Austin Public Health

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Austin Publishing Group

Research Article

The Sensory Processing Dysfunction and Related Postnatal Environmental Factors in Preschool Aged Children in Qingdao, China

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Received: March 26, 2016; **Accepted:** May 04, 2016; **Published:** May 05, 2016

Abstract

Previous studies have shown that prenatal chemical or non-chemical exposure may contribute to the Sensory Processing Dysfunction (SPD). To date, few studies have examined the possible influence of postnatal environmental factors on the SPD. We hypothesized that the postnatal environment in early childhood might also influence the SPD. Parents or guardians of pre-school children completed questionnaires about their postnatal living environment. The sensory processing dysfunction profile was used to measure the possible SPD. Results showed girls invulnerable to the SPD in dyspraxia and visual senses with OR (95% CI) 0.42 (0.30, 0.59) and 0.64 (0.48, 0.86), respectively. Strict or let-alone or not special care style seemed averse to the sensory processing compared to generous care style. Lower frequency of floor vacuuming or cleaning indicated higher risk of SPD in vestibular and tactile sensory. Consistently, child with dirty hands usually showed higher risk of SPD in all 6 sensory except proprioceptive senses. Child living in the home having more furniture in bad materials commonly releasing more volatile or semi-volatile organic compounds indicated higher risk of SPD in vestibular or tactile sensory with OR (95% CI) 1.12 (1.00 – 1.24) and 1.16 (1.04 – 1.30), respectively. Poor gestational nutrition, taken drugs during pregnancy, and gestational passive smoking were also entered the multivariate models and showed adverse association. Our results indicate that a social environment of parental guidance and an indoor environment of exposure to chemical are associated with SPD.

Keywords: Postnatal exposure; Environmental exposure; Play behavior; Sensory processing dysfunction; Preschool

Introduction

The integration of sensory information from the body and the environment is essential for almost every human activity and involves the brain selecting, inhibiting, comparing, and associating sensory information [1]. This information permits the planning and production of organized behavior [2]. The sensory processing patterns could affect the child's daily experiences, and consequently impact their physical growth, social-emotional development, and academic performance [3]. Therefore, Sensory Processing Disorders (SPD) are regarded as impairments of neurological process of recognizing, modulating, interpreting, and responding to sensory stimulus, and these effects can negatively affect development and functional abilities in behavioral, emotional, motoric, and cognitive domains [4]. The aforementioned problems may affect the child's performance in school and daily life.

The fetus' cerebral cortex, one part of the brain which mediates sensory processing, develops during the fetus, and throughout early childhood [5]. The main development period of sensory processing is in preschool childhood ranged from 3 to 6 years, and might contribute to grow after the range of 8 years [6]. Harm to the cortex may negatively impact the ability to sensory integration and other types of information. Previous research has indicated that at least 10-30% of the total children [7,8] and5-10% of children without other known disabilities [3,4,9]are affected by SPD. Very limited studies on mainland of China has reported that up to 29% of children aged 3-6 years were affected with SPD [10-12], and 21-28% was reported in Taiwan [13]. Although such high prevalence rates have been reported, little is known about the neurobiological substrates of SPD. Prenatal stress and alcohol consumption have been reported as the possible contributors of SPD through alterations in the functioning of the dopaminergic regulatory systems [14]. Some reports indicated that gestation, birth/delivery, and neonatal status were also the strong predictors of future sensory problems [15,16]. The effects of physical contact in the early childhood were also investigated. The studies from Eastern Europe and the United States investigated the effects of the length of the institutionalization of the adopted children on the sensory processing, and found that longer time of institution indicated more sensory processing problems, which suggests that poor environment, low contact, poor nutrition, and abuse may exacerbate sensory processing problems [17,18].

In this study, we collected information about the child's living environment from the child's parents or guardians to examine the association of the postnatal environment with sensory processing patterns in kindergarten children.

Citation: Sun Z, Zhang F, Shi X, Zhang Q, Jia X, et al. The Sensory Processing Dysfunction and Related Postnatal Environmental Factors in Preschool Aged Children in Qingdao, China. Austin Public Health. 2016; 1(1): 1001.

Table 1: Characteristics of the subjects.

Contents	Contents
Sex	
Girls (%)	636 (47.5)
Boys (%)	703 (52.5)
Child's age	
Mean ± SD (y)	4.8±1.1
Range	7-Feb
Score of SPD subunit, median (range)	
Vestibular senses	57 (12-70)
Under-responsive senses	51 (8-69)
Tactile senses	55 (16-70)
Dyspraxia senses	57 (18-65)
Visual senses	54 (16-61)
Proprioceptive senses	56 (16-64)
Prevalence of SPD, n (%)	
All subtypes	553 (41.3)
Vestibular senses	171 (12.8)
Under-responsive senses	317 (23.7)
Tactile senses	156 (11.7)
Dyspraxia senses	159 (11.9)
Visual senses	218 (16.3)
Proprioceptive senses	156 (11.7)

SD: Standard Deviation; SP: Sensory Processing; SPD: Sensory Processing Dysfunction

Methods

Participants and recruitment

Four kindergartens were randomly sampled from 11 public kindergartens of a district of Qingdao, China. A total of 2,080 questionnaires were distributed in these four kindergartens, and 1,731 were returned. Of these, 200 questionnaires were excluded because they had insufficient information on the SPD scores. Given that presence and sex of siblings in the home might be the import confounder of the play behavior [19], 192 children from a single-child family were excluded. This left 1,339 participants for inclusion in the analyses.

Questionnaire

A questionnaire was tested with the parents of 100 children in one public kindergarten of the sampled district. The questions were rearranged or changed as needed, based on the pilot data. This was done to ensure that the questionnaire was intelligible to parents. The final questionnaire was taken back home by the children, and the guardians who had lived with the children for at least the past 3 months and knew their health condition and day-to-day behaviors were requested to complete the questionnaire, with reference to the parents if necessary.

The questionnaire included 9 parts: 1) general information about their child, 2) gestational information, 3) the family care environment, 4) the indoor environment of the home, 5) the outside environment of the home, 6) the indoor environment of the kindergarten, 7) the disease history of the child, and 8) the severity of the SPD. Most of these questions were based on the "Questionnaire for national investigation for Sick Building Syndrome and its potential risk factors in Japan" [20,21]. The questions about gestation, asked about drugs taken, passive smoking, and nutrition during pregnancy, as well as the mode of delivery. The family-care environment included the educational levels of the guardian, mother, and father, the care style of the parents, the child's communication time with parents or guardian, and the closeness of the relationship between the child and parents or guardian. Information about the indoor environment of the home included the decorative materials, the nature of the furniture, the ventilation, smoking behavior within the dwelling, frequency of cleaning the floor by vacuuming or other methods, and indicators of dampness (e.g., the presence of dew condensation, mold growth, or water stains) [22]. Given that some semi-volatile organic compounds are released from domestic electric appliances, the number of electric appliances was recorded. Questions about the outside environment mainly concerned exposure to pollutants, including whether the house was near a major street or other known pollution sources. Information about plastic and other chemical odors, uncomfortable feeling or symptoms, and educational mode in the kindergarten were collected. Disease history included any history of allergies, Multiple Chemical Sensitivity (MCS), and newborn diseases, including kernicterus, meningitis, malnutrition, asphyxia, and hypoglycemia, which might influence the development of the nervous system. Other disease-related information included major injuries, such as fractures, infantile convulsions, brain traumas, wheezing, coughing for a long period, frequently catching colds, and frequently taking antibiotics. For the MCS, each child gained one point on the MCS score by setting scale scores to all subjective complaints [23]. Pollution sources near the house were identified as gas station, factory, household waste incineration plant, and other facilities that could cause environmentally related complaints.

The SPD profile is a 60-item guardian questionnaire designed to provide information about the child's ability to process sensory information. The SPD profile was first translated and standardized by the Institute of Mental Health, Beijing Medical University [24]. After several revised versions, now it consists of 6 subtypes of senses: vestibular (10 items), under-responsively (10 items), tactile (14 items), dyspraxia (11 items), visual (5 items) and proprioceptive (10 items) [25]. Responses to the items of the SPD profile correspond to relative frequency of the occurrence of the child's behavior, according to the guardian. The answer to each item is reported on a 5-point, Likert-type scale, ranging from never (scored as 1) to always (scored as 5).

Statistical analysis

The raw subtype scores of the SPD profile were transformed into T standard scores. Therefore, higher scores are indicating more typical behavior, whereas lower scores indicate a difference in behavior compared to children without dysfunction.

Given the different sensory processing between the sub-unit senses, subtype SPD prevalence, not the total SPD prevalence, was used for the analysis. Descriptive and summary statistics for relevant variables were examined first, and then bivariate associations were tested. The Kolmogorov–Smirnov test showed that the sub-unit sensory scores were distributed abnormally. Therefore, Spearman's rho correlations were performed on the continuous variables to test their possible associations with SP scores. The standardized SP scores of the sub-unit sensory were categorized into SPD (≤40) or non-SPD (>40). Then, odd ratio (OR) and 95% Confidential Interval (CI) were calculated by Chi square test to indicate the possible association between categorical variables and the SPD. Both continuous variables in the Spearman's rho correlation test and the categorical variables in the Chi square test with $P<0.05$ were tested the co-linearity by a lasso model tuned by cross-validation. Finally, multivariate logistic regression analysis was performed to examine the association between possible risk factors and the SPD. All independent variables were entered into the models backwards; the p-value for inclusion was 0.05 and the p-value for removal was 0.10. A $p< 0.05$ was considered to be statistically significant. All analyses were performed using IBM SPSS Statistics version 21 (IBM Corp, Somers, NY). The results of the regression analyses for the association between the possible risk factors and the SPD are presented as adjusted OR, together with their 95% Confidence Intervals (CIs) and Wald p-values.

Results

Of all participants, 47.5% were girls and 52.5% were boys. The average age was 4.8 years with the range from 2 to 7 years. About 23.7% subjects were suffered from under-responsive senses, followed by visual, vestibular, dyspraxia, tactile, and proprioceptive senses with 16.3%, 12.8%, 11.9%, 11.7% and 11.7%, respectively (Table 1).

Univariate analysis

Spearman correlation coefficient was used to evaluate the possible influencing factors for SPD subunit (Table 2). Child's age, birth weight and BMI at present were all associated with SPD. More hours playing PC or watching TV every day showed lower SPD score. More disease history or uncomfortable symptoms were also indicated lower SPD score. Although no association was found for the number of electric appliances, more furniture with good materials releasing less volatile or semi-volatile organic compounds was associated with higher SPD score on the contrary, the number of furniture with toxic materials releasing more volatile or semi-volatile organic compounds showed negative association with SPD score. Moisture index was also negatively associated with SPD score.

Chi square test was used for the categorical variables to find the potential risk factors of SPD (Table 3). Not only the child, parents and guardian's demographics, but the child's behavior and parent/guardian-child interaction were all associated with the prevalence of SPD. Gestation status and disease history were also indicated associated with SPD. Indoor environment of the home and the kindergarten, outside environment of the home and some other possible chemical exposure showed possible association to the SPD prevalence.

Multivariate analysis

Lasso models indicated high co-linearity between father and mother's age, father, mother and guardian's education. Therefore, only mother's age and education were selected for further multivariate analysis. Table 4 Illustrated the multivariate logistic regression analysis results for the potential risk factors of SPD. Girls seemed not vulnerable to the SPD in dyspraxia and visual senses with OR

Table 2: Spearman correlation coefficients between SPD subunit scores and possible influencing factors.

	Ves	Und	Tac	Dys	Vis	Pro
Child's demographics						
Child's age	0.083**	0.043	0.103**	-0.005	0.163**	0.011
Birthweight	-0.058*	-0.054*	-0.053	-0.008	-0.025	-0.011
BMI at present	-0.073**	-0.009	-0.025	-0.075**	-0.060*	-0.055*
Parents' demographics						
Father's age	0.062*	0.081**	0.035	0.042	-0.016	0.068*
Mother's age	0.103**	0.081**	0.025	0.05	0	0.079**
Child's behavior characteristics						
Hrs at home per day	0.015	0.007	-0.013	0.032	0.038	-0.008
Hrs sleeping per day	0.007	0.009	0.005	0.01	-0.049	-0.043
Hrs playing PC per day	-0.115**	-0.056*	-0.084**	-0.089**	0.002	-0.055*
Hrs watching TV per day	-0.143**	-0.151**	-0.100**	-0.090**	-0.103**	-0.118**
Child's disease or uncomfortable history						
No. of allergic diseases	-0.101**	-0.088**	-0.125**	-0.077**	-0.073**	-0.079**
No. of NDD diseases	-0.103**	-0.104**	-0.087**	-0.105**	-0.075**	-0.039
Score of MCS	-0.071**	-0.054*	-0.058*	-0.009	-0.012	-0.120**
Indoor environment of the home						
No. of electric appliances	0.013	0.036	0.006	0.003	0.063	0.053
No. of BM furniture	-0.063*	-0.057*	-0.106**	-0.055*	0	-0.028
Moisture index	-0.079**	-0.107**	-0.111**	-0.060*	-0.061*	-0.065*

Ves: Vestibular; Und: Underresponsibility; Tac: Tactile; Dys: Dyspraxia; Vis: Visual; Pro: Proprioceptive; BMI: Body Mass Index; Hrs: Hours; Ms: Months; BM: Bad Materials With More Volatile or Semi-Volatile Organic Compounds; NDD: Diseases Can Causing Neuro Developmental Disorders; MCS: Multiple Chemical Sensitivity

Table 3: Univariate Odds Ratio (OR) and 95% Confidence Interval (CI) for potential risk factors of SPD by Chi squaretest.

Potential factors	Ves	Und	Tac	Dys	Vis	Pro
Child's demographics						
Girls	**0.76(0.91, 0.94)**	**0.78(0.63,0.97)**	0.88(0.70,1.12)	**0.46(0.36,0.60)**	**0.63(0.50,0.79)**	0.95(0.75,1.20)
Parents and guardian's demographics						
Guardian's education						
College or above	1	1	1	1	1	1
TS	**1.54(1.18,2.00)**	**1.30(1.01,1.67)**	1.06(0.80,1.41)	1.12(0.84,1.48)	**1.37(1.05,1.80)**	**1.40(1.05,1.86)**
Lower than TS	**1.50(1.10,2.03)**	**1.44(1.07,1.93)**	1.15(0.83,1.58)	0.95(0.68,1.33)	**1.59(1.16,2.16)**	1.19(0.86,1.67)
Mother's education						
College or above	1	1	1	1	1	1
TS	**1.54(1.20,1.99)**	**1.34(1.05,1.71)**	1.04(0.80,1.35)	1.17(0.90,1.54)	**1.36(1.05,1.77)**	**1.41(1.08,1.86)**
Lower than TS	1.11(0.80,1.52)	1.19(0.87,1.61)	0.81(0.58,1.15)	0.77(0.53,1.11)	**1.51(1.09,2.08)**	1.00(0.70,1.42)
Father's education						
College or above	1	1	1	1	1	1
TS	**1.45(1.14,1.88)**	0.98(0.78,1.25)	0.88(0.68,1.14)	0.97(0.74,1.27)	1.23(0.96,1.59)	1.22(0.94,1.59)
Lower than TS	1.31(0.96,1.80)	1.10(0.81,1.50)	0.81(0.58,1.14)	0.94(0.66,1.33)	1.30(0.95,1.80)	1.07(0.76,1.51)
Gestation						
Gestational age						
Term	1	1	1	1	1	1
Preterm	1.20(0.79,1.83)	1.02(0.67, 1.54)	1.14(0.73,1.79)	1.01(0.63,1.61)	1.30(0.85, 2.00)	1.02(0.64,1.63)
Postterm	1.23(0.89, 1.71)	**1.49(1.08,2.07)**	1.14(0.80,1.61)	1.04(0.72,1.49)	1.31(0.94,1.83)	1.18(0.83,1.67)
Poor gestational nutrition	**1.70(1.27, 2.27)**	**1.85(1.37,2.49)**	**1.64(1.21,2.22)**	**1.80(1.32,2.45)**	**1.37(1.02,1.85)**	**1.78(1.32,2.42)**
Taken drugs during pregnancy	**1.97(1.28, 3.02)**	1.36(0.89,2.10)	**1.80(1.17,2.78)**	**1.86(1.19,2.91)**	**2.55(1.66,3.93)**	1.42(0.91,2.23)
Passive smoking during pregnancy	**1.70(1.32, 2.20)**	**1.92(1.48,2.49)**	**1.54(1.18,2.78)**	**1.33(1.01,1.76)**	1.23(0.95,1.60)	1.26(0.96,1.66)
Not natural delivery	1.13(0.90, 1.41)	1.20(0.97,1.50)	**1.38(1.08,1.76)**	1.25(0.97,1.60)	1.15(0.91,1.44)	1.05(0.82,1.34)
Infant development						
Feeding history						
Breastfeeding	1	1	1	1	1	1
Mixed	1.24(0.97, 1.57)	1.26(0.99,1.59)	1.19(0.92,1.55)	1.11(0.85,1.44)	1.17(0.92,1.50)	1.24(0.96,1.60)
Milk powder	1.46(0.88, 2.49)	1.16(0.68,1.98)	**2.48(1.45,4.25)**	**1.87(1.08,3.24)**	**2.04(1.19,3.47)**	1.58(0.91,2.76)
Parent/guardian-child interaction						
Father's care style						
Generous	1	1	1	1	1	1
Strict	0.93(0.70,1.24)	0.94(0.72,1.24)	0.88(0.65,1.20)	1.17(0.85,1.60)	1.01(0.76,1.36)	1.03(0.75,1.41)
Let-alone or not special	**1.54(1.18,2.01)**	**1.45(1.12,1.89)**	1.20(0.90,1.59)	**1.41(1.05,1.90)**	1.25(0.95,1.64)	**1.54(1.15,2.06)**
Mother's care style						
Generous	1	1	1	1	1	1
Strict	1.24(0.91,1.68)	1.29(0.96,1.72)	1.04(0.75,1.43)	0.92(0.66,1.29)	1.09(0.80,1.48)	1.21(0.86,1.69)
Let-alone or not special	**1.62(1.18,2.22)**	**1.55(1.14,2.10)**	1.14(0.82,1.60)	**1.34(0.96,1.89)**	1.24(0.90,1.71)	**1.59(1.12,2.24)**
Relationship with parents						
Very close	1	1	1	1	1	1
Close	**1.74(1.37,2.21)**	**1.55(1.22,1.96)**	1.63(1.26,2.09)	**1.46(1.13,1.90)**	**1.42(1.11,1.81)**	1.25(0.97,1.62)
Common or not close	**2.82(1.42,5.63)**	1.96(0.98,3.94)	1.69(0.84,3.41)	**2.06(1.03,4.11)**	**1.79(0.91,3.53)**	**2.11(1.06,4.19)**
Single-parent family	**3.34(1.43, 7.79)**	1.79(0.79,4.08)	**2.26(1.02,5.00)**	1.62(0.70,3.74)	1.48(0.67,3.29)	2.03(0.91,4.51)
Poor relationship between parents	1.47(0.88, 2.45)	1.15(0.69,1.91)	**1.93(1.15,3.23)**	1.32(0.76,2.29)	1.19(0.70,2.01)	0.88(0.49,1.58)

Short communication with guardian	**2.25(1.72, 2.94)**	**1.47(1.13,1.92)**	**1.59(1.20,2.10)**	**1.52(1.14,2.03)**	**1.48(1.13,1.94)**	**1.44(1.09,1.92)**
Child's disease history						
Having brain trauma history	**3.91(1.22,12.52)**	2.53(0.79,8.10)	**3.25(1.12,9.43)**	2.04(0.70,5.91)	1.88(0.66,5.40)	1.02(0.32,3.28)
Often wheezing	**1.71(1.13,2.59)**	**2.07(1.34,3.20)**	**1.63(1.06,2.50)**	**2.15(1.40,3.29)**	1.23(0.80,1.88)	1.07(0.68,1.69)
Coughing long period	**1.66(1.20,2.29)**	**1.63(1.18,2.27)**	**1.46(1.04,2.05)**	**2.02(1.44,2.84)**	**1.43(1.03,1.99)**	1.24(0.88,1.76)
Often catching cold	**1.83(1.40,2.37)**	**1.64(1.26,2.13)**	**1.85(1.41,2.44)**	**2.11(1.59,2.79)**	**1.93(1.48,2.51)**	**1.45(1.09,1.91)**
Often taking antibiotics	**1.59(1.12,2.25)**	**1.61(1.13,2.29)**	**1.61(1.12,2.31)**	**2.37(1.66,3.39)**	**1.75(1.23,2.48)**	**1.59(1.11,2.29)**
Indoor environment of the home						
Frequency of natural ventilation through open windows						
> 4 hours	1	1	1	1	1	1
1-4 hours	1.11(0.87,1.41)	**1.31(1.03,1.65)**	1.21(0.94,1.57)	**1.26(0.97.1.65)**	**1.36(1.06,1.74)**	1.27(0.98,1.65)
1 hour or less	1.37(1.00,1.90)	**1.56(1.13,2.16)**	1.40(0.99,1.97)	**1.40(0.99,1.99)**	**1.54(1.11,2.15)**	**1.42(1.00,2.01)**
Frequency of vacuuming or cleaning						
1-3 days	1	1	1	1	1	1
4-7 days	0.82(0.64,1.06)	1.07(0.84,1.36)	1.06(0.81,1.38)	1.07(0.81,1.41)	0.80(0.62,1.03)	1.10(0.85,1.44)
8 days or longer	**1.62(1.19,2.19)**	**1.43(1.05,1.93)**	**1.63(1.19,2.24)**	**1.39(1.00,1.93)**	0.84(0.61,1.16)	1.04(0.74,1.45)
Indoor environment of the kindergarten						
Uncomfortable feeling in kindergarten	1.59(0.95,2.65)	1.09(0.65,1.81)	**1.68(1.00,2.84)**	0.83(0.45,1.53)	1.23(0.73,2.08)	0.95(0.54,1.69)
Good environment around the kindergarten	0.99(0.62,1.58)	**1.59(1.00,2.54)**	1.39(0.86,2.24)	1.22(0.74,2.03)	1.15(0.71,1.84)	1.08(0.65,1.78)
Outside environment of the home						
Near to the major traffic street	1.24(0.99,1.54)	**1.40(1.13,1.74)**	**1.32(1.04,1.67)**	1.07(0.84,1.36)	1.13(0.90,1.42)	1.40(1.10,1.78)
Near to the pollution source	**1.41(1.10,1.81)**	**1.39(1.08,1.78)**	**1.33(1.02,1.73)**	**1.45(1.11,1.90)**	1.27(0.98,1.64)	1.19(0.91,1.57)
Possible chemical exposure						
Postnatal passive smoking	**0.64(0.51, 0.81)**	**0.74(0.59,0.93)**	**0.71(0.56,0.91)**	0.80(0.62,1.03)	**0.71(0.56,0.91)**	0.97(0.75,1.25)
Dirty hand usually	**1.67(1.34,2.08)**	**1.88(1.51,2.34)**	**2.19(1.72,2.77)**	**1.80(1.41,2.30)**	**1.74(1.39,2.19)**	1.25(0.98,1.58)

(95% CI) 0.42 (0.30, 0.59) and 0.64 (0.48, 0.86), respectively. It was not father or guardian but mother's care style was associated with the SPD in vestibular, underresponsivity and proprioceptive senses. Strict or let-alone or not special care style seemed adverse to the sensory processing compared to generous care style. Consistently, short communication indicated risk for the vestibular SPD (OR and 95% CI: 1.78, 1.19 –2.65). Child's behavior characteristics like Watching TV or Playing PC too much time every day might adversely influence the sensory processing, especially the vestibular, underresponsivity, tactile and proprioceptive senses.

For the indoor environments, it was the home environment that was kept in the multiple analyses. Lower frequency of floor vacuuming or cleaning indicated higher risk of SPD in vestibular and tactile sensory. Consistently, child with dirty hands usually showed higher risk of SPD in all six sensory except proprioceptive senses. Child living in the home having more furniture in bad materials commonly releasing more volatile or semi-volatile organic compounds indicated higher risk of SPD in vestibular or tactile sensory with OR (95% CI) 1.12 (1.00, 1.24) and 1.16 (1.04, 1.30), respectively. Indoor dampness also showed association with underresponsivity sensory with OR (95% CI) 1.17 (1.01, 1.36).

The diseases that could cause neurodevelopmental disorders were not contained in the multiple logistic regression analysis. But the child with wheezing in the past year, often catching cold, and coughing long period showed higher risk of SPD than the normal child. Child with higher score of MCS indicated higher risk of SPD in proprioceptive sensory (1.06, 1.02 – 1.10).

Delayed infant development appears associated with SPD. Increased child's age showed lower risk of SPD in visual sensory with OR (95% CI) 0.75 (0.65, 0.86).Poor gestational nutrition, taken drugs during pregnancy, gestational passive smoking, and not natural delivery, four important factors reflecting gestational stress, were also entered the multivariate models and showed adverse association.

Discussion

Our study reported the association of the postnatal living environments with sensory processing difficulties among preschool-age children in single-child families. Variables measuring the social environment of parents and/or guardians and the indoor environment (especially chemical exposure) all tended to be associated with the sensory processing. In addition to the possible postnatal influence on sensory processing difficulties, gestational factors also indicated an association.

Pretest assessment of the SPD profile used in the present study was performed by the Institute of Mental Health, Beijing Medical University [25]. The test-retest reliability is reported to be 0.70-0.79, the split-half reliability is 0.50-0.89, and the homogeneity reliability is 0.74-0.97. If there was at least one sub-unit sensory was defined

Table 4: Multivariate Odds Ratio (OR) and 95% Confidence Interval (CI) for potential risk factors of SPD by binarylogistic regression analysis.

SP	Factors	OR (95%CI)	*P*	SP	Factors	OR (95%CI)	*P*
	Vestabular			***Tactile***			
	Taken drugs during pregnancy	**1.79 (1.04, 3.09)**	**0.037**		Child's age	0.87 (0.75, 1.01)	0.069
	Mother's age	0.96(0.92, 1.00)	0.077		Gestational passive smoking	**1.44 (1.00, 2.06)**	**0.048**
	Mother's education		0.015		Not natural delivery	**1.48 (1.07, 2.05)**	**0.019**
	College or above	1			Short communication time	1.41 (0.96, 2.07)	0.08
	TS	**1.57 (1.10, 2.22)**	**0.012**		Dirty hands usually	**2.11 (1.53, 2.91)**	**<0.001**
	Lower than TS	0.99 (0.63, 1.57)	0.97		Frequency of vacuuming or cleaning		0.035
	Mother's care style		0.051		1-3 days	1	
	Generous	1			4-7 days	0.96 (0.66, 1.38)	0.815
	Strict	1.40 (0.92, 2.15)	0.12		8 days or longer	**1.53 (1.01, 2.32)**	**0.046**
	Let-alone or not special	**1.87 (1.21, 2.88)**	**0.005**		No. of BM furniture	**1.16 (1.04, 1.30)**	**0.008**
	Relationship with parents		0.049		Hrs watching TV per day	**1.26 (1.07, 1.48)**	**0.006**
	Very close	1			Uncomfortable feeling in kindergarten	1.97 (0.94, 4.14)	0.074
	Close	**1.50 (1.06, 2.13)**	**0.022**		***Dyspraxia***		
	Common or not close	1.40 (0.54, 3.59)	0.489		Girls	**0.42 (0.30, 0.59)**	**<0.001**
	Short communication time	**1.78 (1.19, 2.65)**	**0.005**		BMI	**1.02 (1.00, 1.04)**	**0.078**
	Postnatal passive smoking	0.71 (0.51, 1.00)	0.05		Short communication time	1.40 (0.94, 2.08)	0.098
	Dirty hands usually	**1.48 (1.08, 2.03)**	**0.016**		Dirty hands usually	**1.40 (1.00, 1.94)**	**0.05**
	Frequency of vacuuming or cleaning		0.032		Coughinglong period	**1.68 (1.04, 2.70)**	**0.034**
	1-3 days	1			Often catching cold	**2.01 (1.34,3.01)**	**0.001**
	4-7 days	0.85(0.60,1.22)	0.383	***Visual***			
	8 days or longer	**1.71(1.13,2.60)**	**0.012**		Girls	**0.64 (0.48, 0.86)**	**0.003**
	No. of BM furniture	**1.12(1.00,1.24)**	**0.046**		Child's age	**0.75 (0.65, 0.86)**	**<0.001**
	Hrs watching TV per day	**1.35 (1.15, 1.58)**	**<0.001**		Taken drugs during pregnancy	**2.51 (1.51, 4.19)**	**<0.001**
	No. of allergic diseases	**1.21 (0.97, 1.51)**	**0.087**		Mother's education		0.016
	Wheezing in the past year	**1.71(0.94,3.11)**	**0.076**		College or above	1	
	Underresponsivity				TS	**1.46 (1.06, 2.02)**	**0.022**
	Mother's age	0.96 (0.93, 1.00)	0.055		Lower than TS	**1.66 (1.11, 2.48)**	**0.014**
	Gestational passive smoking	**1.73 (1.22, 2.45)**	**0.002**		Relationship with parents		
	Mother's care style		0.019		Very close	1	
	Generous	1			Close	**1.43 (1.06, 1.95)**	**0.021**
	Strict	**1.52 (1.03, 2.26)**	**0.037**		Common or not close	1.49 (0.65, 3.43)	0.345
	Let-alone or not special	**1.73 (1.15, 2.59)**	**0.008**		Dirty hands usually	**1.51 (1.13, 2.01)**	**0.006**
	Relationship with parents				Often catching cold	**1.46 (1.05, 2.02)**	**0.025**
	Very close	1			***Proprioceptive***		
	Close	**1.58 (1.14, 2.19)**	**0.006**		Poor gestational nutrition	**2.27 (1.56, 3.29)**	**<0.001**
	Common or not close	2.54 (0.96, 6.71)	0.061		Mother's care style		
	Hrs playing PC per day	0.79 (0.62, 1.03)	0.077		Generous	1	
	Hrs watching TV per day	**1.29 (1.11, 1.51)**	**0.001**		Strict	**1.56 (1.01, 2.41)**	**0.043**
	Dirty hands usually	**1.48 (1.09, 2.01)**	**0.011**		Let-alone or not special	**1.94 (1.25, 3.02)**	**0.003**
	Moisture index	**1.17 (1.01, 1.36)**	**0.036**		Hrs watching TV per day	**1.42 (1.22, 1.65)**	**<0.001**
	Wheezing in the past year	**2.59 (1.41, 4.75)**	**0.002**		Moisture index	**1.15 (0.99, 1.33)**	**0.062**
					Score of MCS	**1.06 (1.02, 1.10)**	**0.003**

BMI: Body Mass Index; MCS: Multiple Chemical Sensitivity; BM: Bad Materials with more volatile or semi-volatile organic compounds; Hrs: Hours as SPD, the child was classified as SPD. Then the prevalence of SPD in our population was up to 41%, which was much higher than that reported from the main land of China (up to 29%) [10-12], Taiwan (up to 28%) [13], USA (5~13%) [3,4] and Israel (~10%) [9]. However, for the sub-unit SPD, it was from 11.7% (the tactile and proprioceptive senses) to 23.7% (under-responsive sense). As a fairly new concept, SPD has been defined and redefined by many different professionals. Therefore, there is little insight into exactly how many individuals are affected by SPD. It appears that subtype of SPD like sensory modulation disorder (including sensory underresponsivity) is optimal instead of all subtype SPD. The categorical terminology differentiates the condition of SPD from the cellular process of sensory processing. Diagnostic specificity will enhance the homogeneity of the samples used for empirical research and will promote targeting of intervention approaches to specific diagnostic subtypes [26].

A child living in the home with lower frequency of floor vacuuming or cleaning or having more furniture in toxic materials commonly releasing more volatile or semi-volatile organic compounds showed higher risk of SPD. This indicates that exposure to chemical factors in the early postnatal environment is likely to influence sensory processing. Indoor decorations can cause aldehyde and VOC pollution, and some aldehydes and VOCs, like formaldehyde and toluene, have been found to be neurodevelopmental toxicants [27]. The possible influence of plastic furnishings and electric appliances was also investigated. Such appliances and furniture contain a relatively large amount of additives, such as plasticizer and flame retardants. These additives are not covalently bound to the polymers with which they are mixed and they can migrate from the materials to the outside [28]. Most of these additives, including phthalates and polybrominateddiphenyl ethers, are endocrine disrupting chemicals and have been found to cause cognitive damage or neurobehavioral changes [29-32]. These semi-volatile organic compounds are usually attached to the particulate matters and deposited in the house dust. Additionally, our previous studies showed that postnatally current exposure levels of some semi-volatile organic compounds like polycyclic aromatic hydrocarbons, polychlorobiphenyl, and polybrominateddiphenyl ethers were associated with adverse neurodevelopmental effects [33-35].Therefore, we used hand cleanliness as an indirect index of exposure to metal or organic chemicals in children because the hand-to-mouth route has been found to be a major pathway for the ingestion of chemicals by children, especially in pre-school children and toddlers [36].

Although no research has directly investigated the possible effects of postnatal stress on the SPD, maternal interpersonal interactions with children affect stress reactivity and the neural systems regulating stress responses [37,38].Recent studies have established that early child-maternal relationships are associated with differences in brain structure measured at school age [39,40]. Our results suggest that early postnatal communication with parents and guardians may influence sensory processing. Ordinary care of children by tolerant parents or guardians seems to benefit the development of sensory integration. Parents who are older or better educated might know more about how to communicate with a child, so that a closer relationship can be established between parent and child. A generous parent also appears to make a beneficial contribution to sensory development. Some studies also have shown that children from families with higher education level generally develop faster than those with lower education level in respect of the language development of the brain [41,42]. Therefore, the sensory processing becomes mature and some dysfunction could be corrected with the child's natural development. The girls indicating less risk of SPD than the boys in our results confirmed this point of view.

Additionally, it should be known that other childhood disorders and developmental delays, such as Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD), have been shown to be characterized by atopic sensory processing patterns [4,43,44]. Children with ASD have sensory dysfunctions in audition, vision, taste/smell, and tactile sensory discrimination [44]. The sensory dysfunctions in ADHD are visual, tactile, and vestibular sensory discrimination [44]. Sensory underresponsivity usually leads to poor tactile and proprioceptive discrimination, i.e. children with sensory underresponsivity often have concomitant sensory discrimination disorder [26]. This implies that children with ASD, ADHD, and some other developmental disorders or developmental delays are similar in terms of sensory processing issues. Thus, it seems difficult to differentiate whether the developmental delays or some environmental factors contribute to SPD or to some other condition. Despite of this controversy, identification of sensory processing disorder is critical due to the distressing impact associated with these difficulties. SPD may impact the way a child handles new information and accomplishes tasks, which can result in difficulties in classroom functioning or impact a child's social behavior. For example, a preschool child may perceive the incidental contact as excessive and respond aggressively [16].

There is an inherent limitation in the fact that SPD profile scores were obtained by questionnaire-based reports from guardians Therefore, bias in the guardian's preferences or expectations should be considered in interpreting our results. However, guardian reports have the advantage of capturing typical behaviors across time and situations.

The main limitation of this study was its cross-sectional design, and therefore, caution should be exercised in the interpretation of the observed associations. Secondly, our participants were limited to the main public kindergartens in an urban area, and the sample size was not large enough to reflect all of the children in this city; therefore, our results only reflect the urban preschool children to some extent. Further effort will be needed to enlarge the cohort size.

Conclusion

The influence of the postnatal environment on the sensory processing dysfunction of pre-school children should be considered as the much as the influence of prenatal stress. Indoor and outdoor chemical exposure seems to contribute to disorders in sensory processing. Generous and patient guardians, good communication, and a close relationship between the child and guardians all have a beneficial association with the development of sensory integration in children. Gestational stress that might causing developmental delays should also be considered. Our study highlights the importance of assessing postnatal environmental influences on sensory processing during the early years of life and indicates the need for further studies with larger samples.

Acknowledgment

We wish to acknowledge the families who participated in the study. This study was partly supported by grants from the National Natural Science Foundation of China (No: 81372955), and the Qingdao Outstanding Health Professional Development Fund.

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Austin Public Health - Volume 1 Issue 1 - 2016
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Citation: Sun Z, Zhang F, Shi X, Zhang Q, Jia X, et al. The Sensory Processing Dysfunction and Related Postnatal Environmental Factors in Preschool Aged Children in Qingdao, China. Austin Public Health. 2016; 1(1): 1001.