Factors Related to Short-Term Memory Dysfunction in Children Residing Near a Petrochemical Industrial Estate

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The purpose of the present study was to investigate the factors that affect short-term memory dysfunction among children, 6 to 13 years of age, residing near the Petrochemical Industrial Estate, Map Ta Phut sub-district, Rayong province. A population-based cross-sectional study was employed for collecting data on neurobehavioral effects using the Digit Span Test. The present study found one-third of 2,158 children presented with short-term memory dysfunction. It was found an inverse association between short-term memory dysfunction with 2 out of 25 communities; Islam (adjusted OR 0.382) and Taladmabtaput (adjusted OR 0.297). In addition, short-term memory dysfunction was also found an inverse association with distance from residential areas to the industrial park (adjusted OR 0.871). It was also found that an association between short-term memory dysfunction and length of living period in study areas was not clear. The finding on short-term memory dysfunction indicated that children with short-term memory dysfunction were affected by the distance from residential areas to source of pollution and community.

Keywords: *Short-term memory dysfunction, Children, Petrochemical industrial estate, Rayong, Thailand*

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Since the 1980s, a rapid urbanization and industrialization has been taking place in Thailand. Rayong province, located on the east coast of Thailand, is the site of a Gas Separation Plant and Map Ta Phut Industrial Estates. The major types of industries are petrol-chemical and plastic production that produce sulphur dioxide (SO_2) and volatile organic compound (VOCs; Benzene, Vinyl chloride, Styrene etc.), leading to serious environmental and health impacts. The health impacts include acute (irritation; headaches; nausea/vomiting; dizziness; fatigue; epistaxis) and chronic problems (cancer; loss of coordination; damage to liver, kidney, and central nervous system), including mental health effects [1,2]. The Thailand Environment Institute[3] reported that the sources of air pollution were 15 factories in the Map Ta Phut which emitted VOCs from fuel combustion, leakage from manufacturing processes, storage, and incineration.

Students and teachers at a secondary school were hospitalized for breathing in toxic air and suffered from various health effects, both physical and mental, because of chemical vapors released from the factories in the estate in 1997[4]. The present study in Muang district, Rayong province, found that subjects had high blood benzene and low white blood cell count[5]. There were numerous studies revealing that VOCs can cause birth defects among pregnant woman living near an industrial area, in particular a petrochemical industry or oil refinery[6-10]. Several studies found that pollution led to neurobehavioral deficits, which are a major risk factor for mortality, neurological impairment, and disability, with high associated costs of care in hospital, in particular the neurological development of children. If we early define the neurological problem among children, child growth development can be improved.

However, very little research has been conducted in Thailand to examine the effects of air

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pollution on neurobehavioral deficits. The hypothesis of the present study was that children living closer to the Petrochemical Industrial Estates have a higher risk of short-term memory dysfunction than children residing more distant. The present study aimed to explore the factors that affect to short-term memory dysfunction among children 6 to 13 years of age in the Map Ta Phut sub-district.

Material and Method

Study site

The present study was carried out in Map Ta Phut sub-district, comprised of 25 communities, within the Rayong province, Thailand. These communities are located near Petrochemical Industrial Estates which are known to release VOCs. Thus children in the present study areas have a large chance of having been exposed to VOCs due to the proximity of the industrial areas and their homes. There were 40,999 registered residents in 2006 and over 74,502 non-registered residents[11].

Study population

All children 6 to 13 years of age residing in the present study areas were recruited with the consent of their parents. The present study was approved by the research ethical committee of Thammasat Univer-sity. Prior to the data collection, the parents/guardians of participants were briefed on details of the present study and asked to give a signature in an informed consent form and children were also informed before being interviewed.

Sampling method and sample size

A population-based cross-sectional study was employed for collecting data on neuropsychological test as the primary data using the standardized tools. Ninety-four percent of children were enrolled in primary school[12], thus the data collection was administered in school. Non-school children were recruited in communities instead. To gather data on the health impact of air pollution as well as socio-demographic and exposure factors, secondary data on the population-based study in the Map Ta Phut collected by N. Vichit-Vadakan and team (Faculty of Public Health, Thammasat University) was used. To assess ambient air pollutant exposure, the study attempted to geocode participant's residences in the communities. Geocoding, latitude and longitude coordinates, was conducted and performed using GIS (Geographical Information System) software and mapping. The total sample size was 2,956 subjects.

Neurobehavioral test method

To measure the short-term memory dysfunction the Digit Span Test, a sub-test of Wechsler Intelligence Scale for Children third edition (WISC III), was adopted. WISC is a standardized tool for children 6 to 16 years of age (developed by Wechsler, 1949), recommended by WHO. The digit span test aims to predict on short-term memory, attention, concentration, recall, and memory. The test begins with two digits and keeps increasing in length, with two trials at each length until the person commits errors. A list of random numbers is read out loud at the rate of one per second. The cut off point of scaled score is 10, meaning that 10 and over refer to children without short-term memory dysfunction. If the test shows under standardized score, it indicates that people might have left side brain deterioration, particularly the temporal lobe. This brain deterioration affects numerical forward and backward reading. This sub-test has been used for normative setting among Thai people. The validity is 0.69[13].

Data analysis

Data on socio-demographic, maternal exposure, indoor exposure and outdoor exposure variables were compared among children with and without short-term memory dysfunction using univariate analysis, by Chi-square for category data and by T test for continuous data. A p-value $\leq$ 0.15 was considered a statically significant for finding potential factors. A binary logistic regression was performed to study the relationship between potential factors and short-term memory dysfunction which defined in terms of poor vs. normal. A p-value $\leq$ 0.05 was considered a statically significant.

Results

The socio-demographics of children with and without short-term memory dysfunction are presented in Table 1 which revealed 797 and 2,158 children with and without short-term memory dysfunction respectively. More than 80% of the children studied in primary school. Among children with short-term memory dysfunction, a larger percentage were non-residents as compared to residents. One-third of the children with short-term memory dysfunction were those whose parents earned a monthly income of 5,000-10,000 Baht. In terms of maternal exposure, the present study focused on an exposure during pregnancy, including history of delivery and breast feeding as shown in

Table 1. Comparison between children with and without short-term memory dysfunction by socio-demographics

Factors	No short-term memory dysfunction	Short-term memory dysfunction	p-value[a]
Total (n = 2,955)	n (%)	n (%)	
Gender			
Male	1,073 (49.7)	419 (52.6)	0.169
Female	1,085 (50.3)	378 (47.4)	
Age of child in years, mean (SD)	9.4 (2.0)	9.8 (2.2)	<0.001
Communities			
Huaypongnai	274 (12.7)	99 (12.4)	<0.001
Banbon	192 (8.9)	61 (7.7)	
Soiruampattana	158 (7.3)	54 (6.8)	
Banlang	152 (7.0)	44 (5.5)	
Taguan-Aopradoo	128 (5.9)	95 (11.9)	
Islam1	26 (5.8)	33 (4.1)	
Nhongwaisom	120 (5.6)	47 (5.9)	
Chakloogya	112 (5.2)	46 (5.8)	
Taladmabtaput	109 (5.1)	20 (2.5)	
Watmabtaput	89 (4.1)	27 (3.4)	
Nhongfab	83 (3.8)	36 (4.5)	
Taladhuaypong	83 (3.8)	34 (4.3)	
Mabya	80 (3.7)	22 (2.8)	
Kodehin	75 (3.5)	30 (3.8)	
Mabchalood	71 (3.3)	40 (5.0)	
Watsopon	51 (2.4)	11 (1.4)	
Mabka	47 (2.2)	10 (1.3)	
Banplong	45 (2.1)	22 (2.8)	
Kohkook-Nhongtangmae	34 (1.6)	10 (1.3)	
Grokyaicha	28 (1.3)	14 (1.8)	
Nhongnumyen	26 (1.2)	12 (1.5)	
Klongnumhoo	24 (1.1)	11 (1.4)	
Nhongbuadang	21 (1.0)	7 (0.9)	
Kaopai	18 (0.8)	7 (0.9)	
Sumnukgabuk	12 (0.6)	5 (0.6)	
Education			
Pre-school	57 (2.6)	36 (4.6)	0.002*
Primary school	1,881 (87.4)	650 (82.3)	
Secondary school	212 (9.9)	102 (12.9)	
Not meet the criteria for the school	2 (0.1)	2 (0.3)	
Household registration			
Yes	1,055 (52.8)	374 (48.0)	0.022
No	1,000 (47.2)	405 (52.0)	
Living period in study areas in years, mean (SD)	6.3 (3.5)	6.3 (3.7)	0.884
Parental income (Baht/month)			
No income	81 (4.0)	42 (5.7)	0.001
Less than 5,000	78 (3.8)	39 (5.3)	
5,000-10,000	590 (29.1)	256 (35.0)	
10,001-15,000	489 (24.1)	157 (21.4)	
15,001-20,000	349 (17.2)	124 (16.9)	
20,001-30,000	252 (12.4)	67 (9.2)	
30,001-40,000	86 (4.2)	18 (2.5)	
More than 40,000	102 (5.0)	29 (4.0)	

* Non-parametric Chi-square analysis

[a] Values determined using Chi-square for categorical variables and t-test for continuous variables; values significant at $p < 0.15$

Table 2. The percentage of children with mothers who smoked during pregnancy was higher in the short-term memory dysfunction group than children without short-term memory dysfunction. There was no difference between children with and without short-term memory dysfunc-tion in their maternal exposure/history of delivery.

According to individual/indoor exposure, the data analysis suggested that more than half of the children with short-term memory dysfunction were exposed to household environmental tobacco smoke. Table 3 shows household ETS and using fresh air spray and hair spray/deodorant/hair color affected to short-term memory dysfunction in comparison between children with and without short-term memory dysfunction. It also shows there were no differences between both children with and without short-term memory dysfunction on mosquito/insect repellent, fertilizer, pesticide and insecticide uses.

To assess ambient air pollutant exposure from the industrial sources, the present study attempted to geocode participant's residences in the communities using GIS (Geographical Information System) software and mapping. For ambient air pollutant exposure from other sources a questionnaire was used. Table 4 shows that more than two-thirds of children with and without short-term memory dysfunction had lived near a road that has 1-2 motor vehicles/hour, lived within 500 meters from the road and lived within 500 meters of a gas station. In addition, lived within 500 meters of a car repair shop and industrial park proximal to residential areas affected to short-term memory dysfunction in comparison between children with and without short-term memory dysfunction.

Table 5 shows that two out of 25 communities; Islam community (adjusted OR 0.382, 95%CI 0.224, 0.649), and Taladmabtaput community (adjusted OR 0.297, 95% CI 0.148, 0.598), found an inverse association

Table 2. Comparison of children with and without short-term memory dysfunction by maternal exposure/history of delivery

Factors	No short-term memory dysfunction n (%)	Short-term memory dysfunction n (%)	p-value[a]
Pregnancy in study areas	852 (54.3)	272 (53.6)	0.797
Smoking during pregnancy	42 (2.1)	19 (2.7)	0.366
History of delivery			
Normal delivery	1,110 (93.4)	343 (94.5)	0.683
Preterm delivery	34 (2.9)	10 (2.8)	
Low birth weight delivery	44 (3.7)	10 (2.8)	
Breasts feeding	1,757 (86.6)	628 (85.9)	0.622

[a] Values determined using Chi-square for categorical variables and t-test for continuous variables; values significant at $p < 0.15$

Table 3. Comparison between children with and without short-term memory dysfunction by individual/indoor exposure

Factors	No short-term memory dysfunction n (%)	Short-term memory dysfunction n (%)	p-value[a]
Household Environmental Tobacco Smoke	1,087 (50.6)	438 (55.3)	0.024
Using mosquito and insect repellent	1,244 (57.9)	436 (55.3)	0.215
Using fertilizer in residential areas	423 (19.7)	143 (18.1)	0.342
Using pesticide / insecticide in residential areas	324 (15.1)	108 (13.7)	0.361
Using fresh air spray in residential areas	356 (16.6)	111 (14.1)	0.097
Using painting / lacquer in residential areas	155 (7.2)	52 (6.6)	0.561
Exposed to hair spray / deodorant / hair color	35 (1.6)	14 (1.8)	0.781

[a] Values determined using Chi-square for categorical variables and t-test for continuous variables; values significant at $p < 0.15$

Table 4. Comparison between children with and without short-term memory dysfunction by outdoor exposure

Factors	No short-term memory dysfunction n (%)	Short-term memory dysfunction n (%)	p-value[a]
Approx. motor vehicles on the road in regular 1-2 per hour , n (%)	2,014 (93.9)	729 (92.5)	0.178
Experience in living within 500 meters of the road, n (%)	1,847 (86.0)	681 (86.5)	0.706
Gas station is located within 500 meters of residential areas, n (%)	1,631 (76.6)	598 (76.6)	0.982
Car repair shop is located within 500 meters of residential areas, n (%)	1,001 (46.7)	394 (50.1)	0.110
Distance to Industrial Park from residential areas, mean (SD)	5.3 (1.7)	5.2 (1.8)	0.061

[a] Values determined using Chi-square for categorical variables and t-test for continuous variables; values significant at $p < 0.15$

Table 5. Adjusted logistic regression model for potential factors compared between children with and without short-term memory dysfunction

Factors	Adjusted OR	95% CI of OR	p-value[b]
Gender: female	1		
Gender: male	1.145	0.926, 1.415	0.200
Community: Sumnukgabuk	1		
Community: Islam	0.382	0.224, 0.649	0.013
Community: Taladmabtaput	0.297	0.148, 0.598	0.011
Community: Soiruampattana	0.507	0.316, 0.815	0.150
Living period in study areas (years)	0.961	0.923, 1.000	0.048
Parental income: more than 40,000 Baht/month	1		
Parental income: 30,001-40,000 Baht/month	0.654	0.305, 1.405	0.342
Parental income: 20,001-30,000 Baht/month	0.736	0.409, 1.325	0.391
Parental income: 15,001-20,000 Baht/month	0.948	0.544, 1.654	0.978
Parental income: 10,001-15,000 Baht/month	0.823	0.477, 1.423	0.699
Parental income: 5,000-10,000 Baht/month	1.079	0.633, 1.840	0.513
Parental income: Less than 5,000 Baht/month	1.441	0.698, 2.977	0.181
Parental income: No income	0.987	0.179, 5.454	0.947
Age (years)	1.023	0.955, 1.096	0.509
Pregnancy: No	1		
Pregnancy: Yes	1.152	0.902, 1.470	0.100
Household Environmental Tobacco Smoke: no	1		
Household Environmental Tobacco Smoke: yes	1.166	0.938, 1.450	0.245
Distance to Industrial Park from residential areas	0.871	0.807, 0.940	0.022

[b] Values significant at $p < 0.05$

with short-term memory dysfunction. It indicates that children who were residing in these communities have lower risk on short-term memory dysfunction when compared to children who were residing in a reference community. It also found an inverse association between short-term memory dysfunction and length of living period in study areas (adjusted OR 0.961, 95% CI 0.923, 1.000). It indicates that short-term memory dysfunction decreases when the living period in study areas increase by 1 unit.

In addition, short-term memory dysfunction had an inverse association with distance from residential areas to industrial park (adjusted OR 0.871, 95% CI 0.807, 0.940). It indicates that short-term memory dysfunction decreases when distance from residential areas to industrial park increase by 1 unit.

Discussion

The present study found children who were residing in an Islam community and Taladmabtaput

community have lower risk for short-term memory dysfunction when compared to children who were residing in Sumnukgabuk community (reference group). Almost all residents in the Islam community are Muslims, and the majority of women remain at home as housewives. Taladmabtaput is a Buddhist community and most of the women work as vendors, sewing, owner of glossary shop, and own business in the community. These may result in a low risk for chemical exposure at work during pregnancy, a factor that relates to adverse pregnancy outcome, low birth weight or preterm delivery. In a study on the association between petrochemical air pollution and adverse pregnancy outcomes in Taiwan, where the petroleum and petrochemical industries are the main sources of industrial air pollution, the adjusted odds ratios were 1.07 for term low birth weight and 1.03 for preterm delivery when petrochemical industrial municipality compared with reference municipalities[10]. In terms of adverse pregnancy outcome and neurobehavioral effects, Anderson and Doyle[14] studied on neurobehavioral outcomes of school-age children born with extremely low birth weight (ELBW) or born very preterm using full scale of WISC III and found that 12% in ELBW or very preterm cohort exhibited significant neurosensory impairments. Moreover, parents of children in ELBW or the very preterm cohort reported more behavior problems compared to children with normal birth weight[14]. On the other hand, almost of the children in both communities, Islam and Taladmabtaput, are located beside the road and are mostly urban societies. These children were enrolled in private and government schools while children from the reference community were enrolled in a temple primary school. This might affect their learning performance, skills improvement and memory ability.

An inverse association was also found between short-term memory dysfunction and length of living period in the study areas with weakly significant (p-value = 0.048). Although the present study showed short-term memory dysfunction will decrease when length of living period in the study areas increases by 1 unit, an upper of 95% CI OR was 1.000. It was not clear for explanation the relationship of the above mentioned factor.

In addition, short-term memory dysfunction was found to have an inverse association with distance from residential areas to the industrial park. Due to a lack of data on ambient air pollution in the present study, the distance from residential areas to the industrial park was used to assess as a proxy exposure. This indicates that short-term memory dysfunction decreases when children live farther away from this source of air pollution, petrochemical industrial park. Although several studies found the relationship between solvent exposure and neurobehavioral effects using digit span test, these studies emphasized workers or working children, not the general population, specifically focusing on children. Saddik, et al[15] studied the effects of solvent exposure on memory and motor dexterity in working children using non-computerized tests. Saddik found significant differences in performance on the Digit Span test between exposed working children, non-exposed working children, and school children. Working exposed children showed poorer performance on reaction speed for the reaction time.

The limitation of the present study is that a geocode (GIS) was used for assessing ambient air pollutant exposure in participants' residences instead of personal exposure. Therefore, local sources, wind direction and wind speed may have an effect on the level of air pollutant concentration in this area.

Based on the data presented in our current study the authors recommended further investigation of the inverse associations between neurobehavioral effects and some factors such as living period and community.

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ปัจจัยที่มีผลกระทบต่อความผิดปกติของระบบความจำระยะสั้นในเด็กที่อาศัยอยู่รอบนิคมอุตสาหกรรมปิโตรเคมี

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การศึกษานี้มีวัตถุประสงค์ เพื่อศึกษาปัจจัยที่มีผลกระทบต่อความผิดปกติของระบบความจำระยะสั้นในเด็กอายุ 6-13 ปี ที่อาศัยอยู่รอบ ๆ นิคมอุตสาหกรรมปิโตรเคมี ตำบลมาบตาพุด จังหวัดระยอง การศึกษาเป็นแบบภาคตัดขวางโดยใช้แบบทดสอบ Digit Span ซึ่งเป็นแบบทดสอบทางจิตวิทยาที่ได้มาตรฐาน ผลการศึกษาพบว่า 1 ใน 3 ของเด็กจำนวน 2,158 คน เป็นเด็กที่มีความผิดปกติของระบบความจำระยะสั้น และพบว่าความสัมพันธ์ระหว่างความผิดปกติของระบบความจำระยะสั้นกับชุมชนที่อาศัยอยู่ ได้แก่ ชุมชนอิสลาม (adjusted OR 0.382) และชุมชนตลาดมาบตาพุด (adjusted OR 0.297) โดยความสัมพันธ์เป็นไปในทิศทางลบ นอกจากนั้นระยะทางระหว่างนิคมอุตสาหกรรมกับที่อยู่อาศัยยังมีความสัมพันธ์ในทิศทางตรงกันข้ามกับความผิดปกติของระบบความจำระยะสั้น (adjusted OR 0.871) สำหรับความสัมพันธ์ระหว่างความผิดปกติของระบบความจำระยะสั้นกับระยะเวลาที่อาศัยอยู่ในพื้นที่ยังไม่สามารถอธิบายได้ชัดเจน จากการศึกษาสรุปได้ว่าระยะทางระหว่างนิคมอุตสาหกรรมกับที่อยู่อาศัยและชุมชนที่อยู่อาศัยมีผลกระทบต่อความผิดปกติของระบบความจำระยะสั้น