

# Electroencephalographic study of real-time arithmetic task recognition in learning disabilities children



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## ABSTRACT

**Background:** Mathematics form is universally understood in modern society. It is natural to ask whether there is neurophysiological evidence for putative cognitive components of the task and the practice in mental arithmetic will lead to a detectable transition in primary locus of brain activity. **Aims and Objectives:** The purpose of this study was to determine the effect of real-time arithmetic recognition task for cognitive performance and electroencephalographic activities. **Materials and Methods:** While practicing the real-time arithmetic recognition task named SpeedMath developed by NeuroSky, Inc., electroencephalographic activities were also recorded by using the commercial lightweight electroencephalographic device, Mindwave Mobile, NeuroSky, Inc. Eight participants included learning disabilities children participating in this study. All participants were instructed and trained to practice the simple the arithmetic recognition task which included arithmetic and mathematic skills. **Results:** The results showed that both alpha and beta frequency bands were increased with statistically significant at the 0.05 level. **Conclusions:** The real-time arithmetic recognition task might improve the real-time arithmetic recognition task and performance.

**Key words:** Brain; Brain activity; Arithmetic; Cognition; Brain training

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## INTRODUCTION

Mathematics and arithmetic form of a prototypical cognitive system is almost universally understood in modern society. System or domain knowledge and the skills to use that knowledge are acquired relatively early in life, and are used in grossly similar ways by all adults. <sup>1</sup>In several previous studies, cognitive psychologists had employed mental arithmetic problems as a paradigm to study higher order mental processes. Some important facts are beginning to emerge from behavioral studies of arithmetic and mathematical processes. Much of this empirical work using a mental arithmetic task are scored primarily according to speed of answer production.<sup>1,2</sup> However, it is natural to ask whether there is neurophysiological evidence for putative cognitive components of the task and about possible

systematic relationships between these brain activities and variables were known to affect speed and accuracy of performance.<sup>3</sup> Therefore, it is entirely reasonable to expect that practice in mental arithmetic will lead to a detectable transition in primary locus of brain activity.<sup>1-3</sup>

Brain is an organ that is easily affected by the physical changes, especially in the modern time when people are easily poisoned by the increasing pollution.<sup>4-6</sup> Electroencephalography (EEG) is traditionally used to measure the human brain waves. Each type of brain wave is associated with one's state of consciousness and different mood and emotional states.<sup>7,8</sup> The electroencephalography thus offers a way to monitor brain activity in real time and to track any transitions that parallel changes in behavior.<sup>9</sup>

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There are some evidences of an association between slow brain potentials and the task demands of mental arithmetic.<sup>9</sup> One finding is that more difficult tasks are associated with more positive amplitude levels.<sup>10,11</sup> Additionally, mental arithmetic tasks seem to be associated with a relative positivity over the frontal cortex.<sup>11-15</sup> However, the interpretation of this frontal positivity is still somewhat controversial. Rosler and Heil<sup>13</sup> related the frontal positivity to the mental operation of division and also related Ruchkin's study<sup>15</sup> to the allocation of resources and/or to the coordination of processing states.<sup>13,15</sup> In the present study, the measurement of electroencephalographic activity was done by letting participants who were learning disabilities, did the real-time arithmetic recognition task operated by SpeedMath program which was developed by NeuroSky, Inc., and then measured the electroencephalographic activity during the real-time arithmetic performing.

## MATERIALS AND METHODS

**Participants:** The experiment was done with eight learning disabilities children, aged between 5-12 years old, who were in good health, no record of brain surgery, not taking medicines or drugs that affect to nervous system. Exclusion criteria included left handedness; history of medical and neurologic diseases; psychiatric disorders; head trauma; assumption of central nervous system active drugs in the two weeks prior to study entry; and presence of electroencephalographic abnormalities at the baseline electroencephalographic recording. After receiving information about the aims of the study, we provided written consent to parents to sign according to the Helsinki declaration standards and was approved by the local institutional review board of Mae Fah Luang University, Thailand.

**Tools and Equipment:** Recording personal information including age, gender, nationality, and history of illness were recorded. The electroencephalography was applied both before and after brain training. The neuro headset was used to record, analyze, and display the output of electroencephalographic activities. In this study, the effectiveness of commercially available lightweight electroencephalographic devices, NeuroSky's Mindwave Mobile (NeuroSky, Inc.), was considered. Via the application of a single electrode and signal-processing unit in a head band arrangement, the Mindwave Mobile provides two 100-state outputs operating at 1 Hz. Although the Mindwave Mobile provided a much coarser picture of brain activity than multi-electrodes electroencephalographic or other technologies, the principle advantage of the Mindwave Mobile was its unobtrusive nature, which minimizes

the aforementioned difficulties in conducting accurate user studies. In this study, the principles of analytical check were based on the International 10-20 system by displaying the electroencephalographic output. The electroencephalographic frequency analysis was performed by means of a Fast Fourier Transform (FFT) algorithm, with a 2-second interval on the electroencephalographic signal. A single-channel electroencephalogram was designed to collect brain activity data from the participants' brain. Simplicity and efficiency were the main reasons for designing a single-channel electroencephalographic monitoring system. The electroencephalographic data was analyzed offline and the following frequency bands were computed: delta ranging from 0.1 to 3.0 Hz, theta (4.0 to 7.0 Hz), alpha (8.0 to 13.0 Hz), beta (14.0 to 30.0 Hz), and gamma (31.0 to 47.0 Hz), respectively.

SpeedMath, developed by NeuroSky, Inc., used in this study is a computer-based task which is designed to train participants' arithmetic skills to be more precise and efficient. After participants had completed a problem set, the changing of attention levels was then reviewed. In the SpeedMath post reports, each vertical line in the post report represents an answered problem. It helps to build up participants' quick-thinking math skills by answering problems both accurately and quickly. Actually, the SpeedMath is the game for everyone. This game lets participants build up their math skills while working on their problem areas. As the participants improve, so will their attention level and their problem-solving skills. Measuring electroencephalographic activity while real-time arithmetic recognition task was also compared to baseline.

**Statistical Analysis:** Analyzed the basic demographic data of participants by using descriptive analysis with qualitative data summarized in term of frequency and percentage, with quantitative data summarized in term of average and standard deviation. Using inferential statistic compares each type of electroencephalographic activity by compared *t*-test. Every test was set to the statistic significant at  $p < 0.05$ .

## RESULTS

According to Table 1, it was found that after brain training, alpha and beta frequency bands gradually increased while delta, theta, and gamma frequency bands did not change. In addition, both alpha and beta frequency bands increased with statistically significant at the 0.05 level while performing the real-time arithmetic recognition task.

The delta frequency band did not change while performing the real-time arithmetic recognition task compared to baseline (baseline:  $0.63 \pm 0.012 \mu V$ ; arithmetic task:

**Table 1: Comparison of electroencephalographic activities while performing the real-time arithmetic recognition task**

Frequency bands	Before brain training		After brain training		P-value
	Mean	SD	Mean	SD	
Delta	0.63	0.012	0.74	0.15	0.24
Theta	0.21	0.017	0.41	0.21	0.95
Alpha	0.37	0.025	0.71	0.36	0.01*
Beta	0.03	0.013	0.74	0.23	0.03*
Gamma	0.48	0.83	0.36	0.09	0.07

\* $P < 0.05$ 

0.74±0.15µV;  $t(15) = 1.57$ ;  $p=0.24$ ) whereas the theta frequency band increased with no statistically significant while performing the real-time arithmetic recognition task compared to baseline (baseline: 0.21±0.017µV; arithmetic task: 0.61±0.21µV;  $t(15) = 1.81$ ;  $p=0.95$ ). On the other hand, it was found that alpha frequency band was found to be increased with statistically significant at the 0.05 level while performing the real-time arithmetic recognition task compared to baseline (baseline: 0.37±0.025µV; arithmetic task: 0.71±0.36µV;  $t(15) = 0.41$ ;  $p=0.01$ ) while the beta frequency band also increased with statistically significant at the 0.05 level while performing the real-time arithmetic recognition task compared to baseline (baseline: 0.03±0.013µV; arithmetic task: 0.74±0.23µV;  $t(15) = 0.13$ ;  $p=0.03$ ). Finally, it was found that gamma frequency band did not change while performing the real-time arithmetic recognition task compared to baseline (baseline: 0.48±0.83µV; arithmetic task: 0.36±0.09µV;  $t(15) = 1.04$ ;  $p=0.07$ ).

## DISCUSSION

Our findings revealed that after brain training, alpha and beta frequency bands were increased with statistically significant while performing the real-time arithmetic recognition task. Participants have shown significantly mean improvement in speed, memory, attention, flexibility and problem solving, respectively. This is consistent with findings in several previous studies including in healthy adults with mild cognitive impairment and in chemotherapy-treated cancer survivors, respectively.<sup>16-18</sup>

Neuropsychological studies indicated that the frontal brain is involved whenever mental activity is deliberate and controlled.<sup>16,19,20</sup> The more the processing of the arithmetic task becomes automatized, the less frontal cortical activity will be observed. Frontal activity may reflect an executive function which allocates resources and/or organizes the processing stages of the task.<sup>15,21</sup> Some evidences also fit with neuropsychological data, showing that arithmetic deficits in adults, who developed high arithmetic skill prior to brain insult, tend to be associated with parietal brain lesions.<sup>16,17</sup> In

summary, our data show that skill acquisition for real-time arithmetic recognition task in learning disabilities children who had brain training, revealed the electroencephalographic activity changes especially the alpha and beta frequency bands. Skills acquisitions were reflected in systematic electroencephalographic activity changes. However, further empirical studies are needed to evaluate the suggested frequency bands of electroencephalographic related to real-time arithmetic recognition task.

## CONCLUSION

Practicing the real-time arithmetic recognition task might significantly increase both alpha and beta frequency bands in learning disabilities children. The brain training might improve cognitive performance in learning disabilities children indexed by the electro-encephalographic activity.

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**Authors Contribution:**

**PS**-Concept and design of the study, manuscript preparation, statistically analyzed and interpreted, critical revision of the manuscript; **SCC**-supported experimental device, helped in preparing first draft of manuscript.

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