

# Assessment and comparison of auditory and visual reaction time in abacus trained and untrained students aged 8 to 13 years in the south Indian population

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## ABSTRACT

**Background:** Hand-eye coordination is essential for our daily activities. It involves the accuracy and concentration with which an individual performs tasks. Memory tasks like abacus involve the increased use of the superior and middle frontal gyrus, the motor region of the cerebral cortex, which improves the blood supply to this region, and nourishment to the neurons. This enhances neural plasticity in the developing age, which, in turn, improves the rapidity and precision of physical responses to various stimuli. **Objectives:** To assess and compare the reaction times of children who have undergone abacus training and those who have not undergone abacus training in the age group of 8–13 years. **Methods:** It is a cross-sectional study, selected by Indian Council of Medical Research- Short Term Studentship 2018, approved by the undergraduate research monitoring committee, and institutional ethics committee. The research study was conducted in a central school in Puducherry among age-matched and body mass index (BMI)-matched healthy children aged between 8 and 13 years who were undergoing abacus training and who did not receive abacus training. Anthropometric parameters such as weight, height, and BMI were measured. Following that, the auditory (ART) and visual reaction time (VRT) of the participants were measured using a recognition reaction time apparatus. **Results:** The auditory and visual reaction time in the study group was significantly less than that of the control group ( $P = 0.04$  for ART and  $P = 0.001$  for VRT). **Interpretation and Conclusion:** This study concludes that students trained in memory tasks like abacus have better hand-eye coordination as recorded by their enhanced processing speed, thereby decreased response to auditory and visual stimuli when compared with untrained students.

**Keywords:** Abacus, auditory stimuli, hand-eye coordination, precision, reaction time, visual stimuli

## Introduction

Hand-eye coordination is an important component of daily activities including visual and spatial skills that require accuracy and concentration and involve complex cognitive pathways.<sup>[1]</sup> A study by Wang revealed that abacus-based methods enable users to adopt an imaginary abacus to help find rapid solutions to

problems, improving working memory and spatial organization by inducing changes in functional neural anatomy.<sup>[2]</sup> Abacus is also known to increase intelligence, strategic thinking, and general improvement in other subjects.<sup>[3]</sup> A study by Roy *et al.* revealed that the abacus trains working memory by including multiple calculations and numerical. Trained children show improved performance on ascending and descending digit span tests and reaction time scores.<sup>[4]</sup>

A study by Lu *et al.* stated that the abacus can be used as an effective tool for intervention in children with developmental dyscalculia by integrating it into regular education systems.<sup>[5]</sup>

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Received: 13-01-2021

Revised: 01-07-2021

Accepted: 09-07-2021

Published: 29-11-2021

### Access this article online

#### Quick Response Code:



Website:  
www.jfmpc.com

DOI:  
10.4103/jfmpc.jfmpc\_93\_21

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**How to cite this article:** Philip RA, Yerrabelli D, Bhavya RL. Assessment and comparison of auditory and visual reaction time in abacus trained and untrained students aged 8 to 13 years in the south Indian population. J Family Med Prim Care 2021;10:4077-81.

It greatly helps to improve hand-eye coordination and increases the number of synapses in the central nervous system.<sup>[6]</sup> This increases the efficiency of conducting routine activities. They are a nonaddictive and stress-free alternative.

## Novelty

To our knowledge, our study is the first of its kind to study the effectiveness of abacus training in improving auditory and visual reaction time in children aged between 8 and 13 years in Puducherry.

## Study design

Type of study: analytical

Study design: cross-sectional

## Inclusion criteria

Study group:

- Age between 8 and 13 years
- Individuals receiving training in abacus

Control group:

- Age between 8 and 13 years
- Children who did not receive any training in abacus

## Exclusion criteria

Participants with a history of neurological disorder, head injury in the recent past, i.e., within 3–5 years.

## Sample size calculation

The sample size was calculated for an ability to detect differences in cognitive test scores between the abacus-untrained and abacus-trained children. From the data published earlier, the mean and SD values for the cognitive test scores for children untrained and trained in memory tasks were 36.89–5.50 and 89.63–23.82, respectively. Hence, the study was carried out in 35 subjects in each study group. Sample size calculation was based on two samples *t* test with 80% power and 5% level of significance. Data were analyzed by unpaired *t* test using SPSS v. 19. Data were expressed as means  $\pm$  SD. *P* value <0.05 was considered statistically significant.

## Sampling technique

Nonrandomized sampling.

## Materials and Methods

It was a cross-sectional study, in accordance with the ethical standards of the Declaration of Helsinki of 1975, as revised in 2000, selected by ICMR-STC 2018, approved by the undergraduate research monitoring committee and institutional ethics committee. After obtaining informed written and oral consent and assent from the guardians and participants, the research study was conducted in a central school among children in the age group of 8 to 13 years who were undergoing abacus

training and children who did not receive abacus training. The anthropometric parameters such as weight, height, and body mass index (BMI) were measured. Following that, the auditory (ART) and visual reaction time (VRT) of the participants were measured using a recognition reaction time apparatus. (Manufacturer's name: Anand manufacturers).

## Anthropometric Parameters

### Height

The subject's height was measured by using a wall-mounted stadiometer. The subject was instructed to stand on a flat surface with both the heels and knees placed together, legs straight, feet flat on the surface, and looking horizontally straight with arms at their sides. The occiput, shoulder blades, hips, and heels should press against the vertical bar, and the height of the subject was measured (in cm) by bringing the slider down to rest on the top of the head, pressing the hair.

### Weight

It was measured using a weighing machine that has been checked for accuracy by comparing its results with other available machines. The subjects were asked to wear light clothing with no footwear and to stand erect on the foot bar with the legs positioned on either side of the digital scale. The weight was measured in kilograms.

### Body mass index (BMI)

BMI was calculated by using the Quetelet formula, which states that

$$\text{BMI} = \text{bodyweight in kilograms} / (\text{height in meters})^2$$

BMI is an index to measure whether the patient is obese, overweight, or normal.

## Reaction Time Tests

### Auditory reaction time

Two sound stimuli, namely, a click and a beep sound were given. The subject was asked to respond only to the beep sound by releasing the button. The click sound acts as a distractor stimulus, which the subject must ignore and avoid responding to. The beep sound is the memory stimulus. Ten recordings were taken of which the two highest and lowest values were excluded before calculating the mean value.<sup>[7]</sup>

### Visual reaction time

Two visual stimuli, namely, red and green color were shown to the subject. The subject must respond to the red stimulus by releasing the button while ignoring the green stimulus. The mean VRT was calculated similarly to mean ART.<sup>[7]</sup>

### Statistical analysis

The normality of the data was tested using Kolmogorov–Smirnov test. The normally distributed data have been

expressed as means  $\pm$  SD. 'P' value  $< 0.05$  has been considered statistically significant. Non-normally distributed data have been expressed as median with interquartile range. Data between the groups were analyzed using Mann–Whitney 'U' test/Student's 't' test.

## Results

Anthropometric parameters [Table 1]:

The anthropometric parameters measured included age, height, and weight. BMI was calculated using these values.

Reaction time [Table 2]

The parameters were found to be normally distributed and were expressed as means  $\pm$  SD.

[Graph 1: graphical representation of the significant difference in auditory and visual reaction time between study and control population].

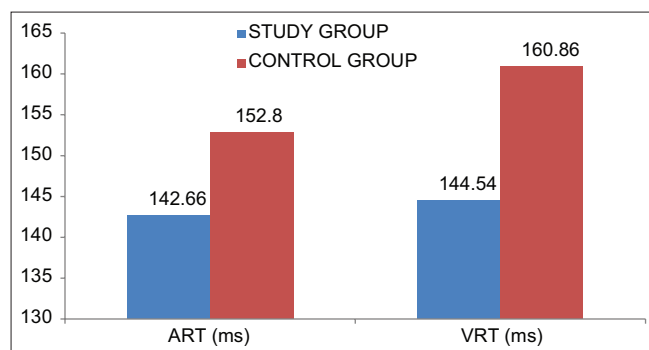
## Discussion

### Memory tasks involve

- Factual aspect: this includes the basic elements that the student must know. It helps the student to be acquainted with discipline.
- Conceptual aspect: this involves relationships among the basic elements within a larger structure that enables them to function together.
- Procedural aspect; it deals with the method to do things using algorithms and skills.

Memory tasks improve the psychomotor domain of cognition. This improved physical skill set promotes the confidence of the child and, in turn, boosts the affective domain. The improved confidence, in turn, improves knowledge and skill. Thus, the memory tasks promote an overall enhancement of cognitive functions.<sup>[8]</sup>

Abacus is an age-old practice renowned for improving mathematical abilities in children.



**Graph 1:** Graphical representation of the significant difference in auditory and visual reaction time between study and control population

Memory tasks such as abacus work by altering the response elicited in the brain to a stimulus by improving synaptic connectivity. Neurons, once formed, lose the ability to divide. Thus, one of the mechanisms to improve cognition is by increasing the number of synaptic connections, which is enhanced by memory tasks. This works better in children as the developing brains have greater plasticity. Capability for developmental plasticity may change for some neural systems at a time called the critical period. This period contains the maximum plasticity for neural remodeling during which certain stimuli have a sustained effect on the learning process and growth of the brain.<sup>[9]</sup> Thus, stimulation of the neurons during this period by memory tasks ensures improved neural plasticity, which, in turn, enhances cognitive development as observed in our study results in the form of rapid response to auditory and visual stimuli.

Memory tasks like abacus involve active movements, which, as described by the neuroimaging studies done in Japan, causes higher activation of the superior occipital gyrus (SOG) and the right supplementary motor area (SMA), whereas untrained individuals used only the language areas of their brain. Abacus-trained children also showed enhanced connectivity to the inferior frontal gyrus that controls attention. Abacus training may increase the functionality of the visuospatial-attention circuit. Increased blood supply to these areas leads to neural plasticity and the formation of new synapses, improving performance.<sup>[10]</sup>

Anthropometrically, the study and control populations were matched for age, height, weight, and BMI, the differences being statistically insignificant shows that the variations seen in the cognitive function tests do not arise from age differences or excessive weight differences or malnutrition, in our study subjects [Table 1].

The reaction time test measures the participant's speed of response to an auditory and visual stimulus. It assesses the level of sensorimotor coordination and alertness to surrounding stimuli in an individual.

**Table 1: Anthropometric parameters of study and control group**

Parameter	Study group (n=35)	Control group (n=35)	P
Age (years)	10.2 $\pm$ 1.28	9.83 $\pm$ 1.15	0.206
Height (cm)	139.49 $\pm$ 11.43	137.77 $\pm$ 8.69	0.482
Weight (kg)	33.83 $\pm$ 7.92	31.09 $\pm$ 8.54	0.168
BMI (kg/m <sup>2</sup> )	17.19 $\pm$ 2.30	16.25 $\pm$ 3.51	0.188

The parameters were found to be normally distributed and were represented as means $\pm$ SD (standard deviation). cm, centimeter; kg, kilogram; m<sup>2</sup>, meter square

**Table 2: Reaction time values of study and control groups**

Parameter	Study group (n=35)	Control group (n=35)	P
Auditory reaction time (ms)	142.66 $\pm$ 21.42	152.80 $\pm$ 18.95	0.04*
Visual reaction time (ms)	144.54 $\pm$ 18.57	160.86 $\pm$ 18.95	0.001*

\*Values are statistically significant. ms, milliseconds

The auditory reaction time in the study group is significantly lesser than in the control group ( $P = 0.04$ ). Subjects untrained in the abacus took a longer time to respond to an auditory stimulus than those trained in the abacus. The visual reaction time of the study group was also much lower ( $P = 0.001$ ) showing that training improves response to both visual and auditory stimuli [Table 2, Graph 1]. This is in accordance with the results obtained by Liu and Sun on a group of 7-year-old elementary school children in China.<sup>[11]</sup>

This improved speed and accuracy to such stimuli show how fast an individual can coordinate and concentrate. Thus, abacus-trained individuals have better hand-eye coordination. The abacus involves the increased use of the superior and middle frontal gyrus, the motor region of the cerebral cortex, which improves the blood supply to this region and nourishment to the neurons, which, in turn, causes enhanced neural plasticity in the developing age, which improves the rapidity of physical responses to various stimuli [Table 2].<sup>[10]</sup>

## Summary

- 8–13-year-old abacus trained and untrained students, 35 each in study and control groups were recruited in this analytical study.
- The auditory and visual reaction time was reduced in the trained when compared with the untrained students indicating better dexterity and improved reflexes.
- The observation could be attributed to the improved synaptic connectivity due to the memory building task abacus, which involves a play way method with less stress, in the study group enabling neural plasticity, which is very important for learning skills at an early stage of life.

## Key message and conclusion

We conclude that abacus training improves the hand-eye coordination and attention span of children as measured by their reaction time.

Cognition is an aspect that affects all walks of life, be it academic, sports, routine activities, and overall basic survival. It is seen invariably that individuals with better cognitive abilities are always ahead of their counterparts. This study emphasizes the importance of memory tasks in enhancing all aspects of cognitive functions such as attention, coordination, and alertness, which, in turn, improves the confidence of the individual thus causing overall healthy development that is essential for successful survival.

Memory tasks like abacus involve a lot of fun and free will for voluntary tasks, which helps to envisage and express logical thinking in young children and promote neural plasticity to a greater extent, which improves the awareness, alertness, and speed of response. These advantages can be used to a great extent as an added tool in the management of diseases such as dyscalculia and attention deficit hyperactivity disorder.<sup>[7]</sup> Hence,

the abacus through an age-old tool, with evidence-based medicine is considered to promote better cognitive performance in a simple, less stressful environment.

Memory training tools are active, innovative, and interesting methods of teaching whose results on improved performance are as palpable as those of orthodox teaching methods.

This study gives impetus to the relevance of clinical history ascertained by the primary care physicians who are the point of the first contact with the patients. This would enable the identification of subjects with mild cognitive impairment if any and to predict their outcome over a period of time. Moreover, this improves the resources and infrastructure, screening, and treatment modalities.

## Institutional ethical approval

Institutional Ethics Committee Approval Date and No: 11.06.2018, JIP/IEC/2018/179.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

## Financial support and sponsorship

Nil.

## Conflict of interest

The authors declare that they do not have any conflict of interest.

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