CHAPTER I

INTRODUCTION

"My darkness has been filled with the light of intelligence, and
Behold, the day-lit world was stumbling and groping in social blindness"

- Helen Keller (1920)

1.0 Introduction

The eye is truly a magnificent organ and our primary link to the outside world. The present study entitled "**Developing Spatial Ability among Visually Impaired Students**" is related to the enhancement of spatial abilities in visually impaired children. Spatial ability is a collection of cognitive skills which are responsible for the performance of the individual in different walks of life. The Spatial Abilities of Visually Impaired was compared with that of Blind-folded Sighted students. Spatial Ability in this study is related to Distance Estimation, Mental Rotation, Delineation, Assembling, and Rotational Displacement.

According to Linn and Petersen (1985) spatial ability refers to "skill in representing, transforming, generating, and recalling symbolic, non-linguistic information". This ability can be viewed as a unique type of intelligence distinguishable from other forms of intelligence. Spatial ability is of great importance for success in solving many tasks in everyday life.

Spatial abilities of the blind have long been of interest to philosophers and researchers. How we come to understand space and how we know where objects and persons are within that space is addressed by considering the perception of, and interactions with space. Emerging from this is a debate over the importance of vision versus haptics (i.e., the combination of tactile, proprioceptive, and kinesthetic information), two senses that provide a great deal of information about objects and their spatial relationships with one another. This is where an interest in blind people's spatial abilities originates; if the blind are unable to perceive or represent some aspect of space, then it is evident that vision is a necessary sense for spatial tasks. Here, follow the historical precedent of examining haptic spatial abilities in the blind. However, it is important to note that binaural auditory perception and locomotion also provide spatial information to the blind, although these are beyond the scope of this study.

In this chapter, the details with respect to Historical Foundations of Spatial ability Meaning and Concept of Spatial ability, Importance of Spatial ability, Possibilities of improving spatial ability, Need to improve Spatial abilities in visually impaired children, Rationale of the present study, Statement of the problem, Objectives of the study, Hypotheses and Delimitations have been given in separate captions.

1.1 Historical Foundations of Spatial Ability

Investigations of spatial ability, as an area of research on intelligence, began to grow in the 1800s. The early work of Sir Frances Galton focused on discovering how people differ in their “mental disposition” through the use of mental imagery. (1). According to Galton, mental imagery is “the different degrees of vividness with which different persons have the faculty of recalling familiar scenes under the form of mental pictures, and the peculiarities of the mental visions of different persons”.

From the 1930 to the 1970s, research focused on defining the major factors of spatial ability. An initial period of research from 1925 to 1938 established spatial ability as a factor apart from general intelligence. However, as factor analytic methods were developed, spatial ability was parsed into an array of factors. This era of research resulted in a multitude of factors and terminology that did not yield a clear taxonomy of spatial abilities.

In 1947, Guilford and Lacy identified two major factors, spatial visualization and spatial orientation, in which the former was described as including “the rotation of depicted objects”.

Thurstone, in 1950, defined a factor via rotations through the ability to identify an object as seen from different angles, such as a front, top, and side views. In Lohman's 1979 meta-analysis, the spatial relations factor contained rotation of objects; however, in 1988, he changed the factor name to speeded rotation. Carroll's 1993 Meta-analysis produced five major factors, including spatial relations, which pertained to the rotation of objects.

In the 1960, research on spatial abilities branched off into three different directions, a focus on the development of spatial abilities, identification of sources of variance, and the reanalysis of data using common methodological frameworks.

1.2 Concept of Spatial Abilities: Different Views

The concept of spatial ability is used for the abilities related to the use of space. Two major components of spatial ability have been identified: spatial relations and spatial visualization (McGee, 1979; Burnett & Lane, 1980; Elliot & Smith, 1983; Pellegrino *et al*., 1984; Clements & Battista, 1992).

The spatial abilities of visually impaired people have been a focus of study within psychology for both theoretical and practical reasons. They can discover a great deal about the nature of spatial representation in general by studying cases of sensory deprivation for instance, whether spatial representations are necessarily based on visually derived codes. In practical terms, a greater understanding of the way in which visually impaired people represent space is important for the development of methods for improving their spatial skills. Spatial ability is the over-arching concept that generally refers to skill in representing, transforming, generating, and recalling symbolic, nonlinguistic information. Spatial ability consists of mental rotation, spatial perception, and spatial visualization. Spatial ability, defined by a capacity for mentally generating, rotating, and transforming visual images, is one of the three specific cognitive abilities most important for developing expertise in learning and work settings. A spatial ability assessment may include items involving mentally rotating an abstract image or reasoning about an illustrated mechanical device functions. All three abilities are positively correlated, such that someone with above average quantitative ability also tends to have above average verbal and spatial ability.

Spatial concepts involve the ability to think and reason through the transformation of mental pictures. Spatial reasoning is involved in geometry, estimation and measurement, use of diagrams, graphs, and drawings, breaking fractions down into geometric regions, or conceptualizing mathematical functions. Researches provide a rationale for a shift in focus in mathematics education towards the development of spatial reasoning skills. Researchers have found a relationship between spatial skills and mathematics achievement (Casey, Nuttall, & Pezaris, 1997; Battista, 1990). In addition, their research (Casey, Nuttall, & Pezaris, 2001) and others' (Johnson & Meade, 1987) have shown that girls perform more poorly on spatial tasks involving mental transformations/rotations when compared to boys. Finally, it has been demonstrated that gender differences on these spatial skills mediate gender differences on the Math SAT's (Casey, Nuttall, & Pezaris, 1997).

According to Tartre (1990) spatial ability is the mental skills concerned with understanding, manipulating, reorganizing or interpreting relationships visually. Additionally, Lohman (1993) expressed that spatial ability may be defined as the ability to generate, retain, retrieve and transform well-structured visual images. And, a more comprehensive definition is stated by Battista and Clements (1998) as the ability to formulate mental images and to manipulate these images in the mind.

McGee (1979) stated that spatial ability has two of principal factors; spatial visualization and spatial orientation. Spatial visualization refers to the ability 'to mentally rotate, manipulate, and twist two and three dimensional stimulus objects' (McGee, 1979). Spatial orientation involves "the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the chancing orientations in which a spatial configuration may be presented, the ability to determine spatial orientation with respect to one's body" (McGee, 1979).

In the standardized spatial ability tests, spatial relations tasks involve two and three dimensional rotations and cube comparisons (Olkun, 2003). These tests aim to measure ability to mentally rotate objects. Spatial relations seem to tap the ability to engage rapidly and accurately in mental transformation or rotation processes for judgments about the identity of a pair of stimuli (Pellegrino et. al., 1984; Odell, 1993). Spatial visualization tasks require the manipulation in which there is movement among the internal parts of a complex configuration (Odell, 1993).

Spatial thinking is essential for scientific thought; it is used to represent and manipulate information in learning and problem solving (Clements and Battista, 1992;

Olkun, 2003). It is also required in many intellectual endeavors such as solving problems.

1.2.1 Spatial Relations and Spatial Visualization

A **s**patial relation, specifies how some object is located in space in relation to some reference object. When the reference object is much bigger than the object to locate, the latter is often represented by a point. In standardized spatial ability tests, spatial relations tasks involve 2D and 3Drotations and cube comparisons. Subjects are required to decide that one of the alternatives is the rotated version of the original stimulus. This factor seems to tap the ability to engage rapidly and accurately in mental transformation or rotation processes for judgments about the identity of a pair of stimuli (Pellegrino, et al., 1984). Indeed, the stimulus is rotated as a whole body.

Spatial Visualization is the mental manipulation of spatial information to determine how a given spatial configuration would appear if portions of that configuration were to be rotated, folded, repositioned, or otherwise transformed (Salthouse et.al.,1990). Spatial Visualization (Lohman, 1979) Ability to solve complex spatial-figural content. Ability in manipulating visual patterns, as indicated by level of difficulty and complexity in visual stimulus material that can be handled successful, without regard to the speed of task solution.

Spatial visualization involves complicated, multi-step manipulations of spatially presented information. These tasks require analysis of the relationship between different spatial representations, rather than a matching of those representations. Mental rotation and spatial perception may or may not be elements of the analytic strategy required to complete the task. Tests in this category include EFT, Hidden Figures and Paper Folding, Paper Form Board, Surface Development, Differential Aptitude Test (spatial relations subtest), Block Design, and Guilford-Zimmerman spatial visualization. Spatial visualization is characterized as complicated multi-step manipulations of spatially presented information

Spatial visualization is described as the ability to imagine rotations of objects or their parts in 3-D space (Burnet & Lane, 1980) by folding and unfolding, for example (McGee, 1979). The manipulation could be in a holistic, as well as piece-by-piece fashion (Battista, Wheatley &Talsma, 1989) and the movements must be imagined (Clement &Battista, 1992). The kinds of activities used to measure spatial visualization ability include form board, paper folding, and surface development. Such tasks frequently require a manipulation in which there is movement among the internal parts of a complex configuration and/or the folding and unfolding of flat patterns (Pellegrino,et al.1984). In a short definition, spatial visualization is the mental manipulation and integration of stimuli consisting of more than one part or movable parts.

Spatial visualization ability or visual-spatial ability is the ability to mentally manipulate 2-dimensional, 3-dimensional and 4-dimensional figures. It is typically measured with simple cognitive tests and is predictive of user performance with some kinds of user interfaces. **V**isualization is composed tasks that have a spatial figural component such as movement or displacement of parts of the figure, and are more complex than relations or orientation tasks.

Spatial Orientation (Lohman, 1979), ability to imagine how a stimulus array will appear from another perspective; there is often a left right discrimination. Ability to comprehend the nature of the arrangement of elements within a visual stimulus pattern primarily with respect to the examinee's body as a frame of reference.

Defines our natural ability to maintain our body orientation and/or posture in relation to the surrounding environment. Genetically speaking, humans are designed to maintain spatial orientation on the ground. The three-dimensional environment of flight is unfamiliar to the human body, creating sensory conflicts and illusions that make spatial orientation difficult, and sometimes impossible to achieve. Statistics show that between 5 to 10% of all general aviation accidents can be attributed to spatial disorientation, 90% of which are fatal. **Spatial Orientation** involves the ability to imagine how an object or array would look from a different perspective by reorienting the observer. These tasks are difficult to design because many can be solved by rotation rather than altering perspective.

1.2.2 Emphasize Spatial Language

Research has shown the importance of spatial words in studies demonstrating that parents' use of spatial words correlated to their children's spatial ability and in studies where children who were taught spatial language performed better on spatial tasks than children who were not (see Tepylo, Moss & Hawes, 2014). For younger students, this language will include words related to location, distance, orientation and direction, for example, left, right, over, under, above, below, middle, parallel, tall and short. For older students, this language will involve the geometric vocabulary of rotations, translations and transformations.

1.2.3 Spatial Perception

Spatial perception is defined as the ability to perceive spatial relationships in respect to the orientation of one's body despite distracting information. It consist of being able to perceive and visually understand outside spatial information such as features, properties, measurement, shapes, position and motion.

Linn and Petersen (1985) and Voyer and his colleagues (1995) perceive this component as the ability to determine spatial relationships with respect to the orientation of one's own body. A very similar definition is given for Spatial Orientation by McGee (1979b). Water Level Test, which involves the orientation of water line in a tilted glass, are the most commonly used tests to measure Spatial Perception skill. Voyer et al. (1995) reported male advantage with an effect size of .42 for the first test and 0.48 for the second one.

Spatial Perception is the ability to evaluate how things are arranged in space, and investigate their relations in the environment. Good spatial perception allows one to grasp the arrangement of the surroundings and his relationship to them. Spatial perception is the ability to sense the size, shape, movement, and orientation of objects. The primary sense used to perceive spatial relationships is the sense of sight, though other senses may also play a role in determining the spatial positions of objects. Like other forms of perception, spatial perception occurs both in the sensory organs that collect data about the environment and in the brain. It is possible to notice the process of spatial perception through the use of tricks such as optical illusions, but the process in which the brain creates a three dimensional map of the area is completely subconscious.

Spatial cognition is concerned with the acquisition, organization, utilization, and revision of knowledge about spatial environments. These capabilities enable humans to manage basic and high-level cognitive tasks in everyday life. Spatial cognition is a branch of cognitive psychology that studies how people acquire and use knowledge about their environment to determine where they are, how to obtain resources, and how to find their way home. Researchers from a wide range of disciplines, including neuroscience, cognition, and sociology, have discovered a great deal about how humans and other animals sense, interpret, behave in, and communicate about space.

Spatial Representation is the way in which space is represented in the brain. There are several competing models: Propositional Models: Consider space to be encoded in a propositional manner in the brain. Relations between objects, persons, and landmarks are described as propositions.

Spatial representation is different from other forms of cognitive representation studied by learning scientists-linguistic, conceptual, logical-because spatial representations partake of perceptual processes and experiences. Neurological evidence, for example, indicates that perceptual regions of the brain activate when people imagine movement (Kosslyn, 1994). Yet, spatial representations are not mere echoes of perception. They can integrate non-perceptual knowledge that allows people to imagine things they have not seen. Spatial representations have four key properties that determine their unique value for education. We begin with a brief review early psychological research on spatial memory, and then describe the four key properties.

A spatial transformation is a mapping function that establishes a spatial correspondence between all points in an image and its warped counterpart. The most elementary formulations are those that stem from a general homogeneous transformation matrix. Spatial transformation defines a geometric relationship between each point in the input and output images. An input image consists entirely of reference points whose coordinate values are known precisely. The output image is comprised of the observed (warped) data.

1.2.4 Definition of Spatial Ability

There are several approaches to how spatial ability should be defined or classified. Olkun divided spatial ability into two main categories: spatial relations and spatial visualization. According to Olkun, the spatial relations category is defined as "imagining the rotation of 2D and 3D objects as a whole body" whereas spatial visualization is defined as "imagining the rotations of objects and their parts in 3D space in a holistic as well piece by piece fashion."

McGee described spatial ability as one that requires "changing, rotating, bending, and reversing an object." In addition, Thurstone divided spatial ability into three categories: "ability to recognize the identity of an object when it is seen from different sights, the ability to imagine the movement of internal displacement among the parts of a configuration, the ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem." No matter the precise definition used, spatial ability as a whole encompasses one's ability to generate, recall, and manipulate 3D objects within one's mind.

The concept of "spatial ability" is not easily defined. Generally spatial abilities entail visual problems or tasks that require individuals to estimate, predict, or judge the relationships among figures or objects in different contexts (Elliot & Smith, 1983). More specifically, spatial abilities have to do with individuals' abilities to search the visual field, apprehend forms, shapes, and positions of objects as visually perceived, form mental representations of those forms, shapes, and positions, and manipulate such representations mentally (Carroll, 1993).

In the existing literature, the terms spatial ability, spatial skills, visualization ability, visual-spatial ability, spatial perception, spatial conceptual ability, three dimensional visualization, visual cognition and ability of visualization are used interchangeably. In this research field, researchers and mathematics educators don't agree on the use of the terminology. In the literature, the concept of spatial ability is used for the abilities related to the use of space (Olkun, 2003) or refers to the skill in representing, transforming, generating and recalling symbolic nonlinguistic information (Linn and Petersen, 1985).

According to Tartre (1990) spatial ability is the mental skills concerned with understanding, manipulating, reorganizing or interpreting relationships visually. Additionally, Lohman (1993) expressed that spatial ability may be defined as the ability to generate, retain, retrieve and transform well structured visual images. And, a more comprehensive definition is stated by Battista and Clements (1998) as the ability to formulate mental images and to manipulate these images in the mind. The existence of these different definitions triggers different definitions of components of the spatial ability. First, McGee (1979) stated that spatial ability has two of principal factors; spatial visualization and spatial orientation. Spatial visualization refers to the ability 'to mentally rotate, manipulate, and twist two and three dimensional stimulus objects' (McGee, 1979).

1.3 Spatial Skill Components

Five major area components are,

1.3.1 Distance Estimation

Estimating distance accurately is an important mobility skill for people with visual impairments. Distance estimation is the ability to an approximation of the judgment of the size, quality, place, calculation, especially value and the mentally calculated moving to far and near. Knowledge of the distance between two places can be gained in at least three ways. First, an appreciation of distance can be gained from the direct experience of walking between place A and place B. Second, even without travelling directly between two places it may be possible for a person to infer the distance between them; for example, a person who knows the relationship of place A to several other features in the environment, and the relationship of place B to the same features may be able to work out the distance between A and B. The latter process depends on the person having an accurate knowledge of the relationships between features in the environment (i.e. an accurate cognitive map of the area), from which such inferences can be made. The third way that distances, especially novel distances, can be known is from indirect sources of information - for instance, a person could be told the distance ('it's ten paces between A and B') or could use a scale map showing the distance between A and B.

Estimation is the process of determining approximate values in a variety of situations. Estimation strategies are used universally throughout daily life, but an examination of the mathematics curriculum of the past leads to the view that the strength of mathematics lies in its exactness, in the ability to determine the “right” answer. The growing use of calculators in the classroom requires greater emphasis on determining whether the answer given by a calculator or paper-and-pencil method is reasonable, a process that requires estimation ability, but efforts in support of this goal have been minimal compared to the time devoted to getting that one right answer. As a result, students have developed the notion that exactness is always preferred to estimation and their potential development of intuition may have been hindered with unnecessary calculations and detail.

1.3.2 Mental Rotation

Mental rotation is the ability to rotate mental representations of two dimensional and three dimensional objects. It means code the stimulus and identifies the motion of the object. Mental rotation is involves the ability to rapidly and accurately rotate a two- or three dimensional figure. Tests for mental rotation include the Shepard-Metzler Mental Rotation Test, Flags and Cards, Primary Mental Abilities space, Hidden Patterns, Paper Form Board, Progressive Matrices, and the Vandenberg test. Mental rotation is imagining what a stimulus would look like if it would be rotated. Mental rotation tasks are difficult. In these tasks, you might see three stimuli like in the example figure. The top one is the one that matches only one shown at the bottom. But the matching stimulus is rotated. Mental rotation on the other hand is the mental ability to manipulate and rotate 2D or 3D objects in space quickly and accurately. Mental rotation time is the time it takes you to find which one matches. It is a well-established fact that men and women perform differently on this task. Mental rotation is also unique and distinct from the other spatial abilities because it also involves areas associated with motor simulation in the brain.

Mental folding is a complex spatial visualization that involves the *folding* of 2D pattern or material into 3D objects and representations. Compared to other studies, mental folding has had relatively little research and study. In comparison to mental rotation, mental folding is a non-rigid spatial transformation ability which means features of the manipulated object end up changing unlike mental rotation. In rigid manipulations, the object itself is not changed but rather it's spatial position or orientation is, whereas in non-rigid transformations like mental folding the object and shapes are changed. Mental folding in tasks usually require a series of mental rotations to sequentially fold the object into a new one. Classic mental folding tests are the Paper folding task which is similar to Origami. Origami also requires mental folding by assessing folding a 2D paper enough times to create a 3D figure.

Mental Rotation tasks have been used to probe the mental imagery of both Visually Impaired and Sighted people. People who have been blind since birth display a response pattern which is qualitatively similar to that of sighted people but tend to respond more slowly or with a higher error rate. It has been suggested that visually impaired people code the stimulus and its motion in a different way from sighted people-in particular, congenitally blind people may ignore the external reference framework provided by the stimulus and surrounding objects, and instead use body-centred or movement-based coding systems. What has not been considered before is the relationship between different strategies for tactually exploring the stimulus and the response pattern of congenitally blind participates. Congenitally blind and partially sighted children were tested for their ability to learn and recall a layout of tactile symbols. Children explored layouts of one, three or five shapes which they then attempted to reproduce. On half the trials there was a short pause between exploring and reproducing the layouts. In an aligned condition children reproduced the array from the same position at which they had explored it; in a rotated condition children were asked to move 90^{o} round the table between exploring and reproducing the layout. Both congenitally blind and partially sighted children were less accurate in the rotated condition than in the aligned condition. Five distinct strategies used by the children in learning the layout were identified. These strategies interacted with both visual status and age. They suggest that the use of strategies, rather than visual status or chronological age, accounts for differences in performance between children.

Two spatial imagery tasks were presented to the three groups of participants: a mental rotation task and a task of mental representation of the path of a spot. In the first one, participants were asked to explore haptically Thermoformed drawings of shapes and to imagine their rotations, whereas in the second task, participants stored in memory the path of an imagined moving spot and then reproduced this path through raised-line drawings. Both tasks have often been used in recent research on mental imagery.

Participants haptically explored a geometrical Thermoformed shape model, and were then asked to indicate whether four rotated comparison shapes were the same or a mirror image of the model. Only the correctness of the response was considered, since this measure has led to contradictory results in the literature.

The angular displacement is defined as the angle through which an object moves on a circular path. It is the angle, in radians, between the initial and final positions. The act or process of turning around a center or an axis.

The Rotation is a circular movement of an object around a center or point of rotation. A three-dimensional object always rotates around an imaginary line called a rotation axis. If the axis passes through the body's center of mass, the body is said rotate upon it, or spin. A rotation about an external point, e.g. the Earth about the Sun, is called a revolution or orbital revolution, typically when it is produced by gravity.

1.3.3 Delineation

Delineation involves operation by spatial images with change in spatial image position only. It means describing and portraying something precisely**.**

1.3.4 Assembling

Assembly means putting together of the parts to make a completed product. It is the act of constructing something.

1.3.5 Rotational Displacement

Rotational Displacement required operation by spatial images with change in spatial image structure only. Rotational displacement tasks, in which participants must track an objects at a hiding locating within an array while the array rotates, exhibit a puzzling developmental pattern in humans. These developmental characteristics are unique to humans by testing rotational displacement skills. In this test is to explore the developmental time course of performance on this rotational displacement task.

Rotational displacement tasks require the participant to track an object hidden within an array while the substrate supporting that array is rotated. The rotational displacement task at first glance appears to involve a simple spatial problem, human children find this tasks relatively difficult (Barth and Call 2006; Okamoto-Barth and Call 2008). The Rotational displacement task illustrates two unique features of this spatial skill. The children take a very long time to develop rotational displacement skill. This capacity appears to be one of the latest emerging object-tracking skills, emerging years later than successful performance of problems involving invisible displacement (Call 2001; Collier-Baker et al., 2006; Piaget 1954).

1.4 How are Spatial Skills Developed?

According to Piagetian theory (Bishop, 1978), spatial skills are developed in three stages. In the first stage, topological skills are acquired. Topological skills are primarily two-dimensional and are acquired by most children by the age of 3-5. With these skills, children are able to recognize an object's closeness to others, its order in a group and its isolation or enclosure by a larger environment. Children who are able to put together puzzles have typically acquired this skill. In the second stage of development, children have acquired projective spatial ability. This second stage involves visualizing three-dimensional objects and perceiving what they will look like from different viewpoints or what they would look like if they were rotated or transformed in space. In the third stage of development, people are able to visualize the concepts of area, volume, distance, translation, rotation and reflection. At this stage, a person is able to combine measurement concepts with their projective skills.

1.5 Importance of Spatial Ability for Learning

Spatial ability is a critical skill in many different fields. The importance of spatial ability in learning different school subjects and being successful at certain jobs has been recognized globally.

Spatial abilities are pivotal constructs of all models of human abilities, for example, Guliford (1967) devoted one slice of his structure of the Intellect model to them. According Shepard (1978) high levels of spatial ability have frequently been linked to creativity, not only in the Arts, but in Science and Mathematics as well.

In Psychology Shepard (1978, 1990) stated the role of spatial imagery in his own thinking. Involuntary dream images were the source of many of his most creative and influential contributions, including the idea for his experiment with Metzler on mental rotation, the first method of non- metric multidimensional scaling, and the Computer Algorithm underlying additive non- hierarchical cluster analysis.

Smith (1964) and Ghiselli (1973) summarized studies in which spatial tests have been used to predict job performances. Spatial tests add little to the prediction of success in traditional school subjects; even Geometry after the general ability has been entered into the regression.

There are several possible reasons for the gulf between the theoretical importance of spatial abilities and their practical utility in predictive studies. First it may be that, beyond some minimum level of competence, spatial abilities are simply not that important for success in school or work. Second, the strength of spatial ability relative to other abilities, particularly verbal and phonemic fluency abilities, may be more important for predicting how problems are represented and solved rather than whether they can be solved. Third, the criterion measures used in most studies may be biased in favor of other abilities, such as verbal or reasoning skills. Fourth, existing tests may not be very good measures of spatial abilities.

Paivio (1971), has long argued for a dual code theory of memory in which verbal and spatial information is stored in different codes. More recently Anderson (1983), a long-standing opponent of this view, proposed a multi code theory of memory, with separate codes for temporarily ordered strings, spatial images, and abstract propositions. Articulated system of symbols is sufficient to account for many of the phenomena that we call mental imagery.

It is important to note that the skills that make up spatial ability are the results of long learning and training processes. The level of spatial performance something may change over time.

1.6 Importance of Spatial Ability in Visually Impaired Students

There are many reasons to be interested in spatial development. First, human spatial cognition plays a central role in our species' evolution, adaptation, and current everyday functioning. Second, spatial skills are a key component of human intellect, and hence need to be incorporated in any successful model of the architecture of the human mind. Third, there is growing evidence that spatial skills are specifically relevant to success in science, technology, engineering and mathematics (STEM) disciplines.

Students assemble puzzles, and short shapes and objects related to the topic. The visually impaired students follow the lines drew the line with pencil to spatial directions given to, locate objects in the corner to another corner, chart with pasted thread. Encourage students to locate shapes within the environment when transitioning through the school or on community outings. Intentionally discuss positional concepts (on, in, on top of, underneath, thick, thin, rough, smooth, hard, soft, etc..) and incorporate counting and patterning activities and pairing numbers with groups of objects. Encourage students to follow directions and use low vision devices to read directions and discriminate between cards. Make math fun by incorporating graphs, charts, card and board games. Incidentally embedded math pattering and positional concepts into activities of daily living as well as waiting games during transitions.

Introduce students to the circle, square, and triangle through three dimensional forms. The wooden shapes pictured to the right are available.

During creation of spatial images and operation by them, the main role belongs to thinking, representation, imagination etc. The spatial thinking is exhibited as essential element of playing, educational, labour activity of the child that is in activities, where it is necessary to use skills to be oriented in space. Therefore the spatial thinking development has very important correctional value for visually impaired children: having seized receptions both modes of creation and operation by spatial images, the children gains skills permitting to them to perfect practice Orientation & Mobility in space, to improve the quality studies of school subjects firstly Mathematics, Arts, Geography, Drawing etc. All this will promote the many-sided development of the school children and their successful social adaptation.

The spatial abilities of visually impaired people have been a focus of study within psychology for both theoretical and practical reasons. A great deal about the nature of spatial representation in general by studying cases of sensory deprivation for instance. Spatial representation are necessarily based on visually derived codes. A great understanding of the way in which visually impaired people represent space is important for the development of methods for improving their spatial skills.

1.6.1 Spatial Ability of Sighted vs Visually Impaired

Arditi et al. (1988) compared the Imagery of congenitally blind and normally sighted subjects in two experiments. The results showed that blind subjects imaged objects "within arms' reach", and with only a slight tendency to image larger objects farther from them. In contrast, sighted subjects tended to image larger objects as if they were farther away. In addition, unlike the sighted, blind subjects' images also failed to overflow an "image space" of fixed size. Finally, blind subjects were, with one exception, unable to mimic successfully the responses of a sighted person, when explicitly asked to do so.

Zimler & Keenan (1983) compared congenitally blind and sighted adults and children on tasks presumed to involve visual imagery in memory with three experiments. In all three, the blind subjects' performances were remarkably similar to the sighted. The blind, like the sighted, recalled more high-visual-imagery pairs than any others. The blind performed as well as the sighted on words grouped by color. These results challenge Paivio's theory and suggest either (a) that the visual imagery used by the sighted is no more facilitating than the abstract semantic representations used by the blind or (b) that the sighted are not using visual imagery. This finding suggests that the haptic images of the blind maintain occlusion just as the visual images of the sighted do.

Aleman et al. (2001) explored the ability of congenitally totally blind people who were contrasted with age, sex and education matched with blind-folded sighted subjects, to perform tasks which are mediated by visual mental imagery in sighted people. The results showed that although blind participants made significantly more errors than sighted participants, they were well able to perform the spatial imagery task as well as the pictorial imagery task. These results shed new light on the question whether early visual experience is necessary for performance on visual imagery tasks, and strongly suggest that vision and haptics may share common representations.

Morrongiello et al. (1995) evaluated the spatial knowledge in sighted and congenitally blind children using a large-scale four-location navigation task adapted from the work of Landau et al. (1984). Performance on the navigation and mapping tasks consistently indicated increasing cognitive mapping skills with age in sighted children. They found that blind children performed comparably to the sighted on all measures except accuracy at final position, for which their performance was worse than that of the sighted.

1.6.2 Spatial Abilities of the Blind and Visually Impaired

Although Lotze (1884) and Von Senden's (1960) extremely negative view of blind people's spatial abilities has been dismissed, several limitations have been proposed. With respect to touch, two limitations have been proposed: the low spatial acuity of touch, and the claim that touch is "sequential" (also referred to as "serial" and "successive"). These complaints have been used to support the idea that, although a spatial understanding can be gained through touch, it is rough and piecemeal compared to that gained through vision (Révész, 1950; Warren, 1984). The proposed limitation due to spatial acuity is not strong, because tactile acuity is not low enough to prohibit the discrimination of spatial relationships, at least between objects. The notion that touch is sequential has more support, and requires more consideration.

William James (1890) provided perhaps the earliest mentions of the sequential nature of touch and simultaneous nature of vision. He explained that a "seeing baby's eyes take in the whole room at once" which must then be analyzed to discern individual objects, whereas the blind child "must form his mental image of the room by the addition, piece to piece, of parts which he learns to know successively". James provided no empirical evidence to support his claim. Later, von Senden (1960) reviewed cases of blind individuals and concluded that "concerning simultaneous touch we do not in fact find any generally applicable evidence" but "there are many examples in our sources of the successive touching of larger objects which cannot be encompassed all at one time". The successive nature of touch also appeared in the influential work by Révész (1950), again with little empirical evidence. Citations attesting to the successive nature of touch often reference these early scholars without acknowledging that they were based on, at best, tenuous and subjective evidence.

The field of touch is small is strongest when a single finger is used, or the fingers are held close together. Symmons and Richardson (2000) found that blindfolded-sighted people would explore some types of raised-line drawings with a single finger a large proportion of the time. However, this may be the result of the stimuli, the participants performing according to perceived expectation, or the relatively little training and experience sighted people have relying on touch without vision. Contrary to these findings, blind people using tactile maps will often adopt a multi-finger or multi-hand strategy (Perkins & Gardiner, 2003).

1.6.3 Spatial Development in Blind Children

According to Piaget (1954), space representation is constructed based on the child's perceptions and actions in his environment. The development of the concept of space is correlated with the development of object concept, or object permanence, because for the child to progressively understand that objects exist independently from him, he has to adopt an allocentric perspective. In other words, he has to conceive of the object within a space where he himself is an object among others and in which all objects can move independently.

Piaget's (1954) words "only the degree of objectification that the child attributes to things informs us of the degree of externality he accords to space". Interacting with space plays a significant role in Piaget's view; reaching allows the child to make a practical distinction between near space (i.e., objects that can be grasped) and distant space (i.e., objects that cannot be grasped without involving locomotion). With locomotion the child is eventually able to perceive planes of depth.

Thus, Piaget postulated that concepts are not innate, nor directly perceived, but the result of a process of mental constructions of representations based on interactions with the environment.

Gibson (1969) proposed that a child directly perceives space from the environmental information gained through his senses. In her theory vision plays a distinctive role, and as the child develops he becomes able to perceive features in any sensory modality. Here again, the child's actions on the environment are of great importance, as perceiving is acting in the environment. It is through actions that affordances (i.e., those properties of the environment that are suited for direct perception) are learned. Infants are not endowed with perception of affordances, and most of their first year of life entails learning how to extract information from stimulation in their environment, which requires exploring it (Gibson, 1969, 1988). Thus, even though the space concept is not constructed, experience acting in the environment does play a role in understanding space. From either perspective, congenitally blind children's perception of space is thought to be impaired in a number of ways. Visual information is critical within both theories. For Piaget, visual cues are essential for the intertwined development of space and object concepts. These depend on the child being able to manipulate objects and thus observe the objects in different positions, as partially or fully covered, from different perspectives, and having different sizes. For Gibson, vision plays a unique role among all the senses; impairments in vision would be extremely detrimental given that development happens through perceptual learning of visual affordances. However, Gibson's idea that with development, children learn to abstract tamodal features implies that blind children could eventually perceive space using their intact senses.

In addition to visual cues, both theories stress the role of acting in the environment. Congenitally blind children show a significant delay in reaching (7-12 months according to Fraiberg, 1968; 13-32 months according to Bigelow, 1986) compared to sighted children (5 months). This delay has been used to propose that blind children are delayed in their spatial and object permanence understanding compared to sighted children. Bigelow (1986) provides an alternative explanation for this delay in line with Piaget's perspective: unlike sighted children, who start reaching in response to seeing interesting objects, blind children must first achieve a certain understanding of object concept before they can start reaching on a sound cue. Additionally, sighted children reliably reach on sound cues (10 months) later than they do on vision cues (5 months). Therefore, blind children are not delayed compared to sighted children in reaching to spatial locations using their available sense of hearing.

A blindfolded-sighted person is not equivalent to a blind person, and the way haptic and auditory cues work may differ between these groups (Warren, 1984). Furthermore, blind and sighted children will have qualitatively different experiences, shaped by their interactions with the environment and people (e.g., teachers and parents) that may have expectations regarding the child’s abilities. Additionally, research on blind infants must be understood in combination with research on blind adults. The fact that many blind adults can successfully and independently navigate their environments supports Vygotsky’s (1993) view that visually-impaired children achieve the same level of development as sighted children, albeit through qualitatively different processes.

Despite these considerations, some specific delays in the blind when compared to the sighted are logically expected and supported by empirical data. For instance, in a longitudinal study that compared blind and sighted children, Bigelow (1996) found that blind children showed a delay in using the overall layout of their homes when compared to sighted peers. These blind children used their knowledge of routes when judging straight-line distances between familiar locations until 12-13.5 years of age, when they started using overall layout. Sighted children did so by 8-9 years of age. This is clear evidence of sophisticated spatial representations by the blind of their environment, albeit delayed.

The literature reviewed here demonstrates that some aspects of blind children’s spatial development are normal when compared to the sighted (e.g., reaching towards a sound cue). Ultimately, blind children do develop an understanding of their spatial environment, but through qualitatively different means than their sighted peers.

1.7 Rationale of the Study

Spatial ability is the pivotal construct of all models of human abilities. How far we understand and represent the space around us is part of how we think and act. Spatial tasks ask where something is, and how locations relate to each other.

Vision is the most obvious source of information they have. But it is paradox to note that persons without sight from birth can be excellent at game like chess which depend essentially on thinking about movement and locations in space. Researchers identified the main difficulty for children who were congenitally totally blind are the spatial tasks especially if these require mental spatial recognizations. Miller (1994) expressed that like vision, touch and movement together provide information about shape, configurations and the relation between the surfaces. Children without sight tend to use body-centered surface frames as well as memory for movement information. Vision is not, of course, the only modality that provides the reference cues which spatial coding demands. Almost all sensory systems contribute to the information on different forms of spatial organization depend.

Spatial abilities are now understood as important to high order thinking in science, mathematics for the ability to generate and rearrange and creativity in many dimensions. Harward Gardner (1997) observed that spatial ability is one of the cognitive skills which collectively called intelligence. As per Clements and Bathisha (1992) spatial thinking is essential for scientific thought. It is used to represent and manipulate information in learning and problem solving.

A number of studies reveal that the spatial ability of Visually Impaired is no way lesser than the sighted when they tested in blind-fold. Spatial ability is of paramount importance to Visually Impaired children to learn science and mathematical concepts, verbal and phonemic fluency, Orientation & Mobility and problem solving. This important area is completely neglected in the academic and functional curriculum of Visually Impaired children. There are hardly studies available in this area in Indian context.

Hence an investigation was planned in this direction to train the Visually Impaired children in spatial ability using appropriate activity. This study intended to give specific information on the spatial ability of Visually Impaired children, activities to develop spatial ability and the training instructions to develop spatial ability. Therefore it was considered important to plan a study in the educational setting.

In this study the performance in the components of spatial ability namely Distance Estimation, Mental Rotation, Delineation, Assembly, Rotational Displacement, and Transformation were studied as dependent variable in relation to Type of children, Gender and Grade as independent variables besides treatment in the present Experimental study.

1.8 Operational Definition

The Statement of the problem is worded as **'Developing Spatial Ability among Visually Impaired Students'**.

The main goal of this study is to Develop Spatial Ability among Visually Impaired Students. Here, in this study, the visually impaired students indicated students with total vision loss who did not have residual vision to do any task visually. They used non-visual techniques to gather information.

This study excluded students having low vision or residual vision who may use both visual and non-visual techniques to gather information.

Blind-folded Sighted students in this study indicated students having normal vision but participated by occluding their vision with a Blind-fold made up of clothes while performing the spatial ability test.

Spatial ability skills in this study used i) Distance Estimation i-e. estimating the distance within the hand reach up to 3 meters, ii) Mental Rotation assessment involves mental representation of 3 dimensional objects, iii) Delineation involves operation by spatial images which means identifying from the outlines of the forms, iv)Assembling here, indicates make a whole form from parts and v) Rotational Displacement indicates track an object/shape at a hiding location within an array while the array rotates.

1.9 Objectives

The Objectives of the study were to:

1. Develop Spatial Ability among Visually Impaired students in terms of Distance Estimation, Mental Rotation, Delineation, Assembly and Rotational Displacement.
2. Compare the Pre and Post mean scores in Distance Estimation, Mental Rotation, and Delineation, before and after intervention.
3. Compare the Pre and Post mean scores of Control and Experimental Group in terms of different skills involved in Spatial Ability.
4. Compare the Gain Score of Experimental and Control group with respect to different spatial skills.
5. Study the Association between Type of Students viz Visually Impaired and Blind-folded Sighted and Time Taken to perform Assembly Test and Rotational Displacement.
6. Study the influence of Gender and Type of Students and their interaction on Spatial Ability.
7. Study the influence of Grade and Type of Students and their interaction on Spatial Ability.
8. Find out the Relationship between Braille Reading Skills and Spatial Ability.

1.10 Hypotheses of the Study

1. There is no significant difference between the Pre and Post mean scores of students belonging to Experimental and Control Group in the Spatial Ability tests namely Distance Estimation, Mental Rotation, Delineation, Assembling and Rotational Displacement.
2. There is no significant difference in the Spatial Ability with respect to different components of spatial skills.
3. There is no significant difference between Control and Experimental Group in terms of different skills involved in Spatial Ability.
4. There is no significant difference between Experimental and Control in their Gain Score.

5. There is no significant influence of Gender and Type of Students and their interaction on Spatial Ability.
6. There is no significant influence of Grade and Type of Students and their interaction on Spatial Ability.
7. There is no significant Association between Type of Students viz., visually impaired and blind-folded sighted students and Time Taken to perform Assembly test and Rotational Displacement test.
8. There is no significant relationship between Braille Reading Skills on Spatial Ability.

1.11 Scope of the Study

Spatial Ability is a neglected area in the case of a Visually Impaired persons. By this study, the importance will be given to improve the Spatial Ability of Visually Impaired students. With the use of training strategies given in this study, the teacher can train the students in developing their Spatial Ability. The student can be benefited through the training package developed, in improving their Spatial Ability. The training institutes can incorporate a component of spatial ability in the curriculum. It will also be helpful for parents to give activities that develop the Spatial Ability of their children.

1.12 Delimitations

The following were the limitations of the study:

1. The present investigation being an Experimental study was confined to 120 samples.
2. The study was confined to only three districts (Coimbatore, Salem, and Madurai in Tamil Nadu).
3. The study was confined to totally blind students.
4. The study was restricted to students from class V to VIII.

1.13 Organization of the Thesis

The present study "**Developing Spatial Ability among Visually Impaired Students"** is organized and reported under the chapters.

Chapter I: The first chapter presents Introduction, History of Spatial Ability, Concept of spatial ability, Developing spatial ability for Visually Impaired children, Spatial ability Blind and Sighted, Rationale of the study, and Scope of the study and Delimitation.

Chapter II: The second chapter presents the review of literature related to the present study.

Chapter III: The third chapter explains the research procedure, which includes the methods adopted in the study, construction of tools, selection of samples, administration of the tools and Data collection procedure.

Chapter IV: The fourth chapter deals with the tabulation, analysis and interpretation of the data in detail.

Chapter V: The fifth chapter reports the findings, recommendations and suggestions. This is followed by bibliography and appendices.

The review of related literature is presented in the next chapter.