AUDITORY LOCALISATION: EFFECTS OF SOUND LOCATION AND SPATIAL SEMANTIC PROCESSING IN INDIVIDUALS WITH RIGHT-LEFT ORIENTATION DIFFICULTY

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CERTIFICATE

This is to certify that the dissertation entitled **"Auditory Localisation: Effects of Sound Location and Spatial Semantic Processing in individuals with Right-Left Orientation Difficulty"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 14AUD029). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
May, 2016

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Mysuru,

May, 2016

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DECLARATION

This is to certify that this dissertation entitled **"Auditory Localisation: Effects of Sound Location and Spatial Semantic Processing in individuals with Right-Left Orientation Difficulty"** is the result of my own study under the guidance of **Dr. Asha Yathiraj**, Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Abstract

Aim: The aim of the study was to investigate the effect of spatial semantic information on auditory localisation in congruent conditions (spatial verbal command & direction of stimuli matched) and incongruent conditions (spatial verbal command & direction of stimuli not matched) in children without and with right-left disorientation.

Method: Two groups of participants in the age range of 8 to 12 years (N = 30, 15 in each group), one group without right-left disorientation and one group with right-left disorientation based on the 'Right-Left Orientation Test' (Rigal, 1994) were evaluated. 'Spatial localisation' that required responses to a source location irrespective of word meaning and 'semantic localisation' that required responses to a word meaning irrespective of source location were studied. Further, responses to congruent (same source location & stimulus word meaning) and incongruent stimuli (different source location & stimulus word meaning) were also compared. The participants responded using a response box that generated different tones for markings indicating 'right', 'left', 'front' and 'back'. The stimuli were presented through four different speakers located at 90º (right), 270º (left), 0º (front) and 180º (back) azimuth. Each stimulus that was presented from a loudspeaker as well as the tone generated when the participant responded was recorded on a laptop loaded with Adobe Audition (Version 3). This recording was further analysed to find response accuracy and measure reaction time.

Results: A Shapiro Wilk test of normality was done initially that revealed that the response accuracy data were not normally distributed while the reaction time data were normally distributed. Hence, nonparametric tests were used to evaluate response accuracy and parametric tests were used for reaction time. The relation between the absolute scores of 'Right-Left Orientation Test' and response accuracy for spatial and semantic localisation revealed no significant correlation between the two. However, the relation between the absolute scores of 'Right-Left Orientation Test' and reaction time for spatial and semantic localisation revealed a significant moderate negative correlation. Within both the groups of participants, no significant difference in response accuracy for

congruent and incongruent stimuli for spatial and semantic localisation was found. However, a significant difference in reaction time was noted for congruent and incongruent stimuli for both localisation types. The reaction time for congruent stimuli was always better than for incongruent stimuli. Further, no significant difference in either response accuracy or reaction time was found between spatial and semantic localisation. When comparisons were done between males and females, a significant difference in response accuracy only for semantic localisation was found. Likewise, comparisons between the participant groups revealed that those without a right-left disorientation always had faster reaction times than participants with right-left disorientation. This was observed for both spatial and semantic localisation. However, no significant difference in response accuracy was found between the two groups.

Conclusions: Thus, from the current study it can be inferred that, the performance would be similar for both spatial and semantic localisation and they can affect each other. Also, it can be concluded that children with right-left disorientation may exhibit a delay in reacting when the activities at hand involve the words right-left. Such a delay in response, may lead to disruptions in school related activities involving the words right-left due to a communication breakdown. Therefore, it is important to detect the situations that may lead to delayed response due to the right-left confusions and training for the same is necessary.

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Chapter 1

Introduction

Auditory localisation is viewed as the act, process, or ability of identifying the physical location of an object or the origin of a given activity in space. This element of auditory spatial perception is considered to be critical for human effectiveness and personal safety (Letowski & Letowski, 2012). Impairment in the ability of auditory localisation of any sound source is reported to reduce a person’s communication skills (Kühnle et al., 2013). Measurement of auditory localisation ability in free field is considered as an integral measure of binaural hearing, since it is a process that utilises binaural hearing (Van Deun et al., 2009).

Human sound localization is reported to be mediated by a wide variety of cues. As reported in several studies on auditory localisation, the primary acoustical cues that are used include the frequency-dependent patterns of interaural time and intensity differences that result from diffraction of incoming sound waves around the head and pinna (Macpherson & Middlebrooks, 2002; Middlebrooks, Makous, & Green, 1989; Shaw, 1974; Wightman & Kistler, 1992). These cues are considered important for horizontal plane localisation of pure-tones, based on the Duplex theory by Rayleigh (1907). Also, for medial plane localisation spectral cues are reported to be utilised (Butler & Belendiuk, 1977; Macpherson & Middlebrooks, 2002). However, research regarding the effect of semantic information in sound localization is limited.

Studies in literature have been carried out with congruent or incongruent spatial semantic stimuli (Palef & Nickerson, 1978; Yao, 2007). Stimuli containing spatial semantic information that match the physical dimension of the stimulus (source direction) have been termed as congruent, and those that do not match have been termed as incongruent. In such conditions an auditory Stroop like effect is considered to take place according to Yao (2007). The Stroop effect has been studied widely in the visual domain, where conflict or the interaction between perceptual and semantic processes have been evaluated (Cowan & Barron, 1987; Joseph & Proffitt, 1996; Lutfi-Proctor, Elliott, & Cowan, 2014; Naor-Raz, Tarr, & Kersten, 2003; Stroop, 1935). Posner and Snyder (1975) reported that Stroop interference was assumed to occur due to the to-be-ignored verbal dimension of the stimulus being processed automatically.

In line with the visual Stroop effect, studies have been conducted using auditory stimuli. Studies in literature have examined the effect of semantic processing in tasks other than localisation such as semantic priming. These studies have investigated processing of words using lexicon decision tasks and they report that subjects make faster responses when a semantically related prime word precedes the target word. However, they make marginally slower responses when the prime is unrelated to the target (Bentin, McCarthy, & Wood, 1985; den Heyer, Briand, & Dannenbring, 1983; McNamara, 2005; Neely, 1991; Tweedy, Lapinski, & Schvaneveldt, 1977).

Similarly, it has been observed that during localisation, human beings have the potential advantage to use verbal stimuli or semantic content in stimuli rather than localising based on just the physical sound. Also, in natural or everyday situations the most frequent sound stimuli remain to be words rather than just sounds. As this verbal information or semantic cues in stimuli can assist in making localisation simpler, they are also noted to result in interferences when the semantic cues and auditory locations vary (Yao, 2007).

Thus, from the review of literature it can be seen that when semantic cues are present in the auditory stimuli they may be processed automatically. The localisation performance has been found to be disrupted when irrelevant or incongruent stimuli are used.

1.1 Need for the study

In everyday situations, individuals are exposed to verbal stimuli and their semantic cues are likely to influence auditory localisation processes. Since these cues influence differently in different situations, it is important to know the conditions in which the cues assist in auditory localisation or degrade localisation performance. According to the American Speech-Language-Hearing Association Task Force on Central Auditory Processing Consensus Development (1996, 2005), those with central auditory processing disorders are observed to have deficiencies in several auditory behaviours, with one of them being deficiency in sound localization and lateralization. Also, studies report comorbidity of central auditory processing disorders with learning disability and/or attention deficit hyperactivity disorder (Gomez & Condon, 2015). Children with these disorders have also been described to have right-left orientation problems and this has been noted to hamper their performance in day-to-day activities, especially in school (Torgesen, 1977).

Inability in correctly localizing the source of stimuli could distract children from attending to the task at hand and thereby disrupt communication. Thus, there is a need to check whether there is any relationship between congruency of semantic stimuli and localization and determine the way they are related in children with and without right-left confusions. This will help detect the localization difficulties of these children so that recommendations for rehabilitation can be provided for them.

1.2 Aim of the study:

The aim of the study was to investigate the effect of spatial semantic information on auditory localisation in congruent conditions (spatial verbal command & direction of stimuli match) and incongruent conditions (spatial verbal command & direction of stimuli do not match) in children with and without right-left disorientation.

1.3 Objectives of the study:

- To investigate the relationship between right-left disorientation and spatial and semantic localisation in terms of response accuracy and reaction time.
- To investigate the effect of spatial semantic information on auditory localisation in terms of response accuracy and reaction time in congruent stimuli (spatial verbal command & direction of stimuli match) and incongruent stimuli in children without and with right-left disorientation.
- Compare spatial localisation and semantic localisation in terms of response accuracy and reaction time in children without and with right-left disorientation.

- Compare the performance of children without and with right-left disorientation in terms of response accuracy and reaction time for spatial and semantic localisation.
- Compare the performance of males and females in terms of response accuracy and reaction time for spatial and semantic localisation.

Chapter 2

Review of Literature

Auditory localisation is known to be a process that utilises binaural hearing. This binaural hearing is considered important for the perception of acoustic space (Kühnle et al., 2013). Auditory localisation, an element of auditory spatial perception is viewed to be critical for human effectiveness and personal safety (Letowski & Letowski, 2012). It has been reported to be an important aspect in everyday life as it aids in various situations like improving orientation, communication in noisy environments and discrimination of multiple speakers (Kühnle et al., 2013). Inability to correctly localize the source of stimuli has been found to cause distractions from attending to the task at hand and thereby disrupt a communication process. Bronkhorst (2000) and Kidd et al. (2005) reported that knowing where to listen improves situational awareness, speech perception, and sound source identification in the presence of other sound sources. Studies in literature have provided information on localisation abilities in typically developing children as well as those with deviancies. This has been studied in terms of 'semantic localisation' and in terms of 'spatial localisation'.

2.1 Auditory localisation in typically developing children

In general, various studies on auditory localisation report that there are mainly two types of cues that aid auditory localisation. These include interaural time difference and interaural intensity difference (Middlebrooks et al., 1989; Middlebrooks & Green, 1990; Shaw, 1974; Wightman & Kistler, 1992). These studies report that interaural time difference (differences in arrival time of the sound at the two ears) mainly provides cues for low frequency sounds whereas interaural intensity difference (differences in amplitude of the sound at the two ears) is important for localising high frequency sounds in the horizontal plane. For broadband signal, both cues are reported to be used by listeners. For the medial or vertical plane localisation, spectral cues are noted to play a crucial role (Butler & Belendiuk, 1977; Macpherson & Middlebrooks, 2002). Although most of these studies have been done in adults, a few studies report that similar cues are utilised by children also (Kühnle et al., 2013; Litovsky, 1997; Litovsky & Ashmead, 1997).

Researchers carrying studies in localization, in children, have modified the procedures used on adults so as to make them suitable for testing them. Adult procedures are not considered suitable for testing young children because they usually require long test sessions, high levels of concentration, and abstract responses. However, it is noted that it is difficult to modify the procedures without losing accuracy (Van Deun et al., 2009).

Kühnle et al. (2013) studied localisation accuracy (sound source identification task) and auditory spatial discrimination acuity (by measuring minimum audible angle) in 136 normal hearing children and adolescents. In the first part of the study, localisation accuracy was investigated, wherein to each of the 14 loudspeakers placed between $+90^{o}$ to -90^{o}, 6 stimuli were presented. The participants were asked to point to the perceived location of sound source using a laser pointer. The second part of the study was done to find the minimum audible angle, wherein a 3-alternative forced-choice procedure was employed. The participants were asked to identify a different stimulus source among a set of 3. A response box was used as a mode to obtain the responses. The results of the study indicated that children acquire similar localisation accuracy as adults by 6 years of age whereas the minimum audible angle thresholds decreased from early school age till adolescence. Thus, the authors concluded that localization accuracy and spatial discrimination acuity showed different developmental courses.

Similarly, Van Deun et al. (2009) investigated the potential developmental trends for sound localisation, lateralisation and binaural masking level difference in a group of 33 children between 4 and 9 years of age. Also 5 adults in the age range of 23 to 27 years were studied. For the sound localisation experiment, the participants had to identify the target speaker out of 9 loudspeaker positions. The mode of response used was different for adults and children. Adults had to say aloud the speaker number from which the sound was perceived. On the other hand the children were required to carry out activities like pointing to pictures or a telephone game that required them to call a particular person designated for each loudspeaker. Similar modifications were done for experiments 2 and 3 wherein pictures were used for children to hold on their attention. Also, practice trials were given only for children. The results of this study showed that the modified procedures were suitable for testing children from the age of 4 to 5 years. Furthermore, they reported that the binaural hearing capacities of the 5 year olds were similar to those of adults.

Thus, from the review of these studies it can be concluded that children use similar cues as adults for auditory localisation. Children acquire similar binaural hearing capacities in terms of sound localisation by 5 years of age. However, the procedure used for testing children requires to be modified to make the task interesting and to hold the child’s attention to get accurate responses.

Besides evaluating localisation abilities of individuals based on acoustic cues, studies have also determined the effects of localisation based on semantic cues. These studies have assessed how individuals are able to localise stimuli based on the meaning of the words. The following section provides details of such studies.

2.2 Semantic localisation

In natural situations, most often human beings are exposed to auditory stimuli that are words or sentences that contain semantic information rather than just non-speech sounds. The influence of semantic information in tasks other than localisation, like semantic priming have been studied. Results of these studies indicate that participants respond faster to those words that are preceded by a related prime (Bentin et al., 1985; den Heyer et al., 1983; McNamara, 2005; Neely, 1991; Tweedy et al., 1977).

It has been demonstrated that the reaction time and accuracy of localisation are influenced by the semantic properties of stimuli. Words or sentences that contain semantic information are processed automatically and are considered to aid in localisation rather than just localising based on physical sound. However, it has been noted that there may be situations where this semantic information could interfere with the localisation process (Yao, 2007). Depending on the semantic information contained in the stimuli, localisation may be become an easier task or more difficult task. Thus, semantic information may either help or interfere with auditory localisation.

2.2.1 Advantage of semantic information in localisation

Support that semantic processing could assist in localising faster was reported by Muller and Bovet (2002). Using first names of the subjects and first names of other people as stimuli, they measured response accuracy and reaction time for localising stimuli. Although they did not report of a significant difference in terms of response accuracy, they found that subjects localised early when their first name was given as the stimulus. This study suggested that if localisation was supposed to take place based only on the auditory information irrespective of the semantic content in the stimuli, then there should have been no difference in reaction times for localising any linguistic stimuli. The authors report, the fact that subjects were able to localise faster when their own names were given, indicates that semantic content is processed automatically and thus affects localisation.

Similar to the study by Muller and Bovet (2002), Loomis, Lippa, Klatzky, and Golledge (2002) evaluated the influence of spatial language and sound localisation in a navigation task. The participants had better and precise localisation when given special based instructions such as ‘1 O’clock, 3 m’ rather than localisation based on just the 3D sound. This showed that the semantic content in the stimuli helped in more precise localisation than the physical sound alone.

2.2.2 Interference by Semantic Stimuli

While studies have demonstrated that semantic content in stimuli aids in localisation (Loomis, Lippa, Klatzky, & Golledge, 2002; Muller & Bovet, 2002), it has also been noted that in certain conditions the semantic content could delay or degrade localisation (Loomis et al., 2002; Muller & Bovet, 2002; Yao, 2007). As described in the earlier section, Muller and Bovet (2002) measured response accuracy and reaction time for localisation, when first names of subjects and first names of other people were used as stimuli. They report that when names other than the first name of participants were presented, localisation was delayed. Likewise, Loomis et al. (2002) evaluated the influence of spatial language and sound localisation in a navigation task. Spatial stimuli were given that either matched the actual position of source or were different from the sound source. They reported that if spatial stimuli given were different or did not match the actual position of sound source, then the localisation performance degraded.

Evidence for the same has also been given by Palef and Nickerson (1978) and Yao (2007) who noted that when semantic cues were present in the stimuli did not match the sound source, auditory localisation performance degraded. In the study by Palef and Nickerson (1978) congruent and incongruent stimuli were considered. Stimuli containing spatial semantic information that match the physical dimension of the stimulus (source direction) were termed as congruent, and those that did not match were termed as incongruent. The words right, left, front and back were given randomly from 4 different speakers that were placed to the right, left, front and back of the subject. Subjects were instructed to respond to the source of stimuli (speaker) irrespective of the stimulus word. The results indicate that when the stimulus word was not same as the speaker, auditory localisation was delayed which indicates that semantic information in the stimuli could interfere and hence degrade auditory localisation. Thus, auditory localisation was reported to be faster with congruent stimuli than incongruent stimuli.

Thus, from the review of various studies it can be concluded that semantic content in the auditory stimuli can effect auditory localisation. It has been demonstrated that semantic content can affect response accuracy or reaction time. However, the way the semantic information can affect localisation may depend on whether the conditions are congruent or incongruent.

2.3 Stroop Effect

Studies involving congruent and incongruent stimuli have usually investigated Stroop effect. Stroop effect refers to the difficulty observers have in eliminating meaningful but conflicting information from a task, even when that information is irrelevant or counterproductive in that task (Lu & Proctor, 1995). Stroop effect has been studied widely in the visual domain, where conflict or the interaction between perceptual and semantic processes have been evaluated (Cowan & Barron, 1987; Joseph & Proffitt, 1996; Lutfi-Proctor et al., 2014; Naor-Raz et al., 2003; Stroop, 1935). Originally, the procedure to evaluate Stroop effect was described by Stroop (1935). This method of selective attention has been used later by Jensen and Rohwer (1966) and Dyer (1973). The task is reported to be carried out by asking the participants to name the colours of patterns of ink that spell the names of other conflicting colours, e.g., the word ‘red’ printed in blue ink. Normal individuals have been reported to have unusual difficulty ignoring the irrelevant verbal content and focusing exclusively on the ink colour. This was found to result in disruption and delay in colour naming relative to control conditions such as naming colours of square ink patterns. However, when participants were asked to read the word irrespective of the colour in which it was printed, they were reported to have less difficulty. Hence, although the word was printed in an incongruent colour, the task of reading the word was less affected and did not result in any disruption or delay. Posner and Snyder (1975) reported that Stroop interference was assumed to occur due to the to-be-ignored verbal dimension of the stimulus being processed automatically.

2.3.1 Auditory Stroop Effect

In line with the visual Stroop effect, studies have been conducted using auditory stimuli also. Studies have used physical dimension like high pitch vs. low pitch with the semantic content such as words high vs. low to study auditory Stroop effect (Cohen & Martin, 1975; Shor, 1975). Studies by Cohen and Martin (1975) and Shor (1975) investigated auditory Stroop effect in two conditions. In one condition the participants were asked to judge the pitch of stimuli as high or low irrespective of the word being told and in another condition to respond to the word told irrespective of its pitch. They used congruent conditions (word high told in high pitch and word low in low pitch) and incongruent conditions (word high told in low pitch and word low in high pitch). The results of the study were similar to that of the visual Stroop task. The participants had faster reaction times for congruent conditions as compared to incongruent conditions when they were asked to judge the pitch of stimuli irrespective of the word meaning. However, there was no effect of pitch when they were asked to respond to the word.

Similarly, Green and Barber (1983) studied auditory Stroop effect using the voices of male and female speakers. The voice of male and female speakers was required to be identified by subjects irrespective of words being told in one condition whereas in another condition they were to respond to the words irrespective of the voice. The target words used were ‘man’ and ‘girl’. In the congruent conditions a male voice said ‘man’ and female voice said ‘girl’ and in the incongruent conditions it was vice versa. They too obtained results similar to that of Cohen and Martin (1975) and Shor (1975) wherein the participants had faster reaction times for congruent conditions as compared to incongruent conditions when they were asked to identify the voice of the speaker. However, there was no effect of voice when they were asked to respond to the target words.

Jerger, Martin, and Pirozzolo (1988) developed a paediatric auditory version of the Stroop procedure to investigate its developmental trend. They studied 48 children in the age range of 3 to 6 years wherein a reaction time task was employed. The children were asked to press a particular button for a particular voice irrespective of what was said (mommy button for female voice and daddy button for male voice). Four conditions were included that involved a no semantic content (ba-ba), a neutral condition (baseball or ice-cream), a congruent condition (female saying mommy and male saying daddy) and a conflicting condition (female saying daddy and male saying mommy). It was found that in all children the reaction time increased for conflicting conditions (semantic content and perceptual dimension did not match) whereas reaction time decreased for congruent conditions (semantic content and perceptual dimension matched). Also, since the 3 year old children were also able to complete the procedure accurately, the authors report that mapping of the heard word to meaning occurred automatically during the listening process even in listeners as young as 3 years of age. Additionally, the magnitude of the Stroop interference effect was considered to reflect a developmental course. Using this they noted that most age related changes occurred between 3 to 4 years of age.

2.3.2 Spatial Stroop Effect

In a variation of a Stroop task, spatial interference was investigated and this has been termed as spatial Stroop effect (MacLeod, 1991). Lu and Proctor (1995) reported that spatial Stroop tasks are measured using verbal or symbolic stimuli, combining a semantic attribute that designates spatial 1ocation or direction with a physical stimulus position attribute. By manipulating the semantic and physical position variables, the spatial Stroop stimulus was presented in a congruent or incongruent condition with the meaning signified by the semantic attribute.

White (1969) used a procedure wherein the directions north, south, east, and west were signified by a stimulus that was presented inside of a square, at the top, bottom, right, or left respectively. The participants were required to respond to the location in which the stimulus appeared by saying the appropriate direction name or moving a lever in one of four corresponding directions. In an incongruent condition, the stimulus was a direction word (North, South, East, or West) that did not match the word's position. In the control condition, the stimulus was a row of asterisks. Interference scores were computed by calculating the ratio of the time to respond to a list of 80 items for the incongruent condition with respect to the time to respond to a list of the same length in the control condition. The interference score was 1.2 for the naming responses but close to 1.0 for the manual responses, indicating that an incongruent word slowed vocal responses to stimulus location but not manual responses.

A study by Harvey (1984) investigated spatial Stroop effect where the location of two, 2-letter words (HI, LO) were to be judged as high or low. The participants were instructed to press a key indicating if the stimuli were same or different. It was reported that subjects responded 76 ms faster on an average for congruent conditions as compared to incongruent conditions.

The spatial Stroop effect has also been obtained for more complex displays in which all elements are not integrated within a single stimulus. Philip and Seymour (1973) used stimulus-displays in which both a location word (Above, Below, Left, or Right) and a dot were presented simultaneously. The subjects were asked to name the position of the dot relative to the word or the location of the word relative to the dot. It was found that the meaning of the word had little effect on the time to name the dot location, but it had a significant effect on the time to name the location occupied by the word. Responses to the word's location were particularly slow when the word specified the opposing location on the same dimension (e.g., the word Left in the right location).

Thus, from the review of various studies it can be concluded that reaction time is better or faster for congruent conditions than incongruent conditions. Also, it can also be concluded that the reaction time for a Stroop activity varied depending on the task involved. In visual Stroop tasks, naming acolour of a printed word was reported to be more affected in incongruent conditions than just reading a word. Likewise, in auditory tasks, judging the pitch was found to be more affected in incongruent conditions than just responding to the word meaning. Similar asymmetry was noted in spatial Stroop tasks also. Thus, there were variations in responses depending on stimuli used within each modality.

2.4 Acquisition of Right-Left orientation in children

Right-left discrimination or orientation is described as a skill that all normal children acquire, to varying degrees, in the process of growing and developing. There are indications that the discrimination of right-left is one of several essential skills that form the basis for the acquisition of more complex sensorimotor, perceptual, and intellectual skills. Also, it is considered important to test right-left discrimination in school-going children and train those children who have a problem as such difficulties may hamper learning of reading, writing, arithmetic and music (Boone, 1965).

Studies in literature report that acquisition of right-left orientation happens in three phases. At first, children learn to distinguish right and left on their own bodies, then on other persons, and finally they can describe the position of a number of objects in relation to one another (Belmont & Birch, 1963; Elkind, 1961; Lacoursiere-Paige, 1974). Several tests have been developed to find the normative developmental schedules of right left orientation.

Belmont and Birch (1963) used the Piaget battery of right-left awareness that measures right-left discrimination in relation to objects as well as body parts. The study was carried out on 148 normal children aged 5 to 12 years. It was found that children were able to discriminate right-left on themselves by 7 years. However, right-left discrimination in relation to objects in environment was achieved only by 9 to 11 years.

The normative data regarding the acquisition of right-left discrimination was established for children aged 5 to 10 years by Boone and Prescott (1968) using the 'Left-Right Discrimination Test'. The test was conducted on 600 normal children who were required to identify left and right using large cards with coloured circles printed on them. The children were required to point to items within the picture such as point to the lower right circle, higher left circle. It was found that right-left errors linearly decreased with increase in age. Children were able to achieve adult like scores by 9 to10 years. However, the study has been criticized by Schulman (1974) as no attempt was made to evaluate right-left discrimination directly on the children themselves.

Rigal (1994) investigated the age at which children begin to use the terms right and left appropriately. They studied three complementary aspects of left-right orientation. The first one was right-left discrimination where the children had to discriminate if two images were same or different. An example of a different task involved a picture of a boy raising his right hand and a picture of same boy raising his left hand. The second aspect involved memory and also involved a discrimination task. This required a child being able to identify all pictures that were similar to one particular target picture. For example child was required to identify all pictures where a boy raised his right hand. In both of the first two aspects there was no usage of the actual terms right and left. The third aspect involved right-left identification wherein actual usage of terms right or left was involved. An example of this task was the ability to answer questions like ‘Which hand did you burn?’ with the answer being ‘right’ or ‘left’ instead of just showing the hand. According to Rigal, children acquire the words in two large steps. In the first step they are able to apply and identify the words right and left on themselves. This occurred by 7 years of age wherein the words right and left were identified in an absolute way. However, as they develop, by the age of 8 to 9 years they were able to identify the words on others and relative to some item in the environment (Eg. The item is to the right of, or to the left of something). They also reported that children were first able to identify right-left orientation on people facing away, and later do so on people facing them around. Further, it was noted that the reaction time decreased and response accuracy increased with increase in age. By 9 to 11 years, adult like responses were achieved.

Thus, from the review of these studies it can be concluded that as cognitive abilities develop, children are able to use the terms right-left appropriately in different aspects. Different tests used across studies lead to similar conclusions that children acquire right-left orientation in three phases and the complete development takes place by 9 to 10 years of age.

2.5 Right-Left orientation problems in children

Knowledge of development of right-left orientation is considered important because of its significance in development of language and reading functions, normal educational functioning and personality patterning (Belmont & Birch, 1963). It has been suggested that knowledge of right-left orientation is essential for the development of learning of reading, writing, arithmetic and music (Boone, 1965).

Studies in literature report right-left orientation problems to be present as a symptom in different disorders. Right-left discrimination was first observed in the form of acquired behavioural deficit in patients with cerebral disease. However, disturbance in right-left discrimination can also occur as developmental deficits in mental defectives, in children with reading disability, and in brain damaged children as well as in adults (Benton, 1959). Benton (1959) reported that right-left confusion is considered as a basic symptom of central nervous system impairment. Children with disorders like (Central) Auditory Processing Disorders and learning disability have also been described to have right-left orientation problems and this has been noted to hamper their performance in day-to-day activities, especially in school (Torgesen, 1977).

The review of various studies in auditory localisation, suggests that similar cues as in adults are used by children for localisation and children achieve adult like localisation skills by 5 years of age. However the method of testing needs to be modified for children to maintain their attention. Also, it is clear that the semantic information in the auditory stimuli can influence localisation differently depending on whether the condition is congruent or incongruent. For spatial Stroop tasks, the stimuli used in the study could be words like right/left. Hence it is important to know the age at which usage of these terms is acquired. Studies reported in literature have shown that right left orientation and usage of these terms is appropriately achieved by 9 to 10 years of age.

From the review of literature it is clear that auditory Stroop tests, similar to the ones used to evaluate the visual modality, have even been found to give a comparison of the ability of individuals to orient semantic and spatial stimuli. While studies provide information about how semantic and spatial orientation develops in children, information about the use of such orientation in children with right-left orientation problems is limited. Such information will provide a guideline to handle such children to help them deal with their problems.

Chapter 3

Methods

The study was conducted with the aim to investigate the effect of spatial and semantic information on auditory localisation in children without and with right-left disorientation. Standard group comparison design was used. This was done using two localisation tasks, one dealing with 'spatial localisation' of the auditory stimuli and the other involving 'semantic localisation' of the auditory stimuli. In each of these, two types of stimuli were present, one being congruent stimuli (same source location and stimulus meaning) and the other being incongruent stimuli (different source location and stimulus word meaning).

3.1 Participants

Two groups of participants were included in the study. Group-I consisted of 15 children with no right-left orientation problems and Group-II consisted of 15 children with right-left orientation problems, classified based on the 'Right-Left Orientation Test' by Rigal (1994). The participants from both groups were regular school-going children above the age of 8 years, the age by which they should have a firm grasp of the knowledge of right-left (Rigal, 1994; Clark & Klonoff, 1990). They were exposed to English language for at least 3 years. A convenient sampling technique was used to select the schools from which the participants were chosen and a purposive sampling technique was used to select the participants from within the schools.

3.1.1 Participant selection criteria for Group I:

The participants had air-conduction and bone-conduction thresholds less than 15 dB HL in the frequencies 250 to 8 kHz and 250 to 4 kHz respectively. They were included in the study only if they had speech identification scores above 80%; A/As tympanogram with reflexes present, confirming the presence of normal middle ear function; and TEOAE amplitudes of > 6 dB SNR in at least 3 consecutive frequencies indicating normal outer hair cell functioning. Further, they were required to have passed the 'Screening checklist of Auditory processing' developed by Yathiraj and Mascarenhas (2003, 2004), and should have had no history of failures in any of the previous academic classes. The absence of any right-left orientation problems was ascertained using the 'Right-Left Orientation Test' by Rigal (1994).

3.1.2 Participant selection criteria for Group II:

The participant selection for Group-II was similar to Group-I. However, they were included in the study only if they were confirmed to have right-left orientation problems as per the 'Right-Left Orientation Test' by Rigal (1994).

3.2 Test Environment

The diagnostic tests for the participants to pass the selection criteria were carried out in a two chamber sound treated room. Ambient noise levels in the testing room met the criteria as per American National Standards Institute (2008). The localization experiments were carried out in a well-illuminated, semi-sound treated room with minimum reverberation and visual distracters. This facility had provision to evaluate localization of the participants.

3.3 Equipment

A calibrated dual channel diagnostic audiometer (GSI Audio StarPro) was used to carry out pure-tone audiometry and speech audiometry. For estimating air-conduction and bone-conduction thresholds, TDH-39 headphones with MX-14 ear cushion and Radioear B-71 bone vibrator were used respectively. Immittance evaluation was carried out with a GSI-Tympstar, to ensure the presence of normal middle ear function. Otoacoustic emission test was done using a laptop loaded with ILO-V6 software to ensure normal outer hair cell functioning.

A computer loaded with Cuebase software along with Lynx Aurora 16 sound card and signal router was used to present the test stimuli for the localization experiments. The stimuli were developed and played using Adobe Audition (Version 3) software that was loaded in a desktop computer with an Intel (R) Xeon (R) processor. The recording of stimuli was done using Motu, microphone and MX-41 adapter in order to get clear stimuli with minimum background noise. Four calibrated Genelee 8020B loudspeakers, connected to the computer were made use of to present the stimuli during the localization experiment. The loudspeakers were placed 2 m from the head of the participants at 90º (right), 270º (left), 0º (front) and 180º (back), as shown in Figure 3.1. The output of all the loudspeakers output were calibrated with the help of a sound level meter (Larson and Davis 824).

A software on a Moto E Android touch screen phone was used as a response box for the participants to select their responses. This consisted of 4 coloured squares labelled ‘right’, ‘left’, ‘front’ and ‘back’, which on pressing produced 4 different tones. To measure the reaction time of the participants to the stimuli presented, a Toshiba laptop loaded with Adobe Audition (Version 3) was utilised.

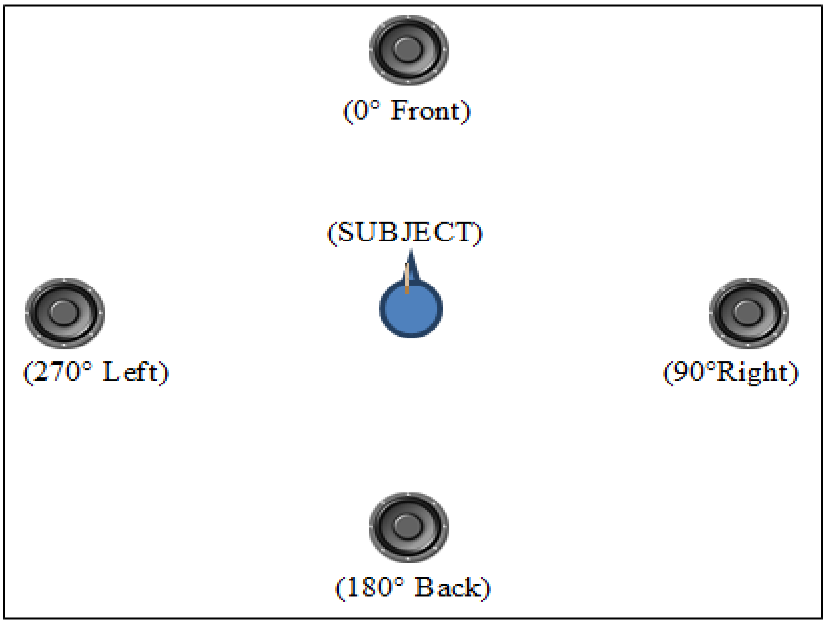


Figure 3.1: Experiment set-up

3.4 Material

The ‘Right-left orientation test’ by Rigal (1994) was used to check for right-left confusions among participants. The test consisted of 3 subsections that included right-left identification on self, right-left identification on others and right-left identification on images. The test had a total of 32 tasks. The test was translated to Kannada to identify right-left orientation problems in the Kannada speaking children. Reverse translation was also done to check if the words used in Kannada were appropriate.

Four words representing spatial information (‘right’, ‘left’, ‘front’ & ‘back’) in Indian-English were audio recorded by a female who was fluent in Indian-English. The recording was done using Adobe Audition (Version 3). The sampling frequency was 44100 Hz with 16 bit resolution. A directional microphone, placed 6 cm away from the mouth of speaker, was used for recording. The female recording the stimuli was instructed to enunciate all words with similar vocal effort, with not much change in intonation pattern. The inter-stimulus interval between the words was 4s. The stimulus duration was about 500 ms and the intensity was maintained at 65 dB SPL. The intensity level of the stimuli played through the computer was calibration using a Sound Level meter (Larson and Davis 824). The required output level was attained by manipulating the volume control in the computer as well as the audio software.

3.5 Procedure

Prior to testing the participants, informed consent was obtained from their caregivers as detailed in the ethical guidelines of AIISH (Ethical guidelines for bio-behavioural research involving human subjects, 2009). The participants, who were tested one at a time, were made to sit facing the front speaker (0^o azimuth), which served as the reference point. The stimuli were presented from the desktop computer, the output of which was routed randomly to any of the 4 loudspeakers placed in front, back, left and right of the participants. The participants were instructed to respond by touching the appropriate coloured square on the Android phone given to them that had markings indicating the four loudspeakers. The touching of each square produced different frequency tones. The responses of each of the participants were instantaneously audio recorded on a Toshiba laptop loaded with Adobe Audition (Version 3). The laptop was placed to the side of the participants in the experimental room, with the recording mode on. The laptop was kept out of the line of vision of the participants to avoid distractions. It was ensured that, the laptop microphone could pick up the stimuli from loudspeakers and the response from Android phone. Each stimulus that was presented from a loudspeaker as well as the tone generated when the participant responded were recorded. Using this recording the reaction time was measured for each stimulus-response set. The participants were informed that in case they were unsure of a response they could guess and were required to respond for every stimulus.

Two forms of localisations were evaluated, ‘spatial localisation’ and ‘semantic localisation’. For ‘spatial localisation’ the participant was instructed to press the appropriate button on the response box (Android phone) with reference to the source of the stimuli, irrespective of the meaning. For example, if the stimulus ‘right’ arrived from the left speaker, the participant was instructed to press the left button, which was the stimulus location. The delivery of the stimuli was congruent or incongruent. The congruent stimuli had the same source location and stimulus meaning (Eg. The stimulus word ‘right’ would be delivered from the right speaker). The incongruent stimuli had different source location and stimulus word meaning (Eg. The stimulus word ‘right’ would arrive from the left, front or back speaker).

For ‘semantic localisation’, the participants were instructed to press the appropriate button on the response box (Android phone) based on the meaning of the stimuli, irrespective of source location or direction. For example, if the stimulus word ‘right’ arrived from the left speaker, the participant was instructed to press the right button. Congruent and incongruent stimuli were presented, as described earlier.

A set of 4 practice trials were given in each condition. Forty-eight stimuli were presented randomly from the 4 loudspeakers. Of them, 12 stimuli were presented through each loudspeaker in a random order, with 3 being congruent and 9 being incongruent.

The ‘spatial localisation’ and ‘semantic localisation’ tasks were counter balanced across participants. Thus, half the participants were first tested with the former task followed by the latter and vice versa for the remaining half of the participants. Adequate breaks were provided if any child showed signs of fatigue or inattention.

3.6 Scoring:

The audio recorded responses of the participants on Adobe Audition were used to calculate the response accuracy and reaction time of each participant. *Response accuracy* was measured by comparing the tone pressed by the participant with the actual response required manually. If they matched it was considered as a correct. If there was no response or the response occurred after the next stimulus, it was considered as a wrong response. Further, if a participant pressed the response button twice for one stimulus, only the first response was considered.

Reaction time was calculated for each response by identifying on the recorded waveform the end of a stimulus and beginning of the tone in response to the stimulus. The duration difference between the end of stimulus and start of tone was calculated as the reaction time. The reaction time was not computed for wrong responses.

The response accuracy and reaction time were computed for the congruent and incongruent stimuli within the 'spatial localisation, and 'semantic localisation' tasks. The above were done for participants from both groups.

3.7 Statistical Analyses

Descriptive and inferential statistics were carried out. Initially a Shapiro Wilk test of normality was carried out that revealed that the reaction time data were normally distributed, whereas the response accuracy data were not. Hence, mixed ANOVA (parametric test) was carried out to compare reaction time across conditions (congruent/incongruent, spatial localisation /semantic localisation) and between groups. On the other hand, Wilcoxin-Signed Rank test (nonparametric) was performed to compare response accuracy across conditions (congruent/incongruent, spatial localisation/semantic localisation) and Mann Whitney U test (nonparametric) was done to compare between groups.

Chapter 4

Results

The correlation between spatial and semantic auditory localisation with congruent and incongruent stimuli in children with and without right-left disorientation was investigated. Thus, right-left disorientation served as the independent variable and 'spatial localisation' and 'semantic localisation' served as the dependent variables. The dependent variables were scored in terms of 'accuracy' as well as 'reaction time'. For each form of localisation ('spatial localisation' & 'semantic localisation'), the performance of the participants to 'congruent stimuli' wherein the stimulus word meaning matched the source location and 'incongruent stimuli' wherein the stimulus word meaning did not match the source location were analysed. The data were statistically analysed using SPSS software (Version 20).

Initially, Shapiro Wilk test of normality was done that revealed that the scores of the response accuracy data were not normally distributed, whereas the scores of the reaction time data were normally distributed. Hence, for the analyses of response accuracy, nonparametric tests were done and for reaction time, parametric tests were done.

The results of study are provided under the following sections:

4.1 Relation between 'Right-Left Orientation Test' and Response Accuracy as well as Reaction Time for 'Spatial Localisation' and 'Semantic Localisation'

4.1.1 Relation between 'Right-Left Orientation Test' and response accuracy for 'spatial localisation' as well as 'semantic localisation' (assessed using Spearman's rank-order correlation)

4.1.2 Relation between 'Right-Left Orientation Test' and reaction time for 'spatial localisation' as well as 'semantic localisation' (evaluated using Pearson's product-moment correlation)

4.2 Comparison of Responses to Congruent and Incongruent Stimuli for 'Spatial Localisation' and 'Semantic Localisation' for each participant group (children without and with right-left disorientation)

4.2.1 Comparison of response accuracy for congruent and incongruent stimuli for 'spatial localisation' as well as 'semantic localisation' for each participant group (tested using Wilcoxon-Signed Rank test)

4.2.2 Comparison of reaction time for congruent and incongruent stimuli for 'spatial localisation' as well as 'semantic localisation' for each participant group (tested using mixed ANOVA)

4.3 Comparison of Responses to 'Spatial Localisation' and 'Semantic Localisation' for each participant group (children without and with right-left disorientation)

4.3.1 Comparison of response accuracy for 'spatial localisation' and 'semantic localisation' for each participant group (tested using Wilcoxon-Signed Rank test)

4.3.2 Comparison of reaction time for 'spatial localisation' and 'semantic localisation' for each participant group (tested using mixed ANOVA)

4.4 Comparison of Responses to 'Spatial Localisation' and 'Semantic Localisation' between participant groups and between genders

4.4.1 Comparison of response accuracy for 'spatial localisation' and 'semantic localisation' between males and females (tested using Mann Whitney U test)

4.4.2 Comparison of reaction time for 'spatial localisation' and 'semantic localisation' between males and females (tested using mixed ANOVA)

4.4.3 Comparison of response accuracy for 'spatial localisation' and 'semantic localisation' between participant groups (tested using Mann Whitney U test)

4.4.4 Comparison of reaction time for 'spatial localisation' and 'semantic localisation' between participant groups (tested using mixed ANOVA)

Given below are details of the findings of the study. Wherever possible, the results of the descriptive statistics as well as inferential statistics are provided for parameters listed above.

4.1 Relationship between 'Right-Left Orientation Test' and Response Accuracy as well as Reaction Time for 'Spatial Localisation' and 'Semantic Localisation'.

The absolute scores obtained in the 'Right-Left Orientation Test' were correlated with response accuracy and reaction time for the 'spatial localisation' and 'semantic localisation' for all subjects. Since the data for response accuracy did not follow normal distribution as revealed by Shapiro Wilk test, Spearman's rank-order correlation was used as a measure to find relationship between response accuracy and absolute scores on the 'Right-Left Orientation Test'. However, data for reaction time followed the normal distribution pattern, hence, Pearson's product-moment correlation was used as a measure to find relationship reaction time and absolute scores of 'Right-left Orientation Test'.

4.1.1 Relation between 'Right-Left Orientation Test' and response accuracy for 'spatial localisation' as well as 'semantic localisation'

The correlation between the absolute scores of the 'Right-Left Orientation Test' and percentage scores of the *response accuracy for 'spatial localisation'* was done with all participants merged (i.e. males, females, & those without and with right-left disorientation). The results of the Spearman's test revealed no significant correlation ($r = 0.29$; $p > 0.05$) between the two. This is also evident from the scatter plot depicting this relationship in Figure 4.1.

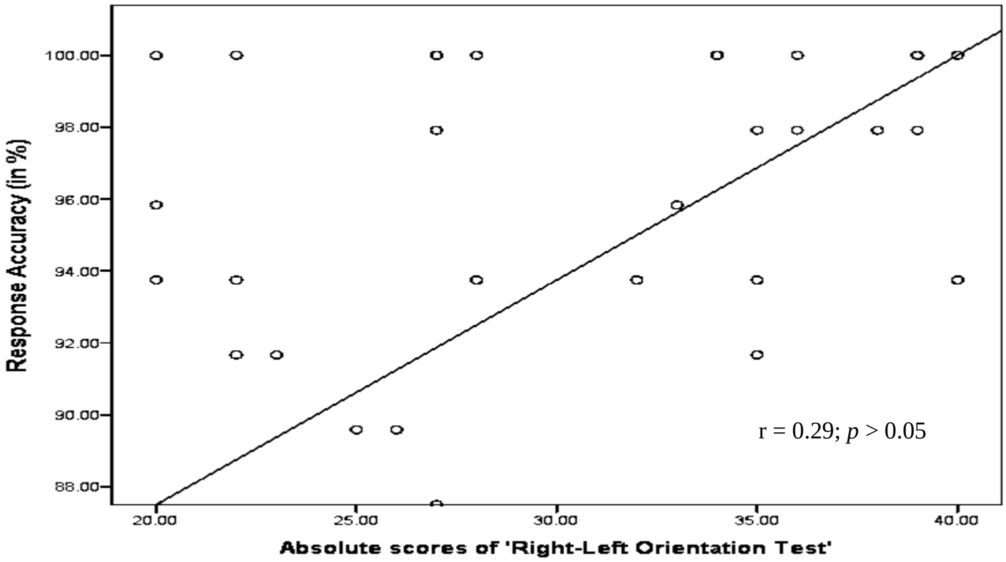


Figure 4. 1: Scatter plot depicting the relation between the absolute scores of 'Right-Left Orientation Test' and response accuracy for 'spatial localisation'

Similarly, the absolute scores were correlated with *response accuracy for 'semantic localisation'*. No significant correlation (r = 0.18; $p > 0.05$) was obtained between them. The lack of correlation can also be seen in Figure 4.2 that shows that the accuracy responses were highly scattered.

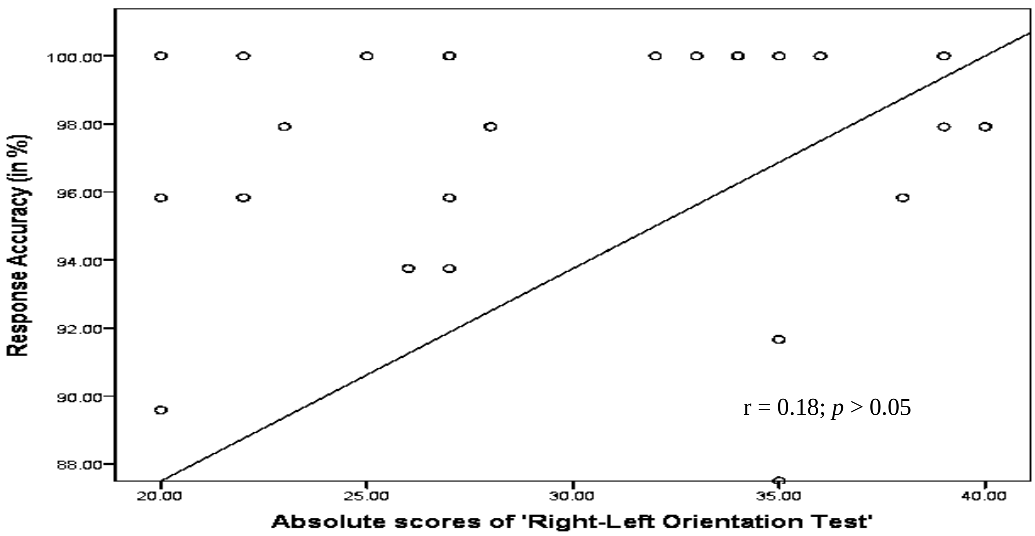


Figure 4. 2: Scatter plot depicting the relation between the absolute scores of 'Right-Left Orientation Test' and response accuracy for 'semantic localisation'

4.1.2 Relation between 'Right-Left Orientation Test' and reaction time for 'spatial localisation'

Correlation between absolute scores of 'Right-Left Orientation Test' and *reaction time for spatial localisation* was measured using Pearson's product-moment correlation. Unlike the results of response accuracy, the results of this analysis revealed a significant moderate negative correlation (r = -0.68; $p < 0.05$) between absolute scores and reaction time. Thus, as scores on the 'Right-Left Orientation Test' increased, the reaction time decreased as can also be seen in the scatter plot (Figure 4.3).

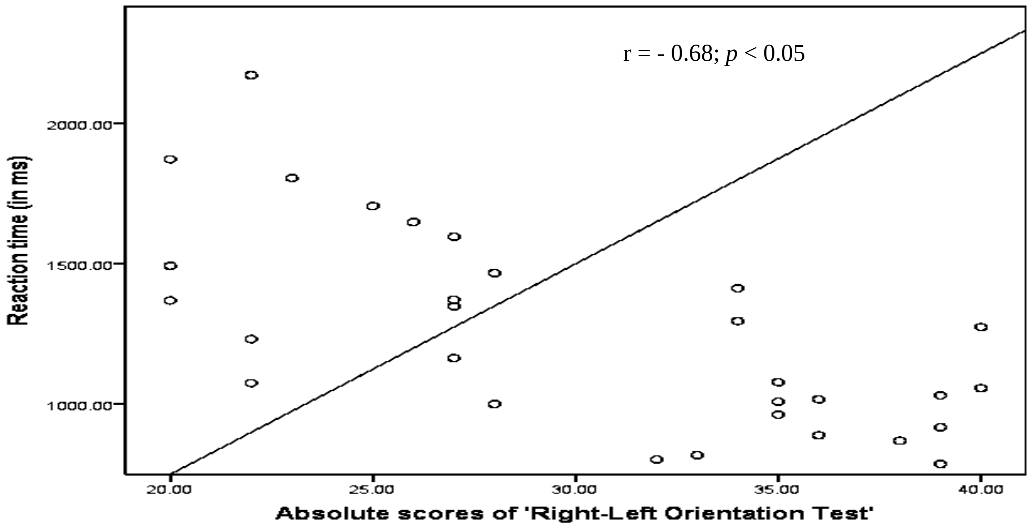


Figure 4. 3: Scatter plot depicting the relation between the absolute scores of 'Right-Left Orientation Test' and reaction time for 'spatial localisation'

Similarly, a Pearson's product-moment correlation was carried out to check if there was a correlation between absolute scores of the 'Right-Left Orientation Test' and *reaction time for semantic localisation*. As seen with the reaction time response for the spatial localisation, a significant moderate negative correlation (r = -0.65; $p <$ 0.05) was seen between absolute scores and reaction time for semantic localisation (Figure 4.4).

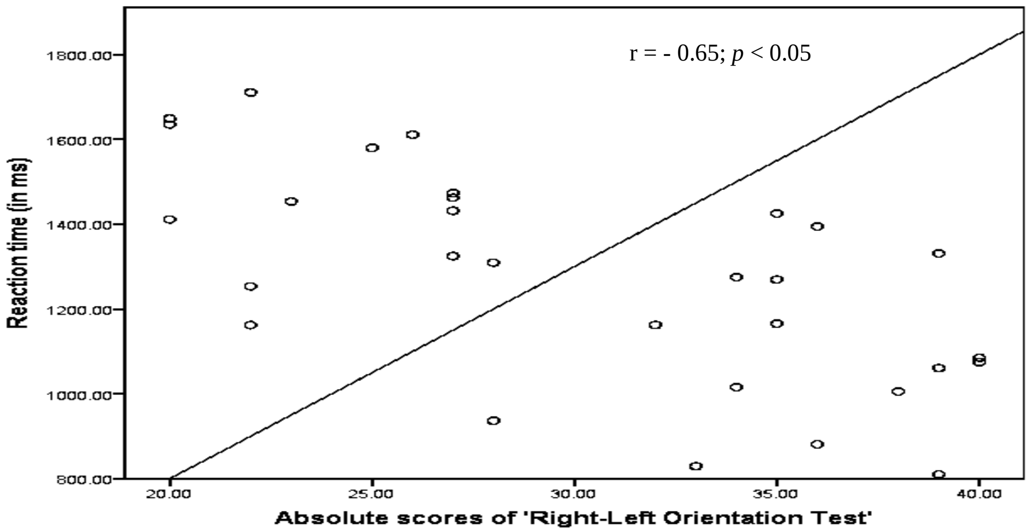


Figure 4. 4: Scatter plot depicting the relation between the absolute scores of 'Right-Left Orientation Test' and reaction time for 'semantic localisation'

4.2 Comparison of Responses to Congruent and Incongruent Stimuli for 'Spatial Localisation' and 'Semantic Localisation' for each participant group (children without and with right-left disorientation)

To find the effect of congruency, response accuracy for congruent stimuli and incongruent stimuli were compared for spatial localisation as well as semantic localisation. This was done separately for the children with no right-left disorientation and for children with right-left disorientation using Wilcoxon-Signed Ranked test. Similar comparisons were made for reaction time using ANOVA.

4.2.1 Comparison of response accuracy for congruent and incongruent stimuli for 'spatial localisation' as well as 'semantic localisation' for each participant group

The mean, median and standard deviation of response accuracy for congruent stimuli and incongruent stimuli for the 'spatial localisation' and 'semantic localisation' are provided in Table 4.1. These descriptive statistics indicated that the accuracy in responses were similar for the congruent and incongruent stimuli. This was true for the spatial localisation and semantic localisation. This group information was also reflected in the individual responses of the participants as can be seen in

Figure 4.5 for response accuracy for spatial localisation and Figure 4.6 for response accuracy for semantic localisation.

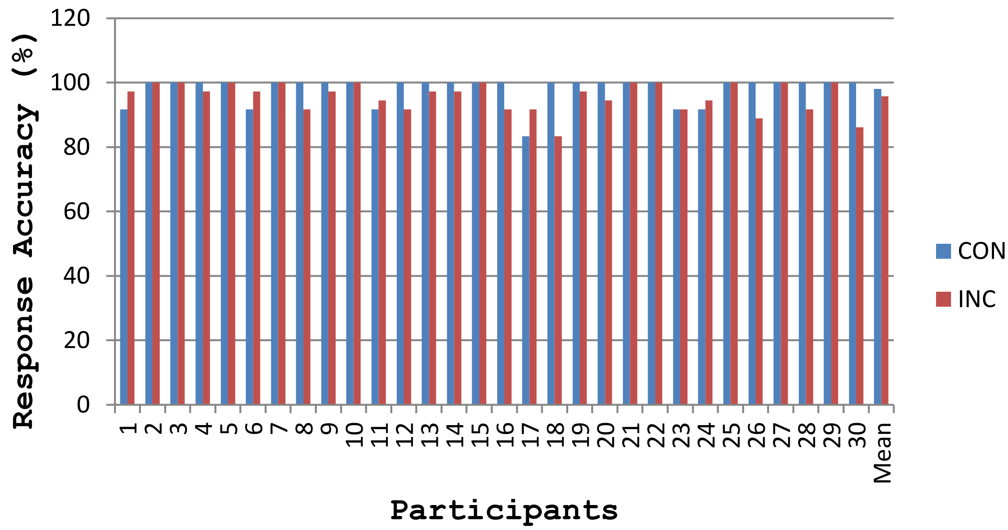
Table 4. 1: *Mean, Median and Standard Deviation (SD) for Response Accuracy (%) of Congruent and Incongruent Stimuli for 'Spatial Localisation' and 'Semantic Localisation'*

			GROUP					
Gender	**Localisation**	**Congruency**	**GROUP I**			**GROUP II**		
			Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
Male	Spatial	CON	97.91	100.00	3.86	96.87	100.00	6.20
	Spatial	INC	97.91	98.61	2.87	93.74	93.05	5.50
	Semantic	CON	96.87	100.00	6.20	96.87	100.00	4.31
	Semantic	INC	96.87	98.61	4.31	94.44	94.44	3.63
Female	Spatial	CON	98.80	100.00	3.15	98.80	100.00	3.15
	Spatial	INC	96.82	97.22	2.97	94.44	94.44	5.78
	Semantic	CON	100.00	100.00	0.00	100.00	100.00	0.00
	Semantic	INC	98.85	100.00	2.08	98.85	100.00	2.08
Total	Spatial	CON	98.33	100.00	3.45	97.77	100.00	4.94
	Spatial	INC	97.40	97.22	2.86	94.07	94.44	5.44
	Semantic	CON	98.33	100.00	4.67	98.33	100.00	3.45
	Semantic	INC	97.73	100.00	3.49	96.50	97.22	3.69

Note. CON = Congruent Stimuli; INC = Incongruent Stimuli;

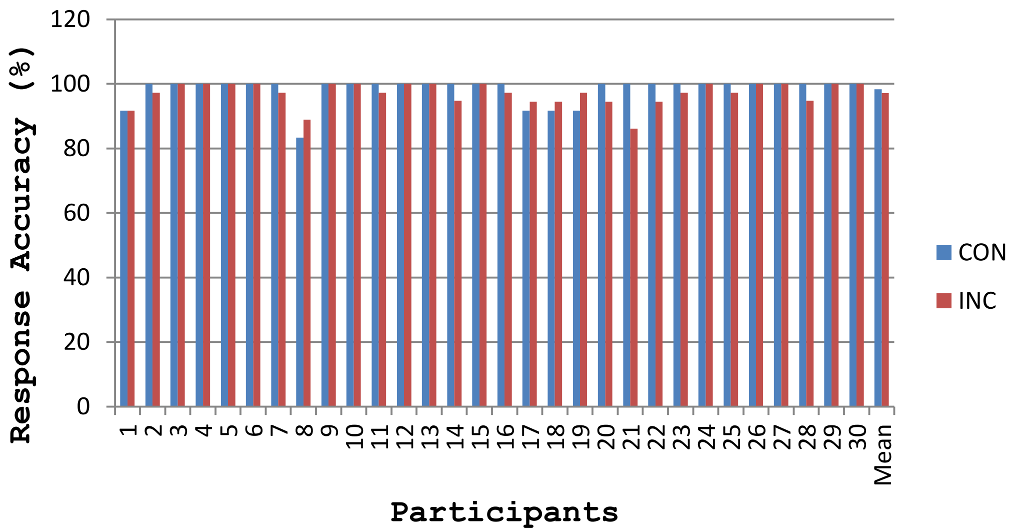
Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation;

Maximum possible score = 100%



Note. CON = Congruent stimuli; INC = Incongruent stimuli

Figure 4. 5: Individual response accuracy (%) for congruent and incongruent stimuli for spatial localisation



Note. CON = Congruent stimuli; INC = Incongruent stimuli

Figure 4. 6: Individual response accuracy (%) for congruent and incongruent stimuli for semantic localisation

Further, to find if there was a significant difference, Wilcoxon-Signed Rank test was done to compare the response accuracy for congruent stimuli and incongruent stimuli for spatial localisation. The results confirmed that there was no significant difference between congruent and incongruent stimuli in terms of *response accuracy for spatial localisation* (Table 4.2).

Table 4. 2: *Effect of Congruency for 'Spatial Localisation' for Response accuracy (%)*

Stimuli (CON-INC)	Males		Females	
	Group I	Group II	Group I	Group II
|z|	0.00	1.21	1.23	1.46
Sig	1.00	0.22	0.21	0.14

Note. Sig = Level of significance; CON = Congruent stimuli; INC = Incongruent stimuli;

Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation

A similar analysis was done for semantic localisation. As seen for the spatial localisation, *response accuracy* was not significantly different between congruent and incongruent stimuli for *semantic localisation* (Table 4.3).

Table 4. 3: *Effect of Congruency for 'Semantic Localisation' for Response accuracy (%)*

Stimuli (CON-INC)	Males		Females	
	Group I	Group II	Group I	Group II
|z|	0.00	1.40	1.34	1.34
Sig	1.00	0.16	0.18	0.18

Note. Sig = Level of significance; CON = Congruent stimuli, INC = Incongruent stimuli

Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation

4.2.2 Comparison of reaction time for congruent and incongruent stimuli in 'spatial localisation' and 'semantic localisation'

The mean and standard deviation of the reaction time (ms) for congruent and incongruent stimuli were calculated for spatial localisation and semantic localisation (Table 4.4). In general, the mean reaction time for congruent stimuli was lower than that for incongruent stimuli in both forms of localisation. It can be observed from Figure 4.7 and Figure 4.8 that the individual data followed the similar trend as that seen in the group data. In most participants the reaction time for congruent stimuli was lesser (better) than reaction time for incongruent stimuli for both forms of localisation. However, the extent to which the reaction time reduced for congruent stimuli varied from one participant to the other.

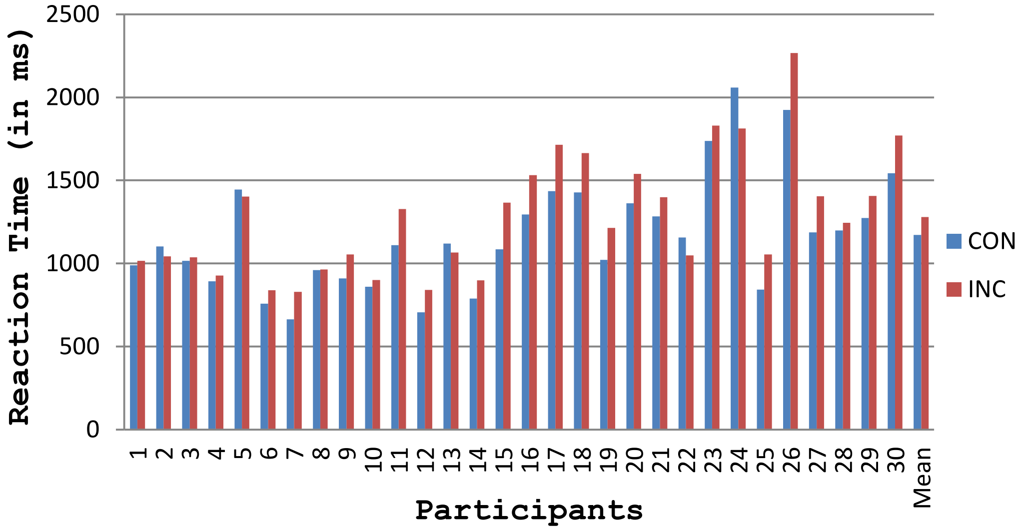
Table 4. 4: *Mean and Standard Deviation (SD) for Reaction Time (ms) of Congruent and Incongruent Stimuli for 'Spatial Localisation' and 'Semantic Localisation'*

Gender	**Localisation**	**Congruency**	**Group**			
			Group I		**Group II**	
			Mean	**SD**	**Mean**	**SD**
Male	Spatial	CON	977.81	236.21	1339.44	212.30
	Spatial	INC	1006.97	180.11	1492.36	261.70
	Semantic	CON	1033.45	223.52	1288.81	125.85
	Semantic	INC	1124.58	234.36	1500.56	155.93
Female	Spatial	CON	939.85	167.54	1432.22	435.12
	Spatial	INC	1064.48	210.70	1565.04	410.31
	Semantic	CON	1080.38	153.98	1394.64	304.80
	Semantic	INC	1157.85	182.78	1408.57	278.03
Total	Spatial	CON	960.09	200.78	1382.74	325.53
	Spatial	INC	1033.80	190.07	1526.28	328.33
	Semantic	CON	1055.35	189.02	1338.20	225.21
	Semantic	INC	1140.11	205.12	1457.63	218.04

Note. CON = Congruent Stimuli; INC = Incongruent Stimuli;

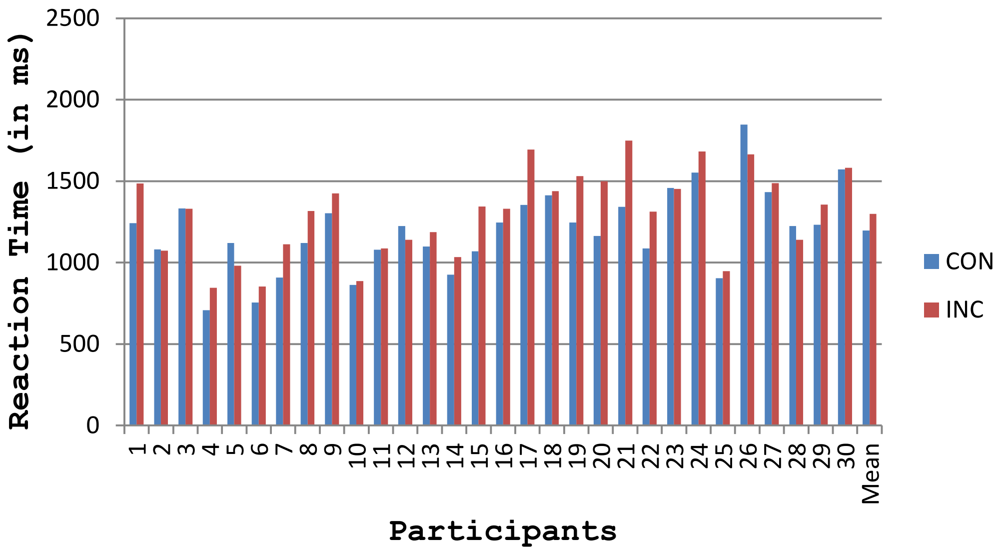
Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation

Maximum possible reaction time = 4000 ms



Note. CON = Congruent stimuli; INC = Incongruent stimuli

Figure 4. 7: Individual reaction time (ms) data for congruent and incongruent stimuli for spatial localisation



Note. CON = Congruent stimuli; INC = Incongruent stimuli

Figure 4. 8: Individual reaction time (ms) data for congruent and incongruent stimuli for semantic localisation

Further, to find if there was any significant effect of congruency, a mixed ANOVA was done by comparing congruent and incongruent stimuli in terms of reaction time for spatial localisation with gender and group as between variables (2 stimuli conditions * 2 genders * 2 groups). Of a total of 48 stimuli used for spatial localisation, 12 were congruent and 36 were incongruent, hence the average reaction time for congruent and incongruent stimuli was compared within the participants. The results revealed a significant effect of congruency [F (1, 26) = 21.79; $p < 0.05$; partial $\eta^2 = 0.45$] with the reaction time for congruent stimuli was significantly lower than reaction time for incongruent stimuli. However, no significant interaction of gender [F (1, 26) = 0.64; $p > 0.05$; partial $\eta^2 = 0.02$], group [F (1, 26) = 1.96; $p > 0.05$; partial $\eta^2 = 0.07$], gender and group [F (1, 26) = 1.50; $p > 0.05$; partial $\eta^2 = 0.05$] was found with the congruent-incongruent stimuli.

Similar analysis was done for semantic localisation that yielded comparable results as spatial localisation. A significant effect of congruency [F (1, 26) = 16.96; $p < 0.05$; partial $\eta^2 = 0.39$] was found and the reaction time for congruent stimuli was significantly lower than reaction time for incongruent stimuli. Also, no significant interaction between group and effect of congruency [F (1, 26) = 0.35; $p > 0.05$; partial $\eta^2 = 0.15$] and no significant interaction between group, gender and effect of congruency [F (1, 26) = 3.70; $p > 0.05$; partial $\eta^2 = 0.01$] was found. However, a significant interaction between gender and effect of congruency [F (1, 26) = 4.88; $p < 0.05$; partial $\eta^2 = 0.12$] was present.

4.3 Comparison of Responses to 'Spatial Localisation' and 'Semantic Localisation' for each participant group (children without and with right-left disorientation)

Within subjects' comparison of 'spatial localisation' and 'semantic localisation' was done in terms of response accuracy and reaction time. The congruent and incongruent stimuli were combined, and thus a total of 48 stimuli used to test 'spatial localisation' were compared with a total of 48 stimuli used to test 'semantic localisation' Along with descriptive statistics, comparisons were made for response accuracy using Wilcoxon-Signed Rank test and for reaction time using mixed ANOVA.

4.3.1 Comparison of response accuracy for 'spatial localisation' and 'semantic localisation' for each participant group

The mean, median and standard deviation of the response accuracy for spatial localisation and semantic localisation were similar. This can be seen from the scores provided in Table 4.5.

Table 4. 5: *Mean, Median and Standard Deviation (SD) for Response Accuracy (%) for 'Spatial Localisation' and 'Semantic Localisation'*

GENDER	**Localisation**	**Groups**					
		GROUP I			**GROUP II**		
		Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
Male	Spatial	97.39	98.95	3.29	94.53	94.79	4.71
	Semantic	96.87	98.95	4.72	95.05	95.83	2.71
Female	Spatial	97.32	97.91	2.61	95.53	93.75	4.40
	Semantic	99.10	100.00	1.63	99.10	100.00	1.63
Total	Spatial	97.36	97.91	2.88	95.00	93.75	4.44
	Semantic	97.91	100.00	3.69	96.94	97.91	3.03

Note. Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation
Maximum possible score = 100%

Wilcoxon-Signed Rank test was done to confirm whether there was a significant difference in spatial and semantic localisation. It was found that there was no significant difference in the two forms of localisation (Table 4.6).

Table 4. 6: *Comparison of 'Spatial Localisation' and 'Semantic Localisation' for Response Accuracy (%)*

Experiment (SPA-SEM)	Males		Females	
	Group I	Group II	Group I	Group II
|z|	0.10	0.59	1.21	1.62
Sig	0.91	0.55	0.22	0.10

Note. Sig = Level of significance; SPA = Spatial localisation, SEM = Semantic localisation; Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation

4.3.2 Comparison of reaction time for 'spatial localisation' and 'semantic localisation' for each participant group (tested using mixed ANOVA)

Comparison of reaction time for 'spatial localisation' and 'semantic localisation' was done within subjects. The mean and standard deviation for reaction time were similar for both spatial and semantic localisation as observed in Table 4.7.

Table 4. 7: *Mean and Standard Deviation (SD) for Reaction Time (ms) of 'Spatial Localisation' and 'Semantic Localisation'*

Gender	**Localisation**	**Group**				**Total**	
		GROUP I		**GROUP II**			
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Male	Spatial	999.76	193.12	1452.82	244.52	1226.29	316.30
	Semantic	1101.96	224.88	1445.98	131.13	1273.97	251.36
Female	Spatial	1033.02	195.79	1529.47	405.78	1281.25	400.05
	Semantic	1138.44	169.36	1405.19	280.72	1271.96	252.01

Note. Group I = Participants without right-left disorientation; Group II = Participants with right-left disorientation
Maximum possible reaction time = 4000 ms

To check if there was a significant difference between the two types of localisation, mixed ANOVA was done. This was done using the average reaction time for the spatial and semantic localisation with gender and group as between factors (2 experiments * 2 genders * 2groups). It was found that there existed no significant difference between the two types of localisations [F (1, 26) = 0.21; $p > 0.05$; partial $\eta^2 = 0.008$]. Also, no significant interaction between gender [F (1, 26) = 0.47; $p > 0.05$; partial $\eta^2 = 0.01$], group [F (1, 26) = 4.31; $p > 0.05$; partial $\eta^2 = 0.13$], gender and group [F (1, 26) = 0.52; $p > 0.05$; partial $\eta^2 = 0.02$] and the two forms of localisation were found.

4.4 Comparison of Responses to 'Spatial Localisation' and 'Semantic Localisation' between participant groups and between genders

For spatial localisation and semantic localisation, comparisons were made between males and females and between the 2 groups (children without right-left disorientation & children with right-left disorientation). From the mean, median and SD provided in Table 4.5 for response accuracy and Table 4.7 for reaction time it can be seen that response accuracy data were almost similar for both groups and genders. However, the reaction time was better for Group I than Group II, although it was similar for males and females.

Further, comparisons were made between gender and between groups for response accuracy using Mann Whitney U test and for reaction time using mixed ANOVA. Details regarding these analyses are provided below.

4.4.1 Comparison of response accuracy for 'spatial localisation' and 'semantic localisation' between males and females

The descriptive statistics provided in Table 4.5 indicates that no observable difference could be seen between males and females for response accuracy for spatial and semantic localisation. Mann Whitney U test confirmed that there was no significant difference in response accuracy between males and females for the spatial localisation (|z|

= 0.25; $p > 0.05$). On the other hand for the semantic localisation, a significant difference was observed in response accuracy ($|z| = 2.66$; $p < 0.05$) between males and females.

4.4.2 Comparison of reaction time for 'spatial localisation' and 'semantic localisation' between males and females

Similar to response accuracy, descriptive scores did not indicate a difference in reaction time between males and females for both types of localisations (Table 4.7). A mixed ANOVA substantiated that there was there was no significant difference in reaction time between males and females for spatial localisation [$F (1, 26) = 0.22$; $p > 0.05$; partial $\eta^2 = 0.00$]. Similarly, for the semantic localisation also, mixed ANOVA did not reveal a significant difference in reaction time between males and females [$F (1, 26) = 0.09$; $p > 0.05$; partial $\eta^2 = 0.00$].

4.4.3 Comparison of response accuracy for 'spatial localisation' and 'semantic localisation' between participant groups

The response accuracy of the two participant groups (children without right-left disorientation and children with right-left disorientation) were compared for spatial localisation. The mean and median scores were for the two groups for the two types of localisation (Table 4.5). Mann Whitney U test was done to check if there was a significant difference in response accuracy between the two groups for spatial localisation as well as for semantic localisation. No significant difference in response accuracy was found between the two groups for both spatial ($|z| = 1.36$; $p > 0.05$) and semantic ($|z| = 1.33$; $p > 0.05$) localisation.

4.4.4 Comparison of reaction time for 'spatial localisation' and 'semantic localisation' between participant groups

The reaction times of the two groups of participants (without right-left disorientation & with right-left disorientation) for spatial and semantic localisation were compared. The mean values for the reaction time was always better for those without disorientation (Group I) than for those with disorientation (Group II) for both types of localisations (Table 4.7 & Figure 4.9). In order to establish if these differences were statistically significant, mixed ANOVA was done. A significantly lower reaction time was seen in the group without right-left disorientation compared to the group with right-left disorientation for both spatial localisation [F (1, 26) = 21.74; $p < 0.05$] and semantic localisation F (1, 26) = 16.10; $p < 0.05$]. Hence, it is clear that reaction time of Group I was significantly better than reaction time of Group II for both kinds of localisations.

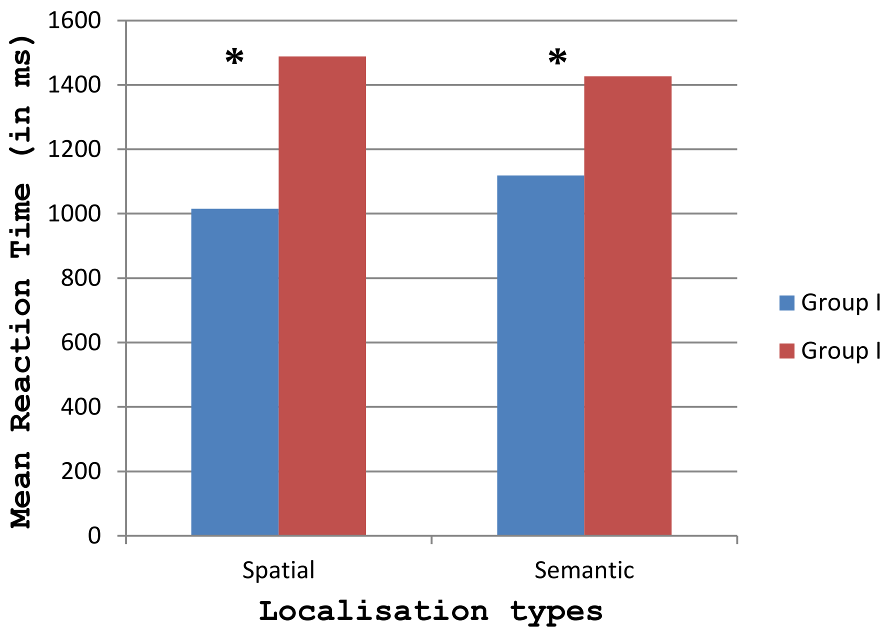


Figure 4. 9: Comparison of reaction time between participant groups for spatial localisation and semantic localisation

Thus, from the results of the study the following conclusions can be made:

1. A statistically significant correlation existed between absolute scores of the 'Right-left Orientation Test' and the reaction time for spatial localisation and semantic localisation. However, no such significant correlation was observed between response accuracy and absolute scores of the 'Right-left Orientation Test' for both types of localisations.
2. No significant difference was seen in response accuracy for congruent and incongruent stimuli for both spatial localisation and semantic localisation.
3. For both spatial and semantic localisation, the reaction time for congruent stimuli was always significantly better than for incongruent stimuli. However, no such significant difference was observed in terms of response accuracy.
4. No significant difference was seen between spatial and semantic localisation either for reaction time or response accuracy.
5. Those without right-left disorientation (Group I) obtained significantly lower reaction time compared to those with right-left disorientation (Group II). However, no significant difference between the participant groups was seen for response accuracy for both spatial and semantic localisations.

Chapter 5

Discussion

The study involved investigating the effect of spatial and semantic information regarding auditory localisation for congruent and incongruent stimuli. This was investigated in children without and with right-left disorientation. The responses of the participants obtained for spatial localisation and semantic localisation were analysed in terms of response accuracy (percentage score) and reaction time (in ms). The results of the study have been discussed as follows: Relationship between the 'Right-Left Orientation test' given by Rigal (1994) and spatial localisation and semantic localisation; Comparison of responses to congruent and incongruent stimuli for spatial localisation and semantic localisation for each participant group; Comparison of responses to spatial localisation and semantic localisation for each participant group; Comparison of responses to spatial and semantic localisation between genders and between participant groups. Each of these results are discussed separately in terms of response accuracy and reaction time.

5.1 Relationship between the 'Right-Left Orientation test' and spatial localisation and semantic localisation

In the present study, the absolute scores of the 'Right-Left Orientation test' and response accuracy was found to have no significant correlation with either spatial or semantic localisation. However, a significant moderate correlation was found between the absolute scores of the 'Right-Left Orientation test' and reaction time for both spatial and semantic localisation. This suggests that higher the score on the 'Right-Left Orientation Test' faster was their ability to respond. They were able to respond faster not only to the correct location but also localise correctly based on the semantic content of the stimuli. On the other hand, obtaining higher scores on the test did not enable the participants to respond more accurately than those who got poorer scores. A possible reason as to why it did not have an impact on the response accuracy was probably because the gap of 4 seconds between two stimuli used in the study was adequate for them to process the direction / meaning of the stimuli and make a correction if required.

Support that children utilise a compensatory strategy when they have difficulty in right-left orientation can be derived from studies reported in literature. It has been reported that children usually learn to discriminate right-left on themselves, and later generalise it to objects in space and begin to use the words relatively (Belmont & Birch, 1963; Elkind, 1961; Rigal, 1994). When children are not able to generalise the terms right-left and not able to use them relatively they tend to have right-left confusions. In such cases, children are noted to make a reference about right-left orientation on their own body before they respond (Schulman, 1974). Thus, in the present study, irrespective if they had a difficulty or not in right-left orientation, within the given time of 4 s, they were able to do the necessary additional processing and make adequate corrections to respond accurately. They may have used strategies such as making a movement to confirm which hand they use to eat or write, or by referring to hand with which they write as ‘right’. Thus, when children with right-left confusions use strategies to overcome the problem, they need to use an additional cue that will result in them requiring more time to respond.

Most of the participants in the current study obtained only 2 to 5% error in both forms of localisation resulting in a ceiling effect. Similar error scores for such localisation activities have been reported in literature (Palef & Nickerson, 1978; Philip & Seymour, 1973). However, they did not study participants with right-left disorientation. Although the participants in the current study were classified as having a right-left disorientation as per the criterion given by Rigal (1994), the lowest score obtained by the participants was 50%. Thus, it can be construed that response accuracy can continue to be like that of those without a right-left disorientation, as long as the scores are not lesser than 50%. It is possible that individuals with scores poorer than that obtained by the participants in the current study, may have deviant right-left orientation scores.

The response accuracy and reaction time followed a similar trend throughout the study. This was seen when congruent vs incongruent stimuli were compared, spatial vs semantic localisation were compared and when males vs females and participant groups were compared. Hence, further discussion is restricted to information related to reaction time.

5.2 Comparison of congruent and incongruent stimuli

In the present study, a significant difference in reaction time was observed for congruent and incongruent stimuli. This is partially similar to findings reported in literature regarding right-left localisation (Palef & Nickerson, 1978; Yao, 2007). These studies reported in literature differ from that of the current study regarding the conditions in which faster reaction time was seen. In the current study, faster reaction time to congruent stimuli was seen for both spatial localisation and semantic localisation. On the other hand, Palef and Nickerson found that such effect of congruency was present only when subjects were tested on a spatial localisation task and not for semantic localisation. They attributed the slower response to the incongruent stimuli for spatial localisation to automatic processing of word meaning that creates conflict when the stimulus meaning and the location are not the same. In contradiction to the study by Palef and Nickerson, Yao (2007) reported that the effect of congruency was present only for semantic localisation and not for spatial localisation. Thus, from the findings of the current study and from that of studies reported in literature, it can be noted that there is no consensus regarding performance to congruent and incongruent stimuli.

Studies dealing with other aspects of auditory Stroop effect other than right-left localisation have also noted that the reaction time is faster for congruent stimuli on specific tasks and not for specific other tasks (Cohen & Martin, 1975; Green & Barber, 1983; Harvey, 1984; Jerger et al., 1988; Muller & Bovet, 2002; Philip & Seymour, 1973). For example Harvey (1984) observed that when the participants were asked to respond to the words ‘high’ and ‘low’ having high pitch / low pitch, the effect of congruency was seen only when the response was required for the pitch of the stimuli and not for the meaning of the stimuli.

In literature it is reported that reaction time is slower for incongruent stimuli due to the interference caused by automatic processing of irrelevant factors. For example, while localising a loudspeaker from the right side for the word ‘left’, the automatic processing of the meaning of the word ‘left’ has been noted to interfere with the localisation process, thereby causing a delay in response. Automatic processing of word meaning is reported to take place in children as young as 3 years old (Jerger et al., 1988). Jerger et al. (1988) reported that such automatic processing of meaning is an evidence for failure of selective attention.

5.3 Comparison of spatial localisation and semantic localisation

The findings of the current study showed that there was no significant difference between spatial and semantic localisation. This indicates that individuals find tasks related to localisation of the source or localisation of the meaning equally easy or equally difficult. This finding was observed with all participants grouped together irrespective of their right-left orientation abilities.

Unlike the above finding of the present study, Palef and Nickerson (1978) reported that participants responded faster for semantic localisation compared to spatial localisation. They ascribed their results to the automatic processing of word meaning that led to faster responses for semantic localisation. The finding of Palef and Nickerson was contradicted by Yao (2007) who reported that spatial localisation responses were faster than semantic localisation. This was felt to occur as spatial localisation depends only on the presence of sound and not on its specific content thereby leading to faster responses for spatial localisation.

In the current study, differences were not noted in the reaction times between spatial and semantic localisation. It is possible that spatial and semantic localisation can affect each other. Thus, the meaning of a word can interfere with detecting the location of a stimulus. Likewise, the location of a stimulus is likely to affect the ability to localise based on the meaning of the stimulus. This could have resulted in the participants of the current study performing similarly on spatial and semantic localisation. Further, the findings of the present research could have different from the study by Palef and Nickerson (1978) mentioned earlier due to the difference in methods used. They evaluated spatial localisation and semantic localisation, each using different groups. The variability in abilities between the participant groups could have resulted in difference in the two tasks. The group that participated in semantic localisation may have been faster than the other group. However, in the study at hand, comparisons were made within the same group of participants who carried out both localisation tasks. Thus, variability due to differences in the abilities of the participants was ruled out. It can thus be construed that reaction time is similar for both localisation types and not different. It is speculated that this similarity occurs due to their effect on each other.

5.4 Comparison of males and females as well as participants without and with right-left disorientation

No significant difference in reaction time was found between males and females for spatial localisation and semantic localisation. However, unexpectedly a significant difference between males and females was found only in semantic localisation but not in spatial localisation. Visual inspection of the data revealed that all the females obtained 100% accuracy responses for semantic localisation unlike the males. This resulted in the standard deviation being ‘0’ for the females. The significant difference between the males and females could have been on account of this higher ability of the latter group.

Similarly, comparison between the two participants groups (children without & with right-left disorientation) for spatial and semantic localisation resulted in a significant difference between the two groups for both localisation types. The reaction time for those without right-left disorientation (Group I) was significantly better than the reaction time of those with a right-left disorientation (Group II) in both localisation types. This was similar to the correlation between the absolute scores of 'Right-Left Orientation Test' and reaction time for spatial and semantic localisation seen in this study. As discussed previously, children with right-left disorientation are noted to refer to themselves to overcome the confusions in right-left before they respond (Schulman, 1974). This could account for the delay in reaction time present in the children with right-left disorientation.

From the findings of the current study, it can be confirmed that right-left confusions in children can lead to a delay in reaction time. This in turn can result in disruptions in daily activities involving the words right and left, and affect school performance due to a communication breakdown. Further, it is speculated that spatial localisation and semantic localisation can affect each other and result in similar performance on both tasks.

Chapter 6

Summary and Conclusions

Stroop effect has been widely studied in literature using visual as well auditory stimuli (Dyer, 1973; Green & Barber, 1983; Harvey, 1984; Jerger et al., 1988; Palef & Nickerson, 1978; Stroop, 1935; Yao, 2007). Using auditory stimuli, the effect of semantic information on auditory localisation has been studied as a variation of the Stroop effect, termed Spatial Stroop effect (MacLeod, 1991). This involves evaluation of localisation to spatial based words such as 'right', 'left', 'front' and 'back'. While spatial Stroop effect has been studied in typically developing children, studies on children with right-left disorientation are sparse in literature. Thus, the current study aimed to investigate the effect of spatial and semantic information on auditory localisation in children without and with right-left disorientation.

Two groups of participants in the age range of 8 to 12 years were evaluated, one without any right-left disorientation and one with right-left disorientation. The grouping was done based on the findings of the 'Right-Left Orientation Test' (Rigal, 1994). *Spatial localisation* that tested responses to a source location irrespective of word meaning and *semantic localisation* that required responses to word meaning irrespective of source location, were studied. Additionally, responses to congruent stimuli (same source location and stimulus word meaning) and incongruent stimuli (different source location and stimulus word meaning) were also evaluated. The participants were instructed to respond by touching the appropriate coloured square on an Android phone that had markings indicating 'right', 'left', 'front' and 'back'. The stimuli were presented through four different speakers located at 90º (right), 270º (left), 0º (front) and 180º (back). Each stimulus that was presented from a loudspeaker as well as the tone generated when the participant responded was recorded on a laptop loaded with Adobe Audition (Version 3). This recording was further analysed to find response accuracy and measure reaction time.

Initially, a Shapiro Wilk test of normality was carried out that revealed the response accuracy data was not normally distributed while the reaction time data was normally distributed. Hence, response accuracy was evaluated using nonparametric tests and reaction time was evaluated using parametric tests. No significant correlation was obtained between the absolute scores of the 'Right-Left Orientation Test' with respect to response accuracy whereas a significant moderate negative correlation was present between the absolute scores of 'Right-Left Orientation Test' and reaction time. This was seen for both spatial and semantic localisation. Further, within both the groups of participants, no significant difference in response accuracy for congruent and incongruent stimuli for spatial and semantic localisation was found. However, a significant difference was found in reaction time for congruent and incongruent stimuli for both localisation types. The reaction time for congruent stimuli was always better than for incongruent stimuli. When spatial and semantic localisations were compared, no significant difference was present either in terms of reaction time or response accuracy. Comparisons were also done between males and females, where a significant difference in response accuracy only for semantic localisation was found. Similarly, comparison between the participant groups revealed that those without a right-left disorientation always had faster reaction times than participants with right-left disorientation for both spatial and semantic localisation. However, no significant difference in response accuracy was found between the two groups.

Thus, it can be inferred that children with right-left disorientation exhibit a delay in responding to activities that involve the words right-left. This could lead to a disruption in school related activities involving the words right-left due to a communication breakdown. Hence, it is important to identify children with right-left disorientation and training for the same is necessary.

Implications of the study:

- The current study will provide information about the effect of semantic cues on auditory spatial localisation and the effect of spatial cues on semantic localisation.
- The difficult situations in which semantic cues result in degradation of auditory localisation can be detected.
- The effect of semantic cues in localization in children with right-left disorientation, present in children with learning disability or (C)APD, can be detected.
- Those detected to have spatial or semantic localisation can be recommended to undergo rehabilitation.

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