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Effect of birth order on stereoacuity in Chinese preschool children: a cross-sectional study

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ABSTRACT

Objective This study aimed to investigate the relationship between birth order and stereoacuity among Chinese children aged 60–72 months.

Design Cross-sectional.

Participants 1342 children with complete data on the questionnaire, stereoacuity and refraction were included.

Results The mean stereoacuity was 53.2±1.7, 56.9±1.9 and 60.9±1.5 s of arc in the first-born group, second-born group and third-born group, respectively. Lower birth order was significantly correlated with better stereoacuity (p=0.036). Third-borns (OR=3.02, p=0.027) were at higher risk of having subnormal stereoacuity compared with first-borns in the multivariate analysis.

Conclusion Later-borns had poorer stereoacuity than first-borns.

Strengths and limitations of this study

- ► To our limited knowledge, no report has demonstrated the correlation between birth order and stereoacuity.
- ► With the two-child policy in China, evaluating the effects of this baby boom on stereoacuity might benefit both families and the society.
- ► This is a population-based study comprising 1342 children aged 60–72 months.
- ► This study provided data, such as mean stereoacuity, which could be valuable to primary eye care in China.
- ► Some children without examinations were excluded which might bias the results, and some inaccurate stereoacuities might exist due to limited compliance.

INTRODUCTION

Due to the Chinese two-child policy, we are caught on the horns of a dilemma of an increasing demand for paediatric vision care and a decreasing professional care due to second-child maternity leave.[1] To the best of our knowledge, studies on Chinese later-borns are insufficient, and there is dire need to identify these Chinese later-borns.

Birth order could predict intelligence, personality and behaviours, according to extensive research conducted around the world.[2–4] In particular, several studies have reported that higher birth order was associated with higher risk of neurodevelopmental disorders.[5 6] As an important part of early neurological development, a reduced level of stereoacuity has a negative impact on the ability of an individual to perform many tasks, thus leading to bad interactions with the world.

As we all know, stereoacuity is the highest fusion sensory of binocular vision and has impact on the performance of fine visual and motor action. Children with poor stereoacuity might have serious visual developmental disorder, which could lead to reading difficulties in kindergarten and to poor intelligence in first-grade children.[7 8] However, to our limited knowledge, there is a serious lack of study on whether birth order is correlated with stereoacuity in Chinese preschool children. In addition, it has been estimated that 90 million Chinese couples could have a second child following the two-child policy in China.[1] Thus, assessing the relationship between birth order and stereoacuity has certain value in China nowadays.

This study is part of the Nanjing Eye Study (NES) and was designed to investigate the association between birth order and stereoacuity in Chinese preschool children and to provide some insights into paediatric care, and is timely with the increasing burden on primary care in China.

MATERIALS AND METHODS

This cross-sectional study is part of NES, a population-based cohort study designed to longitudinally assess the onset and progression of paediatric ocular diseases in Eastern China.[9–12] As described previously,[9 12] all children born between September 2011 and August 2012 and resided in Yuhuatai District, Nanjing, China were invited to participate in NES to undergo comprehensive eye examinations. In 2017, efforts to disseminate the benefits of our study to the legal guardians of these preschool children led to a participation rate of 83.5% (1920 of 2300). The data analysed for this study were obtained in 2017, when these children were 60–72 months old.

Written informed consent was obtained from the parents or legal guardians of all participants. Oral assent was obtained from all children right before the examination.

Ocular examinations

A comprehensive eye examination of participants was performed by a team composed of six trained ophthalmologists and four optometrists. Children roster and basic information including name, gender and birth date were all obtained from each kindergarten's principal and the information was then verified. Measurements included anthropometric parameters, distance visual acuity (VA), anterior segment and fundus examination, refraction before and after cycloplegia, Randot Preschool Stereoacuity Test, ocular alignment and motility, ocular biometric parameters, intraocular pressure, accommodative response, and optical coherence tomography. Children with suspected or confirmed eye problems were referred to senior ophthalmologists and underwent further examinations.

Distance VA was measured with a retroilluminated (ESV1200 Illuminated Cabinet, Good-Lite, Perth Amboy, New Jersey, USA) linear HOTV logMAR (logarithm of the minimum angle of resolution) chart (600 017, Good-Lite) at a distance of 3 m, right eye followed by left eye, as described before.[10 12] Additionally, children who wore spectacles were measured both with and without spectacles. Best corrected VA was recorded with full correction under cycloplegia.

Refractive status of each participant was measured before cycloplegia using table-mounted autorefraction (Canon R-F10, Tokyo, Japan) and photorefraction (PlusoptiX, Nuremberg, Germany). Cycloplegic refraction was performed after cycloplegia using table-mounted autorefraction and retinoscopy. One drop of topical 1.0% cyclopentolate eye-drop (Cyclogyl, Alcon Pharmaceuticals, Belgium) was administered to each eye twice at 5 min intervals. Fifteen minutes later, a third drop was administered if the pupil size was <6 mm or if the pupillary light reflex was still present.

Before cycloplegia, stereopsis thresholds were measured with the Randot Preschool Stereoacuity Test (Stereo Optical, Chicago, Illinois, USA) at a distance of 40 cm, following standardised testing procedure. Disparities in the Randot Preschool Stereoacuity Test ranged from 800 to 40 s of arc in unequal step sizes. Subjects viewed the stereogram through a pair of polarised glasses. Spectacles, if provided, were also worn. At each disparity level, the subject must correctly identify at least two of the three test shapes. Stereoacuity tests were labelled test 1, test 2 and test 3, respectively. The child was first asked to point out the shapes on the left page of the booklet or to name each shape seen in test 1. If the child could respond correctly to the 200 s of arc test object (top of test 1), the child was encouraged to proceed to the 100 s of arc test object (bottom of test 1). If the child passed test 1, testing proceeded to test 2 at 60 and 40 s of arc level, as described in test 1. If correct responses were not obtained at the 200 s of arc level, the child proceeded to test 3 at 800 and 400 s of arc level. If the child was unable to consistently identify most of the two-dimensional shapes on the left-hand pages, the subject was scored with 'unable' stereoacuity. Otherwise the smallest disparity at which the child was able to identify two of the three test shapes was recorded as the final stereoacuity.

Questionnaire

A comprehensive questionnaire composed of six parts was distributed to the legal guardian of each participant. Detailed data concerning basic information of the children and their parents, history of pregnancy, birth and feeding, daily activities, sleep quality of children, home environment, and guardian's concerns over the eyes of each child were all collected. Maternal age, gestational age at birth (weeks), birth weight, Apgar score at 5 min, delivery mode, neonatal oxygen supplementation, birth order, smoking exposure, breast feeding and so on were collected in the history of pregnancy, birth and feeding sections of the questionnaire.

Definitions

Spherical equivalent (SE) was calculated as spherical dioptre (D) plus half of the dioptre of cylindrical power. Myopia was defined as SE ≤−0.50 D in either eye, hyperopia defined as SE ≥+2.00 D in either eye, astigmatism defined as cylindrical power ≥1.00 D in either eye, and anisometropia was defined as SE difference ≥1.00 D between the two eyes. Strabismus was defined if any tropia was present at a distance or near, with or without spectacles. Amblyopia was defined similar to the Multiethnic Pediatric Eye Disease Study.[13] Subnormal stereoacuity was defined as stereoacuity worse than 40 s of arc (stereoacuity value >40 s of arc).[14]

Statistical analyses

Stereoacuity scores in seconds of arc were first transformed into a logarithmic value before statistical modelling, and the results in log units were transformed back to the original value after statistical analysis for easy clinical interpretation of results. Children unable to perform stereoacuity test were assigned 2000 s of arc for statistical analyses.

A t-test was used to compare the means for continuous variables and χ^2 test to compare percentages between groups. Mean test was performed to find the difference in stereoacuity between birth order groups. Univariate and multivariable linear regression analyses were performed to evaluate the association of factors with stereoacuity scores, including gender, age in months, gestational

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age at birth (weeks), birth weight, Apgar score at 5 min, delivery mode, neonatal oxygen supplementation, birth order, smoking exposure and breast feeding. Only factors with p<0.10 in univariate regression analysis were retained in multivariable regression model. Similarly, binary logistic regression models were fitted to determine the factors associated with subnormal stereoacuity. All statistical tests were performed using the Statistical Package for the Social Sciences (SPSS) V.13.0 statistical software, and p<0.05 was considered statistically significant. As to refraction, cycloplegic refraction was used if available and non-cycloplegic refraction was used only if cycloplegic refraction data were not available.

Patient and public involvement

Patients and the public were not involved in any aspects of the study, including the development of study question, study design, conduct of the study and dissemination of results.

RESULTS

Study population

Among the participants, 1342 (69.9%) preschool children with complete data on the comprehensive questionnaire, stereoacuity and refraction were included in the analyses. There were 721 (53.7%) boys and 621 (46.3%) girls, with a mean±SD age of 66.71±3.32 months for boys and 66.88±3.44 months for girls (p=0.36). Table 1 shows the characteristics of early life factors among preschool children in the NES.

Distribution of stereoacuity in preschool children

Table 2 and figure 1 show the distribution of stereoacuity in preschool children overall and by birth order groups. The mean±SD of stereoacuity was 54.0±1.7 s of arc among preschool children, 54.8±1.8 s of arc for boys and 53.1±1.7 s of arc for girls (p=0.31). Children with 40 s of arc accounted for the largest percentage (55.1%), followed by 60 s of arc (34.0%). In addition, 14 (1.0%) children had 'unable' stereoacuity.

The mean stereoacuity was 53.2±1.7 s of arc in the first-born group, 56.9±1.9 s of arc in the second-born group and 60.9±1.5 s of arc in the third-born group. The percentage of children with stereoacuity of 40 s of arc decreased from 56.3% in the first-born group to 30.0% in the third-born group. A significant difference in stereoacuity among birth order groups was found (p=0.034).

Early life factors associated with stereoacuity in Chinese preschool children

In univariate analysis, age in months (p=0.028), maternal age (p=0.039), birth weight (p=0.003), Apgar score at 5 min (p=0.030) and breast feeding (p=0.015) were all significantly associated with stereoacuity (table 3). Other factors such as gender, gestational age at birth, delivery mode, neonatal oxygen supplementation, birth order and smoking exposure were not significantly correlated with stereoacuity. In multivariate analysis, younger age in months (p=0.012), lower birth weight (p=0.003), higher birth order (p=0.036) and less breast feeding (p=0.023) were significantly correlated with poorer stereoacuity (table 3). Higher birth order was associated with poorer stereoacuity, with adjusted mean stereoacuity of 53.3, 56.7 and 62.1 s of arc for the first-born, second-born and third-born groups, respectively.

In the univariate analysis of the early life factors associated with subnormal stereoacuity, younger age in months (p<0.001), older maternal age (p=0.035), lower birth weight (p=0.002), higher birth order (p=0.043) and less breast feeding (p=0.007) were all correlated with higher risk of subnormal stereoacuity (table 4). In multivariate analysis, young age in months (OR=0.94, p<0.001),

Table 1 Characteristics of early life factors among preschool children in the Nanjing Eye Study (N=1342)

Characteristics	n (%)	Mean±SD
Gender		
Male	721 (53.7)	
Female	621 (46.3)	
Age in months		66.79±3.38
Maternal age		26.22±3.86
Gestational age at birth (weeks)		
<37	64 (4.8)	
37–42	1216 (90.6)	
≥42	62 (4.6)	
Birth weight (kg)		3.33±0.52
Apgar score at 5 min		
7–10	1305 (97.2)	
<7	37 (2.8)	
Delivery mode		
Vaginal delivery	756 (56.3)	
Caesarean delivery	586 (43.7)	
Neonatal oxygen supplementation		
Yes	76 (5.7)	
No	1266 (94.3)	
Birth order		
First	1083 (80.7)	
Second	239 (17.8)	
Third	20 (1.5)	
Smoking exposure		
Yes	172 (12.8)	
No	1170 (87.2)	
Breast feeding		
Exclusively	652 (48.6)	
Partially	561 (41.8)	
None	129 (9.6)	

Table 2 Distribution of stereoacuity in preschool children overall and by birth order group

Stereoacuity (in seconds of arc)	All (N=1342) n (%)	Birth order First (n=1083) n (%)	Second (n=239) n (%)	Third (n=20) n (%)
40	740 (55.1)	610 (56.3)	124 (51.9)	6 (30.0)
60	456 (34.0)	364 (33.6)	82 (34.3)	10 (50.0)
100	100 (7.5)	75 (6.9)	22 (9.2)	3 (15.0)
200	12 (0.9)	8 (0.7)	3 (1.3)	1 (5.0)
400	12 (0.9)	11 (1.0)	1 (0.4)	0
800	8 (0.6)	4 (0.4)	4 (1.7)	0
Unable	14 (1.0)	11 (1.0)	3 (1.3)	0
Mean±SD*	54.0±1.7	53.2±1.7	56.9±1.9	60.9±1.5
Median (first quartile, third quartile)	40 (40, 60)	40 (40, 60)	40 (40, 60)	60 (40, 60)

*The stereoacuity values were first transformed to logarithmic values to calculate the mean and SD, then transformed back to arc second values.

low birth weight (OR=0.71, p=0.001), high birth order (OR=1.22, p=0.17 for the second-born group; OR=3.02, p=0.027 for the third-born group) and never breast feeding (OR=1.79, p=0.004) were identified as independent indicators of subnormal stereoacuity.

DISCUSSION

In this study, we found that lower birth order was linked to better stereoacuity and lower risk of subnormal stereoacuity after adjusting for a wide range of factors in Chinese preschool children.

Although the difference among the three groups was small, combining with also a small number of later-borns, as well as the small SD (1.5~1.9), it might indicate those later-borns would have more difficulties in real situation than the first-borns. General findings from individuals with abnormal binocular function, such as poor stereoacuity, expressed impairment in motor control-movement speed, accuracy or both. Each of the activity was correlated with loss of stereoacuity, but not with severity of amblyopia. Impairments were especially marked when the task was time-limited or novel. We suggest paying more attention to later-borns with poor stereoacuity and following up their stereoacuity and stereomotion development.

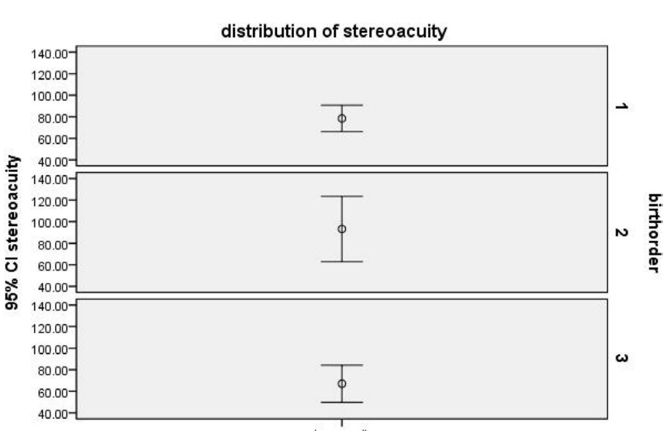

Figure 1 Distribution of stereoacuity. 1: first birth order group; 2: second birth order group; 3: third birth order group. Stereoacuity in seconds of arc.

To the best of our knowledge, this is one of the few population-based studies investigating the association between birth order and stereoacuity in preschool children. Our study found that later-borns had poorer stereoacuity and greater risk of subnormal stereoacuity than first-borns.

From neurological development perspective, there are several reasons for our findings. First, some studies found that higher birth order was associated with higher risk of neurodevelopmental disorders, such as schizophrenia.[5 6] Second, birth order has been reported to be related to grey matter volume. Comparing with first-born twins, second-born twins had smaller grey matter volume, indicating aberrant early brain development in the second-born twins, which could be also generalised to the singleton population.[15] Third, first-borns tend to overtake later-borns in intellectual performance by tutoring younger siblings.[2] Although it was reported later-borns could benefit from interacting with older siblings,[16 17] this benefit might be cast into the shade compared with first-borns tutoring younger siblings. Fourth, the maternal immune hypothesis has suggested the probability of maternal immune attack on the fetal brain increasing with increased parity.[18 19] Similarly, Rostila and Saarela[20] thought increased maternal antibody levels with high birth order might have a negative influence on fetal brain development. Finally, some reports found that later-borns with multiple siblings had a greater risk of exposure to common childhood pathogenic micro-organisms, including bacteria and viruses, at the time of birth than the first-borns,[21–23] which might also be a threat to brain development. Nevertheless, there are no data available demonstrating possible factors in this study, making it difficult to determine the underlying mechanism of poor stereoacuity in later-borns.

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Table 3 Univariate and multivariate linear regression analyses on the associations between early life factors and stereoacuity

		Univariate analysis		Multivariate analysis	
Characteristics*	**n**	**Mean (SE) in arc seconds**	**P value**	**Adjusted mean (SE) in arc seconds**	**P value**
Gender			0.31		
Male	721	54.8 (1.02)			
Female	621	53.1 (1.02)			
Age in months: slope (SE)		0.99 (1.00)	**0.028**	0.99 (1.00)	**0.012**
Maternal age: slope (SE)		1.01 (1.00)	**0.039**		
Gestational age at birth (weeks)			0.57		
<37	64	54.4 (1.06)			
37–42	1216	53.8 (1.02)			
≥42	62	56.2 (1.08)			
Birth weight (kg): slope (SE)		0.92 (1.03)	**0.003**	0.92 (1.03)	**0.003**
Apgar score at 5 min			**0.030**		
7–10	1305	53.7 (1.02)			
<7	37	65.7 (1.14)			
Delivery mode			0.14		
Vaginal delivery	756	52.9 (1.02)			
Caesarean delivery	586	55.4 (1.03)			
Neonatal oxygen supplementation			0.18		
Yes	76	58.7 (1.08)			
No	1266	53.7 (1.02)			
Birth order			0.053		**0.036**
First	1083	53.2 (1.02)		53.3 (1.00)	
Second	239	56.9 (1.04)		56.7 (1.00)	
Third	20	60.9 (1.10)		62.1 (1.02)	
Smoking exposure			0.17		
Yes	172	57.0 (1.05)			
No	1170	53.5 (1.02)			
Breast feeding			**0.015**		**0.023**
Exclusively	652	53.0 (1.02)		52.2 (1.00)	
Partially	561	53.1 (1.02)		55.1 (1.00)	
None	129	63.5 (1.07)		58.5 (1.01)	

Bold type indicates statistical significance (p<0.05).
*Factor was not included in the final multivariate model because it was not statistically significant.
SE, standard error.

In terms of potential psychosocial explanations for the association between stereoacuity and birth order, a dilution of resources for later-borns should be mentioned,[24] which showed parents' attention and material resources were limited. For one thing, children of higher birth order receive less parental attention and supervision partly due to limited time. First-borns might be the only baby when they were born, while later-borns were not. Limited parental attention and supervision also meant less attention paid to later-borns' health and safety, including psychological health and signs of psychiatric deviations, which are a threat to neurodevelopment. For another, the more children raised in one family, the less resource each offspring receives .

As we all know, stereoacuity is the highest form of sensory fusion and reflects neurodevelopment in children.[7 8 25] Thus the poor stereoacuity among later-borns might illustrate compromised global development, including gross and fine motor,[26] language,[27 28] sensory[29] and socialisation.[30] We attempted to find the possible causes of poor stereoacuity among later-borns from the paediatric ophthalmology perspective, but no significant correlation was found between birth order and myopia, hyperopia, astigmatism, anisometropia, strabismus or

Table 4 Univariate and multivariate analyses on the associations between early life factors and subnormal stereoacuity*

Characteristics†	n	Subnormal stereopsis* n (%)	Univariate analysis			Multivariate analysis		
			OR	95% **CI**	**P value**	**OR**	95% **CI**	**P value**
Gender								
Male	721	337 (46.7)	1.00					
Female	621	265 (42.7)	0.85	0.68 to 1.05	0.14			
Age in months			0.94	0.91 to 0.97	**<0.001**	0.94	0.91 to 0.97	**<0.001**
Maternal age			1.03	1.00 to 1.06	**0.035**			
Gestational age at birth (weeks)					0.37			
<37	64	34 (53.1)	1.42	0.86 to 2.36	0.17			
37–42	1216	539 (44.3)	1.00					
≥42	62	29 (46.8)	1.10	0.66 to 1.84	0.71			
Birth weight			0.72	0.59 to 0.89	**0.002**	0.71	0.57 to 0.88	**0.001**
Apgar score at 5 min								
7–10	1305	581 (44.5)	1.00					
<7	37	21 (56.8)	1.64	0.85 to 3.16	0.14			
Delivery mode								
Vaginal delivery	756	343 (45.4)	1.00					
Caesarean delivery	586	259 (44.2)	0.95	0.77 to 1.19	0.67			
Neonatal oxygen supplementation								
Yes	76	40 (52.6)	1.39	0.88 to 2.21	0.16			
No	1266	562 (44.4)	1.00					
Birth order					**0.043**			**0.040**
First	1083	473 (43.7)	1.00			1.00		
Second	239	115 (48.1)	1.20	0.90 to 1.58	0.21	1.22	0.92 to 1.63	0.17
Third	20	14 (70.0)	3.01	1.15 to 7.89	**0.025**	3.02	1.13 to 8.04	**0.027**
Smoking exposure								
Yes	172	88 (51.2)	1.34	0.97 to 1.84	0.08			
No	1170	514 (43.9)	1.00					
Breast feeding					**0.007**			**0.009**
Exclusively	652	283 (43.4)	1.00			1.00		
Partially	561	244 (43.5)	1.00	0.80 to 1.26	0.97	0.99	0.79 to 1.25	0.96
None	129	75 (58.1)	1.81	1.24 to 2.66	**0.002**	1.79	1.21 to 2.64	**0.004**

Bold type indicates statistical significance (p<0.05).
*Subnormal stereoacuity was defined as stereoacuity worse than 40 s of arc (stereoacuity value >40 s of arc).
†Factor was not included in the final multivariate model because it was not statistically significant.

amblyopia. We supposed poor stereoacuity is a marker of compromised global development. It might be necessary to assess later-borns in the long term with regard to both neurological development and health development.

Besides high birth order, low birth weight and never breast feeding were also correlated with poor stereoacuity, suggesting the importance of early intervention during pregnancy and the perinatal period, especially for later-borns. Thus, to improve paediatric healthcare, it is also important to strengthen healthcare during pregnancy and childbirth.

Our study had several limitations. First, 578 children who did not finish the examination or questionnaire were excluded from the analyses, which might bias our results. Second, the stereoacuity measurement of some children might not be accurate enough due to poor compliance. Third, only age in months, gender and early life factors were included in the multivariate analysis. It is possible that other unknown or unexplored factors might also contribute to poor stereoacuity.

In conclusion, later-borns had poorer stereoacuity than first-borns. Given the increasing number of later-borns following the two-child policy in China, there would be an alarming increase in the burden on healthcare for children. To better manage the forthcoming challenge, more attention should be paid to later-borns.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval This study was approved by the Ethics Committee of The First Affiliated Hospital of Nanjing Medical University and followed the tenets of the Declaration of Helsinki.

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