

## Comparison of Intelligence based on Short-term Memory Test between Urban and Rural Children

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### Abstract

**Background:** Cognitive development occurs during childhood and this development is influenced by various environmental factors such as urban and rural environments which can affect child cognitive development. Short-term memory is very important as the first step in processing new information to do cognitive tasks. The aim of this study was to compare the short-term memory of children coming from an urban and rural area.

**Methods:** A cross-sectional design was performed in this observational analytical study, conducted from September to October 2014 in Jatinangor. Students from elementary school students in an urban and rural area in Jatinangor were selected, using a stratified random sampling method. The Digit Span Forward, Backward, and Symbol Digit Modality Test (SDMT) were used to measure short-term memory. Mann-Whitney test and independent T-test were used in this research.

**Results:** There was no significant difference in Digit Span Forward score between urban and rural boys ( $p=0.564$ ); and girls group ( $p=0.982$ ). On the contrary, Digit Span Backward score among urban boys ( $p=0.007$ ) and urban girls ( $p=0.006$ ) was significantly higher compared to those living in the rural areas. Similarly, a significantly higher score of SDMT in the urban areas was found compared to rural for boys ( $p=0.011$ ) and girls ( $p=0.026$ ).

**Conclusions:** Intelligence based on a short-term memory test, consisting of Digit Span Backward and Symbol Digit Modality Test, is higher in urban children compared to children in the rural areas.

**Keywords:** Rural, short-term memory, urban

### Introduction

Intelligence in children is highly associated with cognitive development.<sup>1</sup> Based on Piaget's theory, there are four stages of cognitive development in children, leading to the capacity of adult thought. The rate at which children move through different stages not only depends on genetics but also depends on environmental factors.<sup>2</sup> During the interactions with their environment, there will be a modification of the brain of the children.<sup>3</sup>

The environment is classified into urban and rural areas, with many distinctions between them and can affect the cognitive of the children differently. Due to a lower socioeconomic level in a rural area, it can cause chronic stress and inadequate nutritional

intake that affects the development of brain cells and decreased number of brain cells.<sup>4-6</sup> The less advanced technology in a rural area can cause a decreased verbal and visual stimulation for the cognitive.<sup>4</sup> Furthermore, the low education level of parents in a rural area may also affect the parents' perspective to raise their children. They tend to be less involved in the learning process of their children.<sup>7</sup> Hence, it is important to consider the difference in cognitive level between urban and rural children.

Among all cognitive components, working memory is believed to be a critical contributor to cognitive functions. In children, working memory plays a major role in language comprehension, learning process, planning, reasoning, and problem-solving. Working

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memory is the ability to manipulate or to transform the information that temporarily stored in short-term memory to be applied in cognitive tasks.<sup>8-10</sup> Therefore, short-term memory is very important as the first step in processing new information to do cognitive tasks.<sup>11</sup> The aim of this study was to compare the short-term memory level between children in the urban and rural areas.

## Methods

Students from elementary schools in an urban and rural area in Jatinangor were recruited by a stratified random sampling method. The elementary schools representing schools in urban areas were taken from Cibeusi Elementary School, Cibeusi Village, Jatinangor District; whereas the elementary schools representing rural areas were taken from Karangmulya Elementary School, Cilayung Village, Jatinangor District. This study was conducted from September until October 2014. The method of this study had been approved by the Health Research Ethics Committee Faculty of Medicine, Universitas Padjadjaran, Bandung with the ethical approval number 473/UN6.C2.1.2/KEPK/PN/2014.

The inclusion criteria for this study were students aged 8–10 years old from elementary school students and had lived in a house located in the same village with the school. Consent to participate in this study was signed by the parents. Exclusion criteria were vision and hearing abnormalities, motoric function disorders, metabolic or structural thyroid disease, a state of anxiety and unhealthy when the test was performed, a history of head trauma, consuming any caffeinated drinks such as tea, coffee, carbonated drinks, and energy drinks in 48 hours before the tests were performed, and sleep deprivation for less than 8 hours at the night before the tests performed.

The tools used to measure the short-term memory level in children were (i) Digit Span Forward, (ii) Digit Span Backward, and (iii) Symbol Digit Modalities Test (SDMT). In Digit Span Forward, the students were asked to immediately repeat the digit sequence presented by the examiner in the forwarding sequence. The digit sequences were presented with the speed of one digit per second. Initially, the test began with a length of 2 digits. When the students repeated the whole sequence correctly, the examiner would present the next sequence with one digit longer. For the subjects who failed to repeat the digit sequence

correctly, the examiner would present the next sequence with the same length as another chance. The test was halted if the subjects failed for the second time to repeat the digit sequence with the same length. The Digit Span Backward was performed with a similar procedure as the Digit Span Forward, but the students were asked to repeat the digit presented by the examiner in the reversed sequence. When the number of digits in the last sequence correctly were repeated, it showed the score of the digit span test.<sup>12</sup> On the other hand, SDMT consists of a sheet of paper with a sequence of nine numbers (1–9) and nine corresponding symbols at the top of the paper. The task sequence consists of a series of random numbers, each with a blank space underneath. Within 90 seconds, the students were required to fill the blank spaces with the matched symbol. The number of the blank spaces filled correctly with the matched symbol was the score of the SDMT.<sup>13</sup>

The result of this study was analyzed using IBM SPSS Statistics version 22. Shapiro-Wilk was used to test the normality of the data. When the data were not normally distributed, the Mann-Whitney test was used to compare the score of digit span forward and backward test between children in the urban and rural areas. For SDMT, the independent t-test was used to compare the score of children an urban and rural area, when the data was normally distributed.

## Results

In total, 60 students from the elementary schools were included, who were living in an urban (n 30) and rural (n 30) area, consisting of 16 boys and 14 girls each area. The comparison of short-term memory test scores between boys from an urban and rural areas in Jatinangor had been shown in Table 1.

Table 1 showed that the mean of Digit Span Forward, Digit Span Backward and SDMT scores were higher in urban boys than in rural boys. But the difference of Digit Span Forward score between urban and rural areas was not statistically significant because the p-value was 0.564 ( $p > 0.05$ ). Unlike the Digit Span Forward, the difference between Digit Span Backward score in the urban and the rural area was statistically significant with the p-value was 0.007 ( $p < 0.05$ ). Furthermore, the SDMT score in urban and rural areas also showed that the difference was statistically significant with the p-value was 0.011 ( $p < 0.05$ ).

Similar results were also found in the

**Table 1 Comparison of Short-term Memory Test Scores between Boys in Urban (n16) and Rural (n16) are in Jatinangor**

Short-term Memory Test	Living Place	Mean ± SD	Median (Minimum–Maximum)	P
Digit Span Forward	Urban	4.75±0.77	5.0 (4.0–6.0)	0.564**
	Rural	4.56±0.63	4.5 (4.0–6.0)	
Digit Span Backward	Urban	3.13±0.81	3.0 (2.0–4.0)	0.007**
	Rural	2.31±0.48	2.0 (2.0–3.0)	
SDMI	Urban	22.25±4.93		0.011*
	Rural	18.38±2.63		

Note. SDMI, Symbol Digit Modalities Test. \* independent t-test, \*\* Mann Whitney test

girls’ groups. The table below showed the comparison of short-term memory test scores between urban and rural girls in Jatinangor.

The mean of Digit Span Forward, Digit Span Backward and SDMT scores were higher in urban girls compared to those in a rural area, however, the difference of Digit Span Forward score between urban and rural area was not statistical significant (p=0.982). In the contrary, there was a statistically difference between Digit Span Backward score among girls in the urban and rural areas (p=0.006). Furthermore, the SDMT score in urban and rural areas also showed a statistically higher score among girls in the urban area (p=0.026).

### Discussions

Short-term memory is the ability to store and manipulate the information in the brain for a brief period.<sup>14</sup> Based on experiments conducted using the Brown-Peterson task, the duration of short-term memory is expected to be 0–18 seconds. When short-term memory is functionally used to perform

daily activities, the concept of short-term memory has developed into working memory. Other cognitive component called attention is needed and plays a major role in establishing the working memory. Working memory system itself consists of four subsystems; (i) a phonological loop which serves to process verbal information, (ii) a visuospatial sketchpad which has a function to process visual and spatial information, (iii) an episodic buffer which combines all information from various modalities, and (iv) the central executive system, a system that controls attention in regulating and coordinating other subsystems.<sup>14,15</sup>

The phonological loop is then divided into two subsystems, phonological store, and subvocal rehearsal system. The phonological store is the storage information in the form of primary memory or immediate memory in which the trace memory and storage capacity are limited. The information will be stored in the brain only for a few seconds before the information is lost. Anterior Superior Temporal Gyrus (STG) is an area of the brain that is responsible for phonological store systems.

**Table 2 Comparison of Short-term Memory Test Scores between Girls in Urban (n14) and Rural (n14) area in Jatinangor**

Short-term Memory Test	Living Place	Mean ± SD	Median (Minimum–Maximum)	P
Digit Span Forward	Urban	5.93±1.69	6.0 (4.0–10.0)	0.982**
	Rural	5.36±0.61	6.0 (5.0–7.0)	
Digit Span Backward	Urban	3.71±0.73	4.0 (3.0–5.0)	0.006**
	Rural	2.79±0.61	3.0 (2.0–4.0)	
SDMI	Urban	28.50±5.13		0.026*
	Rural	23.57±5.91		

Note: SDMI= Symbol Digit Modalities Test. \* independent t-test, \*\* Mann Whitney test

Meanwhile, the subvocal rehearsal system is the process of strengthening the information by giving more attention in the form and meaning of information, as well as the process of repetition of the given information. The function of this rehearsal system is increasing the memory trace and preventing decay of the information. The Left Inferior Frontal gyrus or Broca's area and the Rolandic Operculum are brain areas that are responsible for managing this subvocal rehearsal system.<sup>14,15</sup>

Digit Span Test is a subtest of the Wechsler Intelligence Scale for Children (WISC) that can be used to measure verbal working memory or phonological loop subsystem. Digit Span Test consists of two types of tests, namely Digit Span Forward and Digit Span Backward. Digit Span Forward is the test that can be used to measure the phonological store, which is the subsystem of the phonological loop. This type of test uses the phonological store only without entering the rehearsal process system. On the other hand, the Digit Span Backward is the test that should involve the rehearsal process system. The rehearsal process is done by calling the numbers repeatedly or imagining the sequence of the digit.<sup>14,15</sup>

This study has shown that the mean of Digit Span Forward scores, both in boys and girls groups, are higher in an urban area than in a rural area, however, the differences were not statistically significant. On the contrary, the differences between boys and girls Digit Span Backward scores between urban and rural areas are statistically significant. It may be due to the subvocal rehearsal process system that must be done when the Digit Span Backward test is performed. At the time of the rehearsal process, the respondent should imagine the sequence of digit presented by the examiner. By this strategy, the respondent can transform the digit into a new reversed sequence. The process of imagining is called visual processing and this process is one of the strategies that should be done in the Digit Span Backward and rarely used in Digit Span Forward.<sup>16</sup>

Besides, the Digit Span Backward requires better attention to help the process of rehearsal. Attention is controlled by a subsystem of working memory in the central executive system. This is confirmed by a study conducted in Japan that measured the concentration of oxygenated and deoxygenated hemoglobin by using Near-Infrared Spectroscopy (NIRS). The measurement was conducted in the prefrontal cortex, which is the center of the central executive system. Hemoglobin concentration measurements have been

performed both at rest, which is used as a baseline and when the Digit Span Tests are performed. When using NIRS measurement, the activation of neurons would be expressed by an increase in the concentration of the oxygenated hemoglobin and a decrease in the concentration of deoxygenated hemoglobin. As a Digit Span Test Backward has been performed, the concentration of oxygenated blood in the prefrontal cortex is significantly higher compared to the baseline; while the deoxygenated hemoglobin is significantly decreased. On the contrary, when Digit Span Test Forward is performed, the oxygenated and deoxygenated hemoglobin concentrations in the prefrontal cortex are not significantly different from the baseline. The Digit Span Test Backward test requires more neuron activations in the prefrontal cortex compared to Digit Span Test Forward because the central executive system is needed more on the Digit Span Backward.<sup>17</sup>

In brief, Digit Span Backward not only involves the phonological store and subvocal rehearsal system but also the visual processing and central executive system, therefore the Digit Span Backward requires more efforts than the Digit Span Forward. Digit Span Backward is also more sensitive to measure working memory. Digit Span Forward, which only measures the phonological store, has a low level of difficulty and can be easily done by the elementary school students both in the urban and rural areas. Therefore, the difference of Digit Span Forward scores between boys and girls in the urban and rural area is not statistically significant.

Furthermore, the results of the Digit Span Backward in this study which is significantly different between urban and rural area is in contrary to another study that shows the ability of verbal working memory in children of a rural area is better than in an urban area.<sup>4</sup> The urban area has more noise pollution compared to the rural area. Chronic exposure to noise pollution harms verbal memory. Moreover, the urban school participated in this study is located close to the airport, allowing the children in the urban area to have decreased verbal memory because of the chronic exposure of noise pollutant.<sup>4</sup>

Verbal information received by children will be processed into memory through several strategies, such as rehearsal, organization, and elaboration. These processes require another cognitive component, known as attention. The presence of chronic exposure to noise pollution causes the process of information

storage to be interrupted because attention is distracted by unwanted noise in children. As a result, the information obtained will be hard to be remembered by the children and the verbal memory will be decreased.<sup>18</sup> In our study, it seems likely that exposure to noise pollution is not much difference between children in an urban and rural areas in Jatinangor.

Furthermore, our study measured not only verbal memory but also the visuospatial memory, tested by SDMT. The SDMT score of children living in an urban areas was higher and the difference was statistically significant. This result was similar to another study; children who live in rural areas have a weakness for visuospatial memory. This can occur due to the environmental differences between urban and rural areas. The daily visual stimulations in a rural areas are lower than in urban areas. In an urban area, the crowd of the city, office buildings, residential and industrial buildings, as well as advertisement boards and posters can provide visual stimulation to children.<sup>4</sup> These stimulations can give pleasant stimulation and affect cognitive functions, such as attention and memory.

The scores of memory in respondents exposed with a pleasant visual stimulus is higher than in respondents exposed with no visual stimulus or neutral visual stimulus, due to the positive emotions involved in these visual stimulations. There is an increased release of dopamine when positive emotions are induced and this neurotransmitter has a role in the formations of memory. Moreover, positive emotions will also activate the amygdala and when activated, the amygdala will mediate connections with the cortex and facilitate the processes of memory formation such as encoding, recalling, and recognition.<sup>19</sup> On the contrary, if the aversive visual stimulations are exposed, high levels of anxiety are presented and there will be a decline in working memory and attention.<sup>20</sup>

Also, less technological advances in a rural areas, such as Internet access or ownership of computers which also provide visual stimulation would make the children in rural areas to not use visuospatial memory as often as children in the urban areas.<sup>4</sup> Children who have access to a computer may perform better in cognitive development. Computer applications such as computer games can increase some cognitive skills, such as visual intelligence skills, spatial skills, and visual attention skills. Therefore, children in rural area can experience a delay in visuospatial memory development.

There are some limitations encountered that may affect the results of this study. The room used for the test performed is not soundproof, thus, the sound from the outside of the room can interfere child's concentration and affect the results of the tests. It is therefore recommended that soundproof room or other places that can minimize all types of distractions is needed for future study. Besides several confounding factors may also affect the result of this study such as the nutritional status, the activity, the emotion and the motivation of the children during the test, as well as the parenting patterns. Future studies are expected to overcome these confounding factors and to find the association of these factors with child intelligence.

In summary, the intelligence of the children based on short-term memory tests consisting of Digit Span Backward and Symbol Digit Modalities Test is higher in an urban areas compared to a rural areas in Jatinangor. Improving the quality of teaching methods in educational institutions is needed to enhance the intelligence of students in rural area. Parents are also needed to pay more attention to the environment around the children to provide a good stimulus for the cognitive and to eventually improve cognitive abilities in their children.

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