ORIGINAL ARTICLE

Effectiveness of Digital-based Cognitive Remediation (SiPETA) to Improve Attention and Verbal Comprehension in Elementary School

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ABSTRACT

Introduction: Globalization and Indonesia's demographic bonus, characterized by a surge in the productive-age population, may lead to cognitive and behavioural challenges among children. Digital interventions, such as SiPE-TA, offer a promising approach to address these challenges by enhancing children's cognitive development through the implementation of a structured web-based program. This study evaluates SiPETA's effectiveness in improving elementary school students' attention, memory, and comprehension. **Materials and methods:** Using a controlled experimental design, 61 elementary students were randomly assigned to the SiPETA training group or a conventional training control group. Cognitive functions were assessed using P300 event-related potentials, digit span, and information tests in pre- and post-test assessments. Data analysis involved paired T-tests and ANOVA to compare cognitive improvements. **Results:**We found significant improvements in the experimental group's attention and cognitive comprehension levels, evidenced by improved P300 latency and information test scores. **Conclusion:** These findings suggest that SiPETA could be a viable tool in educational settings to address cognitive developmental needs effectively.
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INTRODUCTION

In recent years, Indonesia has witnessed rapid demographic shifts driven by globalization and the phenomenon known as the "demographic bonus"—a marked increase in the proportion of the productive-age population relative to the non-productive. This shift holds great potential for national growth but also imposes new pressures on educational systems, particularly regarding children's cognitive and behavioural development (1). As children face these intensified developmental demands, they increasingly exhibit cognitive and behavioural issues, including difficulties with attention, memory, and self-regulation. Such issues can hinder academic performance, impact self-esteem, and negatively influence social integration, posing a significant challenge for parents, educators, and policymakers alike (2,3).

Research indicates that undiagnosed and unaddressed cognitive difficulties in childhood are strongly associated with long-term educational and social outcomes. Yet, complex cognitive issues are often missed or mismanaged due to the variability of symptoms and limited access to specialized resources, especially in middle-income countries such as Indonesia (4). Traditional interventions, while effective, can be prohibitively expensive and challenging to implement on a large scale, underscoring the need for accessible solutions that enable early detection and targeted support (5). In addition, taking the child to a professional requires more money and each professional gives a different view on each child which is not necessarily effective in reducing the symptoms of

cognitive problems (6).

Digital cognitive interventions represent a promising solution, offering interactive and accessible tools that support cognitive skills development in children without requiring extensive resources. SiPETA is one such digital intervention, specifically designed to improve attention, memory, and comprehension in elementary-aged children. Grounded in Bloom's Taxonomy, SiPETA organizes cognitive exercises into a structured, hierarchical framework aimed at helping children progressively develop key cognitive skills. The program incorporates six levels of interactive, story-driven content, each crafted to capture children's attention and sustain their engagement through the training process. This framework allows SiPETA to address various cognitive skills sequentially, promoting skill development in a way that is both accessible and enjoyable for young learners. The six levels of SiPETA range from simple exercises focused on attention and memory to more complex tasks that require analysis and comprehension, encouraging children to gradually develop higher-order cognitive skills. In addition, SiPETA can be used by parents at home and taught by teachers at school (7).

The effectiveness of digital interventions in education has been increasingly recognized. However, systematic evaluations are essential to ensure that these tools effectively support cognitive and behavioural development in children. This study seeks to evaluate SiPETA's impact on elementary-aged children by examining its influence on key cognitive measures, including attention, memory, and verbal comprehension, compared to conventional learning techniques. This study also use P300, *digit span* and *information tests* to investigate the changes in children cognition before and after the experiment as the indicators for SiPETA's effectiveness (8). By investigating SiPETA's potential, this research aims to contribute to the development of cost-effective, scalable solutions for enhancing children's cognitive and academic outcomes.

MATERIALS AND METHODS

Participants

The study sample consisted of 61 elementary students aged 8-10 years, selected through random stratified sampling to ensure balance across grade levels. Five participants did not complete the study, leaving a total of 56 students—28 in the SiPETA training group and 28 in the control group. Inclusion criteria included active school enrollment, absence of diagnosed neurodevelopmental or mental health disorders, and availability to complete all study requirements. Demographic characteristics, including age and gender, were recorded to ensure baseline comparability between groups (Table I). The inclusion criteria are active students and there is no history of neurodevelopmental disorders and mental disorders. The Exclusion criteria is participants and/or parents are unwilling to participate in the study and did not fully complete the research.

Research Design

This study utilized a controlled experimental design to evaluate SiPETA's effectiveness on cognitive function among elementary school students. Conducted over a three-month period from August to October 2023, the research was based at a public elementary school in Depok, West Java. Participants were randomly assigned to either an experimental group that received SiPETA training or a control group that received traditional study skills training. Cognitive assessments to test the effectiveness of SiPETA were conducted for both groups in pre- and post-test sessions. Data were analyzed using SPSS v23. Paired T-Tests were used to evaluate within-group changes from pre- to post-test, while ANOVA compared between-group differences. Significance was set at $p < 0.05$.

Procedures and Instruments

SiPETA, a web-based cognitive training platform, was developed by researchers using Bloom's Taxonomy, comprises six levels, each designed to progressively build skills in attention, memory, and self-regulation (9). The training includes narrative elements and interactive tasks that make it engaging for children. Each level is based on a story format, integrating visual and auditory stimuli to enhance memory and comprehension.

Each training session lasted approximately 40 minutes, aligning with a typical school period, and included feedback mechanisms to help children track their progress. To ensure the appropriateness of SiPETA's content for elementary school students, the platform underwent expert validation by a panel of 13 child development professionals, who assessed the program's alignment with Bloom's Taxonomy and its suitability for young learners.

SiPETA was developed through an application called Articulate Storyline 3. During the creation of the application, a content validity process was carried out to measure whether the learning of each stage could be understood by children. The content validity used is expert judgement where 13 professional staff in the field of child learning will assess the stories of each stage using the content validity ratio and content validity index methods.

Before each stage of begins, the children need to take a pre-test and post-test to measure their attention, concentration and memory skills. The first level is aimed at improving attention and memory using five short media stories and more pictures. In the second level, stimulation is done with role play. Parents and teachers observed the improvement of attention and comprehension from basic to advanced levels. In the

second level, the five stories were given that were more complex and already used conjunctions so that children were trained to understand the story.

Then, the third level is aimed at training application skills, thinking skills, and how children find solutions to problems. The stories in this level include the concept of applying social behaviour to everyday life. The fourth level presents a long story and children are asked questions about the main idea and other questions that train analytical skills. The fifth level contains a story that is longer than all the previous stories, learners are asked to retell the story that has been read so as to encourage learners to evaluate and assess the story. The sixth level is the last stage that trains self-regulation by instructing learners to answer questions related to self-regulation. In this last level, statements are conditioned to trigger learners to design an activity process that reflects self-regulation.

Outcome Measures

Three primary outcome measures were used to assess SiPETA's impact. First, P300 Event-Related Potential (ERP) was measured through quantitative electroencephalography (qEEG) called P300 ERP that assessed attention by tracking brain responses to auditory stimuli. Electrodes were placed at Fz, Cz, and Pz sites, following standard ERP protocols. Latency scores below 370 ms are considered indicative of good attentional processing, with lower latency scores reflecting quicker processing speeds. Second, Digit Span Test, a component of the Wechsler Intelligence Scale for Children (WISC), evaluated working memory and auditory attention by asking children to repeat a series of numbers. Scores reflect the number of correct repetitions, providing an index of memory and attention. Third, Information Test, also part of the WISC, was used to assess verbal comprehension by asking children questions about general knowledge. Scores reflect comprehension ability, with higher scores indicating better verbal processing skills.

Ethical Clearance

This research, which utilized a P300 machine, administered the information test & digit span and SiPETA, was conducted in accordance with the ethical guidelines established by UPN Veteran Jakarta Ethic Committee, Indonesia. This research has obtained ethical clearance from the UPN Veteran Jakarta review board, guaranteeing the protection and welfare of all participants, as well as the responsible execution of the research. All participants have given informed consent, which included comprehensive and clear information about the study's objectives, approach, potential risks, benefits, confidentiality measures, and right to withdraw. Privacy and confidentiality have been ensured in this study, with data securely stored and accessible only to authorized personnel. The well-being of participants has been always a top priority, ensuring no hazardous side effects following the completion of P300 administration. The research adheres to all applicable laws, regulations, and ethical standards set forth by UPN Veteran Jakarta, World Medical Association (Declaration of Helsinki), and any other guidelines related to the application of P300, assessment using information test & digit span and SiPETA. The following is our ethical clearance identification number from UPN Veteran Jakarta: 393/XI/2023/KEP.

RESULTS

The demographic data from 61 students who participated in the research can be seen in the Table I. Table I indicates that female students and 4th grade are the majority of respondents in this study and mean age of the respondents are 8,67.

Table I: Demographic Data – Gender, Age, Class

Demographic	n	Percentage (%)
Gender		
Male	25	41
Female	36	59
Class		
1st Grade	10 Students	16
2nd Grade	10 Students	16
3rd Grade	10 Students	16
4th Grade	12 Students	20
5th Grade	11 Students	18
6th Grade	8 Students	13
Age		
Minimum	6	-
Maximum	12	-
Mean Age	8.97	-
Mode	8	-

Furthermore, the descriptive analyses, means, and standard deviations of the levels of P300, Information test and digit span are presented in Table II for the SiPETA training and control groups both before and after the intervention. The researcher found many differences between the means of the training group and the pre and post-test groups. Based on Table II, the experimental group had more dominant increase in the level of attention compared to the control group (sig. = 0.043, $p < 0.05$).

Table II: Descriptive Analysis and T-Test

	Training Group (n=28)					Control Group (n=28)				
	Pre-test *M (SD)*		Post-test *M (SD)*		*t* (*p*)	Pre-test *M (SD)*		Post-test *M (SD)*		*t* (*p*)
P300_Fz	337.46	(33.27)	319.43	(35.53)	2.29 (0.3)	311.54	(36.64)	319.14	(41.08)	-.80 (.43)
P300_Cz	328.64	(35.48)	310.46	(31.52)	2.40 (0.2)	312.75	(36.70)	312.43	(33.46)	.04 (.97)
Information test	10.64	(2.78)	11.57	(3.00)	-2.07 (0.4)	10.04	(3.07)	10.71	(2.45)	-1.23 (.23)
Digit span test	10.96	(3.00)	10.36	(3.05)	1.10 (0.28)	9.61	(2.67)	9.07	(2.23)	1.06 (.30)

Furthermore, the ANOVA in Table IV showed significant differences in the experimental group for P300 Fz (mean difference = 18.04, p = 0.030), P300 Cz (mean difference = 18.18, p = 0.024), and the Information Test (mean difference = -0.93, p = 0.048). The control group did not show any significant differences across all tests (p > 0.05). These findings suggested that the SiPETA training program effectively improved performance metrics in the experimental group. Furthermore, to see the average difference of the pre-test and post-test difference between the SiPETA training group SiPETA and the control group using ANOVA.

Table III: Anova

		Mean	F	Sig
P300_FZ	Experiment	18.0357	4.315	.043*
	Control	-7.6071		
	Total	5.2143		
P300_CZ	Experiment	18.1786	2.810	.099
	Control	.3214		
	Total	9.2500		
Information Test	Experiment	-.9286	.124	.726
	Control	-.6786		
	Total	-.8036		
Digit Span	Experiment	.6071	.009	.924
	Control	.5357		
	Total	.5714		

DISCUSSION

This study aimed to evaluate the effectiveness of SiPETA, a digital intervention, on cognitive development in Indonesian elementary school students. The results indicate that SiPETA training led to substantial improvements in attention, memory, and comprehension compared to traditional training methods. The reduction in P300 latency scores within the experimental group suggests enhanced attentional processing, while gains in information test scores reflect improvements in verbal comprehension.

P300 Fz and P300 Cz scores on descriptive analysis table describe the average latency scores of the all participants from experimental and control group. There is a difference in the average latency score in pre test and post test where the score is getting smaller. It means that their level of focus is improved after the training and can processes information quicker than before. Their average latency scores are still considered as normal (between 250-370ms).

The T-Test results for the experimental group revealed significant differences in P300 values at both Fz and Cz. We observed that, on average, P300 values decreased post-training, which is a positive sign. In P300 measurements, values of 300 ms or less generally point to good attentional capacity, with lower scores reflecting improved focus. Research has consistently shown that higher P300 amplitudes are correlated with higher attention, especially for children who struggle with attention problems (10–13). In fact, P300 tasks have been effective in helping train attention (14–18).
These findings suggest that SiPETA plays a role in enhancing children's attention, helping them achieve better focus. In similar studies using other forms of training, results showed that structured cognitive training not only improved children's performance on tasks but also had a positive impact on behavior and even on brain function (19).
Additionally, the experimental group's average scores on the information test increased from pre- to post-training. This test, which looks at cognitive skills like verbal comprehension, indicated that the children were better able to understand and retain information after using SiPETA, highlighting an improvement in their verbal comprehension skills.

When children use SiPETA, they follow structured instructions designed to enhance reading skills. Reading proficiency is crucial, as studies indicate that stronger reading abilities are associated with greater neural efficiency, leading to improved performance

in working memory tasks (19). Additionally, the study that used computerized cognitive remediation Program for children performed significantly better in various measures (20,21).

There are variables that have insignificant results, things like this can occur due to various factors such as the state and readiness of children physically or psychologically when taking P300 data, digit span tests and information tests; the number of samples is not large, for this study only used 28 children for each and small amount of time to training, only for 3 days. Future studies should consider a longitudinal design to assess the long-term impact of SiPETA training on cognitive development. In addition, exploring the applicability of SiPETA in different educational contexts may offer insights into its broader potential as a tool for cognitive remediation.

CONCLUSION

The SiPETA digital intervention programme demonstrates significant potential as an accessible, scalable solution for enhancing cognitive development in elementary school students. By providing structured, engaging activities that target attention, memory, and comprehension, SiPETA can effectively support children's cognitive growth. Further research is recommended to confirm these findings and explore SiPETA's potential as a national resource for cognitive development in Indonesia's growing young population.

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