International Journal of Psychological Studies; Vol. 10, No. 2; 2018
ISSN 1918-7211 E-ISSN 1918-722X
Published by Canadian Center of Science and Education

Relational Language Improves Preschool Children's Performance of Analogical Reasoning

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Received: May 8, 2018 Accepted: May 21, 2018 Online Published: May 23, 2018

doi:10.5539/ijps.v10n2p91 URL: https://doi.org/10.5539/ijps.v10n2p91

Abstract

The current study explored how relational language influenced the analogical reasoning among preschool children in China. Children (aged 4.5 and 5.5) in Experiment 1 were asked to complete a cross-mapped task where the object match competed with the relational match. The ANOVA results showed that the performance of both 4.5-year-olds and 4.5-year-olds were significantly improved after they heard Relational Language, F (1, 68) =44.821, p<0.05, η^2=0.40. In Experiment 2, different distractors were added to the cross-mapped task and the 5.5-year-olds were replaced by 3.5 year-olds. The results demonstrated that the facilitating effect of Relational Language still existed among the youngest children and the performance of 4.5-year-olds was better than the 3.5-year-olds, F(1, 68)=6.76, p<0.05, η^2=0.09. Furthermore, both age groups performed the worst under the distractor condition, indicating that the distractors made analogical reasoning more difficult, especially for the youngest children. Taken together, the current findings suggested that the facilitating effects of relational language in relational reasoning could also be observed in a broader sample.

Keywords: analogical reasoning, relational language, preschool children, cross-mapped task

1. Introduction

Analogical reasoning is the ability to identify and transfer an exploratory structure from a familiar system (the base) to an unfamiliar system (the target). Over the last few decades, the significant importance of analogical reasoning has been repeatedly supported by studies in different areas. For example, Goswami and Mead (1992) found that analogical reasoning was important in children's cognitive development. In addition, some study showed it could benefit the learning of scientific textbooks (Zheng, Yang, Garcia & McCadden, 2008); promote learning transfer (Goswami & Mead, 1992); and enhance certain aspects of creativity (Cubukcu & Cetintahra, 2010). Current empirical research has indicated that analogical reasoning was a predictor of preschoolers' learning effectiveness (Chiu & Alexander, 2014).

Although studies have confirmed the importance of analogical reasoning in problem solving activities, learning outcomes, and academic achievements, there is still much to learn about the mechanism of analogical reasoning in young children, especially for the factors affecting analogical reasoning. Except for well-documented elements such as domain knowledge, working memory, and inhibitory control system (Abdellatif, Cummings & Maddux, 2008), some empirical studies have indicated that Relational Language could also promote children's analogical thought and increase children's performance on spatial mapping tasks.

Loewenstein and Gentner (1998) first designed a spatial mapping task where two groups of children were asked to find hidden objects under the baseline and language conditions. Compared to the baseline condition, children under language condition were provided with learned spatial propositions such as "in", "under" and "in front of" during the experimental instruction. The results indicated that regardless of age group, the children's performance under the language condition was much better than children from the baseline condition, implying that the mapping task was facilitated by language labels highlighting the common relations between objects and locations. A follow-up simulation study created by Structure-Mapping Engine (SME) again resulted that gains in relational representation were a major contributor to the development of spatial mapping ability (Mostek,

Loewenstein , Forbus, & Gentner, 1999).

Apart from the spatial mapping tasks, similar findings have been obtained using other types of mapping tasks. Christie, Gentner, Vosniadou and Kayser (2007) gave a geometric shape mapping task to 4.5-year-olds, 8.5-year-olds, and adult participants to examine how children perceived the relational similarity in the presence of a competing object similarity. The results demonstrated that children failed to show a preference for relational similarity, even with a very simple relational match. However, when given linguistic labels, children's relational matches were significantly increased. Gentner, Simms and Flusberg (2009) also investigated the ability of analogical reasoning among preschool children (3, 5 and 7-year-olds), using the scene analogy task. The results demonstrated that children receiving the relational terms made more relational matches than those who did not. This benefit was still evident when different distractors were added into the experiments. Children who heard Relational Language made as accurate matches under the distractor condition as those with no distractors. In general, these studies suggested that the more likely the relational instruction a student could receive, the more likely they will concentrate on the relationships in the analogy. The usage of Relational Language could take different formats such as verbal statements, key principles in abstract terms or simple relational words during the instruction. Regardless of the format of language input, the Relational Language is always functioning as a powerful support for children to notice relational similarities when solving the analogical reasoning tasks.

Although the language effect has been well documented among children in the U.S., it may need be further investigated under different language systems or social cultures. In the early times, some scholars who investigated the relationship among culture, language, and cognition proposed that East Asians, and Chinese in particular, reasoned in a holistic and relational way, whereas Westerners, in particular European Americans, reasoned in an analytical way (Nisbett, Peng, Choi, & Norenzayan, 2001; Nisbett, 2010). Based on their studies, East Asians' attention is oriented towards the field and to relationships between objects and events. In contrast, North Americans decontextualize objects from the field and attend to their properties so as to establish a category membership in an attempt to understand and predict the object's behavior (Ji, Peng, & Nisbett, 2000). This difference between more individual objects focused attention among Westerners and more relational attention among Easterners was later found in various tasks such as perceptual, social, and reasoning tasks (Kitayama, Duffy, Kawamura, & Larsen, 2003; Richland, Zur, & Holyoak, 2007). Recent studies have indicated that these cultural differences in perceptual and cognitive tasks may even emerge from early preschoolers. Richland, Chan, Morrison and Au (2010) compared the analogical task performance between the Chinese and American children (both ranged from 3 to 4 years old), controlling for the prior relational knowledge. Their results showed that the Chinese children did better than U.S children on the more relationally complex problems, but not on the simple relational problems. Kuwabara and Smith's (2012) study also compared Japanese and American children's performance (age 4) on the relational match-to-standard task. They found out that rich objects strongly limited the performance of U.S. children, but not Japanese children. However, U.S. children outperformed Japanese children in visual search tasks where the relational attention pattern may hinder the performance. In brief, although cross-cultural studies with preschool children are still limited, they have consistently implied that the Western cognitive system may be biased towards decontextualized objects, while the Eastern system towards an object relation to its context.

Motivated by the above cross-cultural findings, our study examined how Relational Language influenced Chinese preschoolers' performance on the analogical reasoning tasks. Gentner et al., (2009)'s work was very inspiring because Relational Language could even facilitate the mapping performance for children as young as age 3. However, one characteristic in their study was that the difference of age group (3 vs. 5 vs. 7) was not consecutive. This age selection may be meaningful in that some studies in the U.S. did not find a marked difference between 3 and 5 year old children with respect to their analogical reasoning (Morrison et al., 2004; Loewenstein & Gentner, 2005). Increasing the age gap between participants may improve the chance to observe the salient age effects on analogical reasoning. However, this may not be applicable to the Chinese preschoolers. First, the cross-cultural study comparing the U.S. with Hong Kong preschoolers (Richland et al., 2010) implied that Chinese children were more skilled and efficient at processing complex relations than either age groups of U.S. children. Second, some studies did not indicate a linear increase for the analogical reasoning ability among Chinese preschoolers (Feng, Li, Li, Su &Long, 2006; Ma, Feng, Li, & Li, 2008). In fact, most of these studies consistently implied that the growth rate of analogical reasoning ability will be slowed down after age 4 since no significant difference was observed among age 4, 5 and 6. Therefore, to what extent the Relational Language could influence preschoolers reasoning may have a cross-cultural variance.

The current study will replicate Gentner et al. (2009)'s experimental design, using cross-mapped scene analogy tasks for the preschool children in Kaifeng, China. Normally, the youngest age to start the kindergarten in China

is 3-years-old and it usually consists of three grades which are called small grade (age 3-4), middle grade (age 4-5) and big grade (age 5-6). In the first experiment, the 4-year-olds and 5-year-olds were compared under different language conditions (Gentner, et al., 2009). Based on the previous finding that analogical reasoning among Chinese preschoolers grow faster around age 3 and slow down again after age 4, we hypothesized that the age effect may not be observed between 4 and 5 year old children. Additionally, in order to expand the explanatory power of language effect, we also hypothesized that regardless of the age group, children hearing the Relational Language will perform better than children hearing Neutral Language in the mapping task.

The second experiment would continue to investigate the language effect by including preschool children, age 3-4 in China. As suggested by Gentner's study (2009), another factor (distractor type) was added to explore any differences that may exist between different distractor pairs. We first hypothesized that the average performance by 4.5-year-olds will be better than that of 3.5-year-olds, and children's overall relational choices will be significantly improved after hearing the Relational Language. In addition, as shown by some studies (Richland, Morrison & Holyoak, 2006; Simms & Gentner, 2009), younger children tend to make more errors when there were distractors present because the maturational limitations in inhibitory control prevents them from ignoring the compelling object matches in favor of relational matches. Thus, we predicted a common pattern across countries showing relatively lower performance on analogies with a distractor compared with those without a distractor.

In order to control the prior knowledge about these relational terms and figures used in the relational pictures, we invited the kindergarten teachers to generate these relational terms and pictures based on their textbooks and daily school activities. The objects shown in these pictures were items frequently encountered by preschool children, such as animal and humans (Gentner & Smith, 2012; Christie & Gentner, 2014).

2. Experiment 1

2.1 Method

2.1.1 Participants

Thirty-six 4.5-year-old and thirty-six 5.5-year-old preschool children were randomly selected from two classrooms (middle grade and high grade) in a public kindergarten located in Kaifeng, a small city in east-central Henan, China. Gender was balanced within each age group, meaning that there were eighteen boys and eighteen girls in each group respectively. By randomly assigning children from each age group, the researchers were able to divide the children into the two groups, *Relational Language Condition* (n=18), and the *Neutral Language Condition* (n=18). This resulted in four different groups: 4.5-year-olds with *Language Condition* (n=18), 5.5-year-olds with L*anguage Condition* (n=18), 4.5-year-olds with *Neutral Language Condition* (n=18), and 5.5-year-olds with *Neutral Language Condition* (n=18). In each age by language group, half the children were boys and the other half were girls. All the participants were from a kindergarten in Kaifeng, China. Although demographic information was not systematically collected, children were mainly from the middle-class neighborhoods.

2.1.2 Design

The current study adopted a 2×2 between-subjects design, where the first factor is age group (4.5 vs. 5.5) and the second factor is the language group (relational vs. neutral). Under the *Relational Language* condition, participants were given relational terms such as "chase" and "tow" within their instruction. While under *Neutral Language*, children did not hear any relational terms directly within their instructions. Participants saw 8 pairs of pictures under different language groups and gave their responses. The dependent variable was the proportion of the correct relational responses on the 8 trails.

2.1.3 Materials

Experiment 1 used a total of 13 pairs of pictures describing different relational scenes, which consisted of 3 practice pairs, 2 fillers pairs and 8 experimental pairs. The experimental pairs were made based on the example pairs used in the study by Gentner et al. (2009). The pictures were drawn by a graduate student who was pursuing a Visual Arts degree. She then standardized the pictures onto A4 sized sheets of paper using Photoshop CS5 software. Each picture pair included a base picture and target picture. Participants were instructed to view different pairs of the pictures and then select a specific object from the target picture corresponding to the actor (the "doer" of the action) from the base picture. *Cross-mapping* was used for each of the experimental trials (Simms & Gentner, 2009), in which the doer used the base picture to indicate if the target picture influenced the response (Fig.1). Therefore, participants were able to select the role within the target picture by choosing either object properties (e.g. cat) or relational inferences (e.g. chaser).

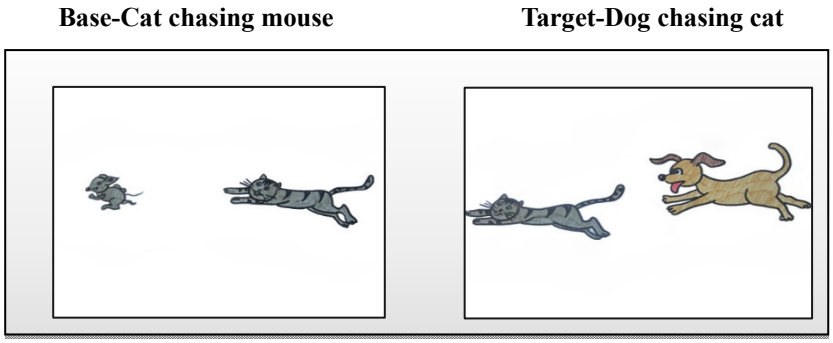

Figure 1. Sample picture pair in experiment 1

The process for making filler pictures and practice pictures followed the same requirement of experimental pictures. The practice pictures were used to introduce the task, and all of them were literally similar to experimental pictures and were presented before the formal experimental trials. Similar practice pictures were used to eliminate the possibility that this practice may bias participants towards either relational or object matches. Two filler picture pairs were also included among the eight experimental pairs in order to check whether participants remained involved across the whole task. Those who failed to correctly answer both filler pairs would not be included in further data analysis.

2.1.4 Procedure

The researchers used similar procedures from Gentner, Simms, and Flusberg (2009). On all trials, the experimenters showed a page to each participants, where the base picture was above the target picture. Then, the experimenter asked the child "what was happening in this picture?" The experimenter would agree with whatever answers the children provided and described the relationships on the paper. After this description, the experimenter put a red sticker on the object from the base picture and asked them to put another sticker on the one that "went with" that object in the target picture (Gentner, Simms, and Flusberg, 2009, p.3).'" The instruction under Relational Language group was given as: "Do you see this one that's chasing? What does this one go with in this [pointing to target] picture?" However, the instruction in the Neutral Language group were given as: "Do you see this one? What does this one go with in this [pointing to target] picture?"

If the children had difficulty during the first practice trial, the experimenter repeated the description of the relationships between the two pictures, and encouraged the child to answer it again. If the child still had difficulty, the experimenter pointed to the correct answer and explained it to them. They repeated this process until the child was able to answer the question correctly. Finally, the experimenter moved on to the experimental trials. The 8 pairs of pictures in experimental trials were randomly presented following the practice trials and all the children were tested individually by a single experimenter. The experimental and filler trials which were not provided with any feedback.

2.1.5 Results

A 2(Age)×2(Language) two-way analysis of variance (ANOVA) were conducted by IBM's statistical software SPSS version 24.0 and the mean correct response proportion were entered as dependent variable. The main effect of Language Type was significant, F (1, 68) =44.82, p<0.05, η_p^2=0.40. The children who heard the Relational Language (M=0.78, SD=0.05) chose more relational match than those who heard Neutral Language (M=0.32, SD=0.05). Within the 4.5-year-olds, the relational match made by Relational Language group (M=0.74, SD=0.33) was significantly higher than that of the Neutral Language group (M=0.30, SD=0.27; t (34) =4.35, p<0.05). A similar trend was also found for 5.5-year-olds, the relational match made by Relational Language group (M=0.82, SD=0.26) was significantly higher than that of the Neutral Language group (M=0.35, SD=0.29; t (34) =5.17, p<0.05). There was no effect of age, nor any interaction effect.

2.1.6 Discussion

As expected, children under the relational condition made more correct choices than those under the neutral condition. More specifically, under the Neutral Language instruction, both 4.5 and 5.5-year-olds made very low relational responses (30% vs 34%). However, after hearing the Relational Language instruction, both 4.5 and 5.5-year-olds greatly increased their relational responses to 74% and 82%, which are very striking improvements (t_1(34) =4.35, p<0.05; t_2(34) =5.17, p<0.05). The results that both age groups made fairly low and very similar performances (29.8% for 4.5-year-olds and 34.7 % for 5.5-year-olds) under Neutral Language condition may be explained by usage of the cross-mapped methodology. Based upon the Structure Mapping on Theory (Gentner, &

Smith, 2012), the cross-mapped condition was deemed as low transparency and would greatly disrupt transfer during reasoning process. In cross-mapping, a given target object looks like one of the base objects, but its role in the relational structure is different. Cross-mappings are especially challenging for younger children because they are highly influenced by object matches and less able to attend to relational matches than older participants (Rattermann & Gentner, 1998). For example, in a series of spatial mapping experiments, Loewenstein and Gentner (2005) found that regardless of language condition, the average performance by 4 year old children in the cross-mapped task was much worse than those in the neutral objects mapping task. After hearing the Relational Language, both age groups made significant improvements. This indicated that the greater difficulty of the cross-mapped task was compensated by the presence of spatial language. However, this finding is different from Gentner et al., (2009)'s results, where the language advantage was found only for the 7-year-olds, but not for 5-year-olds. This difference demonstrated two points: 1) Chinese and U.S. 5-year-old preschoolers are equally able to solve at least the one-dimension analogical problem; 2) The Chinese 5-year-old children gained more language advantage than U.S 5-year-old children, which may indirectly support the cross-cultural views that there is a bias for object-centered comparisons by Western children and for more relational-centered comparisons by Eastern children (Kuwabara & Smith, 2012; Richland et al., 2010). Most of these empirical studies found that the Chinese or Japanese preschoolers were more sensitive to relational structure, especially in contexts with compelling objects compared to the U.S. preschoolers. This relational oriented cognitive style may help strengthen their relational schema, making it more accessible in memory and increasing the likelihood that the learner will perceive the schema again across different circumstances (Gentner & Christie; 2010). For example, after hearing the Relational Language, Chinese preschoolers may quickly encode the "relational structure" in the base problem, and retrieve the meaning such as "chasing" or "towing" within the situation. Once the relational alignment was represented between the base and target situations, the successful inference could be projected across different situations.

Finally, the finding that the age effect is not significant, F (1, 68) =0.943, p>0.05, was consistent with some findings in China. For example, Li and Feng (2002) studied the development of analogical reasoning of children aged 4 to 5 years old using the one-and-two-dimension reasoning tasks. The results showed that the performance of 4.5 and 5.5 years old did not differ at one-dimensional task, but the 5 years old was markedly superior to the 4 years old in the two-dimensional tasks. Ma et al. (2008) also found that 4 year olds are already able to solve many analogical reasoning tasks independently, and 4 and 5 year olds did not show significant difference in both the distractor and non-distractors conditions. All these convergent evidences indicated that 4 years Chinese children were fairly as competent as 5 year olds' children on solving one-dimensional reasoning problems. As the relational knowledge was already controlled in our study, the maturational constraints theory (Morrison, Doumas & Richland, 2006; Halford, 2014) may better explain the invariant performance between 4 and 5 year olds. This theory proposed that analogical development is driven primarily by the maturation of children's cognitive capacity such as working memory and inhibitory control. Therefore, it is possible that Chinese pre-school students' cognitive development between the ages of 4-5 appear to be relatively stable particularly in their working memory and inhibitory control. The development of these capacities were not as mature as adult levels, nor were they quantitatively far enough to differentiate the performance between the two age groups. Although the question of what element of cognitive capacity is driving the development of analogical reasoning is still under debated, this hypothesis is fundamentally consistent with the findings in China that the analogical reasoning ability to solve structure similarity problems developed faster before 4 years old and slow down again after 4 years.

3. Experiment 2

3.1 Method

3.1.1 Participants

All the participants were from the same kindergarten in Kaifeng, China. There were thirty-six 4.5-year-olds (middle grade) and thirty-six 3.5 -year-olds (lower grade) preschool children in the current sample. Gender was balanced within each age group, meaning that there were sixteen boys and sixteen girls in each group respectively. Half of the children into each age group were randomly assigned into the *Relational Language group* (n=18), and a half into the *Neutral Language Group* (n=18). In each age by language group, half the children were boys and the other half were girls.

3.1.2 Design

Experiment 2 adopted a 2×2×3 mixed design, where Age (3.5 vs 4.5) and Language (Relational vs. Neutral) were between-subject factors, and Pair Type (no distractor, external distractor, and cross-mapped distractor) was

a within-subject factor. Like Experiment 1, participants saw 8 pairs of pictures under different language conditions. But in Experiment 2, three different Pair Types were added into each subgroup created by age and language factors. The dependent variable was the proportion of the correct relational responses on the 8 trials.

3.1.3 Materials

Experiment 2 remained using the similar cross-mapped pairs as in Experiment 1. However, in experiment 2, two new pairs were added to mix with cross-mapped pairs, where the object match was external to the relation or there were no distractors (Fig. 2). Thus, there were total three types of pairs used in the current experiment: (1) No-distractor pair, where no object distractor was shown in the target picture (Fig. 2a); (2) External distractor pair, where the distractor did not participate in the target relation but was still shown in the target picture (Fig .2 b); and (3) Cross-mapped pair, in which the object distractor participated in the same relation in the target picture as in the base picture (e.g., towing), but played in a different role (e.g., towee versus tower) (Fig.2 d).The direction of the relation (e.g., towing from left to right) was varied in each pair so that spatial location could not interfere the children's relational match. Children were provided with a total of eight experimental picture pairs, with each presenting a different relation. In addition to the eight experimental trials, children were given three practice pairs and fillers were not used in Experiment 2 in order to reduce participants' workload.

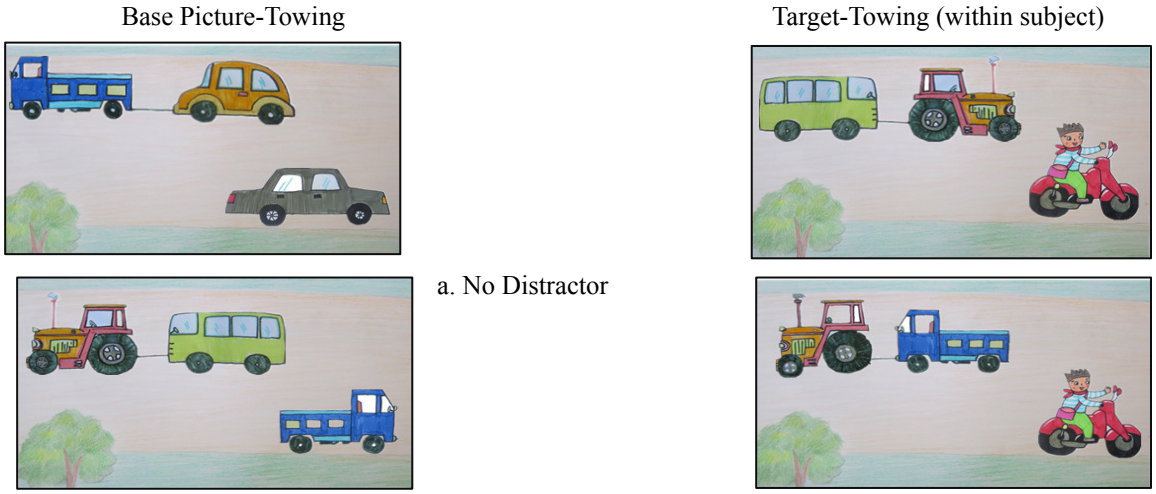

Figure 2. Sample pictures for Experiment 2

3.1.4 Procedure

The general procedure here was similar to Experiment 1 and were made to follow those used by Gentner et al. (2009). That is, participants were told that pictures shared a common "*pattern*" and that they should use the *pattern* to match the pictures. Then, the experimenter showed the practice pictures, and said: "Are you ready? Ok, there is a certain pattern that happens in the top picture, and see, the same thing happens in the bottom one. However, it looks different. Let me explain it. Look at the top picture, a grandma was feeding her grandchild? And the picture on the bottom, the grandma was fed by her grandchild. Ok, now please catch the common pattern here and I will put a sticker to one thing in the top picture. And your goal was to put another sticker on the bottom picture based on what happened in the common pattern. Let us see here we have a grandma feeding her grandchild and if I point the sticker to the grandma, which one is like this one that you should put a sticker to in the bottom picture?

As in Experiment 1, children were provided with feedback about the right answer in the practice trial and any practice trial could be repeated until children fully understood the format of the practice trials. The order of the practice trial for all the students was first shown no distractor trial, and then the one that had the external distractor and finally the cross-mapped distractor.

3.1.5 Results

A 2 (3.5 vs 4.5) ×2(relational vs neutral) ×3(distractor condition) mixed-design ANOVA was conducted, where Age and Language were between-subject factors and pair type with-subject factor. As predicted, the main effects of language, F (1, 68) =230.04, p<0.01, η_p^2=0.77 and age, F(1,68) =6.76, p<0.05, η_p^2=0.09 were significant. The 4.5-year-olds chose the relational match significantly more often than the 3.5-year-olds (*M.D.*= 0.08, p<0.05),

and children hearing the Relational Language chose the relational match significantly more often than those who did not (*M.D.*=0.49, $p<0.05$). A main effect of pair type was also significant, $F(2, 136)=57.90$, $p<0.01$, $\eta_p^2=0.09$. Children's performance under no distractor type was significantly higher than children under external distractor (*M.D.*=0.04, $p<0.05$) and those under cross-mapped distractor (*M.D.*=0.15, $p<0.01$).

Since the interaction effect between the language group and distractor type was significant, $F(2, 136)=15.56$, $p<0.01$, $\eta_p^2=0.19$, the best way was to analyze them simultaneously in light of their interaction. To be more specific, a two-way 2 (language type) ×3 (distractor condition) mixed measures ANOVA were conducted for each language groups separately. For Neutral Language, children's relational choices in no distractor pair were statistically significantly higher than those in external distractor pair (*M.D.*=0.09, $p<0.01$). While children's relational choices in external distractor pair were statistically significantly higher than these in the cross-mapped distractor (*M.D.*=0.14, $p<0.01$). In contrast, for Relational Language, children's relational choices in no distractor type were not significantly different from those in external distractor condition. However, children's relational choices in no distractor (*M*=0.89) and external distractor (*M*=0.90) were statistically significantly higher than these in cross-mapped distractor pairs (*M*=0.83, $p<0.05$).

Finally, in order to know whether the two age groups differ at the relational choice across different distraction pairs after they heard relational terms, we split the data file by language type and conducted the independent sample t test. The results revealed that before given language terms, the performance of 3.5 and 4.5-years-olds were not significant different on either no distractor or external distractor pairs ($t_1(34)=1.06$, $p>0.05$; $t_2(34)=0.61$, $p>0.05$). However, both age groups differ at cross-mapped pair ($t_3(34)=2.81$, $p<0.05$). After receiving language terms, both groups different only at no distractor pair ($t_1(34)=2.93$, $p<0.05$), but not at external and cross-mapped pairs ($t_2(34)=1.64$, $p>0.05$; $t_3(34)=1.37$, $p>0.05$).

3.1.6 Discussion

In Experiment 2, the expected age effect was observed between the 3.5-year-olds and 4.5-year-olds, where 4.5-year-old children had significantly higher proportional match (*M*=68%) than 3.5-year-old children (*M*=59%), which supported our hypothesis. This overall age advantage by the 4.5-year-olds has also been shown in other related studies (Feng et al., 2006; Gu, Feng, Yuan & Ma, 2011). All these convergent results indicated: (1) with prior relational knowledge, 3.5-years-old was able to finish some simple analogical reasoning problems because of their above-change performance on the no distractor/ Neutral Language condition (46.5% in current study). (2) the growth rate of analogical reasoning between 3.5 and 4.5 year olds is relatively faster due to the significant age effect. As suggested by Experiment 1 and previous studies (Ma et al., 2008; Gu et al., 2011), this growth rate may be slowed down again. The underlying mechanism is still unknown, but one possibility may be related to the development of inhibitory control. When children knew the Relational Language, inhibitory control was believed to play a key role in the analogical mapping ability since it can help focus on relevant stimuli in the presence of irrelevant stimuli. (Richland et al., 2006; Simms & Gentner, 2009). This ability is considered to be especially crucial for solving cross-mapped tasks in that the reasoner must inhibit the response to the featural match in order to select a relational match in the analogy. Although the direct evidences about their relationship is still limited, a similar growth pattern for the inhibitory control, which was also developing faster between age 3 and 4 (Zhang & Xu, 2005) may be informative for explaining the underlying theory behind this age effect.

As predicted, both the language type and distractor type were significant, $F(1, 68)=230.04$, $p<0.01$, $\eta_p^2=0.77$; $F(2, 136)=57.90$, $p<0.01$, $\eta_p^2=0.09$, in current study. However, as the interaction effect between language group and pair type was statistically significant, $F(2, 136)=15.56$, $p<0.01$,$\eta_p^2=0.19$, it was much more meaningful to discuss the language condition and distractor type together. Generally, this significant interaction indicated that the Neutral Language influenced children's performance in a different way from Relational Language in terms of different distractor pairs. That is, under Neutral Language group, children's performance on distractor pair was significantly higher than that of external distractor pair. (*M.D.*=0.09, $p<0.01$), which is higher than the performance in the cross-mapped pair (M.D.=0.14, p<0.01). This finding is different from Gentner et al. (2009)'s results in experiment 2. In their study, children made similar performance whether or not the object match participated in the relevant relation, indicating that external distractors and cross-mapped distractors were equally disruptive to children's performance in the Neutral Language condition. She later explained that children may not attend to the relation at all when an object match is present.

However, this interpretation may not be applicable to our case because children's performance on external distractor pair is significantly higher than the cross-mapped pair. One possible postulation for this linear significant decrease was that the children did actually notice this relation when solving different types of problems, which further gave us a hint that cross-mapped distractor pair is more difficult than external distractor

pair for these children. As suggested by recent studies (Chuderska, 2010; Chuderska, & Chuderski, 2014), the strength of the detrimental effect of distraction on mapping is linked to the probability of distracters entering working memory (WM). That is, the featural distractor being participating into the key relational structure (cross-mapped distractor pair) may have larger probability of entering the WM than the external distractor pair, and the subsequently parallel processing of both relational match and feature match would cost more processing resources which are very limited for preschoolers (Andrews & Halford, 2002). That is why children have an average lower performance on the condition of cross-mapped distractor pair.

Similarly, within the Relational Language condition, children's performance did not differ between the no distractor and external distractor condition ($M.D.$=0.03, p>0.05), but both were significant higher than cross-mapped pair condition. This finding once again confirmed that Relational Language could facilitate analogical reasoning because all the performance under three different pairs were significantly increased after hearing the language terms, $t_1(70)$ =10.41, p<0.05; $t_2(70)$ =10.95, p<0.05; $t_3(70)$ =10.30, p<0.05. It is also interesting to find that hearing language actually boosted the performance in external distractor to the level equal to the no distractor condition, but the performance in the cross-mapped distractor was still significantly lower than the external and no distractor condition, even it was also significantly boosted by hearing Relational Language, 27% vs 83%; $t_3(70)$ = 10.30, p<0.05. This pattern again supported the fact that cross-mapped distractor is the most difficult one among them all.

It is also worth noting that this result is also different from Gentner et al. (2009)'s findings where children' relational choice on distractors trial (external or cross-mapped) was similar to no distractor trails after hearing the language terms. One possible reason is that the average age in our experiment is younger than Gentner et al.'s (2009) study, and the younger children are more sensitive to the distractors at mapping problems. According to Richland, et al. (2006), when a match based on object similarity was present the youngest children (age 3 and 4) seem to have limited resources to resist this distractor, even though they reliably demonstrated accurate relational mapping in conditions without a featural distractor. This tendency to make more featural errors than to make relational errors was often observed among 3 and 4-year-olds despite the explicit verbalization of the relevant relations was provided. Therefore, we can image that the cross-mapped distractor was still very challengeable to the youngest children even after they received the Relational Language in current study.

4. Overall Discussion

In sum, our current findings make the following empirical contributions. First the results from the two experiments replicated and expanded the previous finding that Relational Language could facilitate the relational reasoning among young children. One possible interpretation for this common phenomenon is that Relational Language may highlight the relational communality over the featural communality during the matching process. Then this relational structure will play as a higher order or dominating principle over featural structure to make predications across two assignments. Finally, predications made based on this salient relational common structure in the base, but not initially present in the target, will be proposed as the candidate inference in the target. For instance, after hearing the relational verb "chase", children might focus on the chasing relation and the role of the cat within relational structure rather than on cat or mouse themselves. After completing this relational structure matching in their representation, they will make corresponding relational inference, ignoring the featural similarity inference.

Second, the more salient language effect for 5.5-years-olds compared to the same age group in Gentner et al. (2009)'s study may support some cross-culture evidences that Chinese children outperformed U.S. children of the same age on relationally complex analogies, and this cross-cultural bias are event evident as young as preschoolers (Moriguchi et al., 2012). According to Richland et al. (2010), this advantage was more likely caused by the greater experience with socialized relational inputs for Chinese children rather than the group difference in the type of working memory processing required by the tasks. For examples, Asian caregivers are more interested in guiding infants and younger children's attention by using action-oriented language and referential verbs, while English-speaking caregivers prefer using more naming and non-referential verbs (Imai et al., 2008; Waxman et al., 2016). Some scholars even proposed it is the structural differences in English and Chinese that lead to different reasoning styles. For instances certain features of the Chinese language make people think in a relational way whereas certain features of the English language make people think in a categorical way (Ji, Zhang, & Nisbett, 2004). Whatever it may be, one thing should always be kept in mind is that these differences are not all-or-none. Fundamentally, both Easterners and Westerners reason relationally, and Easterners and Westerners can—when the task demands it—sustain attention on individual objects (Kuwabara & Smith, 2012).

Third, the two experiments in the current study resulted that the 4.5-year-olds made significantly more relational choices than the 3.5-year-olds, but not more than 5.5-year-olds in the cross-mapping tasks. This confirmed our hypothesis that the analogical reasoning ability is not increasing linearly across Chinese preschoolers (Ma et al., 2008; Gu et al., 2011). However, the caution should be noted that this growth trend may be limited to the analogical reasoning with unary relation because all the mapping takes used in the current study were just one-dimensional relation. According to the Relational Complexity Theory (Halford, Wilson & Phillips, 1998), the processing load imposed by a given cognitive process depends on the complexity of relations processed, and the increased relational complexity (binary vs ternary) will overload the processing capacity limited by working memory. Therefore, preschoolers' performance on unary relational task was found to be disassociated from that of binary relational tasks controlling for the same age. For example, Li and Feng (2002) studied the development of analogical reasoning ability among Chinese preschoolers in control of the relational knowledge and found that age 4.5 to 5.5 is the "faster growth period" for the binary analogical reasoning, but not unary reasoning. In other words, all these evidences indicated that the increased ability to cope with binary relation was expected to be associated with analogical ability in a different developmental trajectory as with the unary relation.

Overall, the current study expands the finding in western countries that Relational Language facilitated the analogical thought to preschoolers in China and pinpoint the growing calls for understanding the cross-cultural difference of relational reasoning ability, which may set up different growth trajectory of analogical reasoning ability.

5. Limitation

Several cautions should be warranted in interpreting our results. First, the participants in the current study were recruited from a well-known public kindergarten in Kaifeng, China. Our sample may not be able to fully represent preschool children in other areas of China. In bigger cities where parents are more accessible to advanced educational resources, preschool children may have a better chance of gaining these relational terms and language even before kindergarten. Thus, the ability to generalize the current findings is a limitation until more empirical research can be conducted. Second, relational terms used in the current study only used verbs and adjectives. The generalization of the current findings to other categories of relational terms, such as nouns and prepositions, should also be carefully considered since studies (Tardif, 1996; Choi, 2000; Bornstein,2004) indicated that verbs are acquired faster than nouns. They also differ from the communicative functions, which are used to reinforce their function and structure of various words. Thus, researchers could consider using other categories of relational terms in future studies. Finally, assuming the selected relationships were familiar to all the participants, it does not rule out the possibility that the younger children may have failed in some trials because the relationships used in those particular analogies were unfamiliar to them (Lee, 2007). Alternatively, their reasoning may have been based on the relationships that were different from what the experimenters intended. Thus, further studies could record and analyze participants' error patterns to assess whether student performance is language-based, depending on relational familiarity rather than analogical ability.

Acknowledgment

Thank you for the support from the open access subvention fund in Virginia Tech.

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