities in a fixed order, after which the mothers were asked to fill out surveys on demographic information, family language and acculturation experiences (see Appendix). While the mother was filling out the survey, the researcher carried out, in a fixed order, a series of early math and spatial tasks designed to measure early understanding of mathematical concepts.

Parent-child activities (30-35 minutes)

Activity 1: 3D puzzle. A commercially available toy set, "Bunny Peek a Boo" (Figure 1), that is suitable for children from 2 to 5 years was used. The toy set consisted of a wooden rabbit (approximately T 3.25 in x D 2 in) three wooden blocks: (1) a hollow blue cube block (3 in x 3 in) with two star and circle shape opening on the side of the block, (2) a yellow cuboid block (L 2.5 in x W 2.5 in x H 1.5 IN) with a circle opening on top; (3) a red cuboid block (L 2.5 in x W2.5 in x H 1.5 in) with a half circle opening; and (4) a set of game cards (see Figure 1 below).

Figure 1. Image of the "Bunny Peek a Boo" puzzle game. Image taken from the official toy website: https://www.smartgames.eu/uk/one-player-games/bunny-boo

In this activity, mother-child dyads were asked to sit next to each other either in front of a table or on the ground. The researcher placed the puzzle pieces in front of the dyads (from right to left: bunny, blue block, red block, and yellow block). A picture stand was used to hold the game card which was placed next to the puzzle. The dyads were asked to recreate the image shown on the game card (a front view) by using one or more blocks and the rabbit collaboratively[4]. The researcher first demonstrated how to make the front view of the pieces look like the game card. Then the dyads were given up to 9 trials (one trial at a time) to complete. The activity usually lasts around 20-25 minutes. The difficulty level gradually increased from two-block models to four-block models. The game was chosen because of two reasons. First, the game involved variety of spatial concepts especially three-dimensional spatial relations, and it was likely to elicit spatial relational language between the dyads. Second, the design of the blocks was attractive and suitable for 2- to 5-year-olds to play.

Activity 2: Sorting. After the first activity, the researcher provided a total of 9 foam balls for the mother-child dyads to sort however they want for about 5 minutes (see Figure 2). The balls were assorted in three colors (e.g., red, yellow, green) and three sizes: large (2.5-inch diameter), medium (2-inch diameter), and small (1.5-inch diameter). Each color set involved three balls varying in size (e.g., large, medium, small). A plastic egg carton was also provided to place the balls. The set of materials was chosen because it elicits attention to sorting, patterning, relative sizes, and one-to-one correspondence (Mix et al., 2011).

[4] Instructions: "In the activity, I want you and [child name] work collaboratively and try to make the front view of the puzzle pieces look like what shows on the game card."

Figure 2 Nine sorting balls of three assorted colors (red, green, yellow) and sizes (2.5 in, 2 in, 1.5 in).

Activity 3: Book reading. The mother-child dyads received a modified version of the book pages of *Math Counts* (see Figure 3 for sample pages). All of the original texts were removed leaving pictures only, and the pages were laminated and placed in a one-inch thick, three-ringed binder. The book pages covered a wide range of math-related concepts (e.g., size, pattern, sorting, number, shape) that children are commonly exposed to in their everyday life.

Figure 3 Sample book pages of modified Math Counts series by Henry Arthur Pluckrose after removing the texts

Children's early math and spatial tasks (10-15 minutes)

Task 1: Modified TOSA. The children were assessed on a modified[5] *Test of Spatial Assembly (TOSA)* (Verdine et al., 2014). The task required the children to recreate a model made of colored plastic Mega Blocks using a matching set of blocks. The preassembled models were glued together for the children to observe from different angles (see Figure 4). In the task, the researcher started with a demonstration trial to make sure that the children understood the task[6]. Then the researcher

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[5] We included children as young as 30-month-olds (ranged from 30 to 47 months), and 1/3 of children were younger than 36 months. The previous study (Verdine et al., 2014) involved children who were older than 36 months (ranged from 38 to 48 months). Therefore, we modified the original 3-D TOSA to better suit the current sample. The modified version included four models that were used in the original study, and four variations that differed in orientations of the upper piece(s).

[6] The researcher first showed the child a pre-assembled block model and the corresponding pieces, and said, "now I am going to show you how to make these block pieces look like this model right here." The researcher "I am going to try to make my pieces look just like this (point to the model)", then placed the pieces in a certain orientation that did not match the model (small piece was not aligned

proceeded to the test trials, one set at a time in a fixed order. The target model was always visible throughout children's respective trials, and no feedback was given during the trials. A total of 8 trials (see Figure 4) were used and the difficulty level gradually increases from two-block models to three-block models. After the test trials, the researcher took photographs of the constructions for later coding.

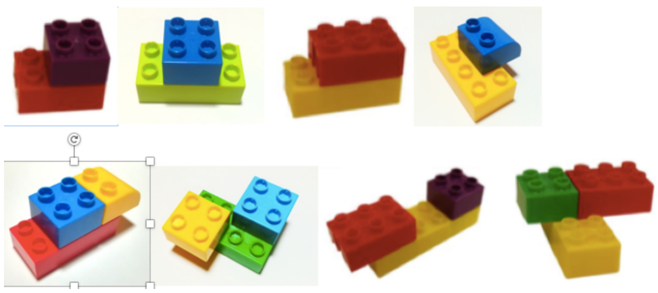

Figure 4 Modified TOSA that consists of four 2-block models (upper row) and four 3-block models (lower row).

Task 2: Matching dots. Next, the researcher carried out a quantity mapping task in which the children were asked to match small quantity of dots to a target picture in each set (Mix, 1999a; 1999b). The children were given a target card and two choice cards in each trial, and the children were asked to point to one choice card that has correct match with the target. The other choice card has the numeriosity either plus or minus 1 to the target set (see Figure 5 for a sample set). Each child received one demonstration trial and 3 practice trials, and then followed by 10 test trials[7]. In each trial, the target set and the choice cards were facing up and visible to

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with the bottom piece). Then as ask, "does this one look like the model?" if the child says No, researcher says, "you are right, it does not look like this model." If the child says Yes, research says, "hmm, no, it does not look like the model, it's different, could you show me where is different?" After confirming the child could identify the non matching model, the researcher then places the pieces in the correct formation.

[7] First, use the target set of one dot, researcher gave a demonstration, instruction: "We are going to play a new game. I will show you how it goes." Then, researcher present the target (at top middle) card with two choice cards at the bottom that's visible to the child. Then say "see, (point to the correct choice card), this goes with this card (point to the target card). Next, researcher proceed to practice

the child. Within each pair of choice cards, both cards were controlled for either density or line length, the order of the trials was counterbalanced.

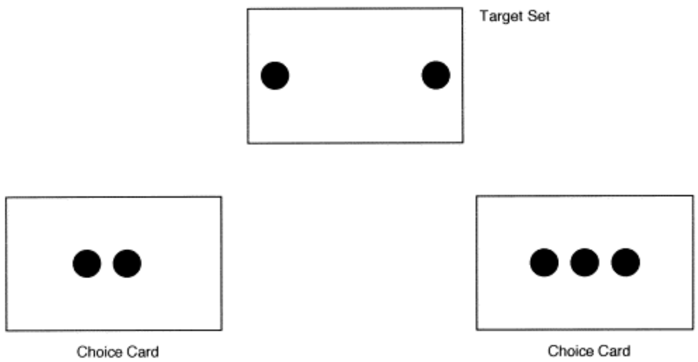

Figure 5 Sample test cards. Image taken from Mix (1999)

Task 3: Counting. The researcher then prompted the children to count from 1 to 10 while the child was pointing to a card with a line of 10 dots[8]. After counting the dots, the researcher asked the children how many dots there were.

Task 4: Give-n-task (Wynn, 1990). This task included 12 toy bananas, a black toy bowl, and a puppet puppy. In each trial of give-n-task, the researcher asked the children to give a number of items to the puppet puppy. The first trial was always a familiarization trial and the researcher asked for 1 banana, and it was followed by 6 test trials.[9] The requested quantity varied from 1 to 6.

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trials, says, "Now it's your turn" and the child receives three practice trials, instruction "see this (point to target), which card goes with this card?" (wait for 5 sec) if the child did not respond, say "could you point to the card that matches this (point to target). If correct, researcher says "That's right! That's the card! Good job!" If incorrect, researcher points to the correct answer and says, "Nope, that's not the matching card, this is the card that matches." After the practice trials, the researcher proceeded to the test trials. No feedback is given during test trials.

[8] Instruction: "could you put up your finger and point to the dots and count them?". After counting the dots, the researcher asked: "so how many dots are there?"

[9] Instruction: "we are going to play a new game now. In this game, you will help me give some fruit to my friend Jojo. Here are some fruits and this is my friend Jojo. Jojo likes to play, but she is very hungry now. Can you give her [number] banana please?"

Coding

Trained research assistants who are native English or Chinese speakers transcribed videotaped recordings of parent-child dyads' speech during the activities. To address our research question about parental relational language use, we developed a coding scheme that was derived from Valle and Callanan (2006) in which researchers investigated parental use of similarity comparisons to help their children understand museum exhibitions. Inter-rater reliability was established on 30% of transcripts (6 transcripts of European-American dyads and 5 transcripts of Chinese immigrant dyads). Simple agreement and Cohen's Kappa are reported below. Once we established reliability, parental language use in English and Chinese were coded in the relevant language by native speakers. Reliability disagreements were resolved through discussions.

Parental relational language in parent-child activities

The current coding scheme of relational language included three main categories, that is, 1) ***Structural relation*** was defined as instances that parents elicit attention to underlying relations among objects at hand. The structural relation could be highlighting spatial relation (e.g., "let's put the red piece on top of the yellow one"), patterns (e.g., "do you want to make these balls go red, yellow and green?"), size relation (e.g., we can make large, medium, and small), or analogous relation (e.g., "this is daddy ball, mommy ball, and baby ball"). 2) ***Object similarity*** was defined as instances when parents make explicit comparisons among the objects or events that are identical or similar in appearance (e.g., "it matches"; "does it look like the picture?", "this [puzzle piece] looks like a red bench"). 3) ***Self association*** was defined as instances that parents make connections between the current objects/events to child's previous experience or knowledge or explanations of real-life situation (e.g., "do you remember last time the teacher taught us this?" "we also have a thermometer at home so we know the temperature").

Besides the three categories of relational language, we also coded for the ***Object label*** instances when mothers direct children's attention to objects or events *without* relating, connecting or comparing to other objects or events. For example, an instance was counted when the parent was labeling an object or directing attention to certain attributes of the object (e.g., "what color is this?" "we need the bunny and the red one."); however, if an instance involved relating or making connections between objects/events, it was counted towards the corresponding relational language category. For example, "a man is in front of the truck" was counted as an instance of *structural relation*, as "in front of" implies a spatial relation between the man and the truck.

The rest of parental talk that did not fit the above categories was coded as instances of the ***others*** category (e.g., "look at this"; "let's see how we are going to make this", "that was fun"). As they did not speak to the research questions, we did not analyze this category except for including them in the total utterances each mother made during the activities.

In coding instances of parental talk, each instance was defined as a sentence or segments conveying a complete thought, even when subjects or verbs were not present. For example, "Ok, do you want to put the green one next to the red?" was counted as two instances ("ok" was counted as one instance of *other* category, "do you want to put the green one next to the red?" was counted as one instance of *structural relation* category). On the other hand, segments that did not convey a complete thought or involved simple repetitions of the same segments (e.g., "let's, let's put it inside") were counted as a single instance.

Inter-rater reliability was established on 30% of the transcripts. Simple agreement ranged from 79% to 95% across categories. Inter-rater reliability using Cohen's *k* was good to excellent, ranged from .74 to .94.

Children's performance on early math tasks

Children's performance of the modified TOSA was scored based on the scoring manual by Verdine et al. (2014) on dimensional score coding which follows two steps. In the first step, the relative location of the component piece to the base piece (the biggest piece or the piece that has the most other block pieces attached) was scored. The child received 1 point when the *vertical location* of a component piece matches the target, 1 point when the *orientation* of the component piece matches the target model, and 1 point when the component piece was placed over the correct pips to the base--*translation*. The second-step scoring was used on the four models involving three pieces (the lower row in Figure 4). Only the relation of the two component pieces was coded in the second step, points were given when the component pieces were placed in correct *vertical location*, *orientation*, and *translation* to each other. The total possible point of the task was 40 points.

For the Matching dots task, there were a total of 10 test trials, the researcher gave one point to every time the child made a correct response (i.e., pointed to the correct corresponding card in responding to researcher's request), resulting a total of

10 possible points. Next, when scoring children's performance on the Counting task, the researcher recorded whether the child was able to count to 10 without making any mistake, and whether they answered the *how many* question correctly. A child could be either correct or incorrect in counting to 10 and answering the *how many* question. In the give-n-task task, each child was given a total of six testing trials, and researcher gave one point to each time the child gave correct number of items, resulting a total of 6 possible points.

Results

The following sections report key analyses pertaining to the primary research questions that this study sought to address. Additional data analyses and results are included in Appendix E.

Parental use of relational language

The primary goal of this study was to examine the similarities and differences in the use of relational language by mothers from European-American (English speaking) and first-generation Chinese immigrant (Chinese speaking) families when they engaged their 3-year-old children in each of the three activities (i.e., 3D-puzzle, sorting, and book reading). Based on past research (e.g., Kuwabara & Smith, 2016b), the Chinese immigrant mothers were expected to use more relational language, especially structural relation in the puzzle and the sorting activities than their European-American counterparts.

As mentioned above, the utterances made by the mothers were coded as one of the five categories (including the *others* category). The number of total instances (aggregated across the five categories: *structural relation, object similarity, self* *association, object label, and others*) showed that in our sample, the Chinese mothers talked more in general (*M* = 431.8 total instances, *SD* = 177.5) than the European-American mothers (*M* = 350.7 total instances, *SD* = 101.6); however, the difference was not statistically significant, $t(34) = 1.73$, $p = .09$. Moreover, the Chinese mothers used significantly more structural relation instances (*M* = 78.9 instances, *SD* = 37.4) than the European-American mothers (*M* = 39.2 instances, *SD* = 19.1; $t(34) = 4.13$, $p < .001$, Cohen's $d = 1.34$). As can be seen in Table 4 that lists the descriptive data, a pattern seemed to emerge across three activities—that the Chinese immigrant mothers made more instances of structural relation than their counterparts in the 3D-puzzle ($t(34) = 2.89$, $p = .001$, Cohen's $d = .93$), the sorting ($t(34) = 4.56$, $p < .001$, Cohen's $d = 1.49$), and the reading ($t(34) = 2.36$, $p = .02$, Cohen's $d = .77$) activity.

To control for the marginally different total utterances made by the two groups, proportions were calculated by dividing the number of instances in each category of relational language by the total instances in each activity. The analyses in the subsequent section utilize the proportional data (see Table 5). Preliminary analyses indicated that demographic factors such as children's gender, age, and mothers' year of education (*p*s > .32) were not significantly linked to any key measures of parental use of relational language. Therefore, these factors were excluded from the subsequent analyses.

We first investigated whether the overall proportion of relational language of three categories (structural relation, object similarity, and self association) across three activities (3D-puzzle, sorting, and book reading) to the total instances mothers used in the three activities differed cross-culturally. An independent sample *t*-test revealed that, overall, the Chinese immigrant mothers used a significantly higher proportion of relational language (*M* = .30; *SD* = .09) than their European-American counterparts (*M* = .23; *SD* = .06; $t(34) = 2.44$, $p = .02$, Cohen's $d = .80$).

Next, we investigated whether parental use of each category of relational language across three activities differed cross-culturally. A series of independent sample *t*-tests revealed that the Chinese immigrant mothers used a significantly higher proportion of structural relation (*M* = .18; *SD* = .05) than their European-American counterparts (*M* = .11; *SD* = .04; $t(34) = 4.82$, $p < .001$, Cohen's $d = 1.59$). In addition, the European-American mothers were more likely to use object similarity comparisons (*M* = .06; *SD* = .03) than their Chinese immigrant counterparts (*M* = .05; *SD* = .03), but the difference did not reach statistical significance ($t(34) = 1.93$, $p = .06$, Cohen's $d = .65$). The mothers from two groups were similar in their use of self-association instances ($t(34) = 0.46$, $p = .7$).

3D-puzzle. An independent sample *t*-test revealed no significant group difference in the proportion of overall relational language used by the European-American (*M* = .26; *SD* = .09) and the Chinese immigrant (*M* = .30; *SD* = .09; $t(34) = 1.23$, $p = .23$, Cohen's $d = .41$) mothers in this activity. However, as alluded to in the Introduction, the 3D-puzzle activity may offer unique affordances for the use of the structural relation terms. This possibility was tested by a 3 (Relational Category: structural relation, object similarity, or self-association) x 2 (Culture Group: Chinese immigrant or European American) mixed ANOVA. As predicted, the results indicated that the Chinese immigrant mothers used a higher proportion of structural relation than their European American counterparts ($F(1, 34) = 7.57$, $p = .009$, partial

$\eta^2 = .18$) in this activity. There were no significant group differences for the categories of object similarity ($F(1, 34) = 2.66$, $p = .11$) and self association ($F(1, 34) = .06$, $p = .82$). See Figure 6.

Additional analyses examined the cross-group pattern of using the three categories. Across the two groups, the mothers tended to use a higher proportion of structural relation (*M* = .17, *SD* = .07) than object similarity (*M* =.08, *SD* = .05, *M* difference = .09, *SE* = .01, $p < .001$, CI of the difference [.06, .12]), and more structural relation than and self association (*M* = .02, *SD* = .02, *M* difference = .15, *SE* = .01, $p < .001$, CI of the difference [.12, .18]), and more object similarity than self association (*M* difference = .06, *SE* = .01, $p < .001$, CI of the difference [.04, .08]) in the puzzle activity.

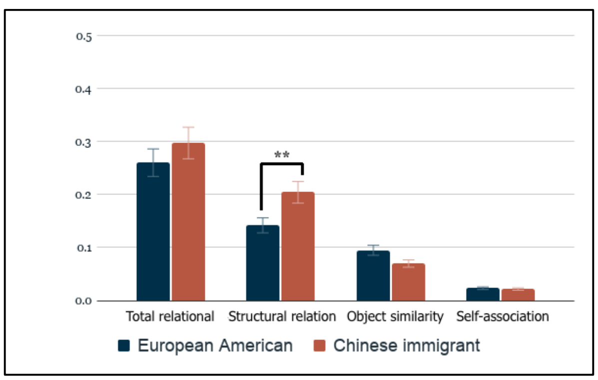

Figure 6. Proportion of relational language in 3-D puzzle activity

Sorting activity. As in the 3D-puzzle activity, the data aggregated across three categories showed that the Chinese immigrant mothers used a significantly higher proportion of relational language (*M* = .39; *SD* = .15) than the European-American mothers (*M* = .21; *SD* = .11, $t(34) = 4.10$, $p < .001$, Cohen's $d = 1.36$). Next, we examined the use of each category by the two groups of mothers. Similar to the puzzle activity, the Chinese immigrant mothers used a higher proportion of structure relation than their European American counterparts ($F(1, 34) = 21.75$, $p < .001$, partial $\eta^2 = 39$). No significant group differences were observed for object similarity ($F(1, 34) = 0.85$, $p = .77$) or self association ($F(1, 34) = 0.56$, $p = .46$). See Figure 7.

Similar to the puzzle activity, the mothers across two groups used a significantly higher proportion of structural relation ($M = .21$, $SD = .13$) than the category of object similarity ($M = .02$, $SD = .03$; M difference = .18, $SE = .02$, $p < .001$, CI of the difference [.13, .24]) and self association ($M = .06$, $SD = .12$; M difference = .15, $SE = .03$, $p < .001$, CI of the difference [.07, .23]) in this activity. There was no significant difference between the category of object similarity and self association (ps > .45).

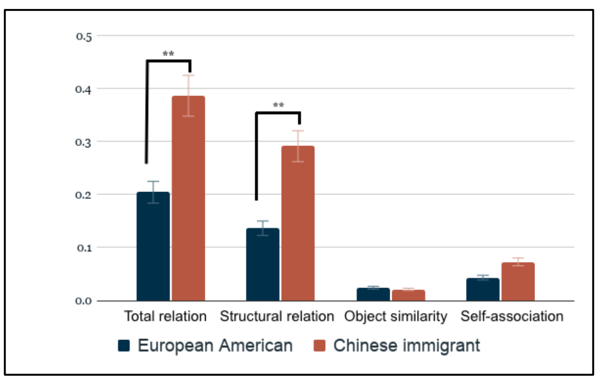

Figure 7. Proportion of relational language in sorting activity

Reading activity. The data aggregated across three categories revealed no significant group difference in the proportion of overall relational language used by the European-American ($M = .22$; $SD = .11$) and the Chinese immigrant ($M = .24$; $SD = .14$; $t(34) = 0.60$, $p = .55$, Cohen's $d = .40$) mothers in this activity. Next, we examined the use of each category**.** Differed from the puzzle and sorting activities, there was no significant culture differences in the type of relational language in the book-reading activity ($F(1, 34) = 0.40$, $p = .53$).

Additional analyses examined the cross-group pattern in their use of the three categories of relational language. Differed from the puzzle and sorting activities, across the two groups, the mothers used a significantly higher proportion of self association ($M = .17$, $SD = .02$) than structural relation ($M = .05$, $SD = .05$; M difference = .12, $SE = .02$; $p < .001$, 95% CI of the differences [.07, .17]) which in turn was used at a higher proportion than object similarity ($M =.01$, $SD = .02$; M difference = .04, $SE = .01$; $p = .001$, 95% CI of the differences [.01, .06]).

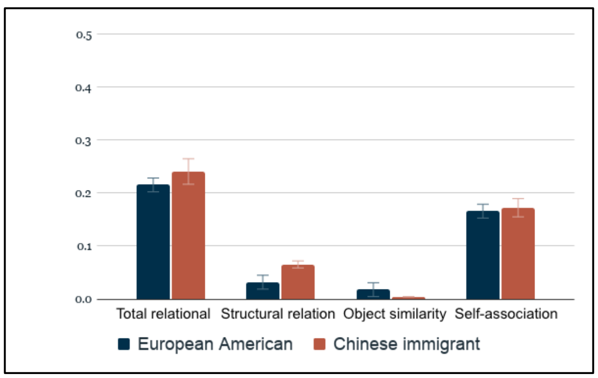

Figure 8. Proportion of relational language in reading activity

Activity type and parental relational language

The results so far have clearly indicated that the use of relational language is sensitive to the type of activities that the dyads engaged in. To further clarify the relation between the activity type and children's language experience, we conducted a two-way repeated measure ANOVA to compare the proportion of relational language used by the mothers in the categories of structure relation, object similarity, and self-association by the activity type of puzzle, sorting, and reading. This 3 x 3 ANOVA revealed a significant interaction of language category and activity type ($F(4, 140) = 53.25$, $p < .001$, partial $\eta^2 = .60$). Pairwise comparisons with Bonferroni corrections (see Figure 10) indicated that the mothers used a significantly higher proportion of structure relation in the puzzle activity (*M* = .17, *SD* =.07) and sorting activity (*M* = .21, *SD* = .12) than the reading (*M* = .05, *SD* = .05) activity (*M* differences = .12 vs .15; *SE* = .01 vs .02, *p*s < .001, 95% CI of the differences [.10, .15] vs [.11, .21]). In addition, the mothers were more likely to speak about object similarity in the puzzle activity (*M* = .08, *SD* = .05) than the sorting activity (*M* = .02, *SD* = .03, *M* difference = .06, *SE* = .01, *p* < .001, CI of the difference [.04, .09]) and the reading activity (*M* = .01, *SD* = .02, *M* difference = .07, *SE* = .01, *p* < .001, CI of the difference [.05, .09]). In addition, the mothers used a higher proportion of self-association in the book reading activity (*M* = .17, *SD* = .11) compared to the puzzle activity (*M* = .02, *SD* = .02; *M* difference = .15, *SE* = .02; *p* < .001, 95% CI of the differences [.10, .19]) and the sorting activity (*M* = .06, *SD* = .12); *M* difference = .11, *SE* = .02; *p* < .001, 95% CI of the differences [.06, .16]). See Figure 9.

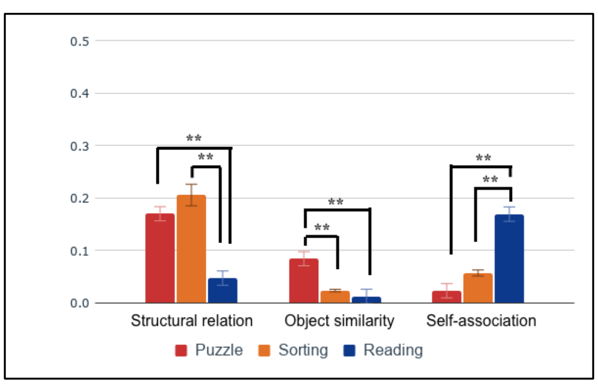

Figure 9. The proportion of parental use of relational language for each category by activity type

Children's math performance

The secondary purpose of this study was to examine children's performance on the four math tasks and test their performance was correlated with parental use of relational language (see the descriptive data in Table 6). Pearson's correlation analyses were conducted to investigate the association between parental use of relational language (across all activities, by each relational category, and by each activity), and children's performance on each of the four tasks (see Table 7 and Table 8). Across the three activities, there were no significant correlations between children's math performance and the proportional use of relational language overall (ps > .20), for each category (ps > .14), or for each activity (p > .07). Further correlation analyses separating two groups of families showed that for European-American families, parental use of structure relation negatively correlated with children's performance on Give-n-task ($r = -0.47$, $p = .05$). There were no other significant correlations between the proportions of relational language and children's math performance for either culture group (ps > .12), see Table 7.

In general, older children performed significantly better than younger children in the modified TOSA ($F(1, 23) = 7.32$, $p = .01$ partial $\eta^2 = .24$) and the Give-n-task ($F(1, 23) = 9.90$, $p = .005$, partial $\eta^2 = .30$), and marginally better than younger children in the matching dots task ($F(1, 23) = 3.81$, $p = .06$, partial $\eta^2 = .14$). In addition, Chi-square analyses showed no significant effects on the performance of counting to 10 based on gender ($\chi^2(1, 32) = 2.33$, $p = .13$), culture group ($\chi^2(1, 32) = .35$, $p = .56$), and age group ($\chi^2(1, 32) = 1.66$, $p = .20$), and there were no significant effects on the performance of answering the *how-many* question based on these characteristics as well (ps > .40). See the descriptive data in Table 6.

Parental use of object labels

Beyond relational language, we examined maternal use of object labels during the three activities. Based on the previous research on cultural variations in children's and adults' attention to object and relation (Kitayama et al., 2009; Kuwabara & Smith, 2012; Masuda & Nisbett, 2001), we hypothesized that the European-American mothers would use more object labels than the Chinese immigrant mothers. However, a reverse pattern was observed in the data aggregated across the three activities and the data from the reading activity. Contrary to the prediction, a 3 (Activity type) x 2 (Culture Group) mixed-ANOVA comparing the aggregated data revealed that the Chinese immigrant mothers in our sample used a significantly higher proportion of object labels (M = .31, SD = .07) than the European-American mothers (M = .26, SD = .06; $F(1, 34) = 8.59$, p <.01, partial $\eta^2 = .20$). Combining the two groups, the mothers used a significantly higher proportion of object labels in reading activity (M = .47, SD = .12) than in the puzzle activity (M = .21, SD = .08, M difference = .26, SE = .02; p < .001, 95% CI of the differences [.21, .31]) and the sorting activity (M = .22, SD = .10, M difference = .25, SE = .02; p < .001, 95% CI of the differences [.19, .31]). See Figure 10.

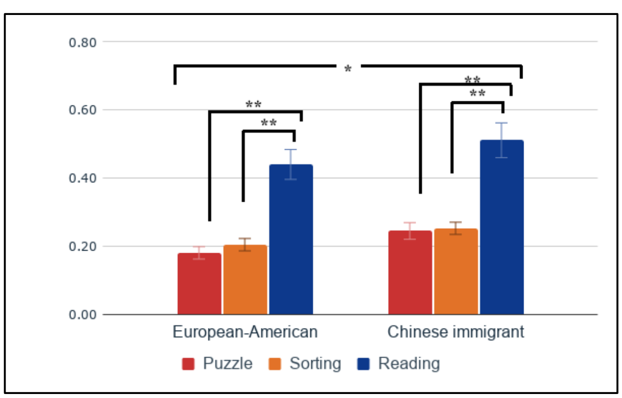

Figure 10. Proportion of object labeling in three activities

Discussion

Parental relational language

Overall, the Chinese immigrant mothers in our sample used a significantly higher proportion of relational language (aggregated across three categories) than their European-American counterparts. This pattern was mainly driven by the difference in mothers' use of structural relation. The Chinese immigrant mothers used a significantly higher proportion of structural relation in the puzzle and the sorting activities than their European-American counterparts. In other words, in the activities that involved arranging or manipulating groups of objects (e.g., puzzle pieces, sorting balls), the Chinese immigrant mothers were more likely to relate objects to one another through spatial organization or pattern arrangement than the European-American mothers. On the other hand, a trend seems to emerge that the European-American mothers, in general, tended to make more explicit comparisons based on object similarities (i.e., object similarity) than the Chinese immigrant mothers, however, the difference did not reach a statistical significance. In addition, the two groups connected children's prior knowledge or experience to the current objects or event (i.e., self association) in a similar proportion of their talk.

The findings partially resonated with the past research on parent-child interaction in toy play situations. In particular, Kuwabara and Smith (2016b) found that compared to the American parents, the Japanese parents in their study tended to group animal figures together and create narratives that relate individual actions to the group. The present study provided a closer look at three types of relational language used by parents in their children's everyday math learning contexts. Of the three types of relational language, the Chinese immigrant mothers only used the structural relation category at a higher rate than their European-American counterparts.

This finding may be explained by the differences in how structural relation, object similarity, and self association depict interrelationships between objects or events. In the structural relation category, individual objects are put in context with other objects. That is, an individual object is described in relation to one another and is viewed as a supporting component of a group. On the other hand, both object similarity and self association draw comparisons between distinct individual entities. Specifically, object similarity stresses the explicit comparisons between separate entities (e.g., whether the puzzle set matches the target picture), and self association highlights connections and similarities between the current event and children's knowledge or experience.

Given the prior finding that East Asians were more likely than North Americans to consider individual objects in context with other components as a holistic group (Duffy et al., 2009; Kuwabara & Smith, 2012; 2016a; Masuda & Nisbett, 2001), it is unsurprising that cultural differences emerged specifically in the type of relational language (i.e., structural relation) that considers individual objects in relation to one another and each individual object is viewed as a supporting component of a group. For example, a common instance by the Chinese immigrant mothers during the sorting activity was "*we can make it large medium small*". In this instance, an individual ball was put in contexts and considered as a part of a group that conveys a relational pattern. Each object was understood through its size relation with the others.

As discussed in the Introduction, Chinese culture, rooted in Confucian ideology, values harmonious relationships (Fung, 1948). This emphasis on relationality could shape people's perception of the physical environment (Ji et al., 2000; Nisbett et al., 2001) and how parents engage their children in everyday interactions (Kuwabara & Smith, 2016b). Through this cultural lens, individual objects in the physical environment shall not be viewed as separate entities independent from their contexts or environment. Rather, individuals are understood as a part of a group (Nisbett et al., 2001). When engaging in activities such as describing vignettes or grouping objects (Kuwabara & Smith, 2016b; Senzaki et al., 2016), the East Asian participants tended to see objects or events as a holistic group in which each component was interrelated with one another as well as related to the group. The present findings supported the cultural phenomenon that certain East Asian participants tended to be more holistic in perception and cognitive processes than their North American counterparts (Masuda & Nisbett, 2001; Nisbett et al., 2001; Nisbett & Miyamoto, 2005).

Besides cross-cultural investigations, a possible future step can examine parental language practice within its own cultural group to understand individual variations in children's learning experiences. For example, families' cultural background could also be intertwined with families' home language and their socio-historical contexts, such as birth place, family tradition, living neighborhood, occupation, income, etc. Thus, further investigations of within group variations can offer insights of children's learning experience at an individual level.

Parental use of relational language is context-dependent

In general, the mothers from both groups adjusted the types of relational language based on the activity at hand. When engaging in activities involving spatial manipulation (i.e., puzzle) or pattern organization (i.e., sorting), the mothers were more likely to use structural relation that draw attention to underlying relations between objects. On the other hand, when engaging in the book reading activity in which the pages depicted everyday math-related events or objects, the mothers were more likely to connect the book content to children's past experience or knowledge.

These findings revealed that children's experience with parental relational language was context-dependent. The results resonated with the previous studies (Ferrara et al., 2011; Verdine et al., 2019) that parents would adjust their use of language based on the context of the activity. Similarly, the mothers in the present study adjusted the types of relational language based on the activity at hand. From the sociocultural perspective, parent-child interaction is usually shaped by the immediate contexts that the dyads are situated in (Bang, 2015; Hatano, 1988; Rogoff et al., 2007). For example, the book reading activity provided an immediate context for the dyads to engage in self-reflection and explanation, whereas the puzzle activity and the sorting activity served as learning grounds for the dyads to engage in spatial arrangement and pattern making. Broadly speaking, children's learning opportunities are embedded in their everyday contexts that involve different kinds of activities. Here, we provided three sets of activities that parents may do with their children in everyday life to look into children's learning experiences. The results speak to the critical role of children's immediate contexts in shaping their everyday learning experiences.

Taken together, the present findings on parental use of relational language carried significant implications in cross-cultural research on relational learning. First, this investigation of relational language encompassed different types of relational concepts in parent-child interactions, which allowed researchers to get a more nuanced view of relational language practices used by the mothers from two cultural groups across different activities. Parental language practice was found to be activity-dependent, underscoring the importance of the immediate contexts in shaping children's learning experiences. Second, the findings speak to a culturally-specific relational learning experiences in Chinese immigrant families. It is possible that continued exposure to relational language that highlights relation of objects to one another and the contexts could help Chinese-heritage children attend to relevant relational aspects more often in their learning experiences than their European-American peers. From this view, the present results could serve as a potential explanation for the observed cultural variations in children's response in various cognitive tasks (Duffy et al., 2009; Kuwabara & Smith, 2012; Masuda & Nisbett, 2001; Richland et al., 2010).

Besides the verbal language that was examined in the present study, future studies could examine parental use of non-verbal relational gestures (e.g., linking gesture, iconic gesture) that connect and compare objects in parent-child interactions because of two reasons. First, researchers have found that the use of relational gestures (e.g., linking gestures, comparative gestures) was positively correlated with mathematical and spatial understanding and learning in children and adults (Goldin-Meadow & Alibali, 2013; Richland, 2015; Richland & McDonough, 2010; So, Shum,

& Wong, 2015). Second, our everyday communication involves both verbal language and non-verbal gestures and cues. Research of non-verbal communication carries functions to widen our understanding of children's cultural ways of learning and education.

Correlation between relational language and children's math performance

The secondary purpose of this study was to tested whether children's math performance was correlated with parental use of relational language. In general, older children performed better than their younger peers in the math tasks. This finding supports the existing literature on the developmental trajectory of children's learning and math understanding, where children's mathematical understanding is positively correlated with their age (Sarnecka & Carey, 2008; Sophian 2007).

In addition, the results showed no significant correlations between parental relational language (across all activities, by each relational category, or by each activity) and children's performance on each of the four tasks, suggesting that parental relational language may not be associated with children's math performance at the moment. It is possible that continued exposure to parents' relational language would contribute to children's math learning in the long run. Children usually undergo gradual transformations in their learning and development. Research shows that parental language serves as an important resource for children's learning (Levine et al., 2010). Still, such influences likely emerge over time and across experiences. Indeed, many previous studies have used a longitudinal design to examine the correlation between children's exposure to spatial and number language and their math performance or academic performance at a later age (Casey et al., 2018; Levine et al., 2010; Pruden et al., 2011). This type of design allows researchers to look into children's long term exposure to certain language practice at home with their parents. A possible future follow-up study could employ a longitudinal design to examine parents' relational language use at different time points and investigate the correlation between parental relational language across time and children's math and spatial understanding at a later age.

Another possibility is that children's own production of relational language might play a more significant role in their math performance than parents' relational language at the moment. Past research suggested that children's spatial word production predicted their performance on subsequent spatial tasks (Hermer-Vazquez et al., 2001; Miller et al., 2016; 2017; Polinsky et al., 2017). For example, 5- to 6-year-old children's own production of spatial words such as *left* and *right* positively associated with their performance on the spatial tasks that were related to those relations (Hermer-Vazquez et al., 2001). Similarly, 4-year-olds' spatial language during parent-child interaction, predicted their subsequent puzzle performance (Polinsky et al.,2017). It is plausible that children's own production of certain relational words is a more accurate representation of their apprehension of certain relational concepts, which in turn is were more likely to correlate with their performance. Future work could consider children's relational language production and its relation to their math performance.

Object labels. Contrary to our prediction, the results showed that compared to the European-American mothers, the Chinese immigrant mothers were more likely to label objects or direct children's attention to certain attributes of objects (e.g., "what color is this?" "we need the bunny and the red one", "I see radishes and carrots"). This finding might seem surprising because past research showed that Canadian parents were more likely than Japanese parents to mention focal objects and their features when describing different vignettes with their 7- to 9-year-olds, whereas Japanese parents were more likely to mention contextual information, such as background objects (Senzaki et al., 2016). However, driven by the purpose of the study, the coding scheme focused on relations, connections and comparisons among objects in mothers' talk. As the non-relational category, object labeling instances direct children's attention to label objects without making connections or comparisons with other objects or events, regardless of whether it referred to focal objects or background objects in the activities. It could be possible that Chinese immigrant mothers in the study used object labels to attend to both focal and background objects during the interaction. Future research could be conducted to examine how often parents draw children's attention to focal objects or background objects to gain a deeper understanding of parental use of object labels.

Linguistic variations

Given the participants in the present study involved Chinese-speaking and English-speaking participants, some might argue that the variation in parental use of relational language could be attributed to the linguistic variations between Chinese and English. Past research has shown that caregivers who spoke Asian languages (e.g., Japanese, Korean, Chinese) used more action-oriented words and verbs such as *ate*, *swimming* than English-speaking parents (Au et al., 1994; Fernald & Morikawa, 1993; Gopnik et al., 1996; Tardif et al., 1999). English speaking caregivers preferentially used common nouns such as naming objects and non-referential verbs such as *looks like*, *watch* (Goldfield, 1993; Gopnik et al., 1996). Researchers argued that by using referential verbs in everyday language, children were more readily to pay attention to the interactions between entities and their relations with one another (Richland et al., 2010). The present study approached parental language in a different way. We coded parental relational language based on whether it was making connections or comparisons between objects or events. A high proportion of relational language involved prepositions (e.g., inside, on top of, behind, etc.) and naming objects (e.g., "let's put the red piece on top of the yellow one," "do you want to make these balls go red, yellow and green?"). We paid close attention to the linguistic meanings when coding parental relational language. For instance, the Chinese immigrant mothers often used the word "里面" to refer to the spatial relation of "inside"; however, sometimes they would use the term to refer to "about something". Thus, the latter case would not be considered towards relational language.

We acknowledge the importance of linguistic variations in different languages, and how they could contribute to our learning and communication. Studies with bilingual participants could be useful to examine the linguistic aspect of language in parent-child interaction. For example, if it was the linguistic variation between Chinese and English predicted the difference in parental use of relational language, then we should expect that fluent Chinese-English bilingual parents would use more relational language (e.g., structural relation) when speaking Chinese and less so when speaking English. However, it is also critical to be aware of how language is an important cultural tool that is intertwined with one's value and historical contexts. We should not see linguistic aspects of a language as independent from one's cultural context and practice.

Concluding remarks

In conclusion, the present study examined parental use of relational language with their 3-year-olds in everyday math and spatial activities across two cultural communities—first-generation Chinese immigrant and European-American families. Both Chinese immigrant mothers and European-American mothers used three types of relational language and the types of relational language varied depended on the immediate contexts (e.g., activity) they were engaging in. The Chinese immigrant mothers were more likely to use relational language that relates objects with one another through spatial organizations or pattern arrangements than their European-American counterparts. On the other hand, the mothers of both groups were similar in making explicit comparisons based on object similarities and children's prior knowledge/experience. The present study showed that the mothers from both groups used the activities as contexts to engage young children in relational learning, complementing the sociocultural view that children's learning is situated in their everyday cultural experiences (Bang, 2015; Rogoff, 2003). In addition, our findings revealed both similarities and variations in parental use of relational language, suggesting a culturally specific way of engaging young children in relational learning by Chinese immigrant parents. These findings offer important insights into how parents from different cultural communities engage their children in relational learning through the use of relational language, and how parental language practice may serve as a potential mechanism of early childhood math and spatial learning.

Table 1. Demographic information of families

		European-American		Chinese Immigrant	
		M (yrs)	*SD*	*M (yrs)*	*SD*
Child age		39.2	5.08	37.1	4.94
Mother age		38.0	4.24	34.4	4.85
Father age		40.9	6.23	38.9	9.36
Mother education		15.9	2.06	15.1	3.19
Father education		15.7	2.46	15.9	2.33
		N	*%*	*N*	*%*
Child gender	Boy	11	55%	8	50%
	Girl	9	45%	8	50%
Family income	<30K	2	11%	3	19%
	30K-50K	0	0%	4	25%
	50K-75K	3	16%	0	0%
	75K-100K	3	16%	3	19%
	>100K	11	58%	6	38%

Table 2. First-generation Chinese immigrant mothers' language and acculturation information (Proportions appear in parentheses)

	Only Chinese	More Chinese than English	Both Equally	More English than Chinese	Only English
In general, what language do you read and speak?	2 (.13)	11 (.69)	3 (.19)	0	0
What was the language you used as a child?	16 (1)	0	0	0	0
What language do you usually speak at home?	12 (.75)	4 (.25)	0	0	0
What language do you usually speak with your friends?	6 (.38)	7 (.44)	2 (.13)	1 (.06)	0
In what language(s) are the television programs you usually watch?	6 (.38)	5 (.31)	4 (.25)	1 (.06)	0
In what language(s) are the online media/websites you usually browse?	5 (.31)	9 (.56)	2 (.13)	0	0
	Only Chinese	More Chinese than Americans	Both equally	More Americans than Chinese	Only Americans
Your close friends are	5 (.31)	11 (.69)	0	0	0
As you grew up, your friend groups were from	8 (.57)	6 (.43)	0	0	0
You prefer going to social gathering at which the people are from	2 (.13)	11(.69)	2 (.13)	1 (.06)	0
The persons you visit or who visit you are from	7 (.44)	8 (.5)	1 (.06)	0	0
If you could choose your children's friends, you would want them to be	1(.06)	1 (.06)	13 (.81)	1 (.06)	0
The people of the neighborhood you grew up in were from	14 (1)	0	0	0	0
The people of your current neighborhood are from	0	2 (.14)	5(.36)	3(.21)	4 (.29)
The people of your current workplace are from (if applicable)	1 (.17)	1 (.17)	1 (.17)	1 (.17)	2 (.33)

Table 3. European-American mothers' language and acculturation information (Proportions appear in parentheses)

	Only English	More English than other language	Both Equally	More other language than English	Only other language
In general, what language do you read and speak?	15 (.79)	4 (.21)	0	0	0
What was the language you used as a child?	17 (.90)	1 (.05)	0	0	1 (.05)
What language do you usually speak at home?	18 (.95)	1 (.05)	0	0	0
What language do you usually speak with your friends?	18 (.95)	0	1 (.05)	0	0
In what language(s) are the television programs you usually watch?	16 (.84)	3 (.16)	0	0	0
In what language(s) are the online media/websites you usually browse?	17 (.90)	2 (.10)	0	0	0
	Only my own ethnic backgrou nd	Mostly my own ethnic background	Equally mixed ethnic backgrou nds	Mostly other ethnic background than my own	Only other ethnic background than my own
Your close friends are from	2 (.11)	12 (.63)	5 (.26)	0	0
As you grew up, your friend groups were from	2 (.13)	12 (.75)	2 (.13)	0	0
You prefer going to social gathering at which the people are from	1(.05)	4 (.21)	14 (.74)	0	0
The persons you visit or who visit you are from	2 (.11)	11 (.61)	4 (.22)	1 (.06)	0
If you could choose your children's friends, you would want them to be	0	0	18 (.95)	1 (.05)	0
The people of the neighborhood you grew up in were from	3 (.17)	11 (.61)	2 (.11)	2 (.11)	0
The people of your current neighborhood are from	2 (.11)	14 (.78)	2 (.11)	0	0
The people of your current workplace are from (if applicable)	0	4 (.29)	9 (.64)	1 (.07)	0

Table 4. Mean frequency of parental use of relational language instances by category and parental use of object labeling (Standard deviations appear in parentheses)

	European-American (*n* = 20)				Chinese Immigrant (*n* = 16)			
Relational (frequency)	Puzzle	Sorting	Reading	**Total**	Puzzle	Sorting	Reading	**Total**
Structural relation	27.3 (15.3)	8.6 (5.6)	3.3 (3.1)	39.2 (19.1)	52.7 (35.5)	19.6 (8.8)	6.6 (5.4)	78.9 (37.4)
Object similarity	18.4 (9.5)	1.7 (2.9)	1.7 (1.4)	21.8 (10.0)	16.1 (11.6)	1.9 (2.8)	.5 (1.1)	18.6 (12.2)
Self-association	4.7 (5.5)	3.0 (3.9)	15.4 (9.8)	23.1 (14.3)	5.9 (7.2)	5.6 (11.5)	18.6 (13.3)	30.1 (25.6)
Total	50.4 (24.3)	13.4 (8.1)	20.3 (25.7)	84.1 (33.7)	74.8 (44.0)	27.1 (14.6)	25.7 (16.0)	127.6 (56.3)
Non-relational (frequency)								
Object labeling	34.6 (17.8)	14.1 (9.6)	41.7 (13.2)	90.3 (26.2)	63.4 (43.6)	18.2 (14.3)	54.7 (19.6)	136.3 (68.7)

Table 5. Mean proportion of parental use of relational language by category and parental use of object labeling (Standard deviations appear in parentheses)

	European-American (*n* = 20)				Chinese Immigrant (*n* = 16)			
Relational (in proportion)	Puzzle	Sorting	Reading	**Total**	Puzzle	Sorting	Reading	**Total**
Structural relation	.14 (.06)	.14 (.10)	.03 (.03)	.11 (.04)	.20 (.08)	.29 (.10)	.07 (.06)	.18 (.05)
Object similarity	.10 (.05)	.03 (.04)	.02 (.02)	.06 (.03)	.07 (.04)	.02 (.03)	.004 (.01)	.05 (.03)
Self-association	.02 (.02)	.05 (.06)	.17 (.11)	.07 (.04)	.02 (.02)	.07 (.16)	.17 (.11)	.07 (.07)
Total	.26 (.09)	.21 (.12)	.22 (.11)	.24 (.06)	.30 (.09)	.39 (.15)	.24 (.14)	.30 (.09)
Non-relational (in proportion)								
Object labeling	.18 (.05)	.20 (.04)	.44 (.11)	.26 (.06)	.24 (.10)	.25 (.11)	.51 (.12)	.31 (.07)

Table 6. Children's mean performance of each math task based on age, gender and culture group. (Standard deviations appear in parentheses)

	Age group		**Gender**		**Culture group**		**Overall**
	Younger (30-39.0m)	Older (39.1-48m)	Boys	Girls	European-American	Chinese immigrant	
TOSA Dimensional score (out of 40 pts; n = 36)	24.79 (7.05)	32.76 (7.08)	29.42 (8.57)	27.59 (7.56)	28.2 (8.87)	29.00 (7.16)	28.56 (8.05)
Matching dots (out of 10 pts; n = 34)	4.94 (3.67)	7.87 (2.16)	6.29 (3.64)	6.35 (3.16)	7.00 (3.02)	5.47 (3.66)	6.32 (3.35)
Give-n-task (out of 6 points, n = 33)	2.37 (1.41)	4.18 (1.42)	3.32 (1.80)	3.29 (1.54)	3.50 (1.76)	3.07 (1.58)	3.30 (1.67)
Counting task (% correct)							
Count to 10 (n=32)	59%	80%	56%	81%	65%	75%	69%
Answer how many question (n=26)	46%	53%	43%	58%	44%	63%	50%

Table 7. Mean, standard deviation and correlation between the proportion of parental language use in each category and children's performance on math tasks (r score for European American and Chinese immigrant appear in parentheses)

	M	*SD*	Overall structural relation	Overall object similarity	Overall self-association	Total relational language	1	2	3	4
Math tasks										
1. TOSA Dimensional score	28.56	8.05	0.03 (-0.04 vs. 0.06)	-0.20 (-0.22 vs. -0.16)	-0.02 (-0.06 vs. -0.01)	-0.06 (-0.15 vs. -0.02)	-			
2. Matching dots	6.32	3.35	-0.17 (-0.37 vs. 0.21)	-0.18 (-0.25 vs. -0.27)	0.12 (0.07 vs. 0.19)	-0.10 (-0.29 vs. 0.19)	**.362***	-		
3. Give-n-task	3.30	1.67	-0.18 (-.47* vs. 0.22)	-0.17 (-0.29 vs. -0.14)	0.11 (0.31 vs. 0.03)	-0.11 (-0.28 vs. 0.11)	0.33	**.454***	-	
Counting (two parts)										
4. Count to 10	0.69	0.47	-0.18 (-0.41 vs. -0.11)	-0.22 (-0.27 vs. -0.02)	-0.07 (-0.11 vs. 0.08)	-0.24 (-0.43 vs. -0.12	**.438***	**.419***	**.466****	-
5. Answer how many question	0.50	0.51	-0.10 (- 0.36 vs. 0.07)	-0.31 (-0.24 vs. -0.45)	-0.02 (-0.14 vs. 0.05)	-0.20 (-0.40 vs. 0.01)	0.31	0.38	0.34	**.607****

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 8. Correlation between the proportion of parental relational language in each activity and children's performance on math tasks.

	3D Puzzle	Sorting	Reading
Math tasks			
1. TOSA Dimensional score	-0.22	0.07	0.06
2. Matching dots	-0.06	-0.20	0.01
3. Give-n-task	-0.10	-0.10	0.06
Counting (two parts)			
4. Count to 10	-0.28	0.10	-0.32
5. Answer how many question	-0.29	0.09	-0.19

Appendix A.
Demographic Survey

Child's name 孩子姓名: _________ Sex 性别: M(男) F(女)

Date of Birth 出生日期: __________

Siblings 兄弟姐妹 Name 姓名 Sex 性别 Date of Birth 出生日期

____

____

Parent 1 家长 1

Name 姓名: __________ Sex 性别: M(男) F(女) Age 年龄: _________
Place of birth 出生地: __________
Number of years lived in the US 在美国境内居住时长: ______(years 年)
Ethnicity 种族:
___Native American 印第安人 ___Asian/Pacific Islander 亚裔/太平洋岛民
___Hispanic 西班牙裔
___Black, none Hispanic 非西班牙裔黑人 ___Caucasian 白种人 ___Other 其他
____

Education 教育程度: (12=high school graduate 高中学位，16=four-year college graduate 大学本科学位，18 or more = advanced degree 高等学位)

11 or less(等于或小于 11 年) 12 13 14 15 16 17 18 or more(大于或等于 18 年)

Current occupation 当前职业: ____________________________
Previous occupation 曾经职业(if different from current occupation 如果和当前职业不一致):___________

Parent 2 家长 2

Name 姓名: __________ Sex 性别: M(男) F(女) Age 年龄: _________
Place of birth 出生地: __________
Number of years lived in the US 在美国境内居住时长: ______(years 年)
Ethnicity 种族:
___Native American 印第安人 ___Asian/Pacific Islander 亚裔/太平洋岛民
___Hispanic 西班牙裔
___Black, none Hispanic 非西班牙裔黑人 ___Caucasian 白种人 ___Other 其他
____

Education 教育程度: (12=high school graduate 高中学位，16=four-year college graduate 大学本科学位，18 or more = advanced degree 高等学位)
11 or less(等于或小于 11 年) 12 13 14 15 16 17 18 or more(大于或等于 18 年)

Current occupation 当前职业: ____________________________
Previous occupation 曾经职业(if different from current occupation 如果和当前职业不一致):___________

What is your family income per year? 您家庭每年收入金额是多少？

____ less than $15,000 少于$15,000
____ $15,000 - $30,000
____ $30,000 - $50,000
____ $50,000 - $75,000
____ over $100,000 超过$100,000

Appendix B
Child Language Survey

Child Name 孩子姓名: Date of birth 出生日期:

Birthplace 出生地 (city, country) (城市，国家):

What language(s) does your child speak?
您的孩子说哪几种语言?

What language(s) does your child understand?
您的孩子能听懂哪几种语言?

Do you consider your child to be bilingual? Yes(是) No(否)
您认为您的孩子可以使用两种语言吗?
If yes, 如果是
Please specify the native or first language of your child: ____________________
请具体写出孩子的母语/第一语言
Please specify the second language of your child: ____________________
请具体写出孩子的第二语言
Please list all languages your child knows in order of most proficient to least proficient. Rate his/her ability on the following aspects in each language. Please rate according to the following scale (circle the number in the table) 请按照熟练程度从最熟练到最不熟练来排列出您孩子知道的所以语言，并且对他/她对每种语言的掌握能力进行评估。请运用以下七个等级来进行评估 (圈出表格中对应的数字):

非常差	差	一般	可以运用	好	非常好	像当地人一样
very poor	poor	fair	functional	good	very good	native-like
1	2	3	4	5	6	7

Language 语言种类	Speaking fluency 口语流畅程度 (circle one 圈出一个数字)	Understanding ability 理解能力 (circle one 圈出一个数字)
	1 2 3 4 5 6 7	1 2 3 4 5 6 7
	1 2 3 4 5 6 7	1 2 3 4 5 6 7
	1 2 3 4 5 6 7	1 2 3 4 5 6 7

What language does your child primarily use when speaking to you at home?
您的孩子在家里主要用哪种语言与您交流?

Besides you, who lives in your household with the child?
除了您以外，还有谁和孩子一起居住?

What language(s) do others in your household speak to your child?
家里的其他成员和您的孩子用哪种语言交流?

Please describe language exposure of your child from other sources (e.g., TV, daycare etc)
请说明您的孩子通过哪些其他渠道接触不同语言 (比如: 电视, 托儿所 等等)

In an average day, what percentage of time is your child exposed to:
您的孩子平均每天不同语言种类接触时间的百分比:

Language 1 (语言种类 1) :____________ ____% Language 2 (语言种类 2) : ____________ ____%

Appendix C
Parent Language Survey

Please read following questions and check (✓) one choice that applies to you in each row.请阅读以下问题并且针对每一行的问题选择并仅选择一个符合您的情况，标记对勾(✓)

	Only Chinese 仅中文	More Chinese than English or Americans 中文多过英语	Both equally 两者均等	More English or Americans than Chinese 英语多过中文	Only English or Americans 仅英语
In general, what languages do you read and speak? 您一般使用哪种语言阅读和交流?					
What was the language you used as a child? 您小时候使用哪种语言?					
What language do you usually speak at home? 您在家的时候经常使用哪种语言与人交流?					
In which language do you usually think? 您经常使用哪种语言去思考?					
What language do you usually speak with your friends? 您和朋友经常使用哪种语言进行交流?					
In what language(s) are the television programs you usually watch? 您经常看哪种语言的电视节目?					
In what language(s) are the online media/websites you usually browse? 您平常浏览哪种语言的社交媒体/网站?					

Appendix D
Parent Cultural Experience Survey

	Only Chinese 仅中国人	More Chinese than English or Americans 中国人多于美国人	Both equally 两者均等	More English or Americans than Chinese 美国人多于中国人	Only English or Americans 仅美国人
Your close friends are from 您的好朋友是					
As you grew up, your friend groups were from 在您成长的过程中，您的朋友圈子是					
You prefer going to social gathering/parties at which the people are from 您经常参加的社会活动/聚会中大多是					
The persons you visit or who visit you are from 您拜访的人或者拜访您的人					
If you could choose your children's friends, you would want them to be 如果您能帮孩子选择他/她的朋友，您最希望他/她的朋友是					
The people of the neighborhood you grew up in were from 您儿时的街坊邻居是					
The people of your current neighborhood are from 您现在的街坊邻居是					
The people of your current workplace are from (If not applicable, please put N/A) 您现在工作的同事是 (如若不适用，请填 N/A)					

Appendix E.
Additional data analyses and results

In this section, we report additional details on data analysis of parental relational language, children's math performance.

Parental relational language in 3-D puzzle activity

Frequency of overall relational language. An independent sample T-test revealed that Chinese immigrant mothers (*M* = 74.8 instances, *SD* = 44.0) used significantly more instances of relational language than the European-American mothers (*M* = 50.4 instances, *SD* = 24.3; *t*(34) = 2.11, *p* < .05, Cohen's *d* = .69) in this activity[10].

Parental relational language by category. Next, we conducted a 3 (Relational category: structural relation, object similarity, self-association) x 2 (Culture Group: Chinese immigrant vs. European American) mixed ANOVA, with category as repeated measures to investigate cultural variations in each of the categories of relational language. See descriptive statistics in Table 4. As predicted, results revealed a main effect of category (F (2, 68) = 92.58, $p < .001$, partial $\eta^2 = .73$), and a significant interaction between the category and culture group (F (2, 68) = 8.25, $p = .001$, partial $\eta^2 = .20$).

The main effect of category revealed that mothers used a higher proportion of structural relation (*M* = .17, *SD* = .07) than object similarity (*M* =.08, *SD* = .05, *M* difference = .09, *SE* = .01, *p* < .001, CI of the difference [.06, .12]) and self-association (*M* = .02, *SD* = .02, *M* difference = .15, *SE* = .01, *p* < .001, CI of the difference [.12, .18]). The mothers also used a higher proportion of object similarity than self-association (*M* difference = .06, *SE* = .01, *p* < .001, CI of the difference [.04, .08]) in this activity.

To understand the interaction between culture group and category, simple main effects analyses were conducted, and results showed that Chinese immigrant mothers used a higher proportion of structural relation than their European American counterparts ($F(1, 34) = 7.57$, $p = .009$, partial $\eta^2 = .18$). There were no significant group differences for the categories of object similarity (*F*(1, 34) = 2.66, *p* = .11) and self-association (*F*(1, 34) = .06, *p* =.82).

Parental relational language in Sorting activity

Frequency of overall relational language. An independent sample T-test revealed that Chinese immigrant mothers (*M* = 27.1 instances, *SD* = 14.6) used significantly more instances of relational language than the European-American mothers (*M* = 13.4 instances, *SD* = 8.1; *t*(34) = 3.58, *p* = .001, Cohen's *d* = 1.16) in this activity[11].

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[10] Chinese immigrant mothers (*M* = 254.1 instances, *SD* = 141.6) used marginally more total talk instances than European-American mothers (*M* = 187.2 instances, *SD* = 70.9, *t*(34) = 1.85, *p* = .07) in this activity.

[11] Chinese immigrant mothers (*M* = 70.3 instances, *SD* = 30.0) and European-American mothers (*M* = 67.8 instances, *SD* = 29.9) used a similar amount of total talk instances in this activity (*p* > .8).

Proportion of overall relational language. A similar analysis was conducted as in the puzzle activity. Results showed that Chinese immigrant mothers (*M* = .39; *SD* = .15) used a significantly higher proportion of relational language than European-American mothers (*M* = .21; *SD* = .11; $t(34) = 4.10$, $p < .001$, Cohen's d = 1.36) in general.

Parental relational language by category. Using the similar analysis in the puzzle activity, I conducted a 3 (Relational category) x 2 (Culture group) mixed ANOVA. See descriptive data in Table 5. Results revealed significant main effects of category ($F(2, 68) = 39.10$, $p < .001$, partial $\eta^2 = .54$) and culture group ($F(1, 34)$ = 16.40, p <.001, partial $\eta^2 = .33$). We also found a significant interaction between category and culture group ($F(2, 68) = 6.58$, $p = .002$, partial $\eta^2 = .16$).

The main effect of category revealed that the mothers used a significantly higher proportion of structural relation (*M* = .21, *SD* = .13) than the category of object similarity (*M* =.02, *SD* = .03; *M* difference = .18, *SE* = .02, $p < .001$, CI of the difference [.13, .24]) and self-association (*M* = .06, *SD* = .12; *M* difference = .15, *SE* = .03, $p < .001$, CI of the difference [.07, .23]) in this activity. There was no significant difference between the category of object similarity and self-association. The main effect of culture group revealed that Chinese immigrant mothers (*M* = .39, *SD* = .15) used a higher proportion of relational language than European-American mothers (*M* = .21, *SD* = .12) across all categories.

To understand the interaction between culture group and category, I conducted simple main effects analyses, and results showed that Chinese immigrant mothers used a higher proportion of structural relation than their European American counterparts ($F(1, 34) = 21.75$, $p < .001$, partial $\eta^2 = 39$). There were no significant group differences for the categories of object similarity ($F(1, 34) = .85$, $p = .77$) and self-association ($F(1, 34) = .56$, p =.46).

Parental relational language in Reading activity

Frequency of overall relational language. An independent sample T-test revealed no significant differences between Chinese immigrant mothers (*M* = 25.7 instances, *SD* = 16.0) and the European-American mothers (*M* = 20.3 instances, *SD* = 10.4) in using relational language ($t(34) = 1.22$, $p = .23$, Cohen's $d = .20$) in this activity[12].

Proportions of overall relational language. Similar analysis was conducted as in the previous activities. We found no significant group difference in the proportion of overall relational language used by the European-American (*M* = .22; *SD* = .11) and the Chinese immigrant (*M* = .24; *SD* = .14; $t(34) = .60$, $p = .55$, Cohen's $d = .40$) mothers in this activity.

Parental relational language by category. Using the similar analysis in the previous activities, I conducted a 3 (Relational category) x 2 (Culture group) mixed ANOVA. See descriptive data in Table 5. The results revealed only a significant main effect of category ($F(2, 68) = 51.92$, $p < .001$, partial $\eta^2 = .60$). The main effect of category revealed that mothers used a significantly higher proportion of self-

[12] Chinese immigrant mothers (*M* = 107.4 instances, *SD* = 28.2) and European-American mothers (*M* = 95.7 instances, *SD* = 22.0) used a similar amount of total talk instances in this activity ($p = .17$).

association (*M* = .17, *SD* = .02) than structural relation (*M* = .05, *SD* = .05; *M* difference = .12, *SE* = .02; $p < .001$, 95% CI of the differences [.07, .17]) which in turn was used at a higher proportion than object similarity (*M* =.01, *SD* = .02; *M* difference = .04, *SE* = .01; $p = .001$, 95% CI of the differences [.01, .06]). There were no significant culture variations in parental use relational language in this activity.

Parental use of object labeling

We conducted a 3 (Activity type: puzzle, sorting, reading) x 2 (Culture Group: Chinese immigrant vs. European American) mixed ANOVA, with activity type as repeated measures to investigate cultural variations in parental use of object labeling. The results revealed significant main effects of activity type ($F(2, 68) = 89.56$, $p < .001$, partial $\eta^2 = .73$) and culture group ($F(1, 34) = 8.59$, $p <.01$, partial $\eta^2 = .20$). The main effect of culture group revealed that Chinese immigrant mothers (*M* = .31, *SD* = .07) used a significantly higher proportion of object labeling in general than European American mothers (*M* = .26, *SD* = .06). The main effect of activity type revealed that the mothers used a significantly higher proportion of object labeling in reading activity (*M* = .47, *SD* = .12) compared to the puzzle activity (*M* = .21, *SD* = .08, *M* difference = .26, *SE* = .02; $p < .001$, 95% CI of the differences [.21, .31]) and sorting activity (*M* = .22, *SD* = .10, *M* difference = .25, *SE* = .02; $p < .001$, 95% CI of the differences [.19, .31]). The difference between the puzzle activity and the sorting activity was not significant ($p = 1.0$) in this category.

Activity type and parental relational language

A two-way repeated measure ANOVA was used to examine whether the proportion of relational language used by mothers in each of the three categories (structural relation, object similarity, self-association) varied by the activity type (puzzle, sorting, reading). Results showed a marginal main effect of activity type ($F(2, 70) = 2.86$, $p = .06$, partial $\eta^2 = .08$), a significant main effect of language category ($F(2, 70) = 31.51$, $p < .001$, partial $\eta^2 = .47$), and a significant interaction between the activity type and language category ($F(4, 140) = 53.25$, $p < .001$, partial $\eta^2 = .60$).

Pairwise comparisons using Bonferroni corrections (see Figure 6) revealed that for the category of structural relation, the mothers used a significantly higher proportion in the puzzle activity (*M* = .17, *SD* =.07) and sorting activity (*M* = .21, *SD* = .12) compared to the reading (*M* = .05, *SD* = .05) activity (*M* differences = .12 vs .15; *SE* = .01 vs .02, *p*s < .001, 95% CI of the differences [.10, .15] vs [.11, .21]). The difference between the puzzle activity and sorting activity was not significant ($p > .30$).

For the category of object similarity, the mothers used a significantly higher proportion in the puzzle activity (*M* = .08, *SD* = .05) compared to the sorting activity (*M* = .02, *SD* = .03, *M* difference = .06, *SE* = .01, $p < .001$, CI of the difference [.04, .09]) and the reading activity (*M* = .01, *SD* = .02, *M* difference = .07, *SE* = .01, $p < .001$, CI of the difference [.05, .09]). The difference between the sorting activity and the reading activity was not significant ($p >.20$).

For the category of self-association, the mothers used a significantly higher proportion in the reading activity (*M* = .17, *SD* = .11) compared to the puzzle activity (*M* = .02, *SD* = .02; *M* difference = .15, *SE* = .02; $p < .001$, 95% CI of the differences

[.10, .19]) and the sorting activity (*M* = .06, *SD* = .12); *M* difference = .11, *SE* = .02; *p* < .001, 95% CI of the differences [.06, .16]). The difference between the puzzle activity and the sorting activity was not significant (*p* > .25) for this category.

Children's performance on math tasks

As the secondary purpose, we examined children's performance on four math tasks and explored the correlation between parental use of relational language and children's math performance. We conducted a series of 2 (Culture group) x 2 (Gender of child) univariate ANOVA, with children's age in months as a covariate. The dependent measures were the performance scores in each of the three tasks (modified TOSA, matching dots, give-n-task). There were no significant main effects or interaction for gender (*p*s > .73), or culture group (*p*s > .26) on the performance of three tasks. However, the results revealed significant main effects of age on the performance of modified TOSA ($F(1, 31) = 14.52$, $p = .001$, partial $\eta^2 = .32$), give-n-task ($F(1, 28) = 6.71$, $p = .02$, partial $\eta^2 = .19$), and a marginal effect on matching dots task ($F(1, 29) = 3.90$, $p = .06$, partial $\eta^2 = .12$). To investigate the age effect, we conducted follow up ANOVA analyses using a median split of children's age (median = 39.03 months). This resulted in two age groups (younger children: 30.07 to 39.03 months vs. older children 39.1 to 47.7 months). The results revealed that older children performed significantly better than their younger peers in modified TOSA ($F(1, 23) = 7.32$, $p = .01$ partial $\eta^2 = .24$) and give-n-task ($F(1, 23) = 9.90$, $p = .005$, partial $\eta^2 = .30$) after controlling for their gender or culture group. In addition, older children performed marginally better than their younger peers in the matching dots task ($F(1, 23) = 3.81$, $p = .06$, partial $\eta^2 = .14$).

For the performance on the counting task, Chi-square analyses were conducted based on children's gender, culture group, and age group. Results showed no significant effects on the performance of counting to 10 based on gender ($\chi^2(1, 32) = 2.33$, $p = .13$), culture group ($\chi^2(1, 32) = .35$, $p = .56$), and age group ($\chi^2(1, 32) = 1.66$, $p = .20$), and there were no significant effects on the performance of answering the how many question based on these characteristics as well (*p*s > .40). The descriptive data seems to hint that older children were more likely to correctly count to 10 and answer the how many question than their younger peers.

Relational language and math task performance

A series of Pearson's correlation analyses was conducted to investigate the association between parental use of relational language (across all activities, and by each relational category), and children's performance on each of the four tasks. Results showed no significant correlations between children's performance in each of the four math tasks and the overall proportions of relational language use across all activities (*p*s > .20), by each category (*p*s > .14), or by each activity (*p* > .07).

Next, we took into consideration of culture group to further investigate the association between parental relational language use and children's math performance. Pearson's correlation analyses for each culture group were conducted (see Table 7). The results showed European-American mothers' use of structural relation negatively correlated with children's performance on give-n-task ($r = -0.47$, $p = .05$). There were no other significant correlations between the proportions of relational language and children's math performance for either of the culture groups ($ps > .12$).

References

Au, T. K., Dapretto, M., & Song, Y. (1994). Input vs constraints: Early word acquisition in Korean and English. *Journal of Memory and Language, 33*(5), 567-582. http://dx.doi.org.oca.ucsc.edu/10.1006/jmla.1994.1027

Bang, M. (2015). Culture, learning, and development and the natural world: The influences of situative perspectives. *Educational Psychologist, 50*(3), 220-233. doi:http://dx.doi.org/10.1080/00461520.2015.1075402

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development & Parenting, 5*(1), 35-45. doi:http://dx.doi.org.oca.ucsc.edu/10.1002/(SICI)1099-0917(199603)5

Carstensen, A., Zhang, J., Heyman, G. D., Fu, G., Lee, K., & Walker, C. M. (2019). Context shapes early diversity in abstract thought. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 116*(28), 13891-13896. doi:http://dx.doi.org/10.1073/pnas.1818365116

Casey, B. M., Lombardi, C. M., Thomson, D., Nguyen, H. N., Paz, M., Theriault, C. A., & Dearing, E. (2018). Maternal support of children's early numerical concept learning predicts preschool and first-grade math achievement. *Child Development, 89*(1), 156-173. doi:http://dx.doi.org/10.1111/cdev.12676

Chang, A., Sandhofer, C. M., & Brown, C. S. (2011). Gender biases in early number exposure to preschool-aged children. *Journal of Language and Social*

Psychology, 30(4), 440-450. doi:http://dx.doi.org.oca.ucsc.edu/10.1177/0261927X11416207

Chang, A., Sandhofer, C. M., Adelchanow, L., & Rottman, B. (2011). Parental numeric language input to mandarin Chinese and English speaking preschool children. *Journal of Child Language, 38*(2), 341-355. doi:http://dx.doi.org.oca.ucsc.edu/10.1017/S0305000909990390

Cheng, P. W., & Holyoak, K. J. (1985). Pragmatic reasoning schemas. *Cognitive Psychology, 17*(4), 391-416. doi:http://dx.doi.org/10.1016/0010-0285(85)90014-3

Dong, X., Bergren, S. M., & Chang, E. (2015). Levels of acculturation of Chinese older adults in the greater Chicago area—The population study of Chinese elderly in Chicago. *Journal of the American Geriatrics Society, 63*(9), 1931-1937.

Duffy, S., Toriyama, R., Itakura, S., & Kitayama, S. (2009). Development of cultural strategies of attention in north American and Japanese children. *Journal of Experimental Child Psychology, 102*(3), 351-359. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.jecp.2008.06.006

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In R. J. Sternberg, & J. E. Davidson (Eds.), *The nature of insight* (pp. 365-395, Chapter xviii, 618 Pages) The MIT Press, Cambridge, MA.

Fernald, A., & Morikawa, H. (1993). Common themes and cultural variations in Japanese and American mothers' speech to infants. *Child Development, 64*(3), 637-656. http://dx.doi.org.oca.ucsc.edu/10.2307/1131208

Ferrara, K., Hirsh-Pasek, K., Newcombe, N. S., Golinkoff, R. M., & Lam, W. S. (2011). Block talk: Spatial language during block play. *Mind, Brain, and Education, 5*(3), 143-151. doi:http://dx.doi.org.oca.ucsc.edu/10.1111/j.1751-228X.2011.01122.x

Ferry, A. L., Hespos, S. J., & Gentner, D. (2015). Prelinguistic relational concepts: Investigating analogical processing in infants. *Child Development, 86*(5), 1386-1405. doi:http://dx.doi.org/10.1111/cdev.12381

Fung, Y. (1948) *A short history of Chinese Philosophy.* (D. Bodde, Ed.). The Free Press.

Gelman, R., Meck, E., & Merkin, S. (1986). Young children's numerical competence. *Cognitive Development, 1*(1), 1-29. http://dx.doi.org.oca.ucsc.edu/10.1016/S0885-2014(86)80021-1

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou, & A. Ortony (Eds.), *Similarity and analogical reasoning; similarity and analogical reasoning* (pp. 199-241, Chapter xiv, 592 Pages) Cambridge University Press, New York, NY. doi:http://dx.doi.org/10.1017/CBO9780511529863.011

Gentner, D. (2016). Language as cognitive tool kit: How language supports relational thought. *American Psychologist, 71*(8), 650-657. doi:http://dx.doi.org/10.1037/amp0000082

Gentner, D., & Rattermann, M. J. (1991). Language and the career of similarity. In S. A. Gelman, & J. P. Byrnes (Eds.), *Perspectives on language and thought: Interrelations in development; perspectives on language and thought: Interrelations in development* (pp. 225-277, Chapter xii, 524 Pages) Cambridge University Press, New York, NY. doi:http://dx.doi.org/10.1017/CBO9780511983689.008

Goldfield, B. A. (1993). Noun bias in maternal speech to one-year-olds. *Journal of Child Language, 20*(1), 85-99. http://dx.doi.org.oca.ucsc.edu/10.1017/S0305000900009132

Goldin-Meadow, S., & Alibali, M. W. (2013). Gesture's role in learning and development. In P. D. Zelazo (Ed.), *The oxford handbook of developmental psychology (vol 1): Body and mind* (pp. 953-973, Chapter xx, 1028 Pages) Oxford University Press, New York, NY.

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth- and eighth-grade students in an international context* (NCES 2009-001). Washington, DC: National Center for Education Statistics, U.S. Department of Education.

Goodman, J. C., Dale, P. S., & Li, P. (2008). Does frequency count? parental input and the acquisition of vocabulary. *Journal of Child Language, 35*(3), 515-531. doi:http://dx.doi.org.oca.ucsc.edu/10.1017/S0305000907008641

Gopnik, A., Choi, S., & Baumberger, T. (1996). Cross-linguistic differences in early semantic and cognitive development. *Cognitive Development, 11*(2), 197-227. http://dx.doi.org.oca.ucsc.edu/10.1016/S0885-2014(96)90003-9

Hatano, G. (1988). Social and motivational bases for mathematical understanding. *New Directions for Child Development, 41*, 55-70. doi:http://dx.doi.org/10.1002/cd.23219884105

Hermer-Vazquez, L., Moffet, A., & Munkholm, P. (2001). Language, space, and the development of cognitive flexibility in humans: The case of two spatial memory tasks. *Cognition, 79*(3), 263-299. http://dx.doi.org.oca.ucsc.edu/10.1016/S0010-0277(00)00120-7

Hiebert, J., Morris, A. K., & Glass, B. (2003). Learning to learn to teach: An "experiment" model for teaching and teacher preparation in mathematics.*Journal of Mathematics Teacher Education, 6*(3), 201-222. doi:http://dx.doi.org.oca.ucsc.edu/10.1023/A:1025162108648

Hofstadter, D. (2001). Epilogue: Analogy as the core of cognition. In D. Gentner, K. J. Holyoak & B. N. Kokinov (ed.), *The Analogical Mind: Perspectives from Cognitive Science* (pp. 499--538). MIT Press.

Hofstede, G. (1980). *Culture's Consequences: International Differences in Work-Related Values*. Beverly Hills, CA: Sage.

Holyoak, K. J., Junn, E. N., & Billman, D. O. (1984). Development of analogical problem-solving skill. *Child Development, 55*(6), 2042-2055. doi:http://dx.doi.org/10.2307/1129778

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology, 27*(2), 236-248. doi:http://dx.doi.org.oca.ucsc.edu/10.1037/0012-1649.27.2.236

Ji, L., Peng, K., & Nisbett, R. E. (2000). Culture, control, and perception of relationships in the environment. *Journal of Personality and Social Psychology, 78*(5), 943-955. doi:http://dx.doi.org.oca.ucsc.edu/10.1037/0022-3514.78.5.943

Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade math achievement from developmental number sense trajectories.*Learning Disabilities Research & Practice, 22*(1), 36-46. doi:http://dx.doi.org.oca.ucsc.edu/10.1111/j.1540-5826.2007.00229.x

Kitayama, S., Duffy, S., Kawamura, T., & Larsen, J. T. (2003). Perceiving an object and its context in different cultures: A cultural look at new look. *Psychological Science, 14*(3), 201-206. doi:http://dx.doi.org.oca.ucsc.edu/10.1111/1467-9280.02432

Klibanoff, R. S., Levine, S. C., Huttenlocher, J., Vasilyeva, M., & Hedges, L. V. (2006). Preschool children's mathematical knowledge: The effect of teacher "math talk". *Developmental Psychology, 42*(1), 59-69. doi:http://dx.doi.org.oca.ucsc.edu/10.1037/0012-1649.42.1.59

Kuwabara, M., & Smith, L. B. (2012). Cross-cultural differences in cognitive development: Attention to relations and objects. *Journal of Experimental Child Psychology, 113*(1), 20-35. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.jecp.2012.04.009

Kuwabara, M., & Smith, L. B. (2016a). Cultural differences in visual object recognition in 3-year-old children. *Journal of Experimental Child Psychology, 147*, 22-38. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.jecp.2016.02.006

Kuwabara, M., & Smith, L. B. (2016b). East vs. West—Developmentally early differences in attention. In C. Roland-Levy, P. Denoux, B. Voyer, P. Boski, & W. K. Gabrenya Jr. (Eds.), *Unity, diversity and culture. Proceedings from the 22nd Congress of the International Association for Cross-Cultural Psychology* (pp. 345–349). Florida, USA: IACCP, Inc. https://scholarworks.gvsu.edu/iaccp_papers/177

Kuwabara, M., Son, J. Y., & Smith, L. B. (2011). Attention to context: U.S. and Japanese children's emotional judgments. *Journal of Cognition and Development, 12*(4), 502-517. doi:http://dx.doi.org.oca.ucsc.edu/10.1080/15248372.2011.554927

Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge? *Developmental Psychology, 46*(5), 1309-1319. doi:http://dx.doi.org.oca.ucsc.edu/10.1037/a0019671

Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50*(4), 315-353. doi:http://dx.doi.org/10.1016/j.cogpsych.2004.09.004

Masuda, T., & Nisbett, R. E. (2001). Attending holistically versus analytically: Comparing the context sensitivity of Japanese and Americans. *Journal of Personality and Social Psychology, 81*(5), 922-934. doi:http://dx.doi.org.oca.ucsc.edu/10.1037/0022-3514.81.5.922

Masuda, T., & Nisbett, R. E. (2006). Culture and change blindness. *Cognitive Science, 30*(2), 381-399. doi:http://dx.doi.org.oca.ucsc.edu/10.1207/s15516709cog0000_63

Miller, H. E., Patterson, R., & Simmering, V. R. (2016). Language supports young children's use of spatial relations to remember locations. *Cognition, 150*, 170-180. http://dx.doi.org.oca.ucsc.edu/10.1016/j.cognition.2016.02.006

Miller, H. E., Vlach, H. A., & Simmering, V. R. (2017). Producing spatial words is not enough: Understanding the relation between language and spatial cognition. *Child Development, 88*(6), 1966-1982. http://dx.doi.org.oca.ucsc.edu/10.1111/cdev.12664

Mix, K. S. (1999a). Similarity and numerical equivalence appearances count. *Cognitive Development, 14*(2), 269-297. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/S0885-2014(99)00005-2

Mix, K. S. (1999b). Preschooler's recognition of numerical equivalence: Sequential sets. *Journal of Experimental Child Psychology, 74*(4), 309-332. doi:http://dx.doi.org.oca.ucsc.edu/10.1006/jecp.1999.2533

Mix, K. S. (2009). How spencer made number: First uses of the number words. *Journal of Experimental Child Psychology, 102*(4), 427-444. doi:http://dx.doi.org/10.1016/j.jecp.2008.11.003

Moriguchi, Y., Evans, A. D., Hiraki, K., Itakura, S., & Lee, K. (2012). Cultural differences in the development of cognitive shifting: East–West comparison. *Journal of Experimental Child Psychology, 111*(2), 156-163. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.jecp.2011.09.001

National Research Council. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity*. Washington, DC: National Academies Press.

Nisbett, R. E. (2003). *The geography of thought: How Asians and Westerners think differently ... and why.* Free Press, New York, NY.

Nisbett, R. E., & Miyamoto, Y. (2005). The influence of culture: Holistic versus analytic perception. *Trends in Cognitive Sciences, 9*(10), 467-473. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.tics.2005.08.004

Nisbett, R. E., Peng, K., Choi, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review, 108*(2), 291-310. doi:http://dx.doi.org.oca.ucsc.edu/10.1037/0033-295X.108.2.291

Organization for Economic Cooperation and Development (2016). *Education in China: A snapshot*. Retrieved from https://www.oecd.org/china/Education-in-China-a-snapshot.pdf

Peng, K., & Paletz, S. B. F. (2011). Cross-cultural psychology in applied settings: Passages to differences. In P. R. Martin, F. M. Cheung, M. C. Knowles, M. Kyrios, L. Littlefield, J. B. Overmier & J. M. Prieto (Eds.), *IAAP handbook of applied psychology; IAAP handbook of applied psychology* (pp. 525-542, Chapter xxix, 796 Pages) Wiley Blackwell. doi:http://dx.doi.org/10.1002/9781444395150.ch21

Polinsky, N., Perez, J., Grehl, M., & McCrink, K. (2017). Encouraging spatial talk: Using children's museums to bolster spatial reasoning. *Mind, Brain, and Education, 11*(3), 144-152. http://dx.doi.org.oca.ucsc.edu/10.1111/mbe.12145

Rattermann, M. J., & Gentner, D. (1998a). More evidence for a relational shift in the development of analogy: Children's performance on a causal-mapping task. *Cognitive Development, 13*(4), 453-478. doi:http://dx.doi.org/10.1016/S0885-2014(98)90003-X

Ratterman, M. J., & Gentner, D. (1998b). The effect of language on similarity: The use of relational labels improves young children’s performance in a mapping task. In K. Holyoak, D. Gentner, & B. Kokinov (Eds.), *Advances in analogy research: Integration of theory & data from the cognitive, computational, and neural sciences* (pp. 274-282). New Bulgarian University.

Richland, L. E. (2015). Linking gestures: Cross-cultural variation during instructional analogies. *Cognition and Instruction, 33*(4), 295-321. http://dx.doi.org.oca.ucsc.edu/10.1080/07370008.2015.1091459

Richland, L. E., Chan, T.-K., Morrison, R. G., & Au, T. K.-F. (2010). Young children’s analogical reasoning across cultures: Similarities and differences. *Journal of Experimental Child Psychology*, *105*(1–2), 146–153. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.jecp.2009.08.003

Richland, L. E., & McDonough, I. M. (2010). Learning by analogy: Discriminating between potential analogs. *Contemporary Educational Psychology, 35*(1), 28-43. http://dx.doi.org.oca.ucsc.edu/10.1016/j.cedpsych.2009.09.001

Richland, L. E., Morrison, R. G., & Holyoak, K. J. (2006). Children's development of analogical reasoning: Insights from scene analogy problems. *Journal of Experimental Child Psychology, 94*(3), 249-273. doi:http://dx.doi.org/10.1016/j.jecp.2006.02.002

Richland, L. E., Zur, O., & Holyoak, K. J. (2007). Cognitive supports for analogies in the mathematics classroom. *Science, 316*(5828), 1128-1129. doi:http://dx.doi.org/10.1126/science.1142103

Rogoff, B. (2003). *The cultural nature of human development*. New York, NY: Oxford University Press. doi:http://dx.doi.org.oca.ucsc.edu/10.1348/000709905X55208

Rogoff, B., Dahl, A., & Callanan, M. (2018). The importance of understanding children's lived experience. *Developmental Review, 50*, 5-15. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.dr.2018.05.006

Rogoff, B., Mistry, J., Goncu, A., & Mosier, C. (1993). Guided participation in cultural activity by toddlers and caregivers. *Monographs of the Society for Research in Child Development, 58*(8), v-179. http://dx.doi.org.oca.ucsc.edu/10.2307/1166109

Rogoff, B., Moore, L., Najafi, B., Dexter, A., Correa-Chávez, M., & Solís, J. (2007). In Grusec J. E., Hastings P. D. (Eds.), *Children's development of cultural repertoires through participation in everyday routines and practices* The Guilford Press, New York, NY.

Saxe, G. B., Guberman, S. R., & Gearhart, M. (1987). Social processes in early number development. *Monographs of the Society for Research in Child Development, 52*(2), 162. doi:http://dx.doi.org.oca.ucsc.edu/10.2307/1166071

Senzaki, S., Masuda, T., Takada, A., & Okada, H. (2016). The communication of culturally dominant modes of attention from parents to children: A comparison of canadian and japanese parent-child conversations during a joint scene description task. *PLoS ONE, 11*(1), 20. doi:http://dx.doi.org.oca.ucsc.edu/10.1371/journal.pone.014719

So, W., Shum, P. L., & Wong, M. K. (2015). Gesture is more effective than spatial language in encoding spatial information. *The Quarterly Journal of Experimental Psychology, 68*(12), 2384-2401. http://dx.doi.org.oca.ucsc.edu/10.1080/17470218.2015.1015431

Son, J. Y., Smith, L. B., & Goldstone, R. L. (2008). Simplicity and generalization: Short-cutting abstraction in children's object categorizations. *Cognition, 108*(3), 626-638. doi:http://dx.doi.org/10.1016/j.cognition.2008.05.002

Son, J. Y., Smith, L. B., & Goldstone, R. L. (2011). Connecting instances to promote children’s relational reasoning. *Journal of Experimental Child Psychology, 108*(2), 260-277. doi:http://dx.doi.org/10.1016/j.jecp.2010.08.011

Tardif, T., Gelman, S. A., & Xu, F. (1999). Putting the "noun bias" in context: A comparison of English and Mandarin. *Child Development, 70*(3), 620-635. http://dx.doi.org.oca.ucsc.edu/10.1111/1467-8624.00045

Valle, A., & Callanan, M. A. (2006). Similarity comparisons and relational analogies in parent-child conversations about science topics. *Merrill-Palmer Quarterly, 52*(1), 96-124. doi:http://dx.doi.org/10.1353/mpq.2006.0009

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2014). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematical skills. *Child Development, 85*(3), 1062-1076. doi:http://dx.doi.org/10.1111/cdev.12165

Verdine, B. N., Zimmermann, L., Foster, L., Marzouk, M. A., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. (2019). Effects of geometric toy design on parent–child interactions and spatial language. *Early Childhood Research Quarterly, 46*, 126-141. doi:http://dx.doi.org.oca.ucsc.edu/10.1016/j.ecresq.2018.03.015

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.) (Revised edition). Princeton, NJ: Harvard University Press.

Wang, W., & Vallotton, C. (2016). Cultural transmission through infant signs: Objects and actions in U.S. And Taiwan. *Infant Behavior & Development, 44*, 98-109. http://dx.doi.org.oca.ucsc.edu/10.1016/j.infbeh.2016.06.003

Wynn, K. (1990). Children's understanding of counting. *Cognition, 36*(2), 155-193. doi:http://dx.doi.org/10.1016/0010-0277(90)90003-3