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ASSESSING THE VISUOSPATIAL WORKING MEMORY OF SCHOOL CHILDREN UNDERGOING ABACUS TRAINING

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BY

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DECLARATION

I, Evangeline Efe Ansah, hereby declare that this research was carried out under the supervision of Dr. Sheriffa Mahama and Dr. Nana Yaa Nyarko. With the exception of references to other people's work which have been acknowledged, this thesis was done entirely by me. I further affirm that this work has never been submitted either in whole or part for any degree in this University or elsewhere.

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ABSTRACT

The main aim of abacus training is to enable children perform fast, accurate arithmetic using an imaginary abacus. The ability to do that accurately, comes from the development of an aspect of working memory called, the visuospatial working memory. The purpose of this study was to assess the influence abacus training has on the visuospatial working memory of school children. A quasi-experiment research with a quantitative approach was used to conduct the study. Purposive sampling technique was used to select 4 schools at New Achimota in the Greater Accra region for the study and all the children in classes 4, 5 & 6 participated in the study. Out of the 4 schools, 2 were exposed to abacus training (experimental group), while the other 2 were not exposed to abacus training (control group).

The sample size used for the study was 90 for the experimental group and 100 for the control group with 10 dropping out of the study. At the beginning of the study, 3 different cognitive test; Raven's Colored Progressive Matrices test (RCPM), Digit Memory test (DMT) and Letter Cancellation test (LCT) as well as a questionnaire on the demographic of the children was administered. After that, the experimental group were trained in abacus 2hours per week in addition to the normal school curriculum for a period of 4months, while the control group was taught the normal school curriculum only. The 3 cognitive tests; RCPM, DMT and LCT, were administered again to the children at the end of the four-month period. With the aid of SPSS version 23, the data was analyzed using bivariate correlation, independent t-test and analysis of variance (ANOVA). The results of the study showed that, gender, age and parents' socioeconomic status had no effect on the visuospatial working memory (VSWM) of school children. Also, in comparing the VSWM of the experimental and control group, there was a significant change favoring the experimental group. The findings prove that, when children learn to use their imaginary abacus for mental calculations, it trains and develops their VSWM as well.

DEDICATION

This dissertation is dedicated to my husband, Mr. Nathaniel Ofori, whose unwavering support made it possible for me to pursue my master's degree and achieve my goal of earning an MPhil.

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To God be the glory, great things He has done and great love He has shown me, beyond my understanding. I am extremely grateful to my selfless supervisors, Dr. Sheriffa Mahama and Dr. Nana Yaa Nyarko for the time and energy they devoted to supervise my work, and for their encouragement, corrections and thoughtful suggestions that saw me through this research.

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Finally, I am very thankful to my brother, Mr. Jeffery Abeiku Ansah, my parents and Mr. Obed Kwame Penu, for their support and prayers.

God bless you all.

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LIST OF ACRONYMS

AMC	Abacus Mental Calculation
ANOVA	Analysis of Variance
CGPA	Cumulative Grade Point Average
CPM	Ravens Coloured Standard Progressive Matrices
DMT	Digit Memory Test
ECBAS	Ethics Committee for Basic and Applied Sciences
GES	Ghana Education Service
GLSS	Ghana Living Standard Survey
GSS	Ghana Statistical Service
IQ	Intelligence Quotient
LCT	Letter Cancellation Test
RCPM	Ravens Coloured Progressive Matrices
SES	Socioeconomic status
SPSS	Statistical Package for the Social Sciences
SWM	Spatial Working Memory
UCMAS	Universal Concept of Mental Arithmetic Ghana Limited
VSWM	Visuospatial Working Memory
VWM	Visual Working Memory
WM	Working Memory

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Abacus is a Latin word that originates from the Greek words abax or abakon meaning table or tablet (Fernandes, 2015). The Japanese refer to it as Soroban while the Chinese call it Suanpan (Alhassan et al., 2018). An abacus is an ancient calculating device used for mental arithmetic (Shanthala, 2011). It is made up of a frame, a beam that divides the upper and lower portions, and vertical rods on which beads move up and down. The beads represent numbers while each rod represents a number place value that increases from right to left (Frank & Barner, 2012).

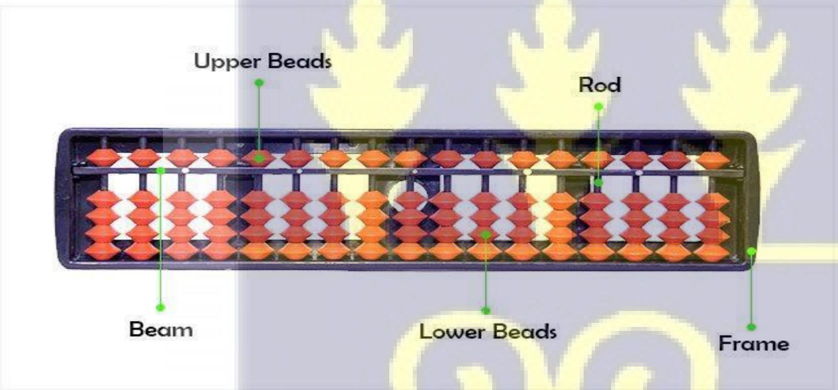

Figure 1: *Parts of an abacus (http://www.anjutr.org/)*

Traditionally the abacus is used to perform arithmetic, such as addition, subtraction, multiplication, division, and root calculations (Li et al., 2016). Apart from the general increase in calculating abilities in children exposed to abacus training, research has shown that abacus training increases visualization, concentration, memorization, and analytical ability in children. Further, patience, alertness, and observation skills are promoted among children (Vasuki, 2013). Research has found that the use of abacus by school children improves their

IQ through the development of an aspect of their working memory called visuospatial working memory (VSWM) (Wang et al., 2019).

Working memory is a cognitive system that allows us to maintain and manipulate information in the mind for short periods (Vuontela et al., 2003). This system plays a critical role in many forms of complex cognition such as learning, reasoning, problem-solving, and language comprehension. Visuospatial working memory is assumed to be responsible for processing and the short-term storage of visual and spatial information hence, it maintains spatial and visual information, thus ensuring that mental images are formed and manipulated (Beni et al., 2014). School children undergoing abacus training are trained to work on the abacus continuously for a period of time after which they can visualize the abacus and move imaginary beads in their mind when questions are read out to them. This process improves their visuospatial working memory (VSWM) as they learn to visualize and imagine whatever has been taught in school, whether presented in diagrams, maps, or essays (School of excellence, 2016). Hence, schools that adopt the abacus program (as a brain development program) integrate it into their school timetable as part of subjects taught, and children are assessed on it at the end of the term.

Certain cognitive tasks (such as the Ravens Coloured Progressive Matrices test, and Digit memory test) require subjects to engage their visuospatial working memory, thereby, generating visual images, maintaining the information in that image, while concurrently transforming and manipulating it to produce an answer. It is believed that performance in these tasks differs by gender; males perform better than females (Loring Meier & Halpern, 1999). As we grow, the brain matures which is also accompanied by faster information processing and an increase in working memory, and the ability of a person to reason. Hence an increase in age, probably leads to an improvement in the performance of working memory as well as

VSWM (Bunge et al., 2002). However, it is noteworthy, that the differences in gender and age could be made up for with training approaches such as abacus training (Loring Meier & Halpern, 1999).

Abacus training is common in the eastern countries as compared to the western countries. As such, their performance in mental arithmetic is higher as compared to their counterparts in the western world ((Elhameh et al., 2015). Abacus training is believed to significantly improve performance in mathematics (Foong, 1998), develop some cognitive abilities of children (Vasuki, 2013), and increase the IQ of children (Khaleefa et al. 2008). However, even though research studies in abacus training have been conducted in many countries, very little literature is found on its relevance in developing countries like Ghana. Hence, this study aimed at assessing if there is significant improvement in visuospatial working memory in children undergoing abacus training in selected schools in Ghana.

1.2 Statement of The Problem

Abacus is an ancient device that is used to solve arithmetic, number problems and calculations. Studies show that the abacus gives children the ability to generate, retain, retrieve, and transform well-structured visual images. Due to its touted benefits and its belief to positively influence children's IQ and their cognitive performance, abacus training is increasingly included in the curriculum in privately owned schools in Ghana. However, studies are yet to be done to empirically evaluate whether abacus training leads to significant improvement in the memory and cognitive performance of children in Ghana. It is therefore crucial to assess the touted benefits of abacus as propagated by the managers of abacus program, hence this study.

1.3 Aim of The Study

The aim of the study was to assess if there is significant improvement in the visuospatial working memory in children undergoing abacus training in selected schools in Ghana.

1.4 Objectives

The objectives of the study were to;

1. Assess the difference in demographic characteristics (gender, age) in visuospatial working memory of school children.

2. Assess the relationship between the socioeconomic status of parents and the visuospatial working memory of their children.

3. Investigate the difference between the visuospatial working memory of abacus trained children and untrained children (control group).

1.5 Hypotheses

- **H_{01}:** There is no significant difference in the visuospatial working memory of males and females

- **H_{02}:** There is no significant difference in age in the visuospatial working memory of school children.

- **H_{03}:** There is no significant difference in the visuospatial working memory of school children based on their parents' socioeconomic status.

- **H_{04}:** There is no difference between the visuospatial working memory of abacus trained and untrained school children.

Independent variables for the hypotheses were gender, age, parents' socioeconomic status, and abacus training as against the visuospatial working memory of abacus trained and untrained children.

1.6 Significance of The Study

1. The findings of this study would give understanding of the benefits of abacus training and the effect it has on the visuospatial working memory of school children.
2. It would also provide empirical evidence on the effectiveness of abacus training on VSWM performance tasks performed by children. This information would be useful especially to organizations and schools offering or considering offering abacus training as part of their curriculum.
3. The study would serve as the basis for further research into other ways of developing the visuospatial working memory and other cognitive abilities of school children
4. As Ghana Education Service (GES) is the main governing body of all basic schools in Ghana, the results of the study would serve as a source of reference for them (GES) should they consider incorporating abacus training in the curriculum of basic schools.

CHAPTER TWO

2.0 LITERATURE REVIEW

The chapter presents a review of relevant literature related to this study. It covers working memory and its related theories, visuospatial working memory, concept of abacus, abacus trainings and its effects and a summary of the reviewed literature and conceptual framework developed for the study.

2.1 Working Memory

Abacus as a brain development program simply means the abacus been used as a tool to enhance some brain cognitive capabilities (Zhang, 2019). These cognitive capabilities are brain-based skills needed to aid in executing simple tasks, to the most complex ones. One of the most relevant mental abilities for cognitive capabilities such as language processing, attentional control, academic achievement (Wang et al., 2019), problem solving, reasoning, and planning is referred to as working memory (Khalid et al., 2020). Working memory as defined by Baddeley and Andrade (2000) is the manipulation and maintenance of goal-oriented information over short periods of time. In other words, working memory ensures that, what an individual is currently thinking is held for short periods before being transferred into permanent memory or lost. The information that is held by working memory comes from outside environment or is retrieved from long term memory (Abadzi, 2006).

Working memory is relevant because before any information can register in the permanent memory it needs to go through the short-term memory or working memory. This means that the greater the capacity of the working memory the more efficient data can be used. In order to remember more, the working memory can undergo certain trainings and tricks such as the repetition of information, fast reading and calculations (Abadzi, 2006). In order to function properly, working memory makes use of areas such as the pre-frontal cortex, hippocampus, entorhinal cortex, superior parietal lobules and anterior cingulate cortex (Lima-Silva et al., 2020).

The aging process has an effect on these sections, which might lead to a decreased ability to complete working memory activities in the elderly (Lima-Silva et al., 2020). Children's working memory capacity grows as they mature. Communication in the brain is facilitated by a rapid increase of neural connections (white matter) in the prefrontal cortex. The phonological loop and the visuospatial sketchpad, two working memory components, do not interact properly in children between the ages of 4 and 5. While children's working memory begins to develop at age 6, it continues to grow throughout the elementary and middle school years and into adolescence, reaching its peak between the ages of 16 and 19. This is coherent with Vuontela et al. (2003), that VSWM in school-aged children improves with age, suggesting also that the working memory of boys mature at a faster degree than girls. Around the age of 20, working memory capacity peaks, then steadily falls (Abadzie et al., 2006). Education lengthens working memory, and it has been discovered that adults with higher education have significantly better working memory than those with few years of education (Abadzie et al., 2005). Also, high performing students tend to have short term memory with longer holding and processing ability, providing a bit more time for comprehension as compared to students with limited working memory (Tietjen et al., 2004). Baddeley's multicomponent model, Cowan's embedded processes model, and Engle's regulated attention model are three diverse working memory viewpoints that affected this study. These models are explained below.

2.1.1 Baddeley's multicomponent model

This model's theoretical foundation is the information processing theory which suggests that the human mind works like a computer that processes stimuli and generates outputs.

According to Baddeley's multicomponent model (Baddeley, 1986; Baddeley & Hitch, 1974), working memory consists of the central executive, phonological loop, and the visuospatial sketchpad which is the same as visuospatial working memory.

Specifically, the central executive, which is the core system, is in charge of drawing attention to relevant information, suppressing irrelevant information and improper behaviors, and coordinating the whole system. The phonological loop stores phonological information by retaining auditory and verbal information such as words, letters or sounds while the visuospatial working memory stores visual and spatial information.

The visuospatial working memory is further divided into two; visual subsystem which deals with objects and their features that are visible (shapes, colours and texture), and the spatial subsystem which aids with location and speed of objects in space (Weitin, 2003). Visuospatial working memory involves generating, perceiving and operating visual patterns and stimuli, and is characterized by tasks that require the manipulation and perception of visual forms (Khalid et al., 2020)

In the year 2000, Baddeley added a fourth component, the episodic buffer, to the original model. This episodic buffer is also controlled by the central executive. Its responsibility is to integrate information from different modalities and sources into one and serves as a border between the various subsystems and long term memory, to generate knowledge (Baddeley, 2000).

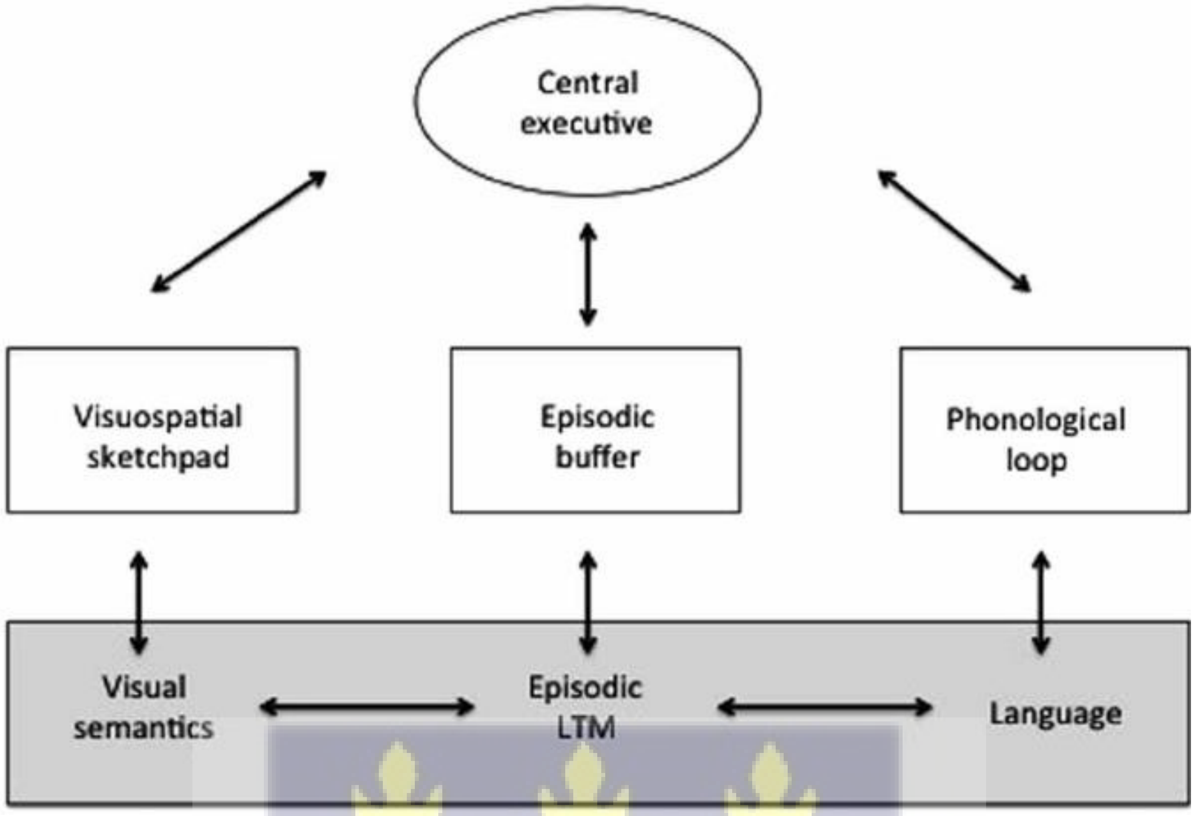

Figure 2: Baddeley's multicomponent model (Baddeley, 2000)

2.1.2 Cowan's Embedded Processes Theory

Nelson Cowan defines Working Memory as "cognitive processes that are maintained in an unusually accessible state" (Cowan, 1999). His theory focuses on the fact that, working memory is a set of embedded processes from both attention and long-term memory. He proposed a hierarchical system of memory, which suggests that short-term memory is the activated portion of long-term memory. This activation he claimed, is limited in duration. When information comes in from the environment, its processing is based on encoding, representation, maintenance and retrieval, and relies on long term memory and attention to make further processing easier. Encoding he claimed could be abstract or sensorial. Visuospatial working memory codes are divided into two; spatial orientation codes (e.g. Left, right, up, down among others) which is an abstract code and visual codes (e.g. shape, color, size, luminosity among others) which is a sensory code. When children keep practicing movement of the abacus beads up and down, from the left of the abacus to the right end, they encode in their working memory spatial orientation codes. This then helps them to visualize the different shapes of beads that create specific numbers on the abacus which encodes their visual codes, thereby activating their VSWM.

Cowan's model consists four elements; central executive (which directs attention and controls voluntary processing), long term memory (which is constantly activated and remains this way while it is needed), and activated sensory memory (a subset of long-term memory in a state of temporal activation). A small part of the activated memory is a brief sensory memory that lasts <250 ms and is available to orient the focus of attention to mainly dangerous or predisposed stimuli or information (Cowan, 1988; Cowan, 1999). Attention and long term memory is responsible for individual differences in working memory tasks.

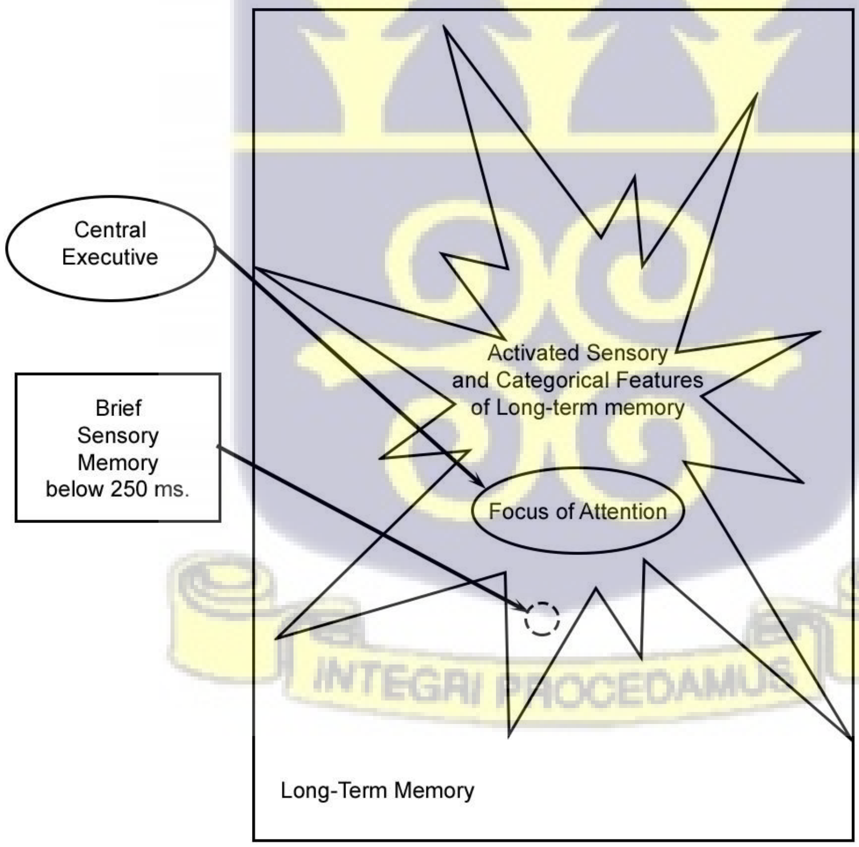

Figure 3: Cowan's Embedded Processes Theory (Cowan, 2010)

2.1.3 Engle's controlled attention model

This model is similar to Cowan's perspective of working memory being an active part of long term memory and is close to controlled attention. The Engle's controlled attention theory suggests that, working memory is not about individual differences in the magnitude of items that can be stored, but about differences in their ability to control attention, suppress interference, avoid distraction and to maintain information in an active fast retrievable state. Working on the abacus is one activity that requires a person to focus and deliberately pay attention in order to remember the movement of the beads and their position. Controlling your attention while working on the abacus helps one to avoid being distracted by beads that are not being moved during practice which interfere with recall of the answer displayed on the abacus during mental arithmetic which will aid in enhancing VSWM. A similar neural system is shared by Kane and Engle (2002), and Van Veen and Carter (2006) on working memory and attentional control.

Engle's controlled attention model is of the view that generally, individuals with high working memory are better able to maintain attentional control and remain focused unlike individuals with low working memory capacity. This is because, individuals with low working memory are not able to inhibit distraction or interference (Barrett et al., 2004; Engle, 2002; Kane et al., 2001; Unsworth et al., 2004).

2.2 Visuospatial Working Memory

Working memory is a term that refers to a cognitive mechanism that enables us to retain and alter data in our heads for brief periods of time. This system is required for a variety of sophisticated cognitive processes, including learning, thinking, problem solving, and language understanding. Working memory is hypothesized to be formed of a central executive control system that monitors two autonomous subsystems: visuospatial sketchpad or visuospatial working memory for spatial processing, and phonological loop for non-spatial, mostly linguistic information processing (Baddeley, 1992).

Visuospatial ability is a phrase that describes how the mind organizes and perceives two- and three-dimensional space, as well as how the body moves through space. It encompasses a wide range of abilities, including spatial memory, mental imagery, rotation, distance and depth perception, navigation, and visuospatial creation, among others (Bigelow & Agrawal, 2015). Visuospatial working memory (VSWM) is a component of working memory that is involved in the recall of stimuli that have perceptual, visual, and spatial interactions with one another. It can also be described as a sub-system specialized for the retention and manipulation of visuospatial information (Colucci et al., 2005). Visuospatial working memory is made up of two storage systems, which are visual working memory (VWM) and spatial working memory (SWM). Visual working memory is a limited capacity system for the active representation of the visual appearance of relevant objects such as processing information related to shape, brightness, colour and static visual layout (Luck & Vogel, 2013; Ma et al., 2014). These skills when acquired makes answering tests such as the Raven's colored progressive matrices easier since it involves identifying shapes and colours that have the same patterns and have a relationship. Object positions are actively represented in spatial working memory, which has a limited capacity (Awh & Jonides, 2001). Spatial memory encompasses information about several different components of one's environment: including geometry, relative position, distance, size, orientation, and coordinates (Bigelow & Agrawal, 2015). Spatial skills are skills very essential in performing tests such as the letter cancellation test and the digit memory test since they involve being attentive to the location, position and order of items in the test.

Visuospatial working memory is a multicomponent system, according to neuropsychological and functional imaging studies. The occipital lobe, which is thought to reflect visual pattern recognition, parietal regions, which are associated with space, and the frontal lobe, which is associated with coordination and control, are all active in this system (Smith & Jonides, 1996). Other studies have shown that visuospatial tasks engage distinct cortical regions, such as the superior parietal lobule, the parieto-occipital junction, and premotor parts of the brain, when they are performed.

Visuospatial working memory is primarily involved in the generation, manipulation, and maintenance of visual and spatial information (Gathercole & Baddeley, 1993). VSWM also plays a role in spatial orientation and in the solution of visuospatial problems and supposedly forms an interface between visual and spatial information accessed through the senses (Coluccia, 2005). Visuospatial working memory has proven to play an essential role in mathematical tasks, text reading and comprehension (Baddeley et al., 1984), in problem solving (Gilhooly et al., 1993; Saariluoma, 1991) and in learning a new language (Baddeley, Papagno & Vallar, 1988; Gathercole & Baddeley, 1989).

Even though VSWM is mainly talked of as a short term memory, it can also be maintained over a period of time. Research conducted by Borella et al. (2014) on the benefits of VSWM indicated that there were gains after VSWM tasks were performed which was maintained even after a period of 8months.

An important part of everyday cognition is based on visual and spatial working memory. Visuospatial WM was linked to academic achievement on the national curriculum for children by Gathercole, Brown, and Pickering (2003). As a result, there appears to be a high correlation between early primary school grades and visuospatial working memory.

2.3 Concept of Abacus

2.3.1 Abacus – Origin and Evolution

Counting, number, and arithmetic have developed together with the advancement of human cognition throughout history (Kinzler & Spelke, 2007). The dawn of human progress may be traced back to the commencement of mathematics and mathematical education (Maričić & Lazić, 2020). The beginnings of mathematics and mathematics education can be traced back to the earliest stage of human development (Maričić & Špijunović, 2016), where knowledge of mathematics was formed without any conscious effort or planning, while engaged in everyday activities, and then handed down from older to younger generations (Carrillo et al., 2013). Mathematics in this era was initially developed as a result of practical considerations like calculating, tallying, and measuring and the start of writing was based on the belief that basic mathematical knowledge was recorded (Hong & Chai, 2017). When ancient civilizations built their settlements, they left behind "monuments" of mathematics that show how advanced mathematics was at the period. Practical arithmetic, or the steady growth of the process of calculating and its applications, is the primary focus of the early stages of mathematical development. The abacus is unquestionably the most well-known of the mathematical "tools" that have been devised for this purpose. The abacus is unquestionably the most well-known equipment in the field of calculus (Maričić & Lazić, 2020).

In ancient Mesopotamia, Egypt, ancient Greece, and Roman times, the abacus was the first known manual calculating instrument (from the Greek word abak, which means "writing board"). People in Russia, China, and Japan continue to utilize the sophisticated abacus for everyday calculations, despite its widespread availability.

Abacus can be described as an effective traditional calculator which dates back to Mesopotamia, ancient Egypt, the middle east, ancient Rome, ancient China and ancient south and central America (Kim, 2016). Abacus is a Latin word which means sand tray. It is called soroban in Japan and suanpan in Chinese (Alhassan et al., 2018). The abacus has gone through changes from its earliest form as a sand table with pebbles being used as counters into its modern design with beads moving on rods (Kim, 2016). Considerable effort was put into learning the various methods that were employed in the past and how the problems that were posed were solved (Dejić, 2020). In recent times the soroban is the most widely used abacus in the world (Srinivasan et al., 2018). The soroban is designed to have two sections, the upper part called “heaven beads” which has a value of five beads each and a lower part called “earth beads” which has a value of one bead each (Alhassan et al., 2018).

In practice, the Abacus is made to have numerical quantities and arithmetic operations over those quantities through the positioning of beads in column (Srinivasan et al., 2018). The zero-position of all abaci is when the upper beads are moved up and the lower beads are moved down. The beads represent a number only if one or more beads are moved toward the beam. In principle, the rods (starting from the right side and continuing to the left side) represent the “ones”, the “tens”, the “hundreds” and so on. The user has to decide which rod the “ones” should be on. If there are numbers with values less than one, it is convenient to put the column with “ones” just in the middle of the abacus. That way, numbers can grow or decrease on both sides. But if there are only numbers with values from one and higher, the user can start just at the right side of the frame, developing the calculation to the left side (Kim, 2016). Fingering technique is important when using the abacus. This involves the use of the hands to move the beads on the abacus in a prescribed way: the thumb is used to add beads (move them upward) in the lower part of the abacus, and the forefinger to subtract beads (move them down). In the upper part of the abacus, the forefinger is used to both add and subtract beads. To add one, the top bead of the lower section is slid toward the crossbar (moving it upward). To add five, the bead in the top section is moved toward the crossbar, downward.

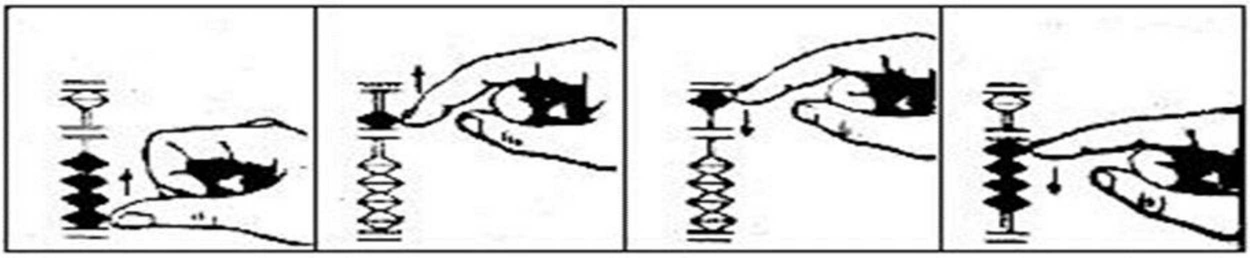

Figure 4: A sample of the fingering technique (Fernandes, 2014)

Unlike adding with pen and paper, where calculation is typically started on the right side and progresses to the left, in abacus usage the learner starts on the left and moves to the right. According to Stigler (1984), he chose to work with the *soroban*, the Japanese abacus, because it best represents our number system. In particular, one can only write the numbers 0 – 9 in any particular column on the *soroban*. This is the same as in the base ten number system.

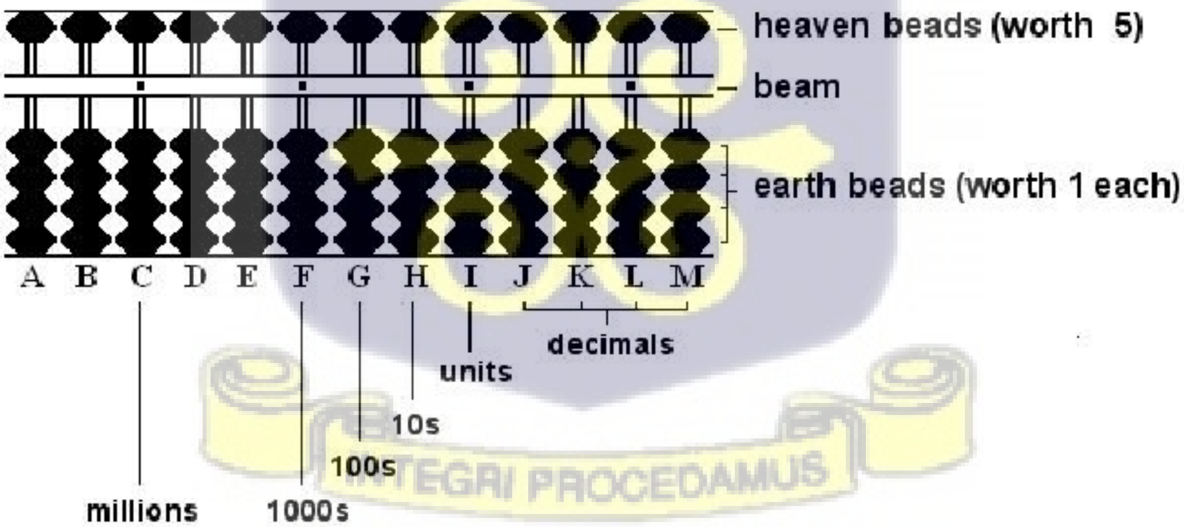

Figure 5: The Soroban Abacus (Samoly, 2012, p.61)

The abacus can be used to perform basic operations such as addition, subtraction, multiplication and division as well as extraction of square and cube roots (Sarvari et al., 2015). It has been identified to be useful in developing the abilities of young brains (Sarvari et al., 2015). Accuracy, decimal understanding, and digit correlation are all learned through the use of abacus calculating procedures (Kim, 2016). The abacus was initially developed as a way to indicate numbers and to compute them quickly and accurately, but currently it is being used as an educational tool. The abacus is used in schools to teach mathematical concepts and used as computational tool for finding answers to problems (Kim, 2016). In respect of this, pupils can benefit from abacus training by being able to solve arithmetical problems more quickly. The pupils may later complete the calculations without the need of an abacus, by just seeing an abacus in their thoughts, which will save them time and effort (Srinivasan et al., 2018). The study of the abacus also assists them in developing fresh and inventive techniques of acquiring mathematics, rather than relying solely on the orthodox methods of learning computations that are taught by the regular educational system (Barner et al., 2017). The ability to bridge the gap between tangible and mathematical symbolism has also been demonstrated to assist children in understanding the link between numbers and abstract notions (Tang, 1993).

Kim (2016), in his research also discovered that abacus training might help young students to enhance their concentration and improve brain activities such as memorization. A number of studies have established the fact that abacus mental calculation experts are supported by gestural and visuospatial representations (Sarvari et al., 2015).

2.3.2 Abacus training

It has been observed that individuals who have been trained using the abacus have the ability to decode the number represented by the abacus in a rapid manner, although this requires attending to the precise locations of a large number of abacus beads (Du et al., 2014; Frank & Barner, 2012). Some abacus experts do not need the physical abacus in order to perform calculations at high speed instead they are able to perform the calculations mentally. The technique involved in doing this is referred to as the abacus - based mental calculation.

Abacus Based Mental calculation (AMC) is an advanced technique learned by abacus users and it involves the trained user being able to visualize the physical abacus and perform mental calculations at very high speed and accuracy. The training involves an individual learning to calculate with a physical abacus. When children use the abacus, they see the beads move, hear the click of beads, and feel the beads as they position them which provides them good visual imaging, improves concentration and makes their sensory organs alert (Cusick, 2010). Upon reaching a certain level of competence the individual stops using the physical abacus and starts visualizing the abacus in their mind. At this point the person is allowed to move their fingers so as to aid their manipulating of the imaginary beads. After sometime the individual is able to perform calculations at high speed by simply visualizing the abacus in the brain. As part of the mental abacus training participants are explicitly instructed at the beginning to create a mental image of the physical abacus and to manipulate the imagined beads to perform mental calculations (Srinivasan et al., 2018).

Experts in abacus-based mental computation (AMC) can quickly and accurately compute figures with more than ten digits (Stigler, 1984). They also have longer digit memory spans and are more numerically efficient (Hu et al., 2011; Huang et al., 2015; Li et al., 2013; Wang et al., 2013). As a result, it's been argued that AMC specialists' abilities are equivalent to those of an electronic calculator, and that they can execute calculations while conversing (Hatano et al., 1977).

Psychological (Frank & Barner, 2012; Hatano, et al., 1977) and neuroimaging (Chen et al., 2006; Hanakawa et al., 2003; Tanaka et al., 2002) studies have shown that the brain activation patterns of AMC experts are different from those of non-experts and that calculation skills were enhanced significantly after abacus training compared with average control subjects. Also studies consistently show that children skilled in mental abacus seem to have better arithmetic ability than those who did not receive mental abacus training (Barner et al., 2016; Donlan & Wu, 2017; Huang et al., 2015; Ku et al., 2012; Na et al., 2015; Wang et al., 2015). Abacus abilities have a direct influence on mental computing skills, spatial ability, and general mathematics accomplishment, according to a number of studies done in Asia including the usage of the abacus and abacus-like setups in the classroom (Kim, 2016). In his research, Stigler (1984) also indicated that his results show that abacus training has quantitative and qualitative effects on the mental calculations of children. Thus, it can be said that abacus mental training is a useful and necessary tool for the development of the mental abilities of a person especially children such as stimulating mental development, encouraging problem solving, enhancing numerical abilities and boosting fluid intelligence. These mental abilities are discussed below.

2.3.2.1 Stimulating mental development

The abacus is a tool to help learners develop and strengthen their skills. The benefits one may gain from using abacus training include development of numerical representations for youngsters. Using an abacus, students may visualize mathematical concepts while bridging the gap between mathematical and symbolic representations (Metallo, 1988). Number recognition and abstract notions are associated with each other, according to research (Tang, 1993).

Mental growth is greatly influenced by the use of mathematics in school, as all tasks are reduced to mental processes. A major part of learning how to conduct mental tasks, such as abstracting, comes from the foundation on which the learning takes place. Moving activities from the level of practical-perceptual thinking to the level of conceptual-logical thinking is a requirement for all activities. Because early in the learning process, the abacus lays a firm visual and manipulative foundation, it has been widely theorized to foster cognitive growth in children. Various studies have demonstrated that abacus may enhance both memory and calculating skills consistently (Bhaskaran et al., 2006; Cui et al., 2020) thereby increasing our mental computations by using the abacus to sharpen our memory (Sarvari et al., 2015). Supporting the same idea, Chen et al. (2006) reiterates that instruction and practice on the abacus causes changes in the brain.

The abacus is thought of as a tool that aids in the visualizing process, which in turn improves brain growth. There is a high correlation between the speed of communication between the hands and the brain, with the result that the total brain growth occurs quickly and smoothly (Bhaskaran et al., 2006). Numerical memory and spatial arrangement memory are both improved by abacus learning (Roy et al., 2020), thus, abacus use may contribute to improved cognitive abilities because of mental calculation, which motivates mental engagement. Visualization is essential in computation, which happens on the mental level. Using abacus helps the learner enhance vision, focus, memory, and analytical abilities, as well as patience (Barner et al., 2016).

2.3.2.2 Encouraging problem solving

Mathematics education encourages students to use problem-solving abilities. To begin solving the problem, we must first have a thorough knowledge of arithmetic at a deep conceptual level. While the importance of mental arithmetic is acknowledged, it is nevertheless vital in teaching and learning mathematics, and more specifically in the development of problem-solving abilities (Zeljić et al., 2017).

Problem solving is based on the skill of mental calculation (Stigler, 1984). In order to deal with every day real-life circumstances, being able to count mentally is a vital talent, and because of this, people should be able to do written calculation (Frith & Happé, 1999). Combination of problem solving and mental processing is needed to finish a task. A pupil is solving the problem while he or she is engaged in mental calculation. Even if we've already noted the critical role of abacus in mental computing, the influence of this discovery can be extended to the solving of problems and the development of human capacities in this field. Computation is supported by visualizing the problem and also by selecting from a wide range of computing techniques (Gallopoulos et al., 1994). Visualization of the problem, transfer to the mental plane, and decision-making in the mental realm are all required for problem solving to be successful (Liu & Stasko, 2010).

Abacus has the potential to answer mathematical problems while aiding in coordinated visual, aural, and sensory inputs (Tiwari et al., 2017). According to Rubenstein (2001), abacus is critical in problem solving since it affords a great deal of flexibility in choosing an approach to resolution. The research concludes that "students who learn abacus-mental arithmetic have greater mathematical problem-solving ability than pupils who do not learn abacus-mental arithmetic" (Lean & Lan, 2005, p.5). Some studies report that, cultivating an interest in arithmetic by using an abacus, is a significant step in the development of mathematical motivation and positive attitudes (Freeman, 2014; Lee et al., 2007; Shwalb et al., 2004).

2.3.2.3 Numerical Abilities and Abacus

Historically, effective numeric processing has been regarded as a key component in developing mathematics such as arithmetic abilities (Bartelet et al., 2014; Holloway & Ansari, 2009). Individuals with learning difficulties, especially in the field of mathematics, commonly have deficits in quantity sense (a quantitative issue). Though some users show greater math skills when using abacus-based mental calculation (AMC), it is possible this benefit is complemented with enhanced capacity to see numbers in their fundamental numerical magnitude (Wang, 2020).

Previous research revealed that young children who underwent 2 years of AMC training performed better in a numerical magnitude comparison test than their classmates who did not get AMC training, but did not show a significant difference in a physical size comparison challenge (Wang, 2020). It appears that numerical magnitude processing could be aided by AMC training, but it does not appear to improve the capability for distinguishing between different sized objects. In addition, Wang et al. (2013) created a numerical stroop paradigm and discovered that children with 3 years of AMC training have a better ability to filter out information that is relevant to their size than children who were not trained in AMC. Children trained to identify math numbers using AMC exhibited higher ability to identify math numbers both on purpose and without conscious thought (Wang et al., 2013).

Many prior research has found that those who utilize AMC may have a more abstract and flexible grasp of numerical magnitudes (Wang et al., 2019). Numerical magnitude from number systems may be accessed both purposefully and automatically via the AMC, allowing the system's users to increase their numerical magnitude knowledge.

According to Cui et al. (2020), trained AMC youngsters showed superior numeric processing and arithmetic abilities as compared to the control group. While correction for other cognitive abilities helped to limit the variance, the disparities in performance across the group could not be explained by differences in other cognitive abilities (Cui et al., 2020). Numerical magnitude processing influenced individual arithmetic achievement, but not group achievement. The study found that, through fundamental numerical magnitude processing efficiency, AMC training may improve numerical magnitude processing.

2.3.2.4 Fluid intelligence and Abacus

A broad range of cognitive activities is attributed to fluid intelligence, which refers to a person's capacity to reason and solve issues without relying on past knowledge and abilities (Gray & Thompson, 2004; Khaleefa et al., 2008). Considering that we know that both working memory and mathematics are linked to fluid intelligence (Primi et al., 2010; Unsworth & Engle, 2005), and since these cognitive skills are associated with each other, one question to consider is if AMC training might boost fluid intelligence.

An earlier research done by Khaleefa et al. (2008) assessed the effectiveness of an AMC training program for 3185 children between the ages of 7 and 11. A 34-week period of AMC instruction was provided to the AMC group, while the control group got no training. In the AMC group, the Raven intelligence increased considerably after training, while in the control group, it only increased little. Some have said that Raven's Progressive Matrices is really a design-oriented problem solving test that uses various mathematical rules, such as addition, subtraction, and geometric progression, in order to give the correct answers (Carpenter et al., 1990). The authors then postulated that those who had had increased mathematical abilities after training with AMC may show improvements on the Progressive Matrices exam.

In addition, the control group in this study did not incorporate other cognitive activities. While passive control group test-retest bias might negate the observed impact, the fact that it is observed has the possibility of being a placebo effect (Shipstead et al., 2012). A recently published study by Wang et al. (2019) found that a sample of 144 elementary school pupils has had 5 years of longitudinal follow-up. The participants were separated into two groups, one group of participants who got AMC training from 1st to 6th grade, and the other group of participants who received additional conventional math instruction in the same quantities. While trained by AMC, children had higher calculation abilities than those in the control group, no significant difference was observed on Raven's test results. Based on these findings, it appears that AMC training does not help fluid intelligence beyond a placebo effect.

Although majority of research demonstrate that cognitive training may increase performance in a range of cognitive tasks, it has been difficult to reproduce this beneficial impact in domains outside of the trained domain. Redick et al. (2013), including the AMC findings in the research of Wang et al. (2019), suggest that very minimal cognitive transfer may occur when distant transmission is involved. Here, the inclusion of AMC training in cognitive training is a new approach to training and may have benefits only in jobs closely connected to the learned jobs. Additional research is necessary to resolve distant transfer because only a Raven test was employed in previous AMC research on the subject (Khaleefa et al., 2008; Wang et al., 2019).

2.3.3 Abacus Based Mental Calculation and Visuospatial Working Memory

Studies have shown that abacus training alters the brain's structural components, including the white matter tracts that connect visual and motor regions, as well as the activity of the brain's neurons (Dong et al., 2016; Hu et al., 2011; Li et al., 2013; Wang, et al., 2013). These changes in the brain's cortical structure are considered to contribute to better computing resources, including more automatic arithmetic processing and enhanced verbal and visual working memory (Dong et al., 2016; Wang et al., 2013; Yao et al., 2015). This is in line with previous research that found brain activation in the visuospatial, visuomotor, and visual-related brain regions, including the superior occipital complex and fusiform gyri, when AMC-trained people do arithmetic tasks (Chen et al., 2006; Li et al., 2013a). The occipital complex is in charge of object recognition, including functional features and our perception of such items, whereas the fusiform gyri is in charge of higher visual processing, such as object identification and differentiation. The fusiform gyrus is involved in memory, multisensory integration, and perception, in addition to high-level visual processing.

Previous research has revealed that persons who have received AMC training are more likely to utilize visuospatial methods to process numerical information rather than the verbal techniques that are employed by the majority of the population (Frank & Barner, 2012; Hatano & Osawa, 1983; Hatta & Miyazaki, 1989). AMC is based on a visuospatial strategy that takes use of the storing and manipulation processes of visuospatial working memory, according to research conducted by Tanaka et al. (2002), Hanakawa et al. (2003) and Chen et al. (2006). In relation to the above (Barner et al., 2016) discovered that individual differences in visuospatial working memory before training have been found to mediate gains of AMC learning.

Using data from 49 papers, Karbach and Verhaeghen (2014) conducted a meta-analysis to determine the benefits of abacus training in both young adults and elderly individuals. Researchers demonstrated that treatments focused on abacus training had favorable effects on the group that received training when compared to the control group in terms of both target tasks and proximal transfer task performance. The experimental group outperformed both the control and the active control groups in terms of overall performance and accuracy. For distal transfer tests, improvements were shown for both groups in fluid intelligence, episodic memory, attention, inhibitory control, and processing speed. Training effects were less pronounced in processing speed than they were in the rest of the tests. Another meta-analysis, this one done by Schwaighofer et al. (2015), included 47 publications in total. Researchers found that age, the number of training days per week, the interval between sessions, the modality (group or individual), and whether or not feedback was provided did not have any influence on the efficacy of the training.

The number of sessions for abacus training was found to have impact on visuospatial short-term memory, and greater number sessions were associated with better abacus performance by participants. Session duration was found to play significant role in the performance of participants in various tests. As observed by Lima-Silva (2020), in long-term cognitive training sessions carried out in schools such as the Instituto Supera de Educacao, which use the abacus as the primary stimulus of cognitive training, participants performed increasingly complex calculations until they reached their maximum level and performance. According to Li et al. (2013), abacus training in children promotes the development of structural and functional changes in the brain, as well as white matter volume, the parameter of white matter diffusion, and activation patterns when performing cognitive tasks. According to Wang et al. (2013) and Na et al. (2015), the training of children in abacus has demonstrated evidence of benefits in learning performance, in the orientation ability of visuospatial attention, in attention and comprehensive arithmetic abilities, as well as in response inhibition via neuroanatomical changes in the areas governing these functions, among other outcomes.

Previous research has revealed that, whereas the mainstream arithmetic operation recruits brain regions associated with phonological working memory and other language-related areas (Dehaene & colleagues, 1999), AMC engages brain networks that are primarily interlaced with the primary neural substrate of visual spatial working memory (Dehaene et al., 1999; Chen et al., 2006; Hanakawa et al., 2003; Ku et al., 2012). As previously mentioned, preceding neuroimaging studies show that long-term AMC training has a positive implication on both white matter integrity (Hu et al., 2011) and functional connectivity (Li et al., 2013, Wang et al., 2017; Xie et al., 2018) in brain regions relating to visuospatial processing and visual spatial working memory (VSWM).

Additionally, some research indicate that AMC practitioners' extraordinary talents are due to the format of their calculations, which are assumed to be supported by gestural and visuospatial representations. This is because both the abacus's form and the computational capabilities of AMC users are congruent with established limits of visual working memory. To demonstrate, the Soroban abacus depicts number by chunking beads into tiny groups of four or five, which conforms to the visual attention literature's anticipated capacity limitations (Alvarez & Cavanagh, 2004; Atkinson et al., 1976; Luck & Vogel, 1997; Todd & Marois, 2004). These facts suggest that AMC enhances learners' visuospatial abilities by transforming a serial linguistic process into a potentially less constrained visual workspace and thus connecting abstract symbolic mathematics to concrete representations of objects and sets – a strategy that is frequently used in math education outside of mental arithmetic in the form of simple manipulative systems (Ball, 1992; Hatano et al., 1987; Uttal et al., 1997).

2.3.4 Effect of Age and Gender on Abacus Training

Researchers over the years have acknowledged the effect of external factors on academic achievement in subjects like mathematics. Some of the external factors that influence academic performance in mathematics and other subjects include socio-economic factors (Muraina & Ajayi, 2011), learning disabilities (Shupe & Yager, 2011), interest of students (Udegbe, 2009), teaching methods (Eniayeju, 2010), attitudes (Acceladjo, 2001), school entry modalities (Cameson & Wilson, 2011; Olayemi, 2009), predictor variables like age and gender (Abubakar & Oguguo, 2011). Now it has been established by a number of studies that the mathematical capabilities of students who have received mental abacus training is higher than those who have not (Amaiwa & Hatano, 1989; Barner et al., 2016; Chen et al., 2006; Donlan & Wu, 2017; Hanakawa, et al., 2003; Huang et al., 2015; Ku, et al., 2012; Na, et al., 2015; Shen, 1999; Stigler, 1984; Wang et al., 2015; Wu et al., 2009). According to Anagbogu (2002) there is a generally accepted belief that boys are better than girls in the area of cognition and logical reasoning and even in academic performance. Not a lot of studies have been done on the impact of age and gender on the academic achievement of students particularly mathematics, when students are using Abacus. Some of these studies showed that age and gender have effects on the academic performance whiles others stated otherwise.

Using factor analysis of variance, multivariate factor analysis of variance, and t-student methods, Mokhberian and Abedini (2019) investigated the effect of mathematical mental calculations using an abacus on the learners' cognitive and psychological-emotional characteristics (intelligent and creative children Institute), and found that there was a statistically significant difference between the groups of mental calculations training and formal training in different subjects.

In addition, Jadhav and Gathoo (2018) conducted research on the impact of Abacus training on children with hearing loss' numerical skills (which includes counting and mathematical operations). The study's findings revealed that the experimental group, who were taught using an abacus, had a greater level of numerical skill than the control group, who were taught using the traditional approach. Gender appears to have an impact on the average numerical ability of pupils with hearing loss. While girls and boys performed equally well on simple tasks like counting, boys outperformed girls in mathematical operations and general numerical competence. Omenda (2018) used a descriptive survey design that was framed from Vygotsky's constructivism theoretical perspective in his study of the Effective Use of Abacus in the Teaching and Learning of Mathematics among Teachers in Public Primary Schools in Kasipul Division Rachuonyo South Sub County, Kenya. The research looked at 170 public primary schools with 1,069 math instructors, 568 of whom were male and 501 of whom were female. The study found that using an abacus enhances math skills in primary school students in Kasipul Division. Teachers had a favourable view about Abacus, according to the study's findings. The abacus is a useful and effective tool for developing new abilities in mathematics teaching and learning. Age differences had no influence on the efficacy of using an abacus to teach mathematics; however, there was a gender difference in the effectiveness of using an abacus to teach mathematics, with male teachers being more effective than female teachers. Tweed (2013), an American researcher, investigated technological implementations on teaching and learning mathematics with an abacus based on gender and found that age, years of experience, professional development quality, and classroom efficacy did not play a significant role, but resource use did. In addition, (lima-silva et al, 2020) discovered that the use of an abacus showed benefits for cognitive functioning in individuals of various ages, including older adults with cognitive impairment, in their review of literature on the benefits of cognitive training using an abacus for different age groups.

Voyer, et al. (2017) were of the opinion that, males have better visual spatial working memory as compared to females when they conducted research on the sex differences in visual-spatial working memory. Fennema and Lenono (1990) conducted a study of age patterns and discovered that male and female pupils achieve differently in mathematics. According to them, a difference exists, although a slight one, with female students achieving less and male students achieving more. Ogunboyede (2001), Agboola (2006), Owolabi and Etuk-Irien (2009), and Zember and Blume (2011) all indicated gender differences favoring men, whereas Ali (2013) reported that age was one of several factors that substantially influenced graduate students' academic performance.

Using the cumulative grade point average of students as the dependent variable in their study, Abubakar and Adegboyega (2012) explored the impacts of age and gender on academic performance in college mathematics. While the dependent variable (CGPA) showed a significant relationship with the independent variables (age and gender), the gender of students did not have a significant relationship with their academic achievement (Abubakar & Ogugua, 2011).

2.4 Summary of reviewed literature and conceptual framework

2.4.1 Conceptual framework

Literature pertaining to working memory examined as well as its related theoretical models. "Baddeley's multicomponent model", "Cowan's embedded processes theory", and "Engle's controlled attention model" explained working memory, how its related to visuospatial working memory and abacus training. These theories collectively suggest that, when you practice on the abacus, the brain encodes spatial orientation and visual codes, and stores it as visual and spatial information. Hence when children practice on the abacus, the brain captures the movement and position of the beads which is then represented in the memory as visuospatial working memory and activated when one needs to perform mental arithmetic.

In accordance with the literature and theories reviewed on how abacus training enhances the visuospatial working memory of school children, the following framework was proposed (Figure 6).

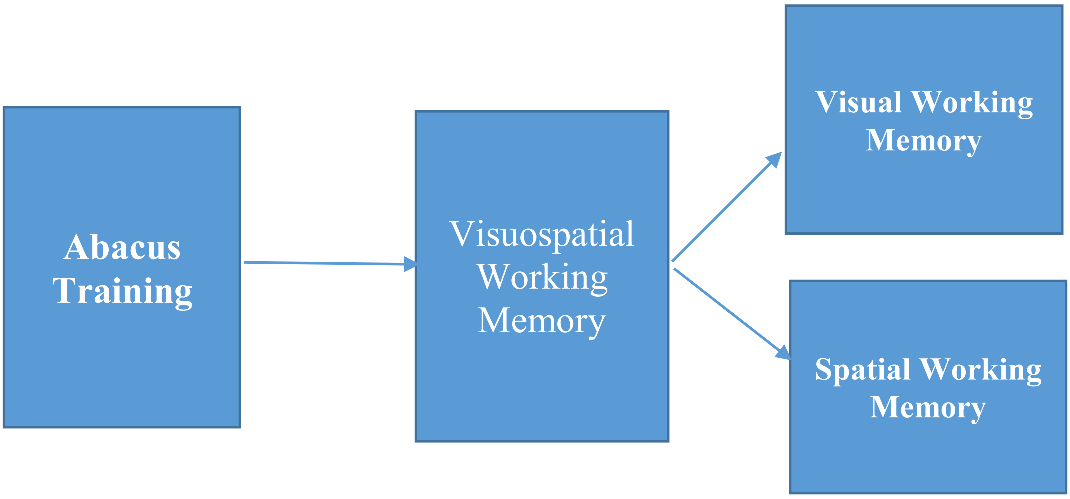

Figure 6: Conceptual framework of the study (Author's construct, 2021)

2.4.2 Summary of reviewed literature

From the literature reviewed, abacus training has been accepted in most part of the world as a calculating device that suggestively aids in mental arithmetic and employs visuospatial working memory in its representations and calculations.

It can also be noted that abacus training is used more in the eastern and western part of the world and less in Africa. Very little literature can be found on its relevance in Sub-Saharan Africa which includes Ghana. Considering that abacus training is believed to improve visuospatial working memory among other benefits such as stimulating mental development, encouraging problem solving, enhancing numerical abilities and boosting fluid intelligence, this study therefore finds it imperative to assess if there is significant improvement in visuospatial working memory in children undergoing abacus training in selected schools in Ghana.

CHAPTER THREE

3.0 METHODOLOGY

This chapter describes and explains the procedures that were followed in order to gather and evaluate the data. The design that was adopted, the location, the population that was targeted, the sample size, method used in sampling respondents, as well as the data collecting instrument used in collecting data. It also includes information on how to conduct the pilot test was done as well as data analysis and presentation tactics.

3.1 Study Design

This study used a quantitative method and an experimental research design (quasi experimental design). A quasi-experiment, according to Plano et al. (2015), is a type of research design where the researcher tests an activity on persons who have not been exposed to the intervention before. The investigator distributes existing teams to the various circumstances rather than assigning persons at randomly to the various situations. It reflects in this study as children who participated in this study were not randomly assigned to the two groups because it would disrupt classroom learning. Instead, the researcher made the assignment at the classroom level by selecting schools that were conducting Abacus classes in addition to the GES curriculum as the experimental group. The control (non-equivalent) group were selected from other schools (see Table 3) which run only the GES curriculum.

The researcher used this design to study the effect of an intervention (abacus training), on school children. The study tested whether the independent treatment variable (abacus training), caused an effect in an outcome variable for a specific group (school children) (Plano et al., 2015).

3.2 Study Location

The study location was New Achimota, a suburb of Achimota Township in the Greater Accra region. It was formally called Achimota village until recent development of the area necessitated its renaming. It is located at northwest of Akweteyman in Accra Metropolitan District of Greater Accra Region. Like most communities in Ghana New Achimota has a mixture of Government and private basic schools. The research was focused on schools in New Achimota because enquiries from a Universal concept of mental arithmetic Ghana limited (UCMAS) revealed that the community has a high concentration of schools offering abacus training to its pupils.

The study was conducted in 4 selected privately owned basic schools; 2 schools providing abacus training and 2 not on the abacus training.

3.3 Target Population

The population that has been targeted for the study were children in primary 4 to primary 6, undergoing abacus training in 2 schools and their mates in 2 different schools who were not on the abacus training. The schools that were chosen shared similar characteristics in terms of size, facilities, the academic qualification of teachers, class size, teaching period and location. Specifically, all the schools have classes starting from nursery to Junior High School. For all four schools, teaching begins at 8:00 am and ends at 2:00pm with two breaks of 15 minutes in between. The schools had facilities like library, play fields and canteen.

The schools were sampled because they were capable of providing the student numbers required and because the leadership of the school was willing to give us access to students. All four schools used GES academic curriculum and their students were subjected to similar tests approved by GES for each class level.

The category and age of students was decided on the basis that the two sampled schools, on abacus training, started introducing their students to abacus training at class four to six with students in that class aged between eight and twelve years.

3.4 Sample size and Sampling Procedure

As defined by Sarantakos (2005), a sample is a carefully selected part of a populace for a specific study that has been carefully chosen by the researcher. This is a critical, although difficult, phase in the process of designing an empirical research study.

The sample size for the study was determined by the use of Yamane's formula for a known population $n = \frac{N}{1+N\,(e)^2}$ cited by Israel (2003); "where 'n' and 'N' are the sample and population sizes respectively". "The letter 'e' is the level of precision". In the present study, the total number of school children in consideration, 'N' was 420 and 'e' is 0.05. Therefore, the sample size,

$$n = \frac{N}{1+N\,(e)^2} = n = \frac{420}{1+420\,(0.05)^2} = 204.88 = 205$$

Following that, the researcher picked a sample size of two hundred (200) youngsters for the investigation. The findings of Barner et al. (2016), who conducted a three-year randomized controlled trial with 204 elementary school students to investigate the nature of mental abacus expertise and whether it can be acquired by large groups of children in a standard classroom setting, are in agreement with this. The sample size comprised One hundred (100) children who were not exposed to abacus training (control group) and one hundred (100) children who were exposed to abacus training (experimental group). However, ten (10) children from the experimental group dropped out during the four-month period of the study. Four of the ten who dropped out of the study left the school in the middle of the term while the remaining six were withdrawn by their parents, to avoid the extra fees abacus training comes with. This brought the final sample size to 190 (100 for control and 90 for experimental group).

Purposive sampling was employed in the selection of the schools and youngsters. Sampling of respondents was done on purpose (purposive sampling). This is a sort of non-probability where respondents are selected from the general population to participate in surveys based on their own personal preferences (Sarantakos, 2005). This sampling appaorch allows the researcher to select participants based on a set of criteria that will allow for relevant data to be collected from those participants (Plano et al., 2015). Since Abacus training in the schools start at the upper primary level all children in class 4, 5 and 6 within the schools were used for the study

Inclusion criteria used for the experimental group

1. Children in the target group classes, primary 4, 5, and 6.
2. Children who partook in the abacus training regularly for a period of 4 months, because it takes three to four months to complete the basics as confirmed by Vasuki (2013)
3. Children whose parents gave and signed the consent to satisfy ethical requirements by the ethics committee.
4. Children who gave their assent to partake in the study,

Exclusion criteria for the experimental group

1. Children who dropped out of the abacus program in the course of the training.
2. Children who joined the abacus program in the middle of the study period, because the student may not have fully grasped all the basic level skill

Inclusion criteria for the control group

1. Children in the target group classes, primary 4, 5, and 6
2. Children who did not partake in the abacus training.
3. Children whose parents gave and signed the consent to satisfy ethical requirements by the ethics committee.
4. Children who gave their assent to partake in the study.

Exclusion criteria for the control group

1. Children who joined the class in the middle of the term because such students would not have fulfilled the four months' requirement. It is also important to establish equality between the two groups.
2. Children who dropped out of school during the study.

3.5 Data Collection

3.5.1 Procedure for data collection

Ethical clearance was obtained. Letters of introduction were sent to the various schools that were eligible to partake in the study. The researcher then selected 4 schools purposively; school A and school B which studied only the GES curriculum for basic schools and school C and D, which studied the GES curriculum and were starting abacus training that particular term. An inception meeting between the researcher and school authorities was held to explain the research. The school authorities agreed to a four-month period for the study, at the end of which the children would have completed the first level of abacus training. Consent forms were sent to the parents of target children for agreement while the accent of children whose parents had agreed was obtained. The tests were administered to the children after school. On the set dates where the children were engaged to the questionnaires were to be administered, the children were again informed on aims and objectives of the study for them to determine whether or not to continue as participants.

Since all target children in the various schools were used for the study, tests were administered in their individual classrooms. At the pretest data collection, with the help of research assistants and the classroom teachers, the children were provided with sanitizers as a precaution against covid-19 before they were provided with the various tests to answer. The researcher used the test question in raven's colored progressive matrices (RCPM) to explain the test to the children and ensured they understood it before they began answering them with pencils. Letter cancellation test's (LCT) instructions was also thoroughly explained to the children after which children independently answered them with pencils. Digit memory test (DMT) is a verbal test and therefore more involving, hence, it required the assistance of research assistants to aid in administering it to the children. Children were made to repeat numbers in a particular order after it had been called out for them. Administering of tests were done within a time space of approximately 30 minutes.

Both the experimental and control groups were taught using the identical elementary GES school curriculum once the first set of tests were completed. Children at the two (2) schools with abacus instruction got two hours of abacus training each week for four months by specially qualified abacus instructors, in addition to the regular GES school curriculum. Abacus training lesson time was included in the regular school timetable, an hour a day on two different days. At the end of the four-month period, the children in the experimental group had completed the first level of abacus training (Vasuki, 2013). Therefore, both the experimental and control groups were provided with the same sets of tests with the same procedure as the pretest. Excluded from the study were ten (10) children due to withdrawal from the abacus training.

3.5.2 Instrument for Data Collection

A questionnaire that was developed in a structured format containing the three (3) memory and cognitive function tests; Raven's Colored Standard Progressive Matrices (CPM), Digit Memory Test, and Letter Cancellation tests as well as other questions on demographic characteristics were used. The questionnaire had four sections.

3.5.2.1 Demographics

Information on the demographics was obtained to help describe and understand the sample better. Data collected on demographics included information on child's age, class, gender, school, whether they are on the program and the educational level and class of occupation of their parents.

The means of both the educational level and occupational class of parents were computed to form the socioeconomic status (SES) of parents. The SES of a person is normally measured by education, occupation and income although the traits of social phenomenon they measure are different (Geyer et al., 2006). This study focused on level of education and class of occupation alone to determine parent's SES without considering their income since the population were minors and may therefore not be in the know. The "Ghana Living Standard Survey Round 6 (GLSS 6) report" provided the occupational class template for parents.

3.5.2.2 Raven's Colored Standard Progressive Matrices (RCPM)

The Raven's colored progressive matrices test can be described as a test of visuospatial ability and non-verbal reasoning ability. The test is non-verbal and do not depend on skills that are taught explicitly in school (Bakhiet & Lynn, 2015). It was first developed by John Raven in 1938 and is administered to children between the ages 5½ and 11½. It comprises of 36 matrices separated into three equal sets (A, AB, B) to assess a child's spatial aptitude as he or she proceeds from the simplest to the most complicated matrix design. Set A matrices rely on the child's capacity to fill in the blanks (pattern recognition), set AB on the child's ability to understand the linkages and relationships between the matrices and the six response options (spatial perception), and set B on the child's ability to think abstractly (abstract thinking) (Eissa, & Alsayed, 2012). By progressing from one level to another, the child adopts a way of thinking using their observation and clear-thinking skills to determine the missing pattern. Therefore, the test aimed at identifying the VSWM of the child at the end the levels (Vasuki, 2013). The total score is the total number of matrices completed correctly, and the test score ranges from is zero to 36. The Cronbach's alpha obtained for the current sample is 0.86 which is marginally higher as compared to 0.79 obtained by Mills-Robertson et al (2019) in Ghana.

3.5.2.3 Digit Memory Test (DMT)

Each task in this test featured multiple digits forward (a series of numbers from 2 to 9 digits in length) and multiple digits backward (a series of numbers ranging from 2 to 8 digits in length), and required examinees to repeat digits sequentially in a predefined order throughout the test (Kaplan et al., 1991). Digits ahead are used to evaluate auditory attention and auditory sequencing, whereas Digits backward are used to test mental tracking, short-term memory, and visuospatial imagery (Ryan & Lopez, 2001). Digit memory test includes digit forward and digit backwards. According to Bhaskaran et al. (2006), comparatively, digit forward is a not so challenging structured test of attention that requires respondents to listen attentively, maintain the digits in short term memory, in order to repeat it back to the researcher and it measures auditory attention and auditory sequencing as explained in Engle's controlled attention theory (Kane & Engle, 2002).

Embedded processes theory by Cowan explains that digit backward puts more focus on attention (Cowan, 1999). It demands participants to not only memorize the numerical list but also mentally alter it so it may be presented in reverse order. Although reversing the numerals involves verbal knowledge, the mental processes required may require visual imagery and visuospatial aptitude. The current sample's Cronbach's alpha is 0.74.

3.5.2.4 Letter Cancellation Test (LCT)

This is a paper and pencil test where children were required to scan, locate, and cross out target letters from a background of distractor letters. It measures selective attention, concentration and visuospatial scanning abilities (Della et al., 1992; Howieson & Lezak, 1995). In answering this test, the respondent is presented with a paper with a number of letters randomly intermixed with a designated target letter. This test is in consistence with Engle's controlled attention theory of working memory where one needs to control attention, suppress interference, avoid distraction and still be able to locate target letters so as to enhance one's VSWM. The Cronbach's alpha obtained for the current sample is 0.53.

3.6 Pilot Test

A pilot test was undertaken, in order to test the research design and the instruments for data collection. 10 children (5 on the abacus and 5 not on the abacus) participated in the pilot test. It was conducted in two schools that had similar characteristics as the main sample size. The pilot test was necessary as it helped the researcher to assess how suitable the instrument for data collection and procedure were for the population under study (Becker et al., 2012). As a result of the pilot, some modifications were made to the design of the instruments and the procedure for data collection. These modifications included the researcher employing the help of trained research assistants because, the Digit Memory test which was verbal was time consuming. The whole test took 30 minutes to administer with the DMT test taking about 17 minutes of the time.

3.7 Data Analysis and Presentation

The diverse data collected in the pre-test and post-test questionnaire allowed several analyses to be carried out to investigate whether there was a change in the level of visuospatial working memory of school children.

The data was manually entered and analyzed using SPSS version 23 to provide frequencies, percentage distributions, means, and standard deviations. The variables measured such as gender, age, class, educational level, and occupation of parents, were presented descriptively using tables.

Analysis of variance (ANOVA) and Independent T-tests technique were used to test for significance in means of the variables on the three types of tests and the hypothesis. These tests are essential as the significance of the scores cannot be deduced from descriptive statistics.

Bivariate correlation was used to examine the significant correlations between the demographic variables of participants and the visuospatial tests.

Independent variables for the hypothesis are gender, age, length of training, and abacus training as against the visuospatial working memory of abacus trained and untrained children.

3.8 Ethical considerations

The ethical standards were strictly adhered to during the research. In compliance with the University of Ghana, Legon's ethical norms, a copy of the study proposal as well as data collecting devices were submitted to the Ethics Committee for Basic and Applied Sciences (ECBAS) at the University of Ghana, Legon for ethical approval. The ECBCAS accepted the research proposal and data collecting tools.

The researcher received approval to conduct the study after the proposal document, study instruments, parents' consent form and respondents assent form were thoroughly reviewed. The approval letter bearing the research protocol code ECBAS 032/20-21 has been attached (Appendix A).

Ethics in social and behavioral sciences research refers to the researchers' responsibility to the general public. This entails maintaining the population's secrecy, privacy, and safety. Ethics, according to Newman (2000), are context-specific and create a set of rules for examining particular subjects that may be "sensitive" and morally undesirable to the group under research.

As a condition of participating in the study, participants were given a consent form that outlines the study's purpose, the possible benefits or risks associated with participating as well as information on how to withdraw from the study. The heads of the selected schools were then given the document for their approval. The ECBAS review board accepted the information on the consent form. A copy each of the respondents' assent and their parents' consent form have been attached (Appendix B & C).

3.9 Limitations of the study

This research took place during the Covid-19 epidemic, which afflicted the whole world. As a result, most schools refused to allow the research to be conducted on their grounds, which had a substantial impact on the schools' selection process. Due to the researcher's time and budget restraints, as well as a variety of restrictions imposed by the government on schools and the country as a whole, the study was limited to only four schools in New Achimota, Greater Accra. However, because New Achimota is home to individuals of many ethnicities and socioeconomic backgrounds, the findings from the four schools may be applied to other areas and towns in the country.

CHAPTER FOUR

4.0 DATA ANALYSIS, INTERPRETATIONS AND DISCUSSION

4.1 Introduction

The purpose of this chapter is to focus on two broad activities; the analysis of data using the statistical package for the social sciences (SPSS), employing descriptive and inferential statistical techniques like frequencies, percentages, correlation, ANOVA and independent t test, to test the hypotheses of the two groups of data. The next activity is the interpretation and discussion of the findings obtained from the analysis.

In describing the results of the study, the first section (4.2) presents demographic information on respondents and their raw scores in the various tests. The second section (4.3) presents the inferential statistics of the study using the ANOVA test and independent sample t test. The third section (4.4) presents the testing of hypothesis.

4.2 Demographic Characteristics of respondents

This section presents key demographics collected such as age, gender, class, abacus training classification, the educational qualifications of participants' parents as well as their occupations. The descriptive statistics for participants' performances on the three tests (Ravens Progressive Matrices, Digit Memory test and Letter Cancellation test) are also presented. Table 1 below presents the demographic characteristics of respondents.

Table 1: *Demographic characteristics of respondents*

Characteristics	Frequency(n)	Percentage(%)
Gender		
Male	85	44.50
Female	105	55.50
Age		
9years	40	21.1
10years	60	31.6
11years	90	47.4
Schools		
School A	80	42.1
School B	20	10.5
School C	56	29.5
School D	34	17.9
Class		
Class 4	57	30.5
Class 5	68	35.8
Class 6	65	33.7
Father's level of education		
Junior high or below	62	32.6
Senior high or Vocational school	50	26.3
Training College or Polytechnic	14	7.4
Bachelor's degree or higher	64	33.7
Mother's level of education		
Junior high or below	64	33.7
Senior high or Vocational school	60	31.6
Training College or Polytechnic	32	16.8
Bachelor's degree or higher	34	17.9
Father's occupation		
Craft and skilled Agriculture	26	13.7
Service and sales worker	62	32.6
Clerical support workers	12	6.3
Technician/associate professionals	21	11.1
Professionals	56	29.5
Managers	13	6.8
Mother's occupation		
Craft and skilled Agriculture	26	13.7
Service and sales worker	111	58.4
Clerical support workers	4	2.1
Technician/associate professionals	2	1.1
Professionals	38	20
Managers	9	4.7
Groups		
Experimental group	90	47.4
Control group	100	52.6

Note, N = 190

4.2.1 Gender distribution of respondents

Out of the 190 school children who participated in the experiment, 85 representing 44.5% were males, while 105 representing 55.5% were females. This means that there were more female participants in the experiment than male. This statistic reflects the general growing levels of female participation in education at all levels. For example, a report by the Ghana Statistical Service (GSS, 2012), highlights that in basic schools, females are more than males.

4.2.2 Age of respondents

The ages of all 190 respondents which ranged from 9 to 11 years. These were the ages of the respondents in classes 4, 5 and 6. These ages are in congruence with a study by León et al., (2021) who investigated how the abacus aids in developing the cognitive abilities of 7 to 12year olds by using the pretest-posttest method. Majority of the 190 respondents were 11years old (47.4%). The mean age of the respondents was approximately 10years.

4.2.3 Distribution of respondents by schools

The names of the schools were left out and represented with letters to satisfy the confidentiality agreement between the researcher and the schools. As indicated in the methodology, four schools participated in the experiment. Two of them have abacus training as part of their school curriculum, while the other two runs the traditional school curriculum only. School A and school B constituted the control group where they were taught with the Ghana Education Service (GES) curriculum for primary schools only. While school C and school D constituted the experimental group where they were trained in abacus alongside being taught with the Ghana Education Service (GES) curriculum for primary schools. Of the 190 participants, majority (42.1%, n=80; 29.5%, n=56) of the respondents for the control group and experimental group, were selected from school A and school C respectively, since they were more populated as compared to school B (10.5%, n=20) and school D (17.9%, n=34).

4.2.4 Respondents' parental education

Generally, more of the mothers (33.7%, n=64) had had some form of basic education than their male partners while a percentage that was about 5% of the fathers of the respondents had no senior high school nor vocational education as compared to their mothers (31.6%). More mothers (16.8%, n=32) of the respondents had attended training colleges than the fathers. However, more fathers (33.7%, n=64) had attained a degree as compared to respondents' mothers. Supporting these findings is the 2019 Ghana Living Standards Survey Round 7 Report (GLSS7, 2019) which reports that a high percentage of females have had at least basic education, Senior high education, vocational education and training college education than males. Nonetheless, the report continued to express that more males had had a bachelor's degree or higher than females. Parents' educational levels are regarded to be a major determinant of their children's academic success (Lara & Saracostti, 2019).

4.2.5 Respondents' parental occupation

The employment classifications were taken from the Round 6 Report of the Ghana Living Standards Survey (2013). Farmers, traders, masons, carpenters, wielders, painters, seamstresses, drivers, hairdressers, and tailors were all classed as craft and skilled agriculture vocations for this research. Security men and women, marketers, salespersons, business men and women, and entrepreneurs were classed as service and sales employees, while receptionists and secretaries were classified as clerical support workers. Factory workers and engineers made up the majority of technicians and associate professionals. Police, soldiers, teachers, nurses, attorneys, social workers, and bankers were among those classed as professionals. Managers of all types were divided into categories.

A shown in Table 1, there was a high representation of females in the service and sales occupational class. This constituted about double the number recorded for the males (n = 111). This corresponds with Ghana Living Standards Survey Round 7 Report (GLSS7, 2019), where females accounted for twice the number of males for the service and sales occupational class. Also, the number of males that were in the craft and skilled agriculture category were the same as females (n = 26).

4.2.6 Respondents' Performances on the three tests

Respondents' score for each of the three tests (pre and posttest) were combined (summed) and grouped to aid in identifying the number of respondents that had low, average and high scores. The results showed some improvement for both experimental and control groups at posttest in the three tests namely; Ravens Colored Progressive Matrices (RCPM), Digit Memory Test (DMT) and the Letter Cancellation Test (LCT). These three tests each measure different aspects of visuospatial working memory.

The overall performance on the three tests of respondents were categorized as poor, low, average or high, depending on the score and presented in Table 2.

Table 2: *Respondents' overall performance on the three tests*

Category (range)	Pretest	%	Posttest	%
Poor (1 – 19)	0	0	0	0
Low (20 – 38)	3	1.6	1	0.5
Average (39 – 57)	85	45.7	69	36.3
High (57 – 76)	102	52.7	120	63.2
Total	190	100	190	100

4.2.6.1 Respondents' performance on Raven's colored progressive matrices test (RCPM)

The summed raw scores of respondents on RCPM, are grouped under low, average and high performance and presented in the table 3.

Table 3: *Respondents' performance on RCPM*

Category (range)	Experimental Group		Control Group	
	Pretest(%)	Posttest(%)	Pretest(%)	Posttest(%)
Low (1-12)	0	2 (2.2)	2 (2)	0
Average (13-24)	40 (44.4)	31 (34.4)	46 (46)	40 (40)
High (25-36)	50 (55.6)	57 (63.4)	52 (52)	60 (60)
Total	90 (100)	90 (100)	100 (100)	100 (100)

From table 3, for the average score category, 44.4% was recorded for the experimental group at the pretest but at posttest, a decrease (34.4%, n=31) was recorded. For high score category, at pretest, 55.6% was recorded for the experimental group but then again, an increase (63.4%, n=57) was recorded at posttest. This means that there was a decrease of 10% at the average score category and an increase of 7.8% at the high score category. On the other hand, the control group at pretest recorded 46.0% at the average score category and a decrease (40.0%, n=40) at posttest. For the high score category, at pretest percentage of 52% was recorded and an increase (60%, n=60) was recorded at posttest. This gives a decrease of 6% at the average score category and an increase of 8% at the high score category. The results (table 8) implies that there was general improvement in the RCPM in both groups regardless of the intervention introduced. This means that at posttest, the respondents for both groups' ability to perceive the relationship and relations between the matrices and to think abstractly to complete the missing parts of the RCPM, increased.

Overall, the performance of both groups was similar which is comparable to studies by Mills-Robertson et al. (2019) whose research identified that between two communities in the eastern region of Ghana, their performance on the RCPM was similar. Comparable also is Bass (2000) where majority of her sample (27%) scored from 25-36 right answers.

4.2.6.2 Respondents' performance on Digit Memory Test (DMT)

Presented below are the combined scores of DMT that have been grouped into low, average and high performance of respondents.

Table 4: *Raw scores of DMT*

Category (range)	Experimental Group		Control Group	
	Pretest(%)	Posttest(%)	Pretest(%)	Posttest(%)
Low (1-10)	10 (11.1)	1 (1.1)	10 (10)	10 (10)
Average (11-20)	77(85.6)	84 (93.3)	87 (87)	87 (87)
High (21-30)	3 (3.3)	5 (5.6)	3 (3)	3 (3)
Total	90 (100)	90 (100)	100 (100)	100 (100)

From Table 4, for the experimental group, at the low score category, there was a decrease of 10% from the pretest to posttest which was an improvement as compared to the low score category for the control group where the same (10%) percentage was recorded at both pretest and posttest. At the average score category of the experimental group, a 7.7% increase was recorded which could be as a result of the 10% decrease that was recorded at the low score category. On the other hand, the control group recorded the same number at the average score level for both pretest and posttest. At the high score level, the percentage of the experimental group increased by 2.3% while the control group remained the same. It can be inferred from the table that there was improvement for the experimental group than there was for the control group. This suggests that the ability of the respondents in the experimental group to repeat digits in the same order either forward or backwards fairly improved.

This result is consistent with a study by Bhaskaran et al. (2006), where they found that abacus experts as compared to their control group had a greater memory span for maintaining and manipulating the number mentally and recalling it in the prescribed order. For their sample, after a period of 1year and 2years, the performance of the abacus experts was significantly higher in the digit memory test than their control group. The same result was found for Tiwari and Tiwari (2016), that the abacus learners performed highly satisfactorily in digit memory test after a period of 1year and 2years as compared to their control group.

Learners of abacus put numbers on their imaginary abacus as they mentally compute numbers that have been called out to produce an answer. Due to that, experts in abacus are able to do a recollection in a forward and backward way digits ranging of between 13-20 (Bhaskaran et al., 2006). This expertise is developed well if learners are consistently trained for a longer period of time, hence, the experimental group of this study would have performed explicitly well if the study had been done for a longer period of time instead of 4months.

4.2.6.3 Respondents' performance on Letter Cancellation Test (LCT)

Table 5 shows the performance of respondents on the Letter Cancellation Test.

Table 5: *Raw scores of LCT*

Category (range)	Experimental Group		Control Group	
	Pretest(%)	Posttest(%)	Pretest(%)	Posttest(%)
Low (0-6)	0	0	1 (1)	0
Average (7-13)	1 (1.1)	1 (1.1)	2 (2)	1 (1)
High (14-20)	89 (98.9)	89 (98.9)	97 (97)	98 (98)
Total	90 (100)	90 (100)	100 (100)	100 (100)

As shown in the results that were analyzed (Table 5), majority of the participants in the study were in a high score category (98.9%, 98.0%) in both the experimental and the control group.

There was a 1% decrease at the low and average score category and an increase of 1% decrease at the high score category for the control group as compared to the experimental group where the figures remained unchanged. This implies that there was a slight improvement in the ability of the control group respondents to scan, locate and cross out target letters from a background of distractor letters, thereby improving their selective attention and concentration span. Generally, both the experimental and control group performed well on this test.

4.3 Testing of Hypotheses

Independent sample t test analyses were conducted to test the hypothesis for gender and abacus training while, Analysis of Variance (ANOVA) was used to test for age and parents' socioeconomic status against visuospatial working memory.

4.3.1 Hypothesis one

H_{01}: There is no significant difference in the visuospatial working memory of males and females.

This hypothesis was analysed using independent sample t test. To determine if there were differences in gender in the visuospatial working memory of respondents, an independent sample t test was used to compare gender and the VSWM components that are measured by RCPM ($VSWM_{RCPM}$), DMT ($VSWM_{DMT}$), LCT ($VSWM_{LCT}$) and the overall total of visuospatial working memory measured in this study ($VSWM_{TOTAL}$). The results ($VSWM_{RCPM}$, $p = 0.499$; $VSWM_{DMT}$, $p = 0.779$; $VSWM_{LCT}$, $p = 0.644$; $VSWM_{TOTAL}$, $p = 0.448$) showed that, at the end of the study, there was no statistically significant difference between males and females (refer to appendix F, Table 2).

This means that after a 4month period of undergoing abacus training and also learning the Ghana education primary school curriculum, there was no significant difference in visuospatial working memory of males and females. Therefore, H_{01} which states that there is no significant difference in the visuospatial working memory of males and females was accepted. Loring Meier & Halpern, (1999) is of the assertion that differences in gender could be made up for with education and training approaches such as abacus training. Hence, the differences in gender, were perhaps made up for with the intervention (abacus training) and the regular classroom instruction (Loring Meier & Halpern, 1999).

Comparable with this finding is Amundsen et al.(2014), Abubakar and Ogugua (2011) and Tweed (2013) who found no difference in gender in visuospatial working memory. This suggests that for this sample, both males and females have no statistically significant difference in their visuospatial working memory. This can be attributed to the fact that though gender differences are often seen as either biologically determined or culturally acquired or conditioned, in this age where gender equality is the main target, it is only right for it to reflect in the area of academics and working memory functions.

There is an irregularity in literature on gender differences in mental arithmetic and other academic areas in general (Lynn & Irwing, 2007). Different studies report differently on gender differences with some supporting and others rejecting there are differences in gender. In their research, Lynn and Irwing (2007), Voyer et al. (2017), Zember and Blume (2011), and others discovered at the conclusion of their studies that there were statistically significant gender differences in working memory tasks in general, and visuospatial working memory tasks in particular favoring males.

4.3.2 Hypothesis two

H_{02}: There is no significant difference in age in the visuospatial working memory of school children.

A test of ANOVA was done to make a determination if there were statistically significant differences in VSWM components that are measured by RCPM ($VSWM_{RCPM}$), DMT ($VSWM_{DMT}$), LCT ($VSWM_{LCT}$) and the overall total of visuospatial working memory measured in this study ($VSWM_{TOTAL}$) when it comes to age. At the end of the study, the ANOVA results found that there was a significant difference in the means of age in $VSWM_{DMT}$ ($F(2,187) = 5.444, p = 0.005$) only as shown in Table 6 below. This implies that the ages of the respondents influenced their visuospatial working memory measured by DMT. Supporting this finding is a research by Gregoire and Linden (2011), on the effect of age on forward and backward digit memory test where they discovered that age had an effect on digit memory test at a p-value of 0.001 ($F(9,990) = 16.861, p < .001$). Digit memory test is a memory test that has been widely used to test different aspects of working memory and visuospatial working memory as is in this study. This kind of cognitive exercise tasks' the brain which makes it easier for the respondents since their ages are at a developmental stage where they can perform different cognitive tasks. Though the results of the test show that age had a significant effect on $VSMW_{DMT}$, it is not enough to make a generalization that it fully affects VSWM. Therefore, the null hypothesis is accepted. This suggests that though the ages of the respondents influenced $VSWM_{DMT}$, it is not enough to deduce that these children did better with the other tests and the overall VSWM.

Table 6: *ANOVA comparison of age and VSWM of respondents*

		Sum of Squares	df	Mean Square	F	Sig.
$VSWM_{RCPM}$	Between Groups	23.419	2	11.710	0.321	.726
	Within Groups	6828.981	187	36.519		
	Total	6852.400	189			
$VSWM_{DMT}$	Between Groups	112.622	2	56.311	5.444	0.005
	Within Groups	1934.331	187	10.344		
	Total	2046.953	189			

$VSWM_{LCT}$	Between Groups	2.465	2	1.233	0.643	0.527
	Within Groups	358.614	187	1.918		
	Total	361.079	189			
$VSWM_{TOTAL}$	Between Groups	122.560	2	61.280	0.982	0.377
	Within Groups	11673.356	187	62.424		
	Total	11795.916	189			

4.3.3 Hypothesis three

H_{03}: There is no significant difference in the visuospatial working memory of school children based on their parents' socioeconomic status. In order to ascertain if there were differences in the means of parental SES and the visuospatial working memory of respondents, an ANOVA test was done to compare parental SES and the VSWM components that are measured by RCPM ($VSWM_{RCPM}$), DMT ($VSWM_{DMT}$), LCT ($VSWM_{LCT}$) and the overall total of visuospatial working memory measured in this study ($VSWM_{TOTAL}$). The results are presented in Table 7.

Table 7: *ANOVA comparison of parental SES and the VSWM of respondents*

		Sum of Squares	df	Mean Square	F	Sig.
$VSWM_{RCPM}$	Between Groups	23.419	16	35.518	.972	.489
	Within Groups	6828.981	172	36.527		
	Total	6852.400	188			
$VSWM_{DMT}$	Between Groups	112.622	16	18.381	1.804	.034
	Within Groups	1934.331	172	10.191		
	Total	2046.953	188			
$VSWM_{LCT}$	Between Groups	2.465	16	1.821	.945	.519
	Within Groups	358.614	172	1.927		
	Total	361.079	188			
$VSWM_{TOTAL}$	Between Groups	122.560	16	59.484	.944	.521
	Within Groups	11673.356	172	63.044		

Total	11795.916	188

From Table 7, parental SES was found to have a statistically significant effect on $VSMW_{DMT}$ (p=0.034) only. This finding is in congruence with studies by Pina et al. (2014), who suggests that parents education and occupation has a positive influence on quantitative concepts. Digit memory test is no exception since its numerical.

The results of the test show that parental SES had a significant effect on $VSMW_{DMT}$. However, this finding is not enough to make a generalization that it fully affects VSWM. Thus, we accept the null hypothesis. This suggests that though the children with parents who had higher SES did better at the DMT test, it is not enough to deduce that these children did better with the other tests and the overall VSWM.

4.3.4 Hypothesis four

H_{04}: There is no difference between the visuospatial working memory of abacus trained and untrained school children.

Independent sample t test was used to determine whether after a period of four months' abacus training, there was a statistically significant difference in the means of the experimental and control groups (refer to Appendix F, Table 5). The experimental group received a 2hour training on abacus per week consistently for 4months alongside being taught with the GES primary school curriculum. During this period, the control group also received teaching on the GES primary school curriculum for a period of 4months. The researcher computed the means of all the measurement of VSWM at the start and end of the intervention and the results are presented in Table 8.

Table 8: *Difference within experimental and control groups*

	Experimental							Control						
	Pre		Post					Pre		Post				
	M	SD	M	SD	Diff	t	Sig	M	SD	M	SD	Diff	t	Sig
$VSWM_{RCPM}$	24.68	5.06	26.68	5.75	1.63	-2.02	0.45	24.93	5.75	26.20	6.28	1.27	-1.37	0.17
$VSWM_{DMT}$	14.36	3.29	16.20	3.16	1.84	-3.42	0.001	14.32	3.16	14.33	3.17	0.01	0.56	0.58
$VSWM_{LCT}$	18.93	1.67	19.52	1.23	0.59	-2.23	0.03	18.65	2.25	19.20	1.49	0.55	-1.92	0.56
$VSWM_{TOTAL}$	57.97	6.39	62.03	7.78	4.06	-3.93	0.000	57.88	7.88	59.73	7.88	1.85	-1.66	0.09

The results in Table 8 above, showed a general improvement in the performance of the experimental and control groups. From table 8, it can be deduced that despite the experimental group receiving two hours extra training in abacus aside the general GES basic primary curriculum, the changes were evident in both groups. This could be because the content of the GES primary curriculum was enough to make the children improve after a period of four months.

However, when both groups are compared, the observation reveal some changes in means for the experimental group were significant while the changes in means of the control group were not.

A such, the null hypothesis, "there is no difference between the visuospatial working memory of abacus trained and untrained school children", is rejected. This finding is consistent with Barner (2016), Kamali et al. (2019), and Dong et al. (2016)'s study that training on the abacus for a period of time consistently, improves the visuospatial working memory of children.

For visuospatial working memory as measured by RCPM ($VSWM_{RCPM}$,) the difference in means was 1.63 ($p = 0.45$) for the experimental group and 1.27 ($p = 0.45$) for the control group. This means that the ability of the experimental group to recognize patterns, perceive spatial arrangement and to think abstractly improved than with the control group.

The difference in means for visuospatial working memory as measured by DMT ($VSWM_{DMT}$) was 0.88 ($p = 0.001$) for the experimental group and 0.01 ($p = 0.58$) for the control group. Digit memory test measure auditory attention, auditory sequencing, mental tracking and visuospatial imaging. A higher change and significance in DMT depicts that the experimental group, after a period of 4months developed more skills that are measured by digit memory test as compared to their mates in the control group.

Visuospatial working memory as measured by LCT ($VSWM_{LCT}$) was somewhat higher for the experimental group (0.59, $p = 0.03$) as compared to the control group (0.55 $p = 0.56$). Letter Cancellation test measures selective attention and concentration and the ability of both groups to achieve it fairly improved.

During abacus training, children are taught to consistently practice on the abacus. As they consistently practice, by moving the beads up and down, they are better able to capture the image of the abacus in their memory and also to capture the position and movement of the beads and rods (figure1) in their memory by employing their visuospatial working memory. After mastering the abacus, an imaginary abacus is formed in the brain which the learner then visualizes and manipulates to produce answers.

Abacus involves carefully listening to the numbers for calculations, moving your fingers as you imagine the abacus and manipulate it with your visuospatial working memory, and capturing and voicing out your answer. Throughout this procedure, the abacus learner is attempting to organize visual, aural, and cognitive information, as well as to evaluate and solve the problems presented (Bhaskaran et al, 2006). The learner is better able to perform mental arithmetic since the abacus represents numbers in a visuospatial format (Wang, 2020). This may explain why from Table 8 the differences in the means of the experimental group were all statistically significant with the overall VSWM which is a combination of all the three components being highly significant at a pvalue of 0.000 ($p < .01$) as compared to the control group. This suggests that after a period of 4months, the results after the intervention of the training for this dissertation, depicts that abacus training significantly improves the VSWM of school children.

4.4 Other Analysis

4.4.1 Correlations among study variables

The findings of the studies of the relationships between the research variables are provided and discussed in this section. To determine if there were any significant links among the research variables (at both the pretest and posttest levels), bivariate correlations using the Pearson-Moment Product (r) coefficient were conducted. The results are provided in Table 9. The statistically significant correlations had moderate connections (ranging from.17 to.83) with one another, which will be examined in more detail below.

Table 9: *Correlations among study variables after intervention*

Study variables	1	2	3	4	5	6	7
Age (1)	1						
Parents' SES. (2)	0.033	1					
Abacus trained (3)	0.112	-0.123	1				
$VSWM_{RCPM}$ (4)	-0.003	0.146	0.038	1			
$VSWM_{DMT}$ (5)	-0.168*	0.081*	0.243**	0.225**	1		
$VSWM_{LCT}$ (6)	0.070	-0.021	0.095	0.230**	0.164*	1	
$VSWM_{TOTAL}$ (7)	-0.075	0.122	0.159*	0.829**	0.615**	0.415**	1

Note. *p< .05, **p< .01 (2-tailed)

From Table 9, age had a statistically significant negative correlation with $VSWM_{DMT}$ (-0.168, $p < .05$). This implies that the younger the children, the better their visuospatial working memory as measured by digit memory test. This results supports Piagets' stages of cognitive development which explains that children grow from picking information through their senses to thinking abstractly about it (Santrock, 2011). Hence, a child trained in abacus at a younger age, is more likely to better visually imagine numbers he/she is hearing, track it mentally, and repeat it in the same order its being mentioned. This helped the younger children to perform better as DMT requires them to repeat digits mentioned, in a prescribed sequence. This may explain why, the younger the children were, the better their VSWM as measured by DMT.

Parents' socioeconomic status, also had a statistically significant positive correlation with $VSWM_{DMT}$ (0.081, $p< .05$). This finding suggests that the ability of respondents to do well in digit memory test was influenced by their parents' socioeconomic status. Similar to this finding is research by Pina et al. (2014), who found that children's ability to grasp quantitative concepts is influenced by parental socioeconomic status.

Table 9 above reveals that $VSWM_{RCPM}$ (0.829, $p< .01$), $VSWM_{DMT}$ (0.615, $p< .01$), and $VSWM_{LCT}$ (0.415, $p< .01$) all significantly correlate with $VSWM_{TOTAL}$. This finding affirms the use of the three tests, RCPM, DMT and LCT to measure the visuospatial working memory of respondents.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

In this chapter, the findings from the research are summarized, along with the conclusions and recommendations for educators and parents to consider.

5.1 Summary

Abacus is increasing in use in many of the schools in Ghana especially private ones. Despite its wide used by private schools, there is however limited empirical literature that investigate whether abacus training leads to significant improvement in the memory and cognitive (visuospatial working memory) performance of children in Ghana. This is probably the reason why abacus training has not been integrated into basic school system by the government. The outcome of abacus after training for a period, is investigated in this current study.

A quasi experimental approach adopted to study the difference in means of gender, age, parents' occupation and education and abacus training in visuospatial working memory of well sampled primary 4, 5 and 6 school children aged 9, 10, and 11years in who live on Achimota, suburb in the capital city of Ghana. The respondents were sampled from four school; school C and D as the experimental group and school A and B as the control group. The experimental group had additional training on abacus 2 hours every week by specially trained instructors, while the control group were only taught on the Ghana education primary school curriculum. The aim of the research was to perform an assessment on the difference in demographic characteristics (gender, age) in visuospatial working memory of school children, assess the relationship socioeconomic status of parents have with the visuospatial working memory of their children and to investigate the difference between the visuospatial working memory of the trained group of children and those untrained (control group).

A Structured questionnaire containing three (3) memory and cognitive function tests; Raven's Colored Standard Progressive Matrices (CPM), Digit Memory Test (DMT), and Letter Cancellation tests (LCT) as well as other questions on demographic characteristics were used in the study. The researcher administered the questionnaires twice, once at the start of the experiment and once at the completion of the four-month training period. The responses were hand-coded and analyzed using SPSS version 23 to provide frequencies, percentages, means, and connections between research variables. The independent sample t test and ANOVA were used to assess the statistical significance of the mean differences. Bivariate correlation was used to examine the significant relationship among study variables.

Also, the experimental group considerably improved on the three measures used to measure visuospatial working memory, RCPM, DMT, and LCT. This improvement was demonstrated by the results. However, though the control group also showed some improvement, it was not statistically significant. This implies that abacus training based on the mean scores alone showed an improvement in the performance of respondents.

5.1.1 Key Findings

Gender of respondents at the end of the study, showed no difference statistically in visuospatial working memory. This finding led to acceptance of the null hypothesis that, there was no significant difference in the visuospatial working memory of males and females.

An ANOVA test revealed that there was no significant difference in age in the visuospatial working memory of school children. However, there was a significant difference in the means of age and $VSMW_{DMT}$ ($F(2,187) = 5.444, p = 0.005$). This means that the ages of the respondents influenced their visuospatial working memory measured by DMT. Also, parental socioeconomic status made no statistically significant difference in their children's visuospatial working memory. The implications of this is that though the occupation parents do couple with their level of education may be related to their children's visuospatial working memory, its influence wasn't strong enough to have had a significant effect.

Finally, based on the findings, statistically, there is significant difference between the performance of the experimental and control group. This is demonstrated by the respondents' scores which showed a significant difference between the experimental and control groups in RCPM, DMT and LCT but more especially in DMT since abacus calculations techniques are utilized more in solving it.

5.2 Conclusions

The conclusions gathered on the study is that gender did not influence the visuospatial working memory of children. For this study, the results based on gender did not differ significantly.

Age as research has it, does not always have an influence on visuospatial working memory. In this study, age significantly influenced visuospatial working memory measured by digit memory test only.

For the current study, the socioeconomic status of parents had no significant effect on the visuospatial working memory of their children.

Improving a child's visuospatial working memory can be achieved by training the child to calculate with abacus. Though the study period was short, it was enough to show some change in the visuospatial working memory of the respondents. It is established in this study that training children to work on the abacus, tends to influence their ability to perform Digit Memory test, Raven Colored Progressive Matrices test, Letter Cancellation test and generally other cognitive tasks.

5.3 Recommendations

Based on the finding that have been brought to bear in this study, the following recommendations are made:

1. The findings among others showed that there is effect on the visuospatial working memory of children as a result of receiving training on abacus. Thus, it is recommended that the Ghana education service (GES), the main governing board of basic schools in Ghana, should consider adding abacus training to the curriculum for primary school children.
2. Since the study covered only the first level of abacus training, it is recommended that future research be conducted using a longitudinal approach to enable participants to complete the full abacus course. This will help researchers to assess the full effects of the abacus training.
3. There is very little literature available on abacus. Although the available literature is relevant, most of them are old and needs to be revised. Therefore, more researchers should investigate abacus training and its effects on the cognitive development of children.

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APPENDICES

Appendix A

ETHICS APPROVAL FOR THE STUDY

UNIVERSITY OF GHANA
ETHICS COMMITTEE FOR BASIC AND APPLIED SCIENCES (ECBAS)
P. O. Box LG 1195, Legon, Accra, Ghana

Ref. No: ECBAS 032/20-21

11th May, 2021.

Ms. Evangeline Efe Ansah
Department of Family and Consumer Sciences
University of Ghana
Legon, Accra

Dear Ms. Ansah,

ECBAS 032/20-21: THE INFLUENCE OF ABACUS TRAINING ON THE VISUOSPATIAL WORKING MEMORY OF SCHOOL CHILDREN.

This is to inform you that the above referenced study has been presented to the Ethics Committee for Basic and Applied Sciences for a full board review and the following actions taken subject to the conditions and explanation provided below:

Expiry Date: 08/04/2022

On Agenda for: Initial Submission

Date of Submission: 09/03/2021

ECBAS Action: Approved

Reporting: Annually

Please accept my congratulations.

Yours sincerely,

ETHICS COMMITTEE FOR BASIC AND APPLIED SCIENCES
APPROVED
11 MAY 2021
UNIVERSITY OF GHANA

Professor Daniel Bruce Sarpong

Appendix B

PROTOCOL CONSENT FORM FOR PARENTS

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

Ethics Committee for Basic and Applied Sciences (ECBAS)

Official Use only
Protocol number

PROTOCOL CONSENT FORM

Section A- BACKGROUND INFORMATION

Title of Study:	ASSESSING THE VISUOSPATIAL WORKING MEMORY OF SCHOOL CHILDREN UNDERGOING ABACUS TRAINING
Principal Investigator:	EVANGELINE EFE ANSAH
Certified Protocol Number	ECBAS 032/20-21

Section B – CONSENT TO PARTICIPATE IN RESEARCH

Please seek the consent of the research participants by informing them (research participants) about your research using the guide below. Develop your form as would be used on the field.

General Information about Research

The purpose of this study, is to assess how abacus training influences the visuospatial working memory of school children. The study will take place for a period of 4months, during which children will be taken through the first level of abacus training. The study involves children that are within the ages of 8 and 12years who are either in classes 4, 5, or 6 only. You have the free will to decide whether you would like your child to partake in the study or not. The researcher will administer 3 different tests to your child and take their demographic data as well. You are free to redraw your child from the study if you change your mid in the course of the study.

Benefits of the study

This study will inform you as to how abacus training helps to improve your child's memory and his/her academic work. Also, it will add to the body of literature in this area and help organizations that provides abacus training to have a stronger evidence of the importance of abacus training to promote its use in schools.

Risk of the study

It is anticipated that children may experience fear and may feel challenged mentally, upon seeing the tests. The researcher will work hand in hand with the class teachers to minimize this risk. If a child feels uncomfortable participating at any point in time, he/she is free to opt out.

Confidentiality

Any information provided will be handled only by principal investigator and research assistants under strict supervision. In addition, all identifying information (such as name of participant) will be withheld to protect the participants' identity. All materials such as consent forms, questionnaire and memory tests will be stored in a locked cabinet, and locked in an office for five years after the study is over. It will then be destroyed. If they are needed for further studies, ethical clearance will be sought. You are free to ask me any question at any point during the research for clarification.

Compensation

Children will be compensated with the supply of nose mask, hand sanitizer, stationery such as pencils, sharpener and eraser, as well as exercise books. The schools involved will be provided with veronica buckets, liquid soaps and tissue paper to minimize the risk of children contracting Corona virus and other possible infections.

Withdrawal from Study

Participation in this study is voluntary. Therefore, you may withdraw from the study at any time without a penalty. A child's academic records will not be affected should he/she withdraw from this study.

Contact for Additional Information

For more enquiries about the research, the principal investigator can be contacted via;

- Email: eeansah005@st.ug.edu.gh.
- Telephone number: 233-540712076.
- If you have any issues on your rights as a participant you can contact the address below:

  Administrator, Ethics Committee for Basic and Applied Sciences
  College of Basic and Applied Sciences
  University of Ghana
  P. O. Box LG 68
  Legon – Accra
  IP No.: 3014
  Email: ethicscbas@ug.edu.gh

Section C- VOLUNTEER AGREEMENT

"I have read or have had someone read all of the above, asked questions, received answers regarding participation in this study, and I am willing to give consent for me, my child/ward to participate in this study. I have not waived any of my rights by signing this consent form. Upon signing this consent form, I will receive a copy for my personal records."

____

Name of Volunteer

______________________________ _______________

Signature or mark of volunteer Date

If volunteers cannot read the form themselves, a witness must sign here:

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

____

Name of witness

________________________________ _______________

Signature of witness Date

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

____

Name of Person who obtained Consent

_____________________________ _______________

Signature of Person who obtained Consent Date

Appendix C

ASSENT FORM FOR CHILDREN

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

Ethics Committee for Basic and Applied Sciences (ECBAS)

Official Use only
Protocol number

CHILD ASSENT FORM

Section A- BACKGROUND INFORMATION

Title of Study:	ASSESSING THE VISUOSPATIAL WORKING MEMORY OF SCHOOL CHILDREN UNDERGOING ABACUS TRAINING
Principal Investigator:	EVANGELINE EFE ANSAH
Certified Protocol Number	ECBAS 032/20-21

Section B – CONSENT TO PARTICIPATE IN RESEARCH

Introduction

My name is Evangeline Efe Ansah and I am from the College of Basic and Applied Sciences at the University of Ghana. I am conducting a research study entitled "the influence of abacus training on the visuospatial working memory of school children". I am asking you to take part in this research study because I am trying to learn more about how the abacus helps with the memory of children.

General Information about Research

You have to be between the ages of 8 and 12years and also be in either class 4, 5 or 6 to partake in this study. If you agree to be in this study, you will be asked to answer 3 different questionnaires, at the beginning of the study. and also at the end.

Benefits of the study

Your participation in this study will help to improve on your memory and your academic work.

Risk of the study

The risks associated are feeling of fear of being around researchers you are not familiar with. You may also feel challenged mentally due to questions that you will be answering. However, the researchers will work with your class teachers so that you wouldn't interact with total strangers only.

Confidentiality

Your information will be kept confidential. No one will be able to know how you responded to the questions and your information will be anonymous.

Compensation

You will be given nose masks, hand sanitizer, stationery such as pencils, sharpener and eraser, as well as exercise books for partaking in the study. Your school will also be provided with veronica buckets, liquid soaps and tissue paper to promote personal hygiene in the school.

Withdrawal from Study

You can stop participating at any time if you feel uncomfortable. No one will be angry with you if you do not want to participate. It will also not affect your academic records if you decide to opt out.

Contact for Additional Information

You may ask me any questions about this study. You can call me at any time 0540712076 or talk to me the next time you see me.

Please talk about this study with your parents before you decide whether or not to participate. I will also ask permission from your parents before you are enrolled into the study. Even if your parents say "yes" you can still decide not to participate.

Your rights as a Participant

If you have any issues on your right as a participant, you can contact the address below:

Administrator, Ethics Committee for Basic and Applied Sciences
College of Basic and Applied Sciences
University of Ghana
P. O. Box LG 68
Legon – Accra
IP No.: 3014
Email: ethicscbas@ug.edu.gh

Section C- VOLUNTEER AGREEMENT

VOLUNTARY AGREEMENT

By making a mark or thumb printing below, it means that you understand and know the issues concerning this research study. If you do not want to participate in this study, please do not sign this assent form. You and your parents will be given a copy of this form after you have signed it. This assent form which describes the benefits, risks and procedures for the research titled "the influence of abacus training on the visuospatial working memory of school children", has been read and explained to me. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree to participate.

Child's Name: ………………………………………… Researcher's Name ……………………………………………

Child's Mark/Thumbprint……………………… Researcher's Signature ……………………………………

Date: …………………………………………… Date: ………………………………………………

IP No.: 3014 Email: ethicscbas@ug.edu.gh

Appendix D

ANOVA TABLES

Table 1: ANOVA comparison of age and VSWM at pretest

		Sum of Squares	df	Mean Square	F	Sig.
$VSMW_{RCPM}$	Between Groups	37.557	2	18.778	0.636	0.531
	Within Groups	5523.622	187	29.538		
	Total	5561.179	189			
$VSMW_{DMT}$	Between Groups	43.936	2	21.968	2.379	0.095
	Within Groups	1727.058	187	9.236		
	Total	1770.995	189			
$VSMW_{LCT}$	Between Groups	2.369	2	1.185	.295	0.745
	Within Groups	749.783	187	4.010		
	Total	752.153	189			
$VSWM_{TOTAL}$	Between Groups	99.521	2	49.761	0.960	0.385
	Within Groups	9697.447	187	51.858		
	Total	9796.968	189			

Table 2: ANOVA comparison of age and VSWM at posttest

		Sum of Squares	df	Mean Square	F	Sig.
$VSMW_{RCPM}$	Between Groups	23.419	2	11.710	0.321	.726
	Within Groups	6828.981	187	36.519		
	Total	6852.400	189			
$VSMW_{DMT}$	Between Groups	112.622	2	56.311	5.444	0.005
	Within Groups	1934.331	187	10.344		
	Total	2046.953	189			
$VSMW_{LCT}$	Between Groups	2.465	2	1.233	0.643	0.527
	Within Groups	358.614	187	1.918		
	Total	361.079	189			
$VSWM_{TOTAL}$	Between Groups	122.560	2	61.280	0.982	0.377
	Within Groups	11673.356	187	62.424		
	Total	11795.916	189			

Table 3: ANOVA comparison of Parents' occupation and education and VSWM at pretest

		Sum of Squares	df	Mean Square	F	Sig.
$VSMW_{RCPM}$	Between Groups	565.642	16	35.353	1.218	.258
	Within Groups	4990.718	172	29.016		
	Total	5556.360	188			
$VSMW_{DMT}$	Between Groups	82.911	16	5.182	.477	.956
	Within Groups	1869.734	172	10.871		
	Total	1952.646	188			
$VSMW_{LCT}$	Between Groups	47.412	16	2.963	.724	.767
	Within Groups	704.122	172	4.094		
	Total	751.534	188			
$VSWM_{TOTAL}$	Between Groups	717.238	16	44.827	.849	.628
	Within Groups	9079.714	172	52.789		
	Total	9796.952	188			

Table 4: ANOVA comparison of Parents' occupation and education and VSWM at posttest-pretest

		Sum of Squares	df	Mean Square	F	Sig.
$VSMW_{RCPM}$	Between Groups	480.481	16	30.030	1.026	.432
	Within Groups	5035.148	172	29.274		
	Total	5515.630	188			
$VSMW_{DMT}$	Between Groups	228.708	16	14.294	1.379	.157
	Within Groups	1782.245	172	10.362		
	Total	2010.952	188			
$VSMW_{LCT}$	Between Groups	78.393	16	4.900	.758	.731
	Within Groups	1111.935	172	6.465		
	Total	1190.328	188			
$VSWM_{TOTAL}$	Between Groups	1008.990	16	63.062	1.010	.449
	Within Groups	10743.338	172	62.461		
	Total	11752.328	188			

Appendix E

CORRELATIONS

Table 1: Pearson r coefficient among study variables at pretest

Study variables	1	2	3	4	5	6	7	8
Gender (1)	1							
Age (2)	0.092	1						
Parents' SES. (3)	0.134	-0.015	1					
Abacus trained (4)	-0.050	-0.098	0.178	1				
$VSWM_{RCPM}$ (5)	-0.064	0.049	0.167	0.023	1			
$VSWM_{DMT}$ (6)	0.006	-0.127	0.022	-0.006	0.076	1		
$VSWM_{LCT}$ (7)	-0.024	-0.051	0.043	-0.071	0.247**	0.039	1	
$VSWM_{TOTAL}$ (8)	-0.053	-0.088	0.141	0.001	0.845**	0.514**	0.478**	1

Note. *p< .05, **p< .01 (2-tailed)

Table 2: Pearson r coefficient correlations among study variables at posttest

Study variables	1	2	3	4	5	6	7	8
Gender (1)	1							
Age (2)	0.094	1						
Parents' SES. (3)	0.130	0.033	1					
Abacus trained (4)	0.065	0.112	-0.123	1				
$VSWM_{RCPM}$ (5)	-0.067	-0.003	0.146	0.038	1			
$VSWM_{DMT}$ (6)	-0.013	-0.168*	0.081	0.243**	0.225**	1		
$VSWM_{LCT}$ (7)	-0.012	0.070	-0.021	0.095	0.230**	0.164*	1	
$VSWM_{TOTAL}$ (8)	-0.066	-0.075	0.122	0.159*	0.829**	0.615**	0.415**	1

Note. *p< .05, **p< .01 (2-tailed)

Table 3: Pearson r coefficient correlations among study variables at posttest-pretest

Study variables	1	2	3	4	5	6	7	8
Gender (1)	1							
Age (2)	0.092	1						
Parents' SES. (3)	0.134	-0.015	1					
Abacus trained (4)	-0.059	-0.184*	-0.193**	1				
$VSWM_{RCPM}$ (5)	-0.034	-0.126	0.115	0.194**	1			
$VSWM_{DMT}$ (6)	0.007	-0.249**	0.008	0.232**	0.164**	1		
$VSWM_{LCT}$ (7)	-0.083	-0.053	0.090	0.288**	0.634**	0.003	1	
$VSWM_{TOTAL}$ (8)	-0.026	-0.198**	0.077	0.197**	0.736**	0.461**	0.418**	1

Note. *p< .05, **p< .01 (2-tailed)

Appendix F

INDEPENDENT SAMPLES T TEST

Table 1: Independent Samples Test of gender at pretest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	0.643	0.424	0.852	187	0.395	0.679	0.796	-0.892	2.249
	Equal variances not assumed			0.860	183	0.391	0.679	0.789	-0.878	2.235
$VSMW_{DMT}$	Equal variances assumed	0.111	0.739	0.181	187	0.856	0.086	0.473	-0.848	1.019
	Equal variances not assumed			0.180	172	0.858	0.086	0.477	-0.856	1.027
$VSMW_{LCT}$	Equal variances assumed	1.351	0.247	-0.016	187	0.987	-0.005	0.293	-0.584	0.574
	Equal variances not assumed			-0.017	182	0.987	-0.005	0.281	-0.560	0.551
$VSWM_{TOTAL}$	Equal variances assumed	0.421	0.517	0.736	187	0.463	0.779	1.058	-1.308	2.865
	Equal variances not assumed			0.740	181	0.460	0.779	1.052	-1.298	2.855

Table 2: Independent Samples Test of gender at posttest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	0.102	0.750	0.678	188	0.499	0.596	0.879	-1.139	2.332
	Equal variances not assumed			0.675	177	0.500	0.596	0.883	-1.146	2.338
$VSMW_{DMT}$	Equal variances assumed	3.368	0.068	0.280	188	0.779	0.135	0.481	-0.815	1.084
	Equal variances not assumed			0.289	187	0.773	0.135	0.467	-0.786	1.056
$VSMW_{LCT}$	Equal variances assumed	0.508	0.477	0.463	188	0.644	0.094	0.202	-0.305	.492
	Equal variances not assumed			0.477	187	0.634	0.094	0.196	-0.294	.481
$VSWM_{TOTAL}$	Equal variances assumed	0.949	0.331	0.760	188	0.448	0.877	1.154	-1.397	3.154
	Equal variances not assumed			0.769	186	0.443	0.877	1.140	-1.372	3.127

Table 3: Independent Samples Test of gender at posttest-pretest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	0.206	0.651	-0.216	187	0.829	-0.171	0.794	-1.738	1.395
	Equal variances not assumed			-0.215	176	0.830	-0.171	0.796	-1.742	1.399
$VSMW_{DMT}$	Equal variances assumed	0.530	0.468	-0.258	187	0.797	-0.123	0.480	-1.072	0.824
	Equal variances not assumed			-0.253	163	0.801	-0.123	0.489	-1.089	0.842
$VSMW_{LCT}$	Equal variances assumed	0.992	0.320	1.139	187	0.256	0.419	0.368	-0.307	1.145
	Equal variances not assumed			1.081	129	0.282	0.419	0.388	-0.348	1.186
$VSWM_{TOTAL}$	Equal variances assumed	0.004	0.950	-0.218	187	0.828	-0.252	1.159	-2.539	2.035
	Equal variances not assumed			-0.217	176	0.828	-0.252	1.163	-2.547	2.042

Table 4: Independent Samples Test of Groups at pretest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	1.694	0.195	-0.319	188	0.750	-0.252	0.790	-1.811	1.306
	Equal variances not assumed			-0.321	188	0.748	-0.252	0.785	-1.800	1.296
$VSMW_{DMT}$	Equal variances assumed	0.145	0.704	0.076	188	0.940	0.036	0.468	-0.889	0.960
	Equal variances not assumed			0.076	184	0.940	0.036	0.469	-0.891	0.962
$VSMW_{LCT}$	Equal variances assumed	0.480	0.489	0.977	188	0.330	0.283	0.289	-0.289	0.855
	Equal variances not assumed			0.993	182	0.322	0.283	0.285	-0.280	0.847
$VSWM_{TOTAL}$	Equal variances assumed	4.555	0.034	-0.013	188	0.990	-0.013	1.049	-2.082	2.056
	Equal variances not assumed			-0.013	186	0.990	-0.013	1.037	-2.060	2.033

Table 5: Independent Samples Test of Groups at posttest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	1.373	0.243	0.241	188	0.810	0.211	0.877	-1.519	1.941
	Equal variances not assumed			0.242	188	0.809	0.211	0.873	-1.511	1.933
$VSMW_{DMT}$	Equal variances assumed	0.041	0.839	4.211	188	0.000	1.930	0.458	1.026	2.834
	Equal variances not assumed			4.210	186	0.000	1.930	0.458	1.026	2.834
$VSMW_{LCT}$	Equal variances assumed	2.481	0.117	1.258	188	0.210	0.252	0.201	-0.143	0.648
	Equal variances not assumed			1.271	187	0.205	0.252	0.199	-0.139	0.644
$VSWM_{TOTAL}$	Equal variances assumed	0.653	0.420	2.023	188	0.044	2.303	1.139	0.057	4.549
	Equal variances not assumed			2.024	186	0.044	2.303	1.138	0.059	4.548

Table 6: Independent Samples Test of Groups at posttest-pretest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
VSMW$_{RCPM}$	Equal variances assumed	1.090	0.298	-2.256	188	0.025	-1.752	0.777	-3.284	-0.220
	Equal variances not assumed			-2.268	188	0.024	-1.752	0.773	-3.276	-0.228
VSMW$_{DMT}$	Equal variances assumed	0.809	0.369	-3.114	188	0.002	-1.444	0.464	-2.359	-0.529
	Equal variances not assumed			-3.104	183	0.002	-1.444	0.465	-2.363	-0.526
VSMW$_{LCT}$	Equal variances assumed	0.727	0.395	-3.667	188	0.000	-1.297	0.354	-1.994	-0.599
	Equal variances not assumed			-3.769	159	0.000	-1.297	0.344	-1.976	-0.617
VSWM$_{TOTAL}$	Equal variances assumed	7.701	0.006	-2.461	188	0.015	-2.783	1.131	-5.014	-0.553
	Equal variances not assumed			-2.503	179	0.013	-2.783	1.112	-4.978	-0.589

Table 7: Independent Samples Test of experimental group at posttest-pretest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	2.040	0.155	-2.024	178	0.044	-1.633	0.807	-3.226	-0.041
	Equal variances not assumed			-2.024	175	0.045	-1.633	0.807	-3.226	-0.041
$VSMW_{DMT}$	Equal variances assumed	0.738	0.392	-3.416	178	0.001	-1.644	0.481	-2.595	-0.694
	Equal variances not assumed			-3.416	178	0.001	-1.644	0.481	-2.595	-0.694
$VSMW_{LCT}$	Equal variances assumed	6.757	0.010	-2.234	178	0.027	-0.489	0.219	-.921	-0.057
	Equal variances not assumed			-2.234	164	0.027	-0.489	0.219	-.921	-0.057
$VSWM_{TOTAL}$	Equal variances assumed	2.847	.093	-3.925	178	0.000	-4.167	1.061	-6.261	-2.071
	Equal variances not assumed			-3.925	171	0.000	-4.167	1.061	-6.262	-2.071

Table 8: Independent Samples Test of control group at posttest-pretest

		Levene's Test for Equality of Variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Err. Diff.	95% Confidence Interval of the Difference Lower	Upper
$VSMW_{RCPM}$	Equal variances assumed	1.705	0.193	-1.373	198	0.171	-1.170	0.852	-2.851	0.511
	Equal variances not assumed			-1.373	196	0.171	-1.170	0.852	-2.851	0.511
$VSMW_{DMT}$	Equal variances assumed	0.111	0.739	0.561	198	0.576	0.250	0.446	-0.629	1.129
	Equal variances not assumed			0.561	198	0.576	0.250	0.446	-0.629	1.129
$VSMW_{LCT}$	Equal variances assumed	2.441	0.120	-1.924	198	0.056	-0.520	0.270	-1.053	0.013
	Equal variances not assumed			-1.924	172	0.056	-0.520	0.270	-1.053	0.013
$VSWM_{TOTAL}$	Equal variances assumed	0.213	0.645	-1.659	198	0.099	-1.850	1.115	-4.049	0.349
	Equal variances not assumed			-1.659	198	0.099	-1.850	1.115	-4.049	0.349

Appendix G

QUESTIONNAIRE FOR RESPONDENTS

UNIVERSITY OF GHANA
DEPARTMENT OF FAMILY AND CONSUMER SCIENCES

This exercise is purely academic and all responses or information will be treated confidentially. Your honest and sincere responses to the items in the interview will be highly appreciated.

Be assured that responses given will be treated confidentially and will only be used for this study.

SECTION A: DEMOGRAPHIC DATA

Please, tick [√] the appropriate box ☐ or write in the blank space provided.

1. Name ……………………………………………………………………………….
2. Gender:

   ☐ Male ☐ Female
3. Age

   ☐ 9years ☐ 10years ☐ 11years
4. Class

   ☐ class 4 ☐ class 5 ☐ class 6
5. School name …………………………………………………………….
6. Are you on the abacus training program?

   ☐ YES ☐ NO

   ☐ above 2 years
7. Fathers' highest education level

   ☐ Junior high or below ☐ Senior high or Vocational school

   ☐ Training College or Polytechnic ☐ Bachelor's Degree or higher
8. Mothers' highest education level

   ☐ Junior high or below ☐ Senior high or Vocational school

   ☐ Training College or Polytechnic ☐ Bachelor's Degree or higher

9. Fathers' occupation

- ☐ Craft and skilled agriculture
- ☐ Service and Sales worker
- ☐ Technician
- ☐ Professionals
- ☐ Managerial
- ☐ Administrative work

10. Mothers' occupation

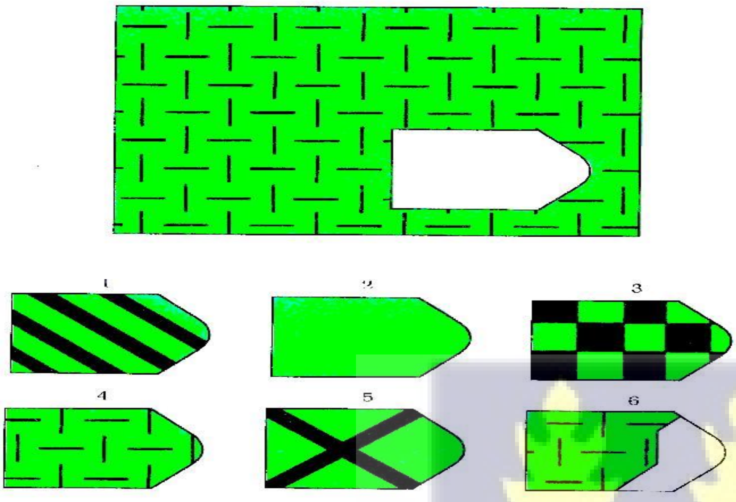
- ☐ Craft and skilled agriculture
- ☐ Service and Sales worker
- ☐ Clerical support workers
- ☐ Technician/associate professionals
- ☐ Professionals
- ☐ Managers

SECTION B: RAVENS' COLORED PROGRESSIVE MATRICES TEST

Directions: Select the correct answer from the alternatives provided.

SET A

A1



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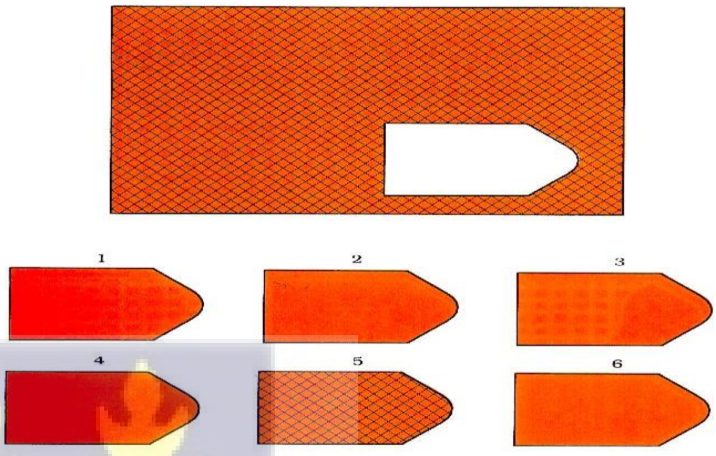

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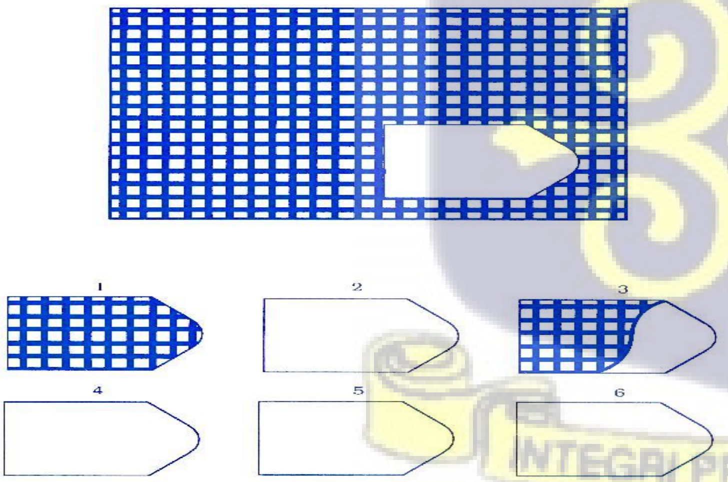

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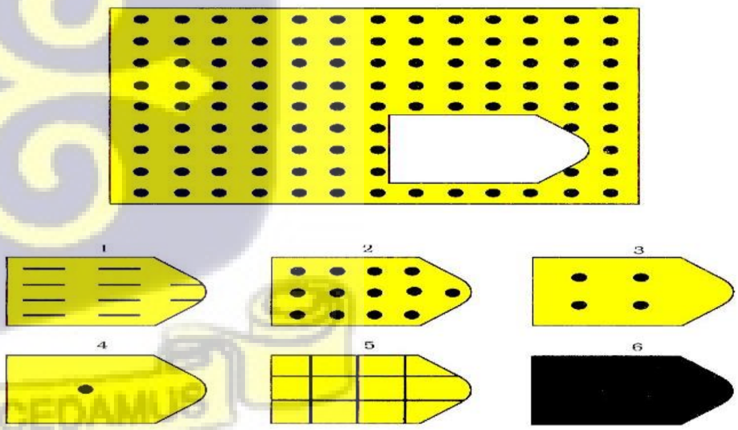

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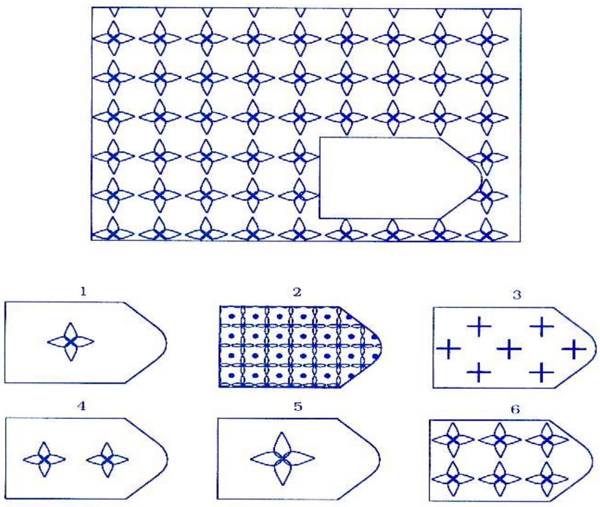

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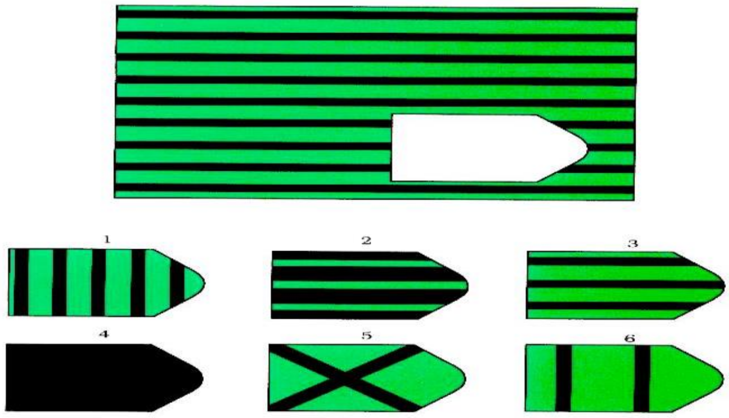

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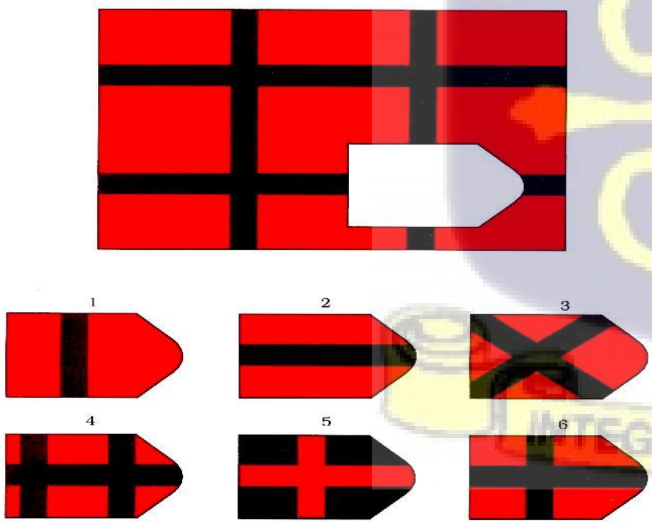

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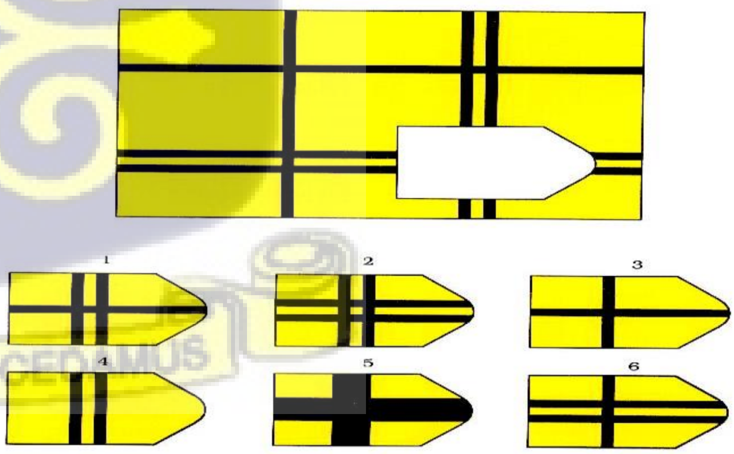

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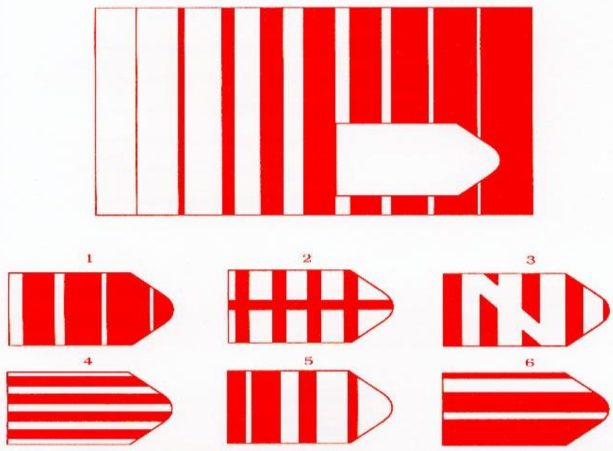

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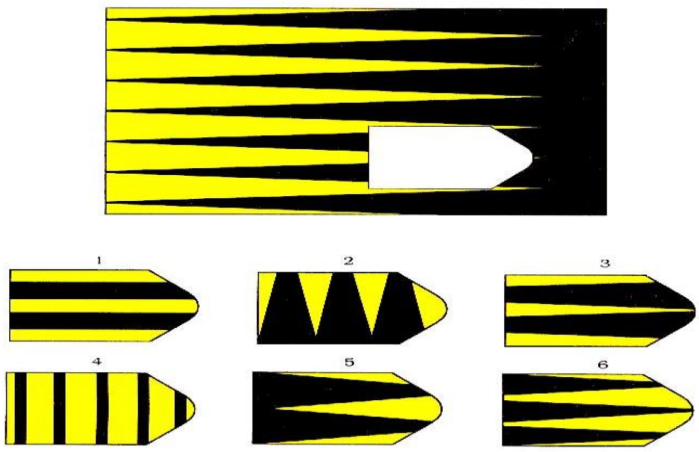

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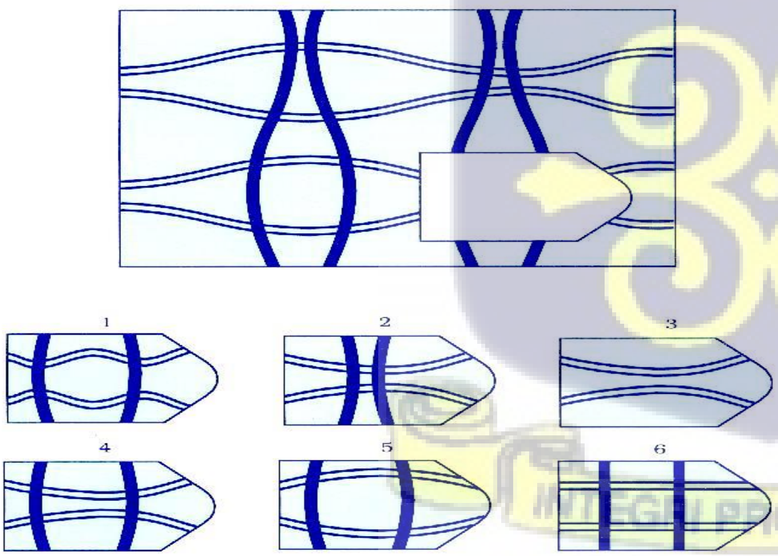

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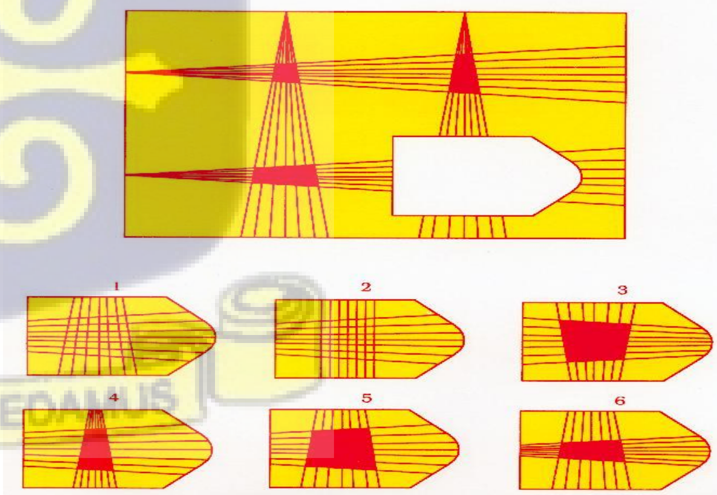

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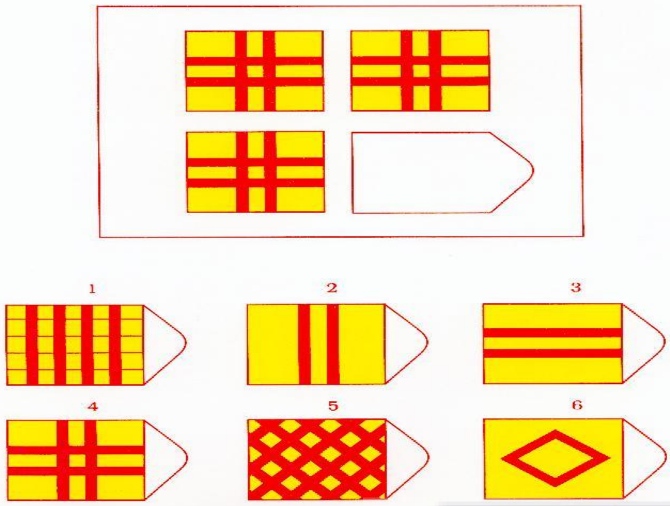

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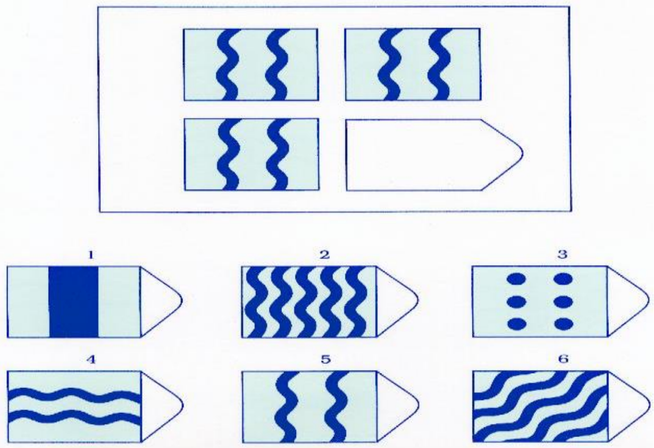

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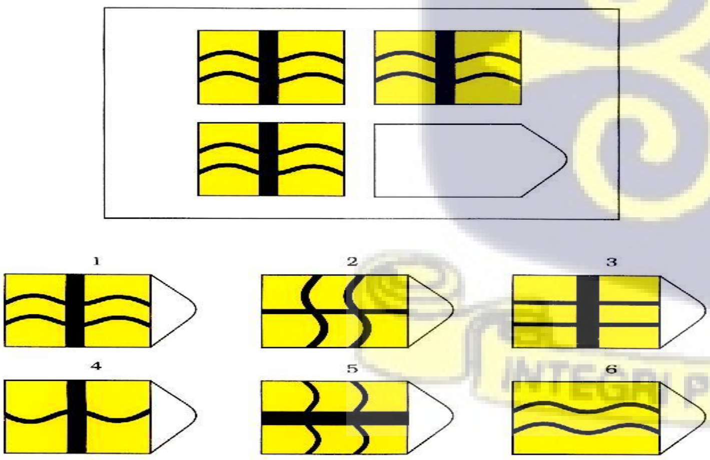

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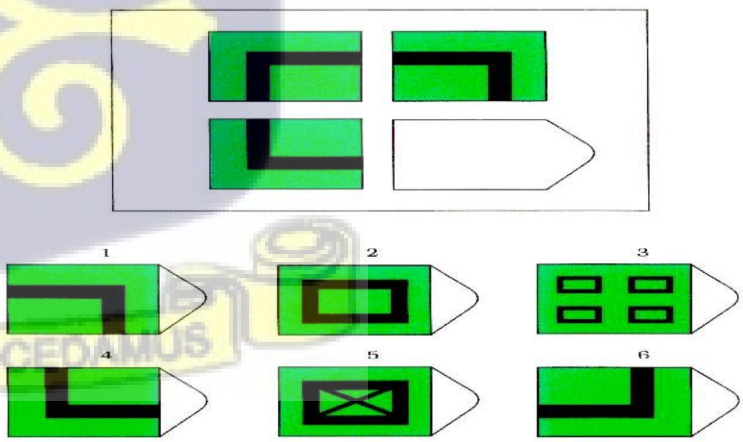

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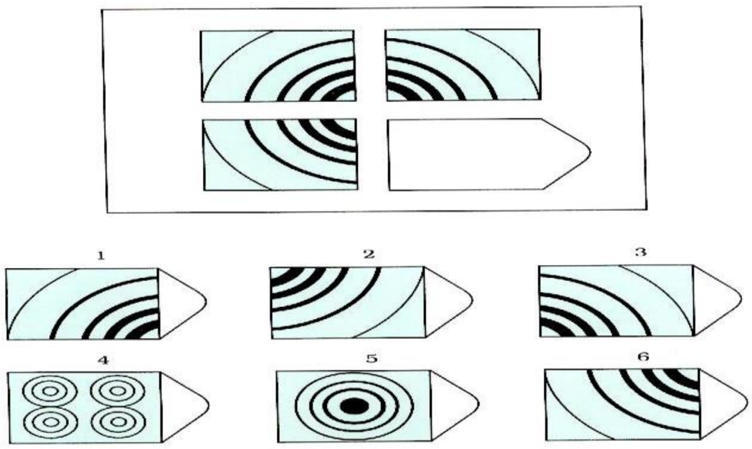

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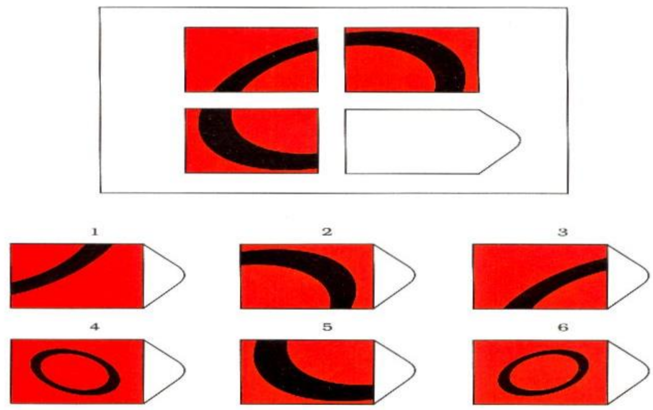
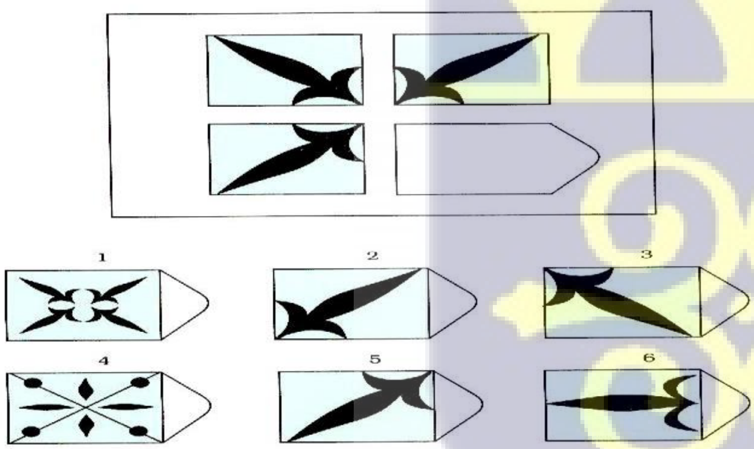


A_B7



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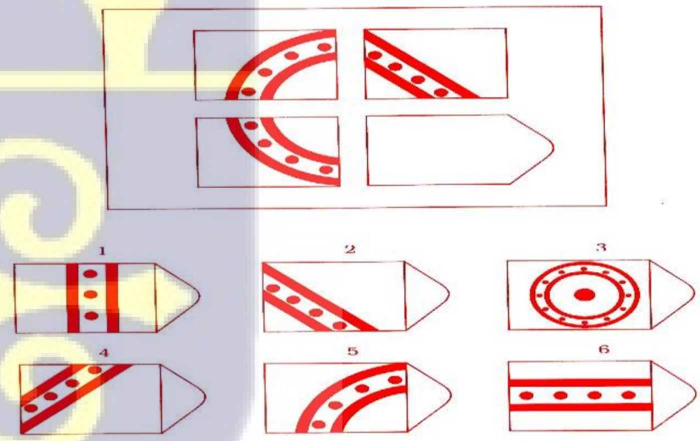

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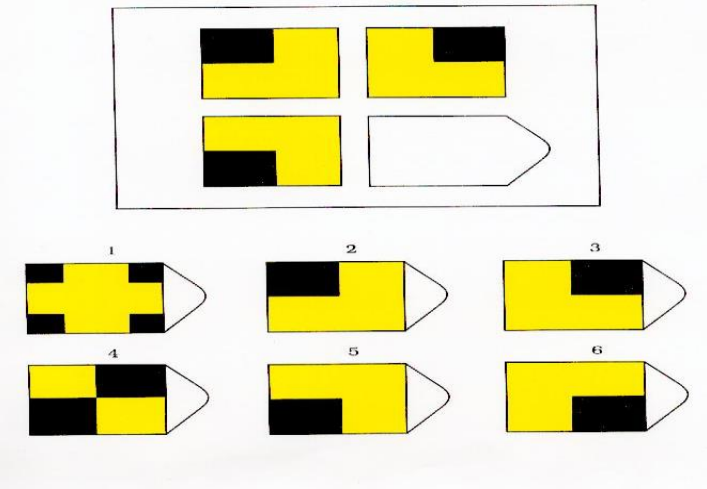

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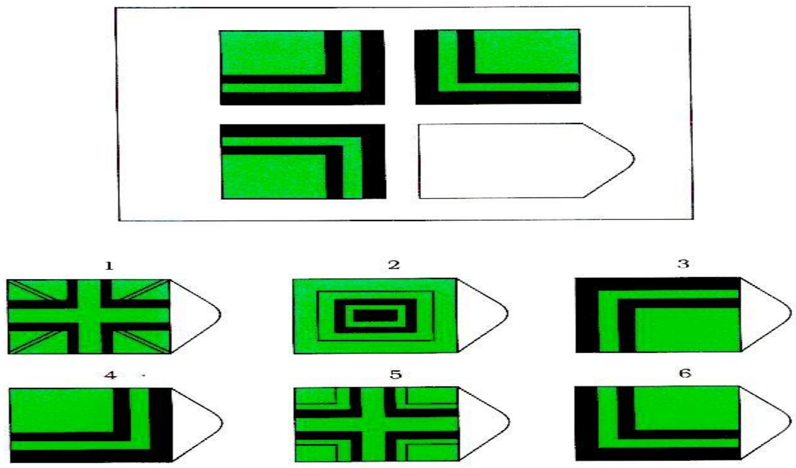

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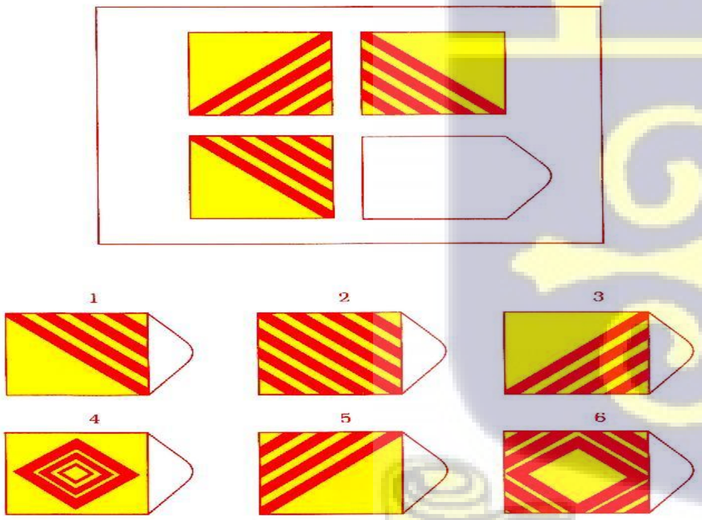

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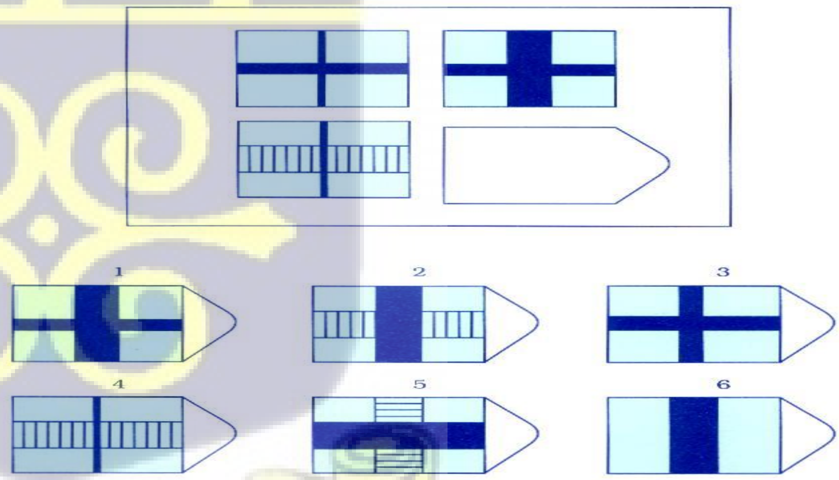
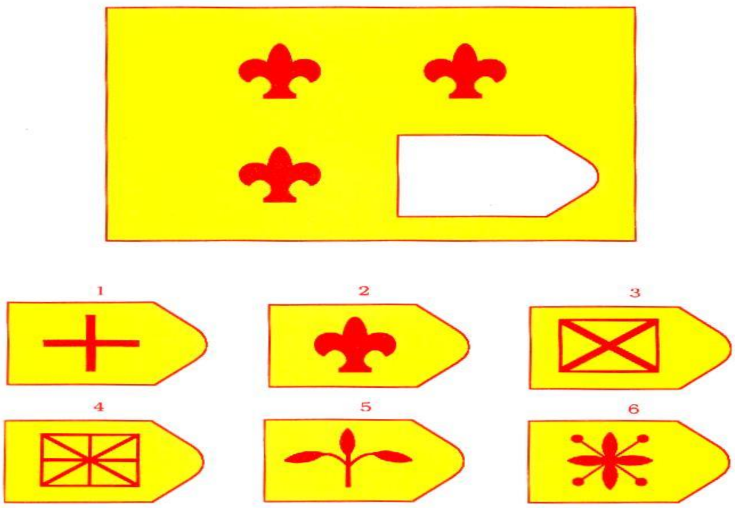


SET B

B1



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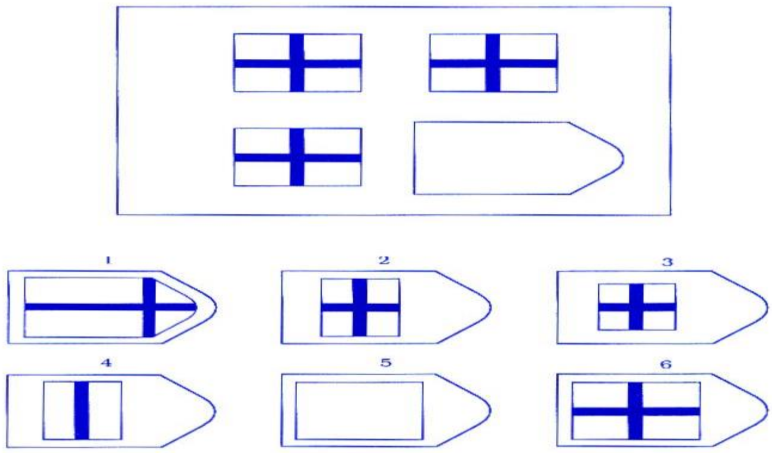

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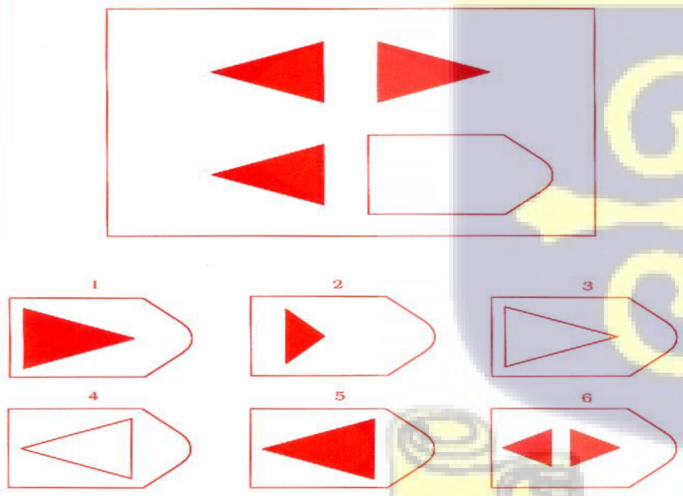

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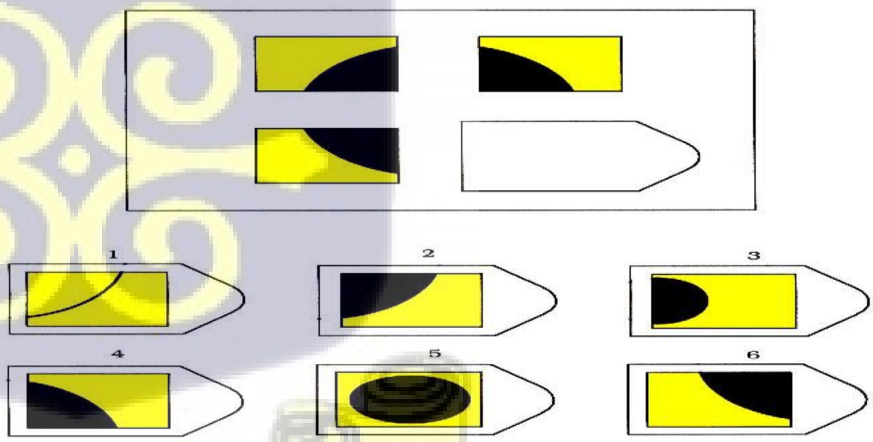

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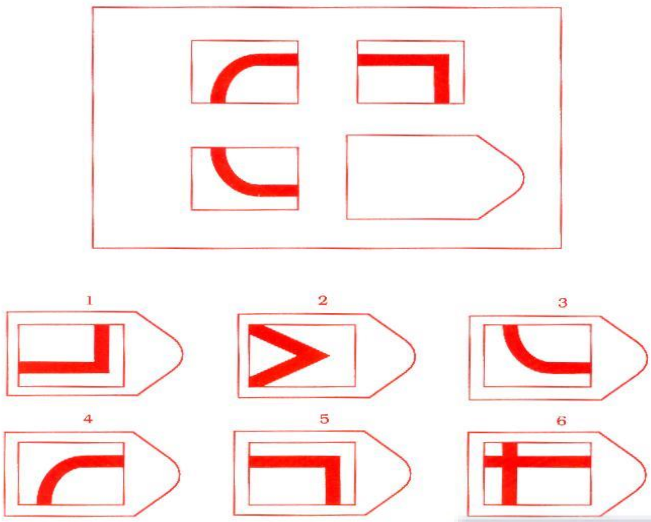

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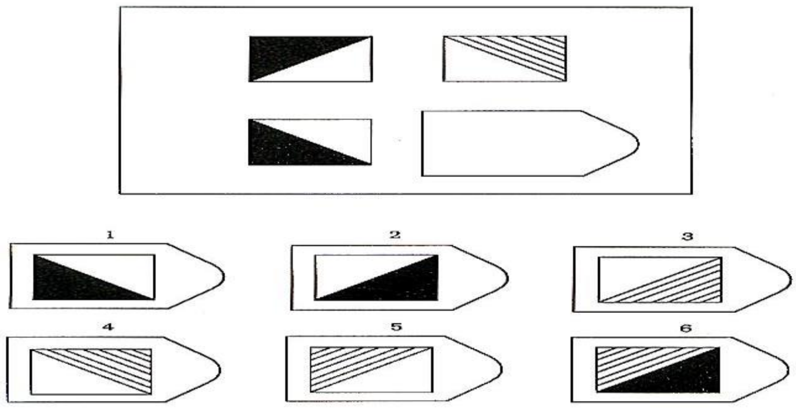

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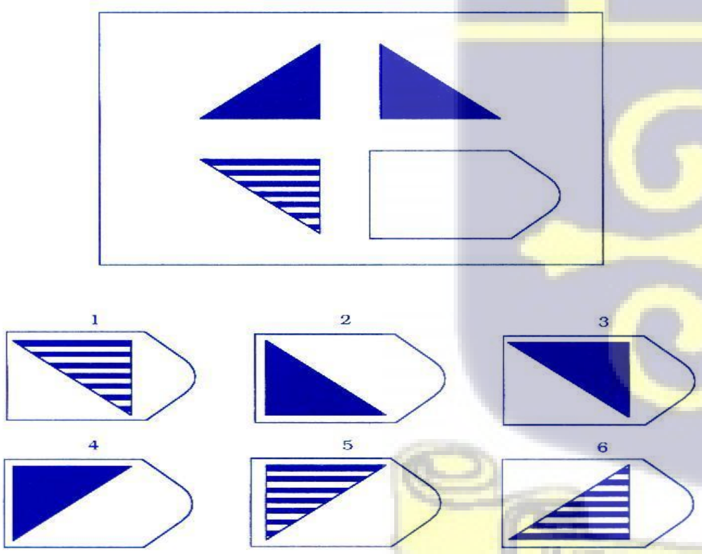

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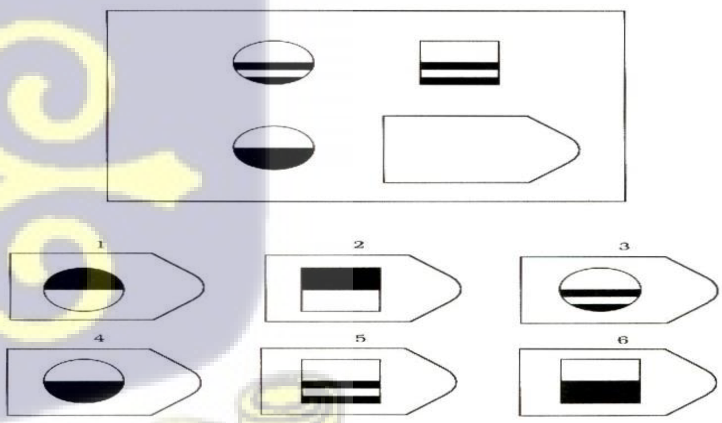

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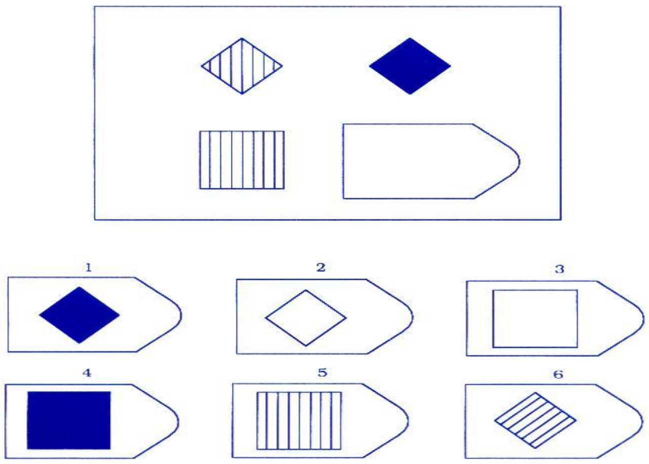

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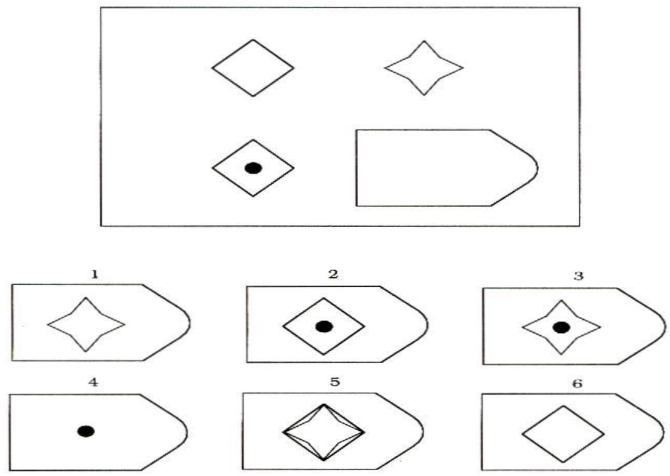

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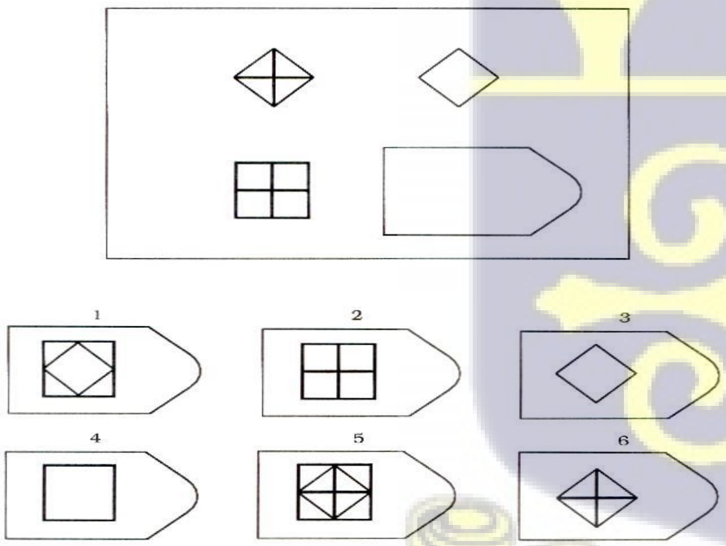

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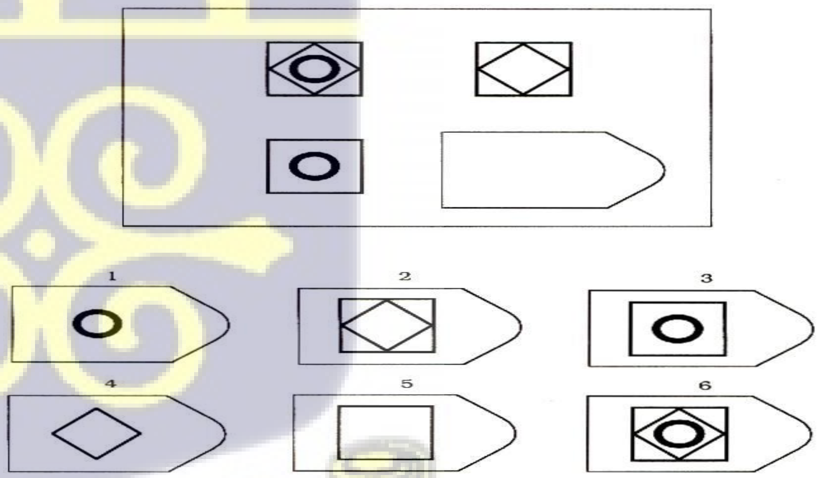

SECTION C: Letter cancellation test

LETTER CANCELLATION TEST

DIRECTIONS:

1. Cross out the letter "A" each time it appears below

A B D R T A N D L W A L D O D W

B N M D W L T S E A C T X S W G

D G A E T H B I L E A O C L O P I

A F Y U N H J I R V E Y O B E E J

N D R I H D V A Q R J I L M O T B

A W T Y I N G Y I R U I I T G R R

J T T I N R U O H T K A W F H R E

2. Cross out the letter "b" each time it appears below.

h r s h u k b f d e t u i m b f e b

d t h i p n f r y I p j g r d e t y g

r u h b d v e v o p n b c d w z w r

e f r t j b n m l o d r g b d w e r u

e r y b d r y I o m y r w r t u i o r

e r t y u n f e r t y I o p r e w x b

e r y b f e u i o t y v e c d e r y v

SECTION D: Digit memory test

1. Digits Forward

"Listen carefully as I say some numbers. When I finish, you say them in the same order".

Item	First trial	Response	/ or x	Second trial	Response	/ or x	Total
A	4 3			1 6			
B	7 9 2			8 4 7			
C	5 9 4 1			7 2 5 3			
D	9 3 8 7 2			7 5 3 9 6			
E	1 5 2 6 4 9			2 1 6 7 4 8			
F	3 7 4 5 2 6 1			4 9 2 5 3 1 6			
G	8 2 9 7 3 5 4 6			6 9 1 7 4 2 5 3			
H	2 4 6 9 3 7 1 8 5			3 7 1 6 2 5 9 4 8			
					Forwards score:		

Observations:

2. Digits Backwards

"Repeat these numbers after me, but this time I want you to say them backwards. For example, if I said '7 1', you would say ……
Lets begin…"

Item	First trial	Response	/ or x	Second trial	Response	/ or x	Total
A	8 3			2 9			
B	4 5 7			6 1 5			
C	2 6 1 9			3 8 5 2			
D	2 8 7 3 6			5 9 4 1 3			
E	6 2 4 7 1 9			2 7 6 3 9 1			
F	4 1 8 3 6 2 7			1 5 8 6 9 3 7			
G	5 2 6 2 4 1 9 7			9 6 4 1 7 3 8 5			
					Backwards score:		

Observations: