Journal of Mathematics Education
December 2009, Vol. 2, No. 2, pp.80-93

A Study of Children's Spatial Reasoning and Quantitative Reasoning Abilities

Zhong Tian

Xingfeng Huang
Changshu Institute of Technology, China

This study was conducted to explore the spatial reasoning ability of 1,872 children aged 4-7 years old. Three questions were employed in this study to investigate the children's spatial reasoning ability and quantitative reasoning ability. It was found that the rapid improvement stage of children's spatial reasoning ability exists from 5-years and 6-months to 5-years and 11-months, and the rapid improvement stage of children's reasoning exists from 7-years to 7-years and 5-months.

Key words: children, spatial reasoning ability, reasoning.

Many researchers in psychology and mathematics education are interested in children's cognitive development, in which topics related to children's mathematical abilities of identifying shapes, spatial ideas, and numerical concepts have been paid special attention. Since the 1990s, when cognitive psychology came into prominence, questions of children's cognition were explored deeply by extending and moving beyond Piaget's initial work (Zhu & Fang, 1997). In order to offer the theoretical support for improving children's education, researchers began to look for evidence from their lived experiences as well as their experiences within a school context.

Background

In an elementary school located in a city in southwest of China, a mathematics teacher in a Grade 1 classroom required students to count the number of doors and flower beds based on a picture adapted from their textbook (see appendix). Within a minute, all the students in the class raised their hand to answer the question, and some of them answered "15 doors, 9 flower beds." No students disagreed with their answers which were, in fact, correct. These students' performance counting doors and flower beds based on the picture drew our attention because there are three rows of houses in the picture, but part of the last two rows is "hidden" from view by the front row. This means that children's counting of the total number of doors and flower beds must rely on their spatial reasoning and quantitative reasoning abilities. The Grade 1 students' performance showed that they had sufficiently developed spatial reasoning ability as well as quantitative reasoning ability to answer these questions correctly. This led us to become interested in examining the spatial reasoning ability and quantitative reasoning ability of children younger than Grade 1, something we explored by using this picture as an instrument for data collection.

Specifically, we explored how young children's spatial reasoning ability and quantitative reasoning ability develop and what relationship exists between these two abilities. The participants included children from two-year preschool classes in kindergartens and from Grade 1 classes in primary schools (47 months to 96 months of age).

Method

Instrument

The picture adapted from the textbook was modified to increase the overlap of the houses. Three questions were written that related to the situation in the picture that could be used as an instrument to test children's spatial reasoning ability and quantitative reasoning ability.

Question 1 is, "How many rows of houses are in the picture?" Question 1 is used to test specifically children's spatial reasoning ability. Children, as adults, live in three-dimensional space. The images projected to the retina of their eyes are the same. If a 4-7 year old child faces three rows of houses, he or she who has number sense can count the number of rows. When three rows of houses are represented in a picture they are changed into a two-dimensional image; there are no houses but icons of them. We can say this process from house to its icon is an abstract process, so the understanding of differently aged children of this iconic representation may vary. In other words, children's understanding of the icons of houses depends on their spatial reasoning ability. It was assumed that there are three levels of spatial reasoning ability. High level is defined as *spatial level* and is characterized by the successful icon-house connection, meaning the child can cognitively convert a two-dimensional figure into a three-dimensional object. If a child answers, "three rows of houses" in response to Question 1, he or she will be categorized in the spatial level. Low level is defined as *plane level* and is characterized by an inability to make the icon-house connection, meaning the child has the images of houses but cannot make the connection to the icons of houses. If a child answers, "one row of houses" in response to Question 1, he or she will be categorized in the plane level. Middle level is defined as the *fuzzy level* meaning the connection between the house and its icon is weak but present.

Questions 2 and 3 are intended to test children's quantitative reasoning as they require more than just spatial reasoning. Question 2 is, "How many doors are in the houses altogether in the picture?" Question 3 is, "How many flower beds are in front of the houses altogether in the picture?" A child's quantitative reasoning ability is fundamental to correctly answer the two questions. Because some doors and flower beds are covered in the picture, children would compute the numbers of all doors and flower beds by reasoning on the basis of some information such as the shapes of the roofs of the houses and the patterns of the uncovered doors and flower beds in the picture. It was assumed that there exist three quantitative reasoning levels. *Abstract computation level* is characterized by correctly answering that there are 15 doors and 9 flower beds. *Conjecture computation level* is characterized answering that there are more than 12 doors (but not giving the correct answer of 15) and/or that there are more than 6 flower beds (but not giving the correct answer of 9). Finally, *literal computation level* is characterized by answering that there are 12 doors and/or 6 flower beds (which represent the number of each item visible in the picture).

Method

The instrument was administered to 1,887 children of ten elementary schools (Grade 1 students) and five kindergarten classes (two-year preschool class and one-year preschool class children) from October 2004 to October 2005. Of these children, 1,001 of them were male and 876 female. 1,576 were in Grade 1 and 311 were in kindergarten. Of the 1,576 Grade 1 children, 1,015 were in urban primary schools, and 561 were in rural primary schools. Of the 311 of kindergarten children, 198 were in urban schools and 113 were in rural schools.

All the participants had no time limit to answer the three questions, but they were required to answer the questions as best by themselves. For each participant demographic information such as date of birth and gender was recorded. Based on observed responses, a subset of the participants across the various levels of spatial and quantitative reasoning was selected and interviewed by the first author to gain insights into their reasoning processes. The selected children's oral explanations and their gestures and emotion were recorded.

Results

The 1,872 valid responses were recorded and classified by age into successive three-month interval groups. For each group the % responding correctly (highest level) was determined (see Table 1). Analyses were then performed using SAS.

Table 1

Accuracy of Children's Answers to the Three Questions by Age

Group	Age	Sample		Question 1		Question 2		Question 3	
		N	%	*N*	%	*N*	%	*N*	%
1	48—50	12	0.64	6	50.00	0	0.00	0	0.00
2	51—53	44	2.35	19	43.18	2	4.55	1	2.27
3	54—56	30	1.60	15	50.00	3	10.00	2	6.67
4	57—59	26	1.39	14	53.85	0	0.00	1	3.85
5	60—62	37	1.98	17	45.95	4	10.81	3	8.11
6	63—65	53	2.83	20	37.74	0	0.00	4	7.55
7	66—68	26	1.39	12	**46.15**	3	11.54	2	7.69
8	69—71	46	2.46	34	**73.91**	8	17.39	9	19.57
9	72—74	171	9.13	138	80.70	51	29.82	58	33.92
10	75—77	269	14.37	199	73.98	85	31.60	114	42.38
11	78—80	309	16.51	237	76.70	91	29.45	123	39.81
12	81—83	369	19.71	296	80.22	131	35.50	183	49.59
13	84—86	317	16.93	256	80.76	129	**40.69**	160	**50.47**
14	87—89	102	5.45	78	76.47	68	**66.67**	69	**67.65**
15	90—92	44	2.35	34	77.27	17	38.64	25	56.82
16	93—95	17	0.91	13	76.47	6	35.29	9	52.94
Total		1872	100.00	1388	74.15	598	31.94	763	40.76

Accuracy of Children's Answers

Table 1 shows the results of children's correct answers to the three questions. One can reflect upon the children's spatial reasoning and quantitative reasoning abilities from these data.

As seen from Table 1, 74.15% of all participants answered Question 1 correctly. This means that these children overall have high spatial reasoning ability. Importantly, there is a considerable increase in their success with this item from five-a half years old (Group 7) to 5 years and 11 months (Group 8) – an increase of 26.62%. However, the participants' quantitative reasoning ability develops more slowly compared with their spatial reasoning ability. Overall just 31.94% of the children correctly answered Question 2 and 40.76% correctly answered Question 3. According to the development of a children's spatial reasoning ability, their quantitative reasoning ability improves when they are five and a half years old and above, whereas a rapid improvement stage is from 7 years (Group 13) to 7 years and 5 months (Group 14) – an increase of 26.62% for Question 2 and 17.18% for Question 3. Taken together, the data suggest that children's spatial reasoning ability develops earlier than their quantitative reasoning ability, and furthermore the fast improvement stage of their spatial reasoning ability occurs roughly 18 months earlier than the rapid improvement stage of their quantitative reasoning ability.

It is interesting to note that the percentage of children who answered Question 3 correctly is greater than for those who answered Question 2, as seen in Table 1. One explanation for this is that the number of flower beds in Question 3 is less than 10 while the number of the doors in Question 2 is more than 10 (a two-digit number). We understand young children count numbers less than 10 more easily than those greater than 10.

Plane Level and Visual Computation Level

Table 2

Plane Level and Visual Computation Level

Group	Age	Answer "1" in Question 1		Answer "12" in Question 2		Answer "6" in Question 3	
		N	*%*	*N*	*%*	*N*	*%*
1	48—50	0	0.00	6	50.00	5	41.67
2	51—53	0	0.00	15	34.09	18	40.91
3	54—56	1	3.3	6	20.00	13	43.33
4	57—59	1	3.85	9	34.62	14	53.85
5	60—62	2	**5.41**	12	32.43	17	45.95
6	63—65	0	**0.00**	26	49.06	36	67.92
7	66—68	0	0.00	11	**42.31**	15	**57.69**
8	69—71	0	0.00	13	**28.26**	21	**45.65**
9	72—74	1	0.58	71	41.52	87	50.88
10	75—77	1	0.37	112	41.64	131	48.70

11	78—80	0	0.00	136	44.01	164	53.07
12	81—83	0	0.00	141	38.21	156	42.28
13	84—86	1	0.32	105	**33.12**	134	**42.27**
14	87—89	0	0.00	18	**17.65**	24	**23.53**
15	90—92	0	0.00	15	34.09	14	31.82
16	93—95	0	0.00	7	41.18	7	41.18
	Total	7	**0.37**	703	**37.55**	856	**45.73**

Table 2 shows that few children's spatial ability is on the plane level (0.37%), whereas 25.98 percent of the children are on the fuzzy level. Table 2 also shows that 37.55 percent of the children who answered Question 2 and 45.73 percent of those answered Question 3 are on the visual computation level. Therefore, 30.51 percent (Question 2) of the children and 13.51 percent (Question 3) of them are on the guess computation level. Similarly, we understand children's cognition of different numbers results in the difference between these two questions.

According to the above discussion, we know that the first stage where children's reasoning ability improves occurs from 5 years and 6 months to 5 years and 11 months; whereas their spatial ability improves fast, the rapid improvement stage of reasoning occurs from 7 years old to 7 years and 5 months. If a child's spatial ability and reasoning could be seen as a representation of his or her knowing and understanding the world, he or she grow up beyond unenlightened to awakens before entering primary school, and this is accelerated by formal education.

Gender Difference

Table 3 shows:

(1) The rapid improvement stage of the female children in spatial ability is similar to that of the male children, however in this stage the male children's improvement is 10.38% lower than the sample's and the female's improvement is 49.28% higher than the sample's. It indicates that female's spatial ability improves significant more than the male's in the rapid improvement stage. There are 73.73% of the male and 74.63% of the female children whose answers to Question 1 are correct. This means that there is no difference of spatial ability between male and female. However, compared with the performance of the male and female in each three-month stage, it is found that male's spatial ability is better than female's at the early stage, and the female's spatial ability is better than male's at a later stage.

(2) According to the children's performance on Question 2, it is found that the rapid improvement stage of female children on numerical reasoning is similar to that of the male children, whereas in this stage the male children's improvement is 1.91% lower

than the sample's and the female's improvement is 2.69% higher than the sample's. 32.87% of the male and 30.88% of the female children's answers to Question 2 are correct. It shows that the male's performance on counting numbers within 20 is better than female's. The same conclusion can be drawn from their performance on Question 2 in each three-month stage.

(3) According to the children's performance on Question 3, it is worth noting that the rapid improvement stage of the female children on numerical reasoning is 3 months earlier than that of the male children, whereas in this stage the male children's improvement is 2.28% higher than the sample's. However, the female's improvement is 1.11% lower than the sample's means in their rapid improvement stage. There are 41.96% of the male and 39.38% of the female children whose answers to Question 2 are correct. This means that the male's numerical reasoning within 10 is better than female's. Compared with the children's performance on Question 3 in each three-month stage, it is found that the male's performance is better than the female's in 9 three-month stages, and in other 5 three-month stages the female's performance is better than the male's, and in another 2 three-month stage, the male' and female's performance are same.

Table 3

Gender Difference in the Three Questions

		Sample		Question 1		Question 2		Question 3	
	Age	Male (Female)	Male (Female)	Male (Female)	Male (Female)	Male (Female)	Male (Female)	Male (Female)	Male (Female)
	48—	5	0.50	3	60.00	0	0.00	0	0.00
1	50	(7)	(0.80)	(3)	(42.86)	(0)	(0.00)	(0)	(0.00)
	51—	23	2.30	13	56.52	1	4.35	1	4.35
2	53	(21)	(2.41)	(6)	(28.57)	(1)	(4.76)	(0)	(0.00)
	54—	17	1.70	8	47.06	2	11.76	2	11.76
3	56	(13)	(1.49)	(7)	(53.85)	(1)	(7.69)	(0)	(0.00)
	57—	12	1.20	7	58.33	0	0.00	0	0.00
4	59	(14)	(1.61)	(7)	(50.00)	(0)	(0.00)	(1)	(7.14)
	60—	23	2.30	13	56.52	3	13.04	3	13.04
5	62	(14)	(1.61)	(4)	(28.57)	(1)	(7.14)	(0)	(0.00)
	63—	28	2.80	10	35.71	0	0.00	4	14.29
6	65	(25)	(2.87)	(10)	(40.00)	(0)	(0.00)	(0)	(0.00)
	66—	12	1.20	7	58.33	2	16.67	1	8.33
7	68	(14)	(1.61)	(5)	**(35.71)**	(1)	(7.14)	(1)	(7.14)
	69—	26	2.60	17	**65.38**	2	7.69	2	7.69
8	71	(20)	(2.30)	(17)	**(85.00)**	(6)	(30.00)	(7)	(35.00)
	72—	87	8.69	72	**82.76**	22	25.29	25	28.74
9	74	(84)	(11.94)	(66)	(78.57)	(29)	(34.52)	(33)	(39.29)
	75—	154	15.38	111	72.08	55	35.71	74	48.05
10	77	(115)	(13.20)	(88)	(76.52)	(30)	(26.09)	(40)	(34.78)
11	78—	162	16.18	119	73.46	43	26.54	58	**35.80**

	80	（147）	（16.88）	(118)	(80.27)	(48)	(32.65)	(65)	（44.22）
	81—	190	18.98	156	82.11	78	41.05	105	**55.26**
12	83	（179）	（20.55）	(140)	(78.21)	(53)	(29.61)	(78)	（43.58）
	84—	171	17.08	133	77.78	69	**40.35**	85	49.71
13	86	（146）	（16.76）	(123)	(84.25)	(60)	**(41.10)**	(75)	**（51.37）**
	87—	59	5.89	43	72.88	38	**64.41**	40	67.80
14	89	（43）	（4.94）	(35)	(81.40)	(30)	**(69.77)**	(29)	**(67.44)**
	90—	22	2.20	18	81.82	10	45.45	14	63.64
15	92	（22）	（2.53）	(16)	(72.73)	(7)	(31.82)	(11)	(50.00)
	93—	10	0.10	8	80.00	4	40.00	6	60.00
16	95	（7）	（0.80）	(5)	(71.43)	(2)	(28.57)	(3)	(42.86)
Total		1001	100.00	738	73.73	329	32.87	420	41.96
		(871)	(100.00)	(650)	(74.63)	(269)	(30.88)	(343)	(39.38)

Compared among Different Schools (Kindergartens)

All children in this study can be classified into three categories according to their schools or kindergarten: urban key school (kindergarten), urban un-key school (kindergarten), rural school (kindergarten). These are few children of the sample in some three-month interval groups, Tables 4-6 list just a few interval groups.

(1) Table 4 shows that these are 78.63 %, 34.38%, and 39.09% of the children (730) from urban key schools (kindergartens) whose answers to Question 1, Question 2, and Question 3 are correct. These percentages are 4.48%, 2.44%, and -1.72% higher than those of the sample children. It indicates that on spatial ability and counting within 20, the performance of children from urban key schools (kindergartens) is better than others.

(2) Table 5 shows that these are 73.50 %, 35.40%, and 46.79% of the children (483) from urban un-key schools (kindergartens) whose answers to Question 1, Question 2, and Question 3 are correct. These percentages are -0.65%, 3.46%, and 6.03% higher than those of the sample children. It is interesting that the children form un-key schools (kindergartens) whose answers to Question 2 and Question 3 are correct are more than those from key schools (kindergartens). We understand that in the study sample children from key kindergartens are much more.

(3) Table 6 shows that these are 69.35 %, 26.40%, and 37.94% of the children (659) from rural schools (kindergartens) whose answers to Question 1, Question 2, and Question 3 are correct. These percentages are 4.80%, 5.54%, and 2.82% lower than those of the sample children, and 4.15%, 9.00%, and 8.85% lower than those of un-key urban children. It means that rural children’s space ability and numerical reasoning fall behind urban children’ space ability and reasoning.

Table 4

Urban Key Schools (Kindergartens)

Group	Age	Sample		Question 1		Question 2		Question 3	
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
10	75-77	118	16.21	93	78.81	36	30.51	39	33.05
11	78-80	112	15.38	95	84.82	39	34.82	47	41.96
12	81-83	135	18.54	116	85.93	50	37.04	62	45.93
13	84-86	136	18.68	119	87.50	56	**41.18**	63	**46.32**
14	87-89	68	9.34	56	82.35	42	**61.76**	46	**67.65**
Total		730	100.00	574	78.63	251	34.38	285	39.04

Table 5

Urban Un-key Schools (Kindergartens)

Group	Age	Sample		Question 1		Question 2		Question 3	
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
10	75-77	64	13.31	46	71.88	20	31.25	28	43.75
11	78-80	68	14.14	50	73.53	22	32.35	36	52.94
12	81-83	104	21.62	81	77.88	45	43.27	59	56.73
13	84-86	94	19.54	80	85.11	34	**36.17**	47	**50.00**
14	87-89	42	8.73	33	78.57	27	**64.29**	27	**64.29**
Total		483	100.00	355	73.50	171	35.40	226	46.79

Table 6

Rural Schools (Kindergartens)

Group	Age	Sample		Question 1		Question 2		Question 3	
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
8	69-71	11	1.67	4	**36.36**	0	0.00	0	0.00
9	72-74	30	4.57	22	**73.33**	3	**10.00**	4	**13.33**
10	75-77	78	11.87	60	76.92	22	**28.21**	28	**35.90**
11	78-80	112	17.05	76	67.86	24	21.43	34	30.36
12	81-83	120	18.26	87	72.50	34	28.33	51	42.50
13	84-86	143	21.77	104	72.73	46	32.17	74	51.75
14	87-89	68	10.35	51	75.00	27	39.71	33	48.53
Total		659	100.00	457	69.35	174	26.40	250	37.94

Correlation between Spatial Ability and Numerical Reasoning

We are interested in whether children have to identify three rows in the picture in order to count the numbers of the doors and parterres. For the sake of this purpose, correlation coefficients among the three questions are computed as follow.

To the children's correct answers (*N*=1463), the coefficient between Question1 and Question 2 is 0.225. To the female of them (*N*=675), the coefficient between Question1 and Question 2 is 0.195, and to the male of them (*N*=788), the coefficient between Qustion1 and Question 2 is 0.246.

To the children's correct answers (*N*=1491), the coefficient between Question1 and Question 3 is 0.243. To the female of them (*N*=687), the coefficient between Question1 and Question 3 is 0.219, and to the male of them (*N*=804), the coefficient between Question1 and Question 3 is 0.257.

These coefficients are less than 0.3, therefore it means that there is no direct relationship between children's spatial ability and numerical reasoning.

Interview

Fifteen children who correctly answered the three questions and twenty-seven children who incorrectly answered the three questions were interviewed. The ages of these children are from 50 months to 85 months; 29 children of them were from kindergarten, and 13 children of them were from primary school. All of them correctly answered Question 1. This indicates that their spatial ability has developed. There are 15 children who correctly answered Question 2 and Question 3, and 11 children of them are 65 months and above. They could see three rows of houses, understood some of the doors and parterres were covered, and knew how to count the covered doors and parterres in the picture. They employed sentences "5+5=10, 10+5=15"and "3+3=3=9" to count numbers.

Below is part of interviews with Xu, a 79 month old male child who could mentally compute the numbers:

Interviewer: How do you know 15 doors and 9 parterres?

Xu: You know some of them are covered.

Two children's interviews are very interesting because they just counted the number of the doors or parterres. Below is part of interviews with Qie and Qian, two 56 month old female children:

Interviewer: How do you see three rows of houses?

Qie: Counting.

I: How do you know 12 doors?

Q: Counting (she counts the uncovered doors in the picture).

I: How do you know 9 parterres?

Q: Counting (she counts the uncovered and covered parterres in the pictures)

……

Interviewer: How do you see three rows of houses?

Qian: Thinking.

I: How do you know 15 doors?

Q: Counting (she counts the uncovered and covered doors in the picture).

I: How do you know 6 parterres?

Q: Counting (she counts the uncovered parterres in the pictures)

Twenty-six of all interviewed children counted 12 doors and 6 parterres in the picture, and although 17 of them understood there were three 3 rows of houses, they could not make sense of the covered objects. Below is part of interviews with Chen, a 60 month old female child:

Interviewer: How do you see three rows of houses?

Chen: Counting,

I: Twelve doors, right?

C: Let me try again,……. Yes, 12 doors?

I: Six parterres, right?

C: Yes, some parterres just can be seen a half.

Discussion

It was found that 4-6 year old children have much informal mathematical knowledge about arithmetic, geometry and measurement (Dong, 2001). Compared with maturation and genetic factors, interactions between the individual and the environment are fundamental factors for children's development. For example, children's experience on manipulation and communication improves their numerical conception, provides them with platforms for building further interactions between children and environment, and also affects children's spatial ability and numerical reasoning.

Numerical Conception

A Child's counting activity contains two kinds of information processing activities: the learning of association and the learning of the rule of number string (Mo, Wang & Chen, 2000). Counting numbers is the first step on a child's numerical conception development (Lu, 2001). It was found that 3-7 year old children develop their counting ability by passing through three phases, as following: oral singing numbers, counting objects, and counting, then telling the amount. Piaget claimed that children making sense of numerical conception means counting numbers and understanding quantity conversation (Fang, 2001). It was also found that 7-year old Chinese children could understand various conservations (Fang). Constructing conservation conception refers to finding out an internal invariance among various external variations. We understand that children’s building with conservation conceptions depends on their intuitive imagination, reasoning, and experience. In this study, many children could understand that three rows of houses are same, so they reasoned that each row of house should have 5 doors and 3 parterres. Here, children’s conservation conception and reasoning played an important rule to counting numbers.

Piaget claimed that a child’s numerical conception development doesn’t depend on being taught but on individual maturation, however, other researchers argued that their experiment study got different results that do not support Piaget’s claim (Lu, 2001). We understand that informal education involving family education and kindergarten education play an important role in improving children’s numerical conception, whereas children’s experience could not be overlooked. In this study, many kindergarten children were found that had numerical conception and applied it in spatial ability and reasoning. Children’s rapid improvement stage of spatial ability occurs from 5 years and 6 months to 5 years and 11 months, and their rapid improvement stage of reasoning occurs from 7 years to 7 years and 5 months. These results are consistent with mathematics teaching because knowing numbers within 20 is usually studied in the first unit in Chinese primary mathematics curriculum.

Spatial Ability

Table 2 shows that few children could not identify space patterns in the picture. It means that children’s understanding space patterns is earlier than understanding plane geometry figures. Some psychologists suggest that children’s crawling experiences after 6-months old provides them with opportunities to understand space (Lu, 2001). Brain science researches provide us with a perspective to interpret children’s space ability development. It is claimed that there exist two kinds of learning: explicit learning and implicit learning (Dong & Tao, 2000). Implicit learning was characterized as a passive process, where people are exposed to information, and acquire knowledge of that information simply through exposure. Explicit learning, on the other hand, is characterized as an active process where people seek out the structure of any information that is presented to them. Much of children’s information learning during their earlier life is learned implicitly, not explicitly. Children’s living situations provide them with implicit understanding of space patterns, such as, playing with building blocks, looking for toys under a bed, or looking into a mirror, these could provide them with opportunities to make sense of space. Children’s implicit learning could also help them identify space patterns or geometric figures. For example, in the beginning a child sees real object, images in a mirror, and figures in a book as same, and scratch them indiscriminately. Over time, their accumulating experience becomes an implicit learning process, which drives them to identification.

Numerical Reasoning

On the reasoning ability of preschool children, some studies drew different conclusions. Piaget claimed that preschool children could not reason. Bi and Peng (2003) argued that children reasoning ability involved semantic speech, but with no significant developmental effects of age. In this study, 42 children below 6 years old and 109 children aged 6 years and 2 months and above could answer Question 2 and Question 3 correctly. It means that preschool children demonstrate numerical reason.

There existed two different perspectives on children's cognitive development. Piaget claimed that children's cognitive development has four different phases. However, some psychologists argued that children's cognitive development is successive (Lu, 2001). Our study results supported a perspective that children's cognitive process is a phase with successive integration. Because this study found that the children's spatial ability and numerical reasoning increased not linearly but sometimes folded back.

Some children could count parterres correctly, but they could not count the amount of doors. It was interpreted therefore that children can count numbers within 10 more easily than those outside of 10. However, 69 out of 598 children who correctly answered the amount of doors could not count the number of parterres. We understand that children's living experiences (for example, in general, the same house has the same door, but parterres are not like that) would affect their reasoning.

References

Bi, H.Y., & Pen, R. L. (2003). An experiment on the direct inference ability and strategies of 4-6 years old children. *Psychology Science, 26*, 228-231.

Dong, Q. (2001). An overview of basic and applied research on children's learning. In *Contemporary Chinese psychology* (pp. 299-303). Beijing: Beijing Normal University Press.

Dong, Q., & Tao, S. (2000). *Bain and behavior-the frontiers of science in 21st century*, Beijing: Beijing Normal University Press.

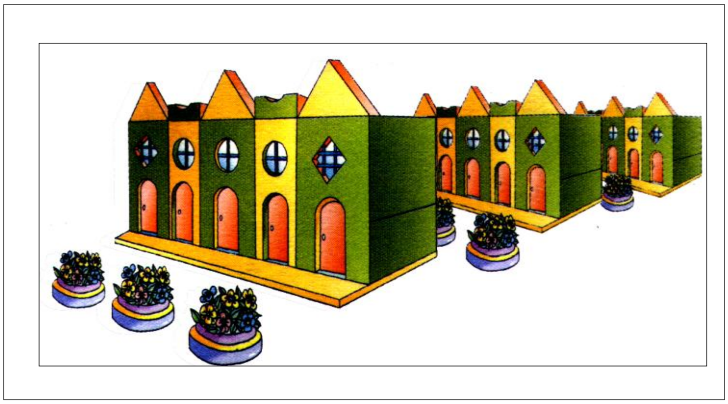
Lu, J. (2001). The study of several of cognitive development. In *Contemporary Chinese psychology* (pp. 259-264). Beijing: Beijing Normal University Press.

Fang, F. X. (2001). Exploring children's cognitive development and promoting children's mental quality. In *Contemporary Chinese psychology* (pp. 265-269). Beijing: Beijing Normal University Press.

Mo, L., Wang, H. P., & Chen, Z. (2000). A study on the characteristics of information processing of Chinese children's counting. *Psychology Science*, *25*, 641-644.

Zhu, L. Q., & Fang, F. X. (1997). The new trends of researches on children's cognitive development. *Psychology Science*, 20, 151-155.

APPENDIX



Authors:

Zhong Tian
Changshu Institute of Technology, China
Email: Tianzhong@cslg.edu.cn

Xingfeng Huang
Changshu Institute of Technology, China
Email: xfhuang0729@gmail.com