CLOSED SET VERSUS PERIMETER SPATIAL ARRANGEMENT ON SYMBOL IDENTIFICATION IN CHILDREN WITH DOWN'S SYNDROME

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MANASAGANGOTHRI, MYSURU—570006

SEPTEMBER 2023

CERTIFICATE

This is to certify that the dissertation entitled "**Closed Set versus Perimeter Spatial Arrangement on Symbol Identification in Children with Down's syndrome"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: **P01II21S0029**. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

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DECLARATION

This is to certify that the dissertation entitled "**Closed Set versus Perimeter Spatial Arrangement on Symbol Identification in Children with Down's syndrome**" is the result of my own study under the guidance of Dr. Reuben Thomas Varghese, Scientist-B, Department of Speech Language Sciences, All India Institute of Speech and Hearing, Mysore and co-guidance of Dr. Jayakumar. T, Associate Professor in Speech Sciences, Department of Speech Language Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Chapter I

INTRODUCTION

Down's syndrome (DS) is the most common chromosomal condition associated with cognitive impairment (Shin et al., 2009). It occurs in approximately 1 in 700 live births (Parker et al., 2010). Children with DS have impairments in the neurological, cardiovascular, and musculoskeletal systems. Further, children with DS exhibit short height, muscular hypotonia, atlantoaxial unsteadiness, decreased neuronal volume, cerebellar hypoplasia, cognitive impairment, hearing impairment, vision impairment and congenital cardiac defects.

Few of the facial characteristics of children with DS include up-slanted palpebral cracks, straight nose bridges, nuchal folds, a single palmer wrinkle, reduced tone, and a small oral cavity. Oral anomalies include soft palate insufficiency as well as insufficient development of the palate in terms of length, height, and depth. The masseter, temporalis, orbicularis, and zygomatic muscles all exhibit hypotonia. In addition, for children with DS mouth breathing is accompanied by drooling, tongue protrusion, tongue thrust, and macroglossia. Dental problems include microdontia, hypodontia, supernumerary teeth spacing, and delayed eruption.

Due to orofacial abnormalities such as a tiny oral cavity, teeth problems, decreased muscular tonus, and apraxia of speech, children with DS are likely to have speech and language difficulties (Kent & Vorperian, 2020; Kumin, 2006). The communication difficulties in children with DS includes articulation, voice, resonance, phonology, prosody, fluency and intelligibility. The communication difficulties result in receptive and expressive language deficits and impairments in activities of daily living.

Communication is the process of exchanging information between the speaker and the listener. It plays a significant role in children during their speech and language development. Through the development of communication, many children with DS acquire excellent speech and language skills, and they experience reduced restrictions to access to the environment and increased interaction with peers and adults (Light, 1997). In addition to communication difficulties, children with DS show difficulties in executive functioning, such as difficulty in controlling one's attention, shifting thoughts into actions, storing of information and inhibition of distractions (Daunhauer et al., 2017; Daunhauer et al., 2020; Dube & Wilkinson, 2014; Lanfranchi et al., 2009; Tungate & Conners, 2021). However, visuo-spatial perception and processing are generally viewed as relative strengths in an individual with DS (Fidler et al., 2006; Jarrold et al., 1999; Klein & Mervis, 1999). In these situations, Augmentative and alternative communication (AAC) will support effective communication to meet their challenges.

AAC can facilitate speech and language development for children with DS (Wilkinson & Na, 2015), leading to a better quality of life (Channell & Loveall, 2018). AAC support enhances early language development in children with DS (Romski et al., 2020). Wilkinson and Madel (2019) investigated the effect of clustered and distributed arrangement conditions of line drawings in children with DS, and the findings revealed that no changes were found in the accuracy of target symbols. However, the latency to locating targets was better under clustered than distributed conditions. Wilkinson et al. (2022) studied the effect of background colour cues of symbols in visual attention and latency of identification of adolescents with DS on

AAC display, and the results revealed that background colour enhances the latency of target symbol identification and not in visual search.

Attention and processing are needed for visual communication systems (Thistle & Wilkinson, 2015). AAC systems must be created to suit children's abilities and requirements. (Blackstone et al., 2007). The actual arrangement of the display, where the symbols are positioned with the desired colour and size, is essential in an AAC display system. In a survey conducted by Thistle and Wilkinson (2015) on the efficacy of symbol arrangement, clinicians found that symbol arrangement is extremely important when designing a display. Further display designs might benefit from considering visual processing concepts; otherwise, it can lead to visual crowding among users (Van den Berg et al., 2007). Classifying symbols according to their structural characteristics (colour or shape) or grammatical structure (parts of speech) is necessary.

Well-designed AAC display system facilitates the preparation of accurate and timely messages. The quick and accurate message preparation is essential for a person using AAC to meet higher expectations and levels of competence. In assisted AAC, dependable metrics like accuracy and response time are crucial. A key component of good communication is accuracy, which is accurately locating a target symbol. On the other hand, response time is the time taken to locate a target symbol and hinders assisted AAC. It may result in a message preparation pace that is slow. It may have detrimental effects, including stifling individual dialogue, speaking partner dominance, and frustration. Increasing the visual search reaction time speeds up message preparation. The speed and accuracy of target symbol recognition behaviour outcomes may be affected by symbol arrangement. A visual signal called spatial arrangement makes it easier to locate target symbols, eases cognitive load, and speeds up learning. Reducing the total amount of time needed to create a message and satisfy attention display demands will aid the participant in lowering working memory. Participants with and without disabilities responded faster and high accurately when some spatial arrangement was given (Wilkinson et al., 2008; Wilkinson & McIlvane, 2013).

Frequently used spatial arrangements of symbols in AAC devices include closed set and perimeter arrangements. In a closed set, the symbols are ordered from top to down according to grammatical categories (Figure 1.1). For perimeter arrangement, symbols within each semantic category are clustered along the left, top, right and bottom locations (Figure 1.2). Further, closed set spatial arrangement is used more than perimeter spatial arrangement. With the aid of an eye-tracking device, Wilkinson et al. (2022) investigated the effect of spatial layouts on visual attention skills in adolescents with DS. The findings revealed that compared to perimeter spatial arrangement, closed set spatial arrangement has a higher proportion of fixations to inattentive symbols. Similarly, Carelli (2011) found that accuracy and response time were better in the perimeter than in a closed set arrangement for identifying the target symbols in children with DS.

Figure 1.1

Figure Depicting a Closed set Spatial Arrangement of 16 Line Drawing Symbols

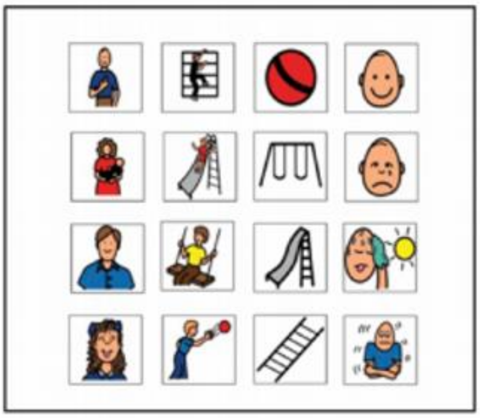
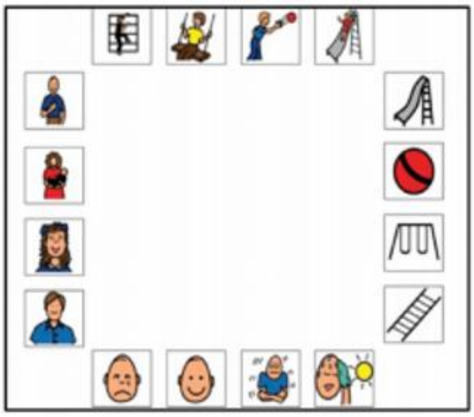


Figure 1.2

Figure Depicting a Perimeter Spatial Arrangement of 16 Line Drawing Symbols



Visuospatial perception and processing are the strengths, and restricting attention to distractions and over-selective attention are the challenges in children with DS. Therefore, studies have reported that modifying the spatial arrangement of AAC devices or displays improves the visual search for symbol identification and reduces attention to nearby symbols. However, the effect of spatial arrangement in the symbol identification skills are mostly done in adults with DS and in children with DS has been less explored. Further limited studies are done in the Indian context. Hence the present study was undertaken to address these gaps.

Objectives of the study

- To measure the response time and accuracy for identifying the target symbol using a closed set spatial arrangement in a communication board for children with Down's syndrome in the age range of 6-12 years.
- To measure the response time and accuracy for identifying the target symbol using a perimeter spatial arrangement in a communication board for children with Down's syndrome in the age range of 6-12 years.
- To compare the response time and accuracy for identifying the target symbols using closed set versus perimeter spatial arrangements in a communication board for children with Down's syndrome in the age range of 6-12 years.

Chapter II

REVIEW OF LITERATURE

AAC in DS significantly improves expressive speech intelligibility and language comprehension difficulties (Brady, 2008). For these population, AAC can help with the early stages of language development (Romski et al., 2020). For children with DS, AAC can enhance early speech and language development (Wilkinson & Na, 2015). According to studies, AAC can also help children with DS communicate more effectively, enhancing their quality of life (Channell & Loveall, 2018). When constructing a display, 93% of respondents in a poll of therapists who work with young children who use AAC, regarded symbol layout as extremely important (Thistle & Wilkinson, 2015). When a spatial arrangement was provided, participants with and without disabilities performed more quickly and accurately (Wilkinson et al., 2008; Wilkinson & McIlvane, 2013). Recent research on how humans process visual information has found that this spatial layout may result in users experiencing visual crowding (Van den Berg et al., 2007; Yildirim et al., 2020). Visual crowding limits object sight, the ocular motion of the hands, image search, and the reading rate in ordinary people (Bulakowski et al., 2011).

2.1 Speech, Language and Cognitive Skills in Children with Down's syndrome

Children with DS exhibit severe impairments in speech intelligibility (Kent & Vorperian, 2013), and comprehensive language is less affected than production (Ferreira & Lamonica, 2015). Speech motor abilities and coordinated speech motions can be affected by lips, tongue, and velopharynx structure variations in children with DS (Barnes et al., 2006). Children with DS make inconsistent phonological errors (Dodd & Thompson, 2001) and exactly match those of younger kids who are typically growing (Dodd, 1976; Rosin et al., 1988). The syntactic abilities are compromised in comprehensive and production skills (Abbeduto et al., 2003; Berglund et al., 200l; Berglund & Eriksson, 2000; Chapman et al., 1991; Laws & Bishop, 2003). Research done by Price et al. (2007) found that when it came to grasping grammatical morphology and syntax, 45 DS boys performed worse than boys with normal growth who were the same mental age. Comprehensive and expressive vocabulary scores were much lower for children with DS than those of normally growing children (Caselli et al., 2008; Hick et al., 2005; Price et al., 2007). Children with DS can stay on the topic longer and initiate dialogue less than children of the same cognitive age who normally develop (Tannock, 1988). Roberts et al. (2007) examined 29 children with DS and found that they produced more turns and were less elaborate when retaining topics. Chapman (2003) found that many children with DS have high social, adaptive, and pragmatic functioning. Children with DS are sociable, affectionate, and engaging (Moore et al., 2002; Wishart & Johnston, 2008). Communication skills are weaker than socialization and daily routine skills (Dykens et al., 2006; Fidler et al., 2006).

Compared to children who are typically developing, 80% of children with DS have mild to moderate cognitive deficits that limit their communication ability. (Chapman, 2003; Roizen, 2007). Also, DS children have weak visual long-term memory (Jarrold et al., 2007) and phonological memory abilities. Visuospatial processing and perception are their main advantages (Fidler et al., 2006; Jarrold et al., 1999; Klein & Mervis, 1999). However, according to studies, children with DS fight to control their attention when faced with any distractions (Lanfranchi et al., 2009; Munir et al., 2000), and When using AAC devices with a crowded symbol set, they may exhibit excessively selective attention (Dube & Wilkinson, 2014).

Munir et al. (2000) examined the executive function and attention of children with Fragile X syndrome, DS, and typically growing children with and without attention deficits. 25 boys with DS and 25 with Fragile X syndrome, aged 7 to 15 years, were deemed 25 typically developing children with attention deficits. In contrast, the remaining 25 typically developing children, aged 5 to 10 years, had average to good attention skills that matched their mental ages. The computerised Wilding Attention Test for Children (WATT) and Test of Everyday Attention for Children (TEACH) were administered. Measures consider various cognitive elements of attention, including selective, divided, and sustained attention and executive function. The results revealed that no significant differences between the DS and Fragile X syndrome groups under selective attention in a more prolonged search for each desired item than the control teams. Both the syndrome groups showed a much more significant decline in accurate targets detected during split attention than the control groups. In executive functioning, inhibition and response organisation are more negatively impacted in DS than in the other three groups.

Brown et al. (2003) studied the effect of spatial representation and attention in children with DS, Williams syndrome (WS) and who are normally developing with an age range of 2-3 years old. 13 WS, 19 DS, and 17 normally developing toddlers participated in the study. They used a double-step saccade paradigm to study visuospatial representation and sustained attention. Compared to all other groups, the findings reported that visuospatial representations, such as the capacity to orient to target locations appropriately, have a more significant and shorter overall duration of periods of sustained attention in children with DS.

Lanfranchi et al. (2009) examined working memory in visuospatial tasks in DS. 34 children and teenagers with DS and 34 normal subjects with a mean age of 12.6 years were recruited for this study, and four exercises were given to each group. In two tests, participants had to use spatial-sequential working memory to recall a sequence of locations shown on a matrix. In two more, subjects had to use spatial-simultaneous working memory to recall multiple places presented at once. According to the findings, children with DS perform worse than typically growing participants in concurrent spatial exercises but not spatial, successive ones. Demanding to process more than one thing at once may cause simultaneous visuospatial working memory loss in DS children.

Cleland et al. (2010) discovered whether the severity of speech deficits correlates with linguistic and intellectual levels. A total of 15 children and adolescents with DS with a mean age of 14.3 years participated in this study. Subjects were administered with speech, language and cognitive standardized assessment tests, and the results of each test correlated to check the relationship between each domain. Results revealed that children with DS have deficiencies in comprehensive and expressive language skills, which are not fully accounted for by cognitive impairment. Most of the speech errors are developmental, and few are atypical. The study concluded that there is no association between speech, cognition, or language estimate, indicating that the speech issues in DS are not due to intellectual delay.

Knight et al. (2015) compared the effect of reading, picture naming and repetition on the expression skills of children with DS. Eight children with DS within the age range of 10-14 years were recruited for the study. 10 single words were taken that were appropriate for reading, naming and repetition tasks and were usually acquired early in developmental stages. The examiner recorded the responses for picture naming, reading and repetition for the exact 10 words then the responses were converted into transcriptions for assessing the accuracy and consistency of productions. The findings revealed that the accuracy was significantly higher in reading conditions than in naming and repetition conditions, and consistency of productions was better in reading than in other conditions. The study concluded that children with DS are more accurate and consistent when reading words than when they produced those words in naming or repetition tasks.

2.2 AAC Studies in Children with Down's syndrome

Wilkinson et al. (2008) examined how colour signals helped children with DS locate desired symbols more quickly and accurately. 10 DS children with a mean age of 11.9 years took part in this investigation. Food or apparel was depicted in 12-line drawings. Symbols with the same colour (cherry and tomato red) in one scenario were grouped; in the other, they were dispersed throughout the display. The kids must click on the 12-line drawing using the mouse after hearing the target symbol's audio sample played through the computer speakers. The target symbol's speed and accuracy were evaluated. The results revealed that grouped circumstances improved the accuracy and speed of finding the target symbols.

Wilkinson and McIlvane (2013) investigated the influence of perceptual characteristics on the visual scanning for desired meaningful symbols in children with DS and Autism spectrum disorder (ASD). For the study, 24 adolescents with DS and ASD with a mean age of 15.4 years were recruited. Both groups were given two tasks: the first required clustering the 16 symbols by interior colour, and the second required distributing the 16 symbols randomly without an arrangement cue. The 16-line drawings took the place of the target, which was displayed in the centre of the computer screen. They measured the latency and precision. Both responses were much better when the symbols were clustered by interior colour as opposed to when they were distributed, and the visual search was more evident in children with ASD than in those with DS. The study concluded that consideration of the physical and perceptual characteristics of children with developmental disabilities might be advantageous when creating assisted AAC displays.

Wilkinson and Madel (2019) evaluated the use of modifying the design display for AAC communication to aid the visual search in DS and ASD adolescents using eye tracking techniques. The study enrolled six DS adolescents with a mean age of 19.3 years and six ASD adolescents with a mean age of 16.11 years. On two different displays, a total of 16-line apparel drawings are presented. In one, groups of the same-coloured symbols appeared; in the other, they were scattered throughout the display. After presenting a target line drawing, the participant must use the mouse to pick the target from one of the 16 displayed symbols. By giving a gap between each condition, both were administered. The Tobii T60 eye tracker was used to measure eye gaze motions. The target fixation and latency were examined. The latency to fixate the target was better under clustered conditions than distributed display and no differences between the disordered populations and clustering of symbols based on internal colour reduces the fixations to irrelevant symbols.

Wilkinson et al. (2022) examined the effect of backdrop colour cues of symbols on AAC display promotes visual attention in adolescents with DS. This investigation involved 14 DS adolescents with a mean age of 19.3 years. An array of 16-line drawings with a white and coloured background, an initial digital image, and an audio sample of the target symbol then showed on the screen. They must locate the target line drawing that goes with the photograph. The Tobii T60 eye tracking device was used to assess the eye gaze on 16-line drawings divided into four categories (subjects in yellow, actions in green, objects in orange, and descriptions in blue). According to the findings, backdrop colour cues facilitated latency in finding the target but not the visual process of the search. The limitation of the study was restricted small sample size. Additionally, it ought to handle various developmental problems.

2.3 AAC Studies in Other Disordered Population

Mcewen and Karlan (1989) assessed the effects of position on communication board access by children with cerebral palsy (CP). They have taken two children with spastic CP at three years old. They considered four different positioning devices such as an adapted wooden chair, a stander, a prone edge and a sidelier and the ability of the children to use their hands when placed in each of the different positioning devices was assessed. The up-rite stander allowed the best functioning of the hands on communication board.

Travis and Geiger (2010) examined the influence of the picture exchange communication system (PECS) on the communicative behaviours in two children with ASD. The quantitative and qualitative data were gathered in both formal and informal settings during the PECS pre-practising, practising, post-practising, and further investigation stages. Quantitative data indicates how effective PECS is, and qualitative data shows how PECS affects other areas like communication and pragmatic skills. The results revealed that PECS has an immediate effect on commanding and requesting communication behaviour.

Brock et al. (2017) compared the influence of visual scene and grid displays during conversational participation along with a communication partner in persons with chronic aphasia to improve communication using AAC. Two English speaking participants diagnosed with chronic aphasia at 61 years old were recruited in this study. The participants practised using visual scene and grid displays for communication purposes and taking part in conversations with a communication partner with either visual scene or grid displays. The findings revealed that participants could communicate with more complex utterances and higher conversational turns with visual scene displays than grid displays.

Lesser and Ebert (2020) examined the effectiveness of a picture communication board for social communication in a child with ASD. A verbal ASD boy with three years of old participated in this study and provided six intervention sessions. The frequency of communicative acts and percentage of communication acts using AAC are evaluated. The results revealed that an immediate effect of picture communication board on frequency and percentage of communication acts, concluding that low-technology AAC devices could quickly improve communication frequency.

Venkatachalam et al. (2022) compared the effect of the Visual Scene Display (VSD) system and grid-based AAC system in six children with CP in the age range of 5-12 years. The authors divided the six participants into two groups. The first group was evaluated and trained using a grid-based AAC system, and the second group was evaluated and trained using a VSD system. A total of 30 images from three different categories, such as fruits, food items and furniture, were considered for the study. The percentage of correctly identified images on the screen was measured in pre and post-training conditions in both groups. The result indicates no significant difference in the accuracy of identification in the pre-training condition in both groups. In the post-training condition, the accuracy of identification was higher for the group where the VSD system was used than the grid-based AAC system. The study concluded that these differences may be due to the availability of the factors such as contextual cues and background familiarity in the VSD system.

Philip and Goswami (2022) investigated the effect of grid size of the AAC display, spatial organization, background colour cues and grammatical category of symbols on target symbol identification in persons with Aphasia (PWA) and compared it with neuro typical adults (NTA). A total of 20 Malayalam speaking PWA and NTA with an age range of 20-80 years were recruited for this study. Three tasks were included for symbol identification skills. Participants had to identify the desired symbol from a set of symbols, and the accuracy and response time were measured. In the first task, participants must identify symbols in varied grid sizes. Here the noun symbols were arranged at different grid sizes, such as four, eight, twelve and sixteen symbols per display. Findings revealed that accuracy and response time were poorer in the PWA group than NTA group. In the PWA group, the accuracy of target symbol identification decreased as the grid size expanded from four to sixteen, and response time increased with a rise in the grid size. In the second task, they assessed the effect of symbol organization and background colour cues on identifying target symbols. It includes two conditions; in the first condition, symbols were arranged in a hierarchical grid display with colour coding for each semantic category. In the second condition, symbols were randomly arranged without any categorization. Results found that accuracy and response time were poorer in PWA than in NTA. Higher accuracy and better response time were found on the first condition. The third task studied the effect of identification symbols belonging to different grammatical categories, such as nouns, verbs, adjectives and prepositions. Participants were expected to identify 60 symbols belonging to grammatical categories. Results conveyed that accuracy and response time were better for nouns and lesser for prepositions. The study concluded that the AAC display's grid size, spatial arrangement, background colour cue and grammatical category of symbols affect symbol identification in PWA.

2.4 Spatial Arrangement Studies in AAC for Typically Developing Children

Wilkinson and Snell (2011) explored the sway of the spatial layout of emotion symbols on the efficiency and precision of the target symbol searches. A total of 30 typically growing children within the age range of 3 to 6 years participated in this study. After viewing a single image of the target emotion symbol followed by a display of 8-line drawings, the child must recognise it using the mouse. The software was used to provide a total of 16 trials. There was no perceptual clue in the presentation for the initial four trials. The succeeding four trials had colour cues, the ones after that had spatial cues (clustered and distributed), and the trials after that had both. Accuracy and latency were tested. The results revealed that latencies were better for children with spatial cues in clustered than distributed arrangement, and spatial cues did not affect accuracy. The study was conducted on a small group of kids who had no disabilities, which was a significant barrier.

The impact of symbol arrangement cues on the development of multi-symbol knowledge in typically developing children was examined by Thistle and Wilkinson (2017). The study involved 67 typically developing children aged 3 to 7.11 years. Beginning with a digital snapshot of the target symbol followed by 16-line drawing symbols, the kid must select the target line drawing corresponding to the digital photograph. Subject, verb, object, and descriptor were among the four categories that made up the 16-line drawing symbols, which were then shuffled and grouped spatially on a background of white and colour. Accuracy and response time were evaluated. The findings disclosed that grouped arrangement with a white background improved accuracy and response times. They concluded that spatial layout affects how ordinarily developing children generate multi-symbol communications. The study's main weakness is that it only included normally developing children.

2.5 Spatial Arrangement Studies in AAC for Children with Down's syndrome

In order to ascertain the impact of spatial cues on detecting the speed of locating the target symbol and boosting the accuracy, a study on an aided visual AAC display was carried out by Carelli (2011). The authors changed the spatial layout into a perimeter arrangement and a row-column grid (closed set grid). In this study, six DS children with a mean age range of 2.11 to 6 years, were enrolled. They considered 16 symbols and grouped them into closed sets and a perimeter. The accuracy and average speed of finding the target symbols were calculated in both spatial arrangement settings. The results revealed that accuracy was improved, and the average speed of finding the target symbols was faster in a perimeter spatial arrangement than in a closed set grid. The study's limitation was that it was conducted in a small group of participants.

Wilkinson and Bennett (2021) investigated the effect of how tiny and simple adjustments to the physical layout of communication displays may alter visual attention and communicative behaviours in adults with DS. Three DS adults with an age range of 20-24 years were considered for this study. Research assistants created four chapters, one for each of the following four tale themes: beauty and the beast, curious george, star wars, and toy tale. Research assistants cut photographs from each story to make the picture symbols and produced AAC symbol displays for the study. For each chapter of each narrative, a unique AAC display was created. AAC display design that is optimal; the symbols in this layout were organised spatially in to perimeter arrangement. In non-optimal AAC, display designs used symmetrical row-column grids without spatial organisation for the symbols. Participants put on the portable Tobii Glasses 2 for eye gaze measurement before reading the stories. During the social engagement with a trained communication partner, those people received either the non-optimal (closed-set grid) or the optimal (perimeter arrangement) spatial layout. The appropriately constructed (perimeter) AAC display significantly increased the participant's communication rate. They concluded that adjustments to the communication tools those people employ could quickly and favourably affect both the effectiveness of visual attention.

Wilkinson et al. (2022) used eye-tracking technology to research how critical spatial signals are for improving visual attention in adolescents with DS. They took into account 14 adolescents with DS with a mean age of 19.3 years. 16 line-drawing symbols for pictures were chosen from the topic, action, object, and descriptor items categories. Four different spatial arrangements have been created; the first is a closed set grid, and the second is a widely spaced grid with symbols placed at regular intervals. The next type of organisation is the perimeter layout, and the last type is the corner arrangement, in which the symbols belonging to each category are gathered in the assisted system display's corners. The participants were given eight trials for each arrangement with white and coloured cues by mixing them. The target symbol's aural sample and digital image first appeared on the screen. The assisted display will then show 16 symbols. The participant had to choose the desired line drawing corresponding to the image using a mouse while the Tobii T60 eye tracking equipment recorded their eye movements. The findings revealed that no statistically significant difference in latency for any altered spatial arrangement circumstances for locating the targets. Fixations on inattentive symbols were significantly more frequent on a closed set grid than on a widely spaced, perimeter and corner arrangements. Furthermore, visual searching is governed by spatial layout. The limitations they identified were the small sample size and the need to include conditions like autism and cerebral palsy.

2.6 Research gaps

The above studies on the spatial arrangement of symbols in AAC display are primarily carried out in typically developing children, and findings are consistent with an improvement in accuracy and faster latency of locating the target symbols when the symbols were arranged in clustered than distributed manner. The rest of the studies were focused on the disordered population in that they considered children and adolescents with DS because of their difficulty in controlling their attention, shifting thoughts into actions and storage and processing of information behaviours. In children and adolescents with DS studies, they have introduced different kinds of spatial arrangements such as widely spaced, perimeter and corners other than closed set arrangement. However, studies compared mainly close set and perimeter arrangements. Findings revealed accuracy and response time were better in perimeter than in closed set arrangement. So, we can conclude that designing AAC devices can facilitate communicative effectiveness through faster response time and highly accurate selection of target symbols.

The main drawbacks of the above studies were that majorly carried out with a small sample size of children with DS and restricted studies on other disordered populations. Spatial arrangement design was done on high-tech devices and did not focus low tech devices such as communication board which is also commonly used in AAC intervention, and limited studies have been done in the Indian context. Most studies are done in typically growing children and less explored in children with DS. Furthermore, studies in the Indian context with communication boards have not been done. These suggest a need for research in this area to address these gaps. The present study explores whether changes in the closed set and perimeter spatial arrangement of symbols influence the symbol identification skills in children with DS using a communication board.

Chapter III

METHOD

The aim of the present study was to evaluate whether changes in the spatial arrangement (closed set versus perimeter) of symbols influence the symbol identification skills in children with DS using a communication board.

3.1 Research Design

A counterbalanced research design (within subjects) was used in this study to compare the effects of closed set and perimeter spatial arrangement on symbol identification in children with DS using a communication board.

3.2 Ethical Considerations

The study was carried out while adhering to the AIISH ethical committee guidelines for Biobehavioral Sciences for human subjects. All ethical standards were met for participant selection and participation. Before the field testing, the study and its purpose were explained to the caregivers and consent was obtained from them (Appendix I).

3.3 Participants

Twenty Kannada speaking children with Down's syndrome in the age range of 6-12 years (mean age = 7.7 years) were recruited for the study. The participants were selected from special schools in Karnataka. Table 3.1 below includes details of children with DS, including the chronological age, receptive language age and intellectual quotient (IQ) score. The children were further divided into two groups consisting of 10 participants each. Participants were assigned to each group on a random basis. Participants from both groups were evaluated using the closed-set and a perimeter spatial arrangement on a communication board.

Table 3.1

Details of the Participants in Group I and Group II

Group I				Group II			
Sr. No.	Age (yrs)	RLA (yrs)	IQ	Sr. No.	Age (yrs)	RLA (yrs)	IQ
1	10.4	4.1-4.6	61	1	6.8	3.0-3.6	55
2	6.5	3.0-3.6	54	2	7.3	3.7-4.0	57
3	11.10	5.1-5.6	62	3	6.2	3.0-3.6	52
4	6.1	3.0-3.6	51	4	7.9	3.7-4.0	58
5	8.1	3.0-3.6	52	5	7.6	3.7-4.0	56
6	6.3	3.0-3.6	52	6	7.10	4.0-4.6	59
7	8.6	3.7-4.0	55	7	6.5	3.0-3.6	51
8	7.0	3.7-4.0	54	8	7.4	3.7-4.0	53
9	6.9	3.0-3.6	52	9	10.8	3.7-4.0	54
10	8.3	4.0-4.6	56	10	6.11	3.0-3.6	52

Note. ‘Yrs’ = ‘Years’

3.3.1 Inclusion Criteria (for both groups)

The participants were selected based on the following inclusion criteria:

- Receptive Language Age (RLA) should be above three years (Assessment was done using Checklist for Speech- Language Skills, ACSLS; Swapna et al., 2010).
- Children who were native speakers of Kannada.
- Children with adequate vision.

- Children with adequate pointing skills.
- Children with a mild intellectual disability within the range of 50-69 (Wechsler's IQ Classification).

3.3.2 Exclusion Criteria (for both groups)

The participants with the following characteristics were excluded from the study:

- Those who have attended AAC therapy before this study.
- Those who have any associated major behavioural issues.

3.4 Materials

Four semantic categories with three picture symbols were chosen (as shown in Table 3.2). A total of 12 picture symbols were selected from the Avaz application (Version 6.6.4) with white background colour and a consistent size of 5cm X 5cm and arranged in a closed set and perimeter spatial manner on a 29cm X 38.5cm black colour communication board. Figure 3.1 and 3.2 depicts the closed set and perimeter spatial arrangement of picture symbols on a communication board.

Table 3.2

Selected Categories for the Study

Sr. No.	Categories	Items in each category
1	Food items	Dosa, Water, Idli
2	Animals	Hen, Cow, Dog
3	Fruits	Apple, Banana, Orange
4	Common objects	Window, Chair, Table
	Total	12 items

Figure 3.1

Figure Depicting a Closed set Spatial Arrangement of 12 Picture Symbols on the Communication board

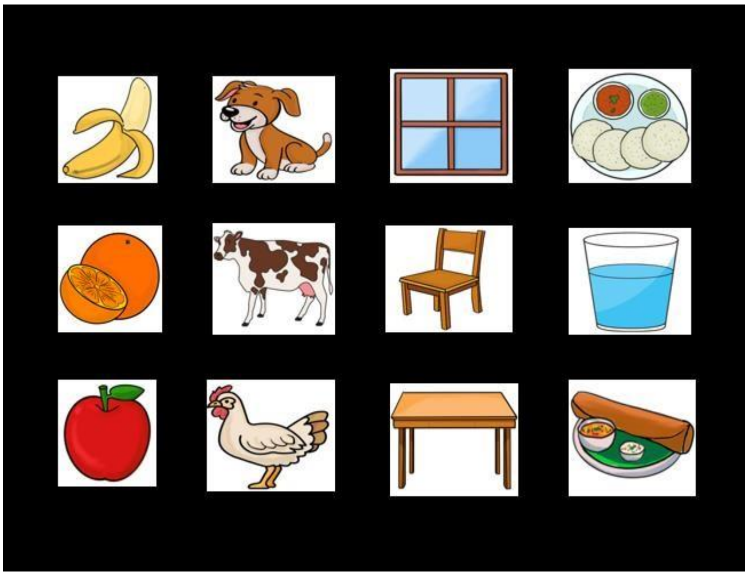
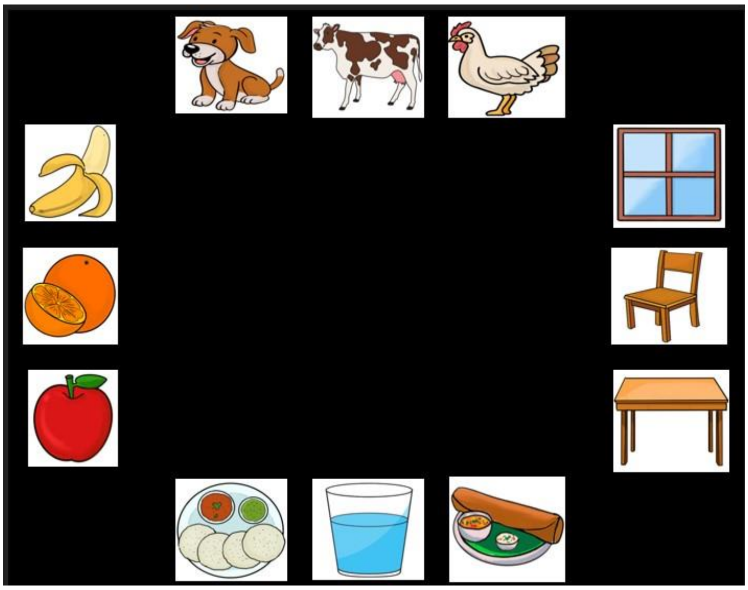


Figure 3.2

Figure Depicting a Perimeter Spatial Arrangement of 12 Picture Symbols on the Communication board



3.5 Pre-assessment Measures

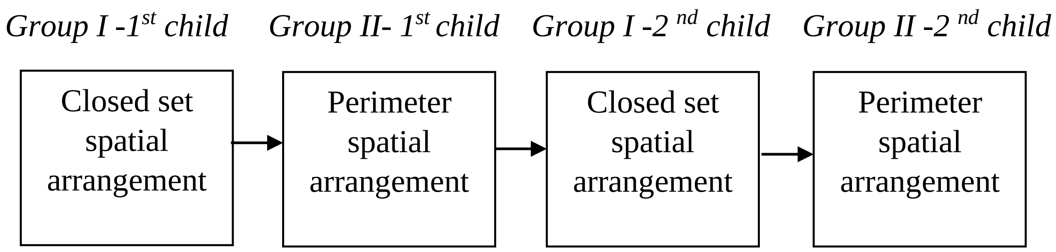
In order to select participants for the study, the student researcher conducted a thorough assessment of the child's language skills using the Assessment Checklist for Speech-Language Skills (ACSLS; Swapna et al., 2010). AAC assessment protocol kit was administered (Saxena & Manjula, 2005) before finalising the participants for the study. Detailed evaluation of all other skills required for the study was documented, and children who fit the inclusion criteria were chosen. Initially, the student researcher did pre-assessment testing on participant's accuracy and pointing abilities using 4, 8 and 12 grid sizes. Only those participants who could point to 12 grid symbols were taken in the present study.

3.6 Clinical Conditions

Group I participants were evaluated for their symbol identification skills using closed set spatial arrangement followed by perimeter spatial arrangement. Similarly, group II were evaluated for their symbol identification skills using the perimeter spatial arrangement first, followed by closed set spatial arrangement. Closed set and perimeter spatial arrangements were carried out alternatively. A gap of three days was provided between both conditions. Stimuli in both arrangements will be the same, but the order of presentation of stimuli will be different in both conditions.

3.6.1 Block diagram indicating testing conditions for both groups

Condition I



Condition II

Group I -1st child → *Group II -1st child* → *Group I -2nd child* → *Group II -2nd child*

Perimeter spatial arrangement → Closed set spatial arrangement → Perimeter spatial arrangement → Closed set spatial arrangement

3.7 Clinical Procedure

The testing for both spatial arrangement conditions was administered in a silent room with the mother's presence and adequate lighting. Initially, the computer speakers provided an auditory sample of the target symbol. Then, the arranged symbols on the communication board were introduced to the participants; he/she had to identify the correct target symbols from the array of 12 stimuli. Before starting the evaluation, three trial stimuli (milk, cat and grapes) not included in the testing conditions were provided for better familiarity with the procedure.

The outcome measures, such as response time for the target identification and the accuracy of identified target symbol were measured. The response time for identifying the target symbol was measured using a stopwatch by another experimenter to reduce procedural bias, and the experimenter itself measured the accuracy of identifying the target symbol. Figure 3.3 and 3.4 depicts the measurement of accuracy and response time of the target symbol using a closed set and perimeter spatial arrangement conditions.

Figure 3.3

Photo Depicting Measurement of Accuracy and Response Time of Target Symbols Using Closed set Spatial Arrangement

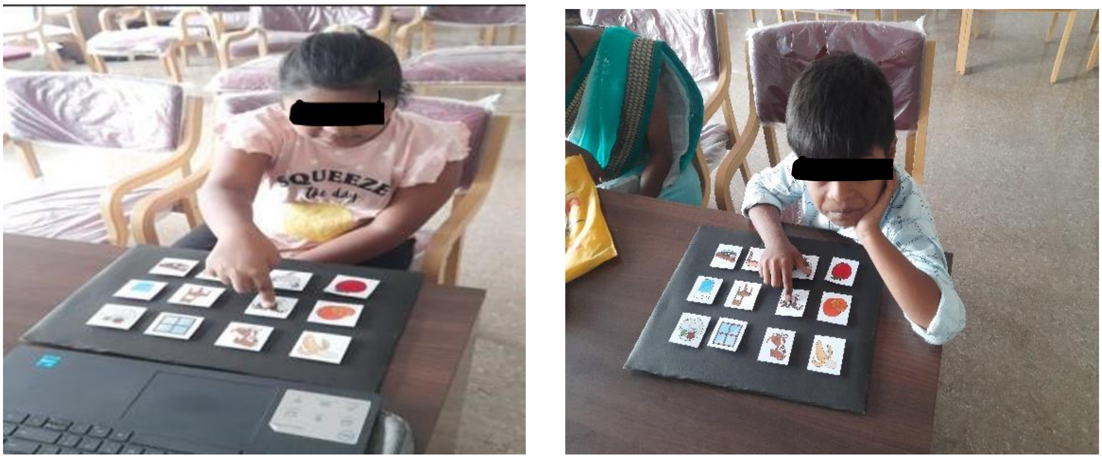


Figure 3.4

Photo Depicting Measurement of Accuracy and Response Time of Target Symbols Using Perimeter Spatial Arrangement

3.8 Test- retest Reliability

Test-retest reliability was measured by following the same procedure on 20 % of the participants using all the stimuli two weeks later in both groups in order to determine whether there was a statistically significant change in the results between the test and retests.

3.9 Analysis of the Outcome Measures

In the present study, the outcome measures, such as accuracy for correct response and response time for identifying the target symbol, were assessed using a closed set and perimeter spatial arrangement to examine the preparation of accurate and timely messages. The response time in seconds was measured for each participant only for correctly identified symbols. Moreover, a score of “1” was given for correct response and for incorrect response or no response “0” score was given and converted into a percentage.

The raw scores obtained from the two group participants were tabulated and subjected to statistical analysis using the SPSS software (Statistical Package for the Social Science package, version 26) to compare the performance of both groups. Descriptive statistics were done to obtain the mean, standard deviation, and median scores for closed set and perimeter spatial arrangement conditions. Normality was checked using the Shapiro Wilks test of normality. Since the sample did not follow assumptions of normality, non-parametric test, Wilcoxon Signed Ranks test, was done to determine if a significant difference exists between the response time and accuracy scores for closed set versus perimeter spatial arrangement conditions in both groups. The test-retest reliability was established by calculating the Cronbach's alpha values for the response time and accuracy scores.

Chapter IV

RESULTS

The present study investigated the accuracy and response time of closed set spatial arrangement compared to perimeter spatial arrangement in children with DS aged 6-12 years using a communication board. Twenty children with DS participated in the study. Group I consisted of 10 DS children, and Group II consisted of 10 children with DS. Both closed set and perimeter spatial arrangements were administered in both groups alternatively with a gap of three days. All the participants were instructed to identify the target picture symbol on the communication board when the auditory sample of the target picture was given through the computer speaker. Then the response time and accuracy for identifying all the 12 picture symbols in both closed set and perimeter spatial arrangement on a communication board was measured. Further, using SPSS software (version 26), the results of the response time and accuracy of the tasks administered to the participants were analyzed in various aspects.

4.1 Measurement of Response Time and Accuracy for Identifying the Target Symbols Using Closed set and Perimeter Spatial Arrangement in a Communication board

Descriptive statistics was used to describe the characteristics of the response time and accuracy score. The response time and accuracy for the correctly identified target symbols were computed for a closed set and perimeter spatial arrangement conditions in both groups. The Mean, Standard Deviation (SD) and Median scores were calculated for response time and accuracy for correctly identified target symbols in a closed set and perimeter spatial arrangement conditions are tabulated in Table 4.1.

Table 4.1

Mean, Standard Deviation (SD) and Median Scores of Response Time and Accuracy for a Closed set and Perimeter Spatial Arrangement Conditions in Both Groups

	Response Time (sec)			Accuracy (%)		
Conditions	Mean	SD	Median	Mean	SD	Median
Closed set spatial arrangement	9.60	2.36	9.65	50	6.04	50
Perimeter spatial arrangement	4.79	1.12	4.73	86	7.21	87.5

Thus, the results of the descriptive statistics revealed that the symbol identification in a perimeter spatial arrangement condition has faster response time and better accuracy than in a closed set spatial arrangement condition.

4.2 Comparison of Response Time and Accuracy for Identifying the Target Symbols Using Closed set versus Perimeter Spatial Arrangement in a Communication board

First, the Shapiro Wilk test of Normality was done to check the normality distribution of the data. The result of the Shapiro Wilk test revealed that the data did not follow a normal distribution. Hence, a non-parametric Wilcoxon Signed Ranks test was administered to compare both group's response time and identification accuracy between the closed set and perimeter spatial arrangement condition. The results of the Wilcoxon Signed Ranks test are tabulated in Table 4.3.

Table 4.2

Results of the Wilcoxon Signed Ranks Test for Response Time and Accuracy Between Closed set and Perimeter Spatial Arrangement Conditions

Closed set vs Perimeter	|Z|	*p*-value	Effect size
Response Time	3.920	< 0.001*	0.87
Identification Accuracy	3.950	< 0.001*	0.88

Note. '' indicates the significance of the 'p'-value at 0.05 level*

Wilcoxon Signed Ranks test results revealed a statistically significant difference ($p < 0.001$) between the response time and accuracy in the closed set versus perimeter spatial arrangement conditions. The effect size results showed high effect (effect size > 0.8) between the response time of the closed set and perimeter spatial arrangement condition as well as the accuracy of the closed set and perimeter spatial arrangement condition.

The mean scores obtained by both response time and accuracy score for closed set and perimeter spatial arrangement conditions are represented in Figures 4.1 and 4.2.

Figure 4.1

Bar Graph with Standard Error Bar Representing Mean Response Time Obtained by Closed set and Perimeter Spatial Arrangement Conditions

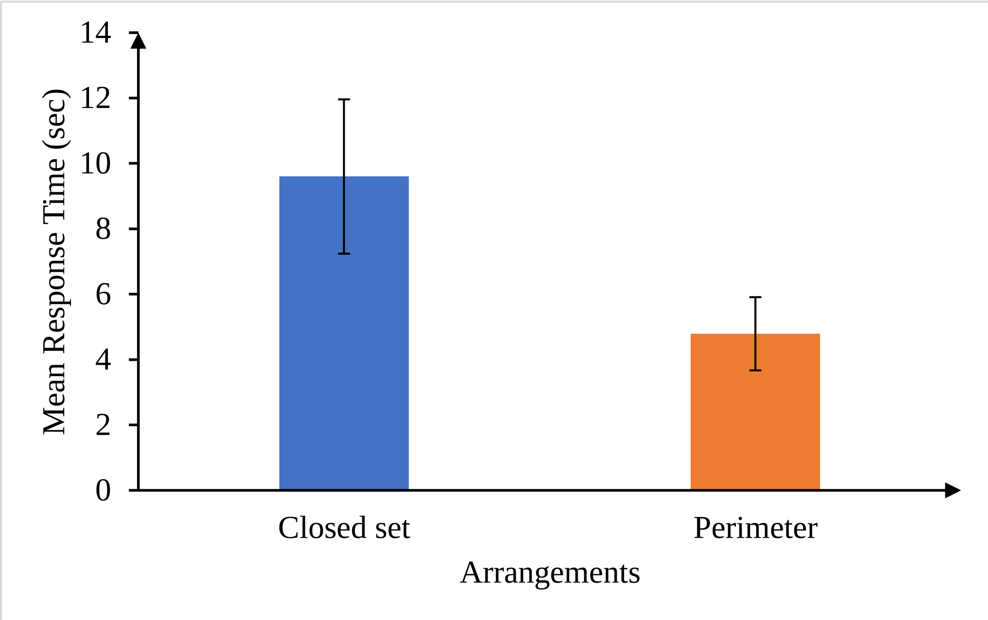
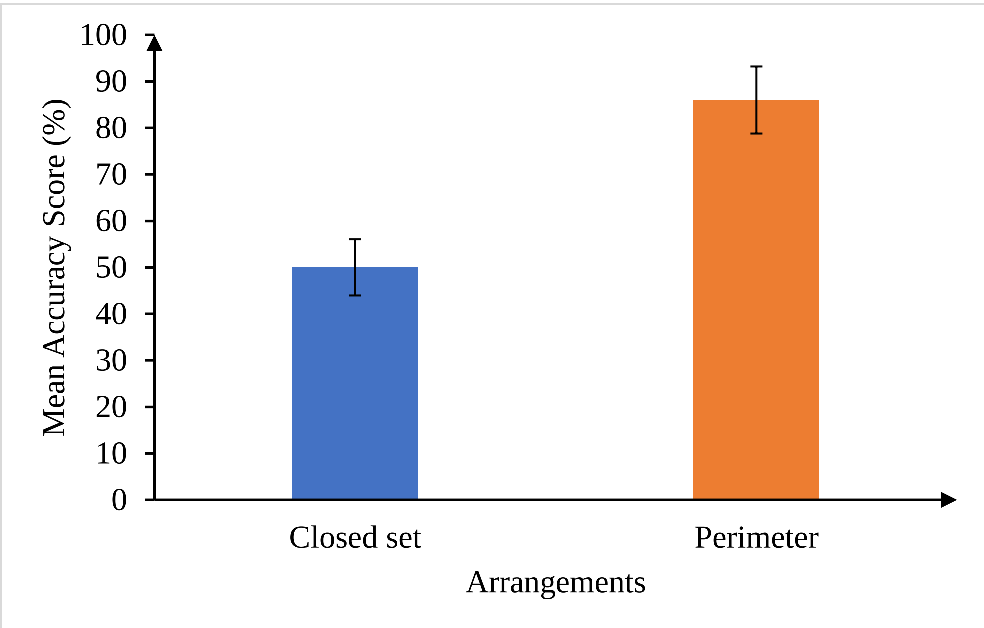


Figure 4.2

Bar Graph with Standard Error Bar Representing Mean Accuracy Score Obtained by Closed set and Perimeter Spatial Arrangement Conditions



Therefore, it is evident that the performance of response time and accuracy on a perimeter spatial arrangement condition was statistically significantly better than a closed set spatial arrangement condition.

4.2 Test-retest Reliability

Test-retest reliability was measured using Cronbach's alpha test after the gap of two weeks by following the same procedure on 20% of the participants (four children with DS) using closed set and perimeter spatial arrangement. The test results revealed that $\alpha = 0.89$ and 0.81 for accuracy and response time, which indicate good internal consistency ($0.9 > \alpha \geq 0.8$) between the test and retest scores obtained at different points of time.

To summarize, upon visual inspection of the graph as well as when comparing the mean and median values, there was a marked difference between the response time and accuracy in the symbol identification skills when the symbols were arranged into a perimeter spatial arrangement condition than closed set spatial arrangement condition on a communication board in children with DS. Further, the Wilcoxon Signed Ranks test was done to check for the statistical difference. The Wilcoxon Signed Ranks test results suggested a statistically significant difference in the response time and accuracy between the closed set versus perimeter spatial arrangement conditions in both groups.

Chapter V

DISSCUSSION

Several studies done in the western context indicated that the target symbol's response time and identification accuracy were enhanced when the symbols were spatially arranged in an AAC system for communication development in children and adolescents with DS and in typically developing children. There is a paucity of such studies in the Indian context. The current study aimed to determine whether changes in the spatial arrangement of symbols influence the symbol identification skills in children with DS using a communication board. This study demonstrates that spatial arrangement changes affect the symbol identification skills on a communication board in children with DS. This investigation provides preliminary evidence that the spatial arrangement facilitates the latency and accuracy of identifying the desired symbol.

On a communication board, 12 picture symbols from Avaz were taken and arranged into a closed set and perimeter spatial manner. Field testing was conducted with 20 children with DS, dividing them into two groups of 10 each. Both groups were assessed using closed set and perimeter spatial arrangement alternatively in a quiet room. Children with DS have to identify the target symbol out of the 12 picture symbols when the auditory sample of the target symbol was given through the computer speaker in both closed set and perimeter spatial arrangement. The response time and accuracy were measured for the picture symbols for both groups.

5.1 Response Time Between the Closed set and Perimeter Spatial Arrangement Condition

The present study's finding indicates a statistically significant difference in the response time of the closed set and perimeter spatial arrangement conditions, and the response time was faster under the perimeter spatial arrangement condition than the closed set spatial arrangement condition. So, under perimeter spatial arrangement conditions, it results in faster and more timely messages by reducing frustrations and improving communication for children with DS using AAC devices.

The present study demonstrated that arranging symbols in perimeter conditions facilitated the response time for identifying picture symbols. This study builds on earlier studies that illustrated the effect of closed set and perimeter spatial arrangement conditions on the response time for identifying target symbols in children with DS (Carelli, 2011). The result is contrastive to a similar study in which there is no significant difference in latency for any altered spatial arrangement conditions (Wilkinson et al., 2022). The difference in result might be due to the different age group taken. The study's result is consistent with the earlier studies on the influence of symbol arrangement on response time in adolescents with DS in which the symbols are grouped by shared internal symbol colour that aids the identification of a single symbol (Wilkinson et al., 2008; Wilkinson & McIlvane, 2013; Wilkinson & Madel, 2019). As well as the present study is consistent with previous studies of the influence of spatial arrangement in response time for symbol searching and identification in typically developing children (Wilkinson & Snell, 2011; Thistle & Wilkinson, 2017). The evidence highlights how crucial symbol arrangement is for children with DS.

5.1.1 Reasons for Faster Response Time in Children with DS Using Perimeter Spatial Arrangement Condition

Individuals with DS may respond faster if they fixate on distractions less frequently. (Wilkinson & Madel, 2019). Additionally, individuals with DS may be vulnerable to distraction because they cannot control their attention from irrelevant stimuli (Lanfranchi et al., 2009; Munir et al., 2000). Response time is a hallmark of cognitive processing (Goldstein, 2008). Typically, better response time equates to less complex processing due to less complex stimuli. Thus, across the present study, symbols' perimeter spatial arrangement condition represents a less complex array than the closed set spatial arrangement condition. Better response time under the perimeter spatial arrangement condition highlights that condition as less complicated and possibly simpler to understand and apply. Robillard et al. (2013) found that sustained attention, categorization, and fluid reasoning were significant indicators of navigational skills. A symbol arrangement likely provided better sustained attention, categorization and fluid reasoning that enhanced the ability to navigate the display, resulting in better response time for symbol identification.

5.2 Accuracy Between the Closed set and Perimeter Spatial Arrangement Condition

The finding of the present study indicates that there is a statistically significant difference in the accuracy for identifying the target symbols in a closed set and perimeter spatial arrangement conditions, and the accuracy was better and highly accurate for choosing the desired symbols under a perimeter spatial arrangement condition than closed set spatial arrangement condition. So, under perimeter spatial arrangement conditions, the children with DS select more symbols for their needs with high accuracy, leading to better communication with partners rather than increasing worries and discomforts while using the AAC devices. Children with DS under perimeter spatial arrangement conditions achieved 86% average accuracy in identifying the target symbols. Clinically, a cut-off score of 80% is frequently used, with 80% or better reflecting an acceptable level of learning and less than 80% indicating a need for more instruction (Glass, 1978). Participant's average accuracy in the present study was 86% only in the conditions in which symbol arrangement was provided.

The result of the present study is consistent with earlier research studies. It illustrates that the accuracy score is higher in a perimeter spatial arrangement condition than in the closed set arrangement condition in children with DS (Carelli, 2011). The study's result is consistent with the earlier studies on the influence of symbol arrangement on accuracy score for symbol identification in adolescents with DS in which the symbols are clustered and distributed based on internal colour (Wilkinson et al., 2008; Wilkinson & McIlvane, 2013). As well as it is consistent with previous studies done in typically developing children on the effect of spatial arrangement cues on accuracy scores (Thistle & Wilkinson, 2017), but the result is contrastive in another similar study in typically developing children, which revealed that spatial cues do not influence the accuracy score in identifying symbols (Wilkinson & Snell, 2011). It might be due to the presence of background colour along with spatial cues resulting in no change in accuracy scores compared to the absence of background colour.

5.2.1 Reasons for Better Accuracy in Children with DS Using Perimeter Spatial Arrangement Condition

When the symbols are arranged in a perimeter spatial arrangement, it reduces the visual crowding by spreading symbols apart significantly, inducing a reduction of the likelihood of fixations to irrelevant distracters (Wilkinson et al., 2022) and increasing the distance between the target symbol and its neighbours symbols

(Bulakowski et al., 2011) restrict the over selective behaviour in children with DS (Dube & Wilkinson, 2014) its leads to better accuracy in identifying the desired picture symbols. Symbol arrangement likely provided an underlying perceptual cue that guided the visual search (Wilkinson et al., 2008; Wilkinson & McIlvane, 2013), so under perimeter spatial arrangement conditions, visual search and attention results more accurate selection of target picture symbols.

To summarize, the present study found a statistically significant difference in response time and accuracy between both group's closed set and perimeter spatial arrangement conditions. In perimeter spatial arrangement conditions, it was noticed that the participants had faster response time and better accuracy than closed set spatial arrangement condition for picture symbol identification. This difference in response time could be attributed to factors such as complexity, inhibition skills, short term memory and navigational skills, and the difference in accuracy could be attributed to factors such as visual crowding and perceptual cues such as visual search and attention. Thus, spatial arrangement can be considered potentially efficient to be utilized in AAC systems for the communication development of Indian AAC users.

Chapter VI

SUMMARY AND CONCLUSIONS

Children with DS and other communication disorders require AAC systems to augment and support their language learning and, in some instances, completely substitute for spoken language. DS children have difficulty inhibiting fixations to distractions and over-selection of symbols because of disturbed executive functions. By altering the spatial layout of AAC devices or displays, one might enhance the visual search for symbol identification and decrease focus on surrounding symbols. By making these changes, behavioural outcome barriers, such as accuracy and response time, can be reduced, resulting in effective communication and faster pace of message generation. It is essential to make the intervention possible in such a situation. The study involved two groups of participants, with 10 children with DS in each group. Four categories, such as fruits, animals, food items and common objects, were selected from ACSLS, and each category included three items taken from the Avaz app. Then the 12 picture symbols were arranged into a closed set and perimeter spatial arrangement conditions on a communication board. The children had to select the target picture symbols when the audio sample of the target symbol was delivered via a computer speaker. Then both groups alternatively assessed the outcome measures such as response time and identification accuracy score in the form percentage using both closed set and perimeter spatial arrangement conditions after three days. Statistical analysis was done to determine if there was a significant difference in the response time and identification score between the closed set and perimeter spatial arrangement conditions. Results revealed a statistically significant difference in the response time and identification accuracy score between the closed set and perimeter spatial arrangement conditions. However, a comparatively faster response time and greater identification accuracy score were obtained for the children in DS when the symbols were arranged in the form of perimeter conditions on a communication board.

6.1 Clinical implications

- The present study can help in designing high-tech AAC devices and communication boards for persons with communication disorders, especially for children with DS.
- The perimeter spatial arrangement of symbols in AAC can be incorporated by SLPs during AAC therapy sessions for faster response time and better accuracy while identifying picture symbols for communication.

6.2 Limitations of the study

- The present study involved a small sample size of 20 children, with 10 participants in each group.
- The present study considered only two spatial arrangement conditions, closed set and perimeter.
- The present study included only 12 picture symbols to evaluate symbol identification skills.

6.3 Future directions

Future studies can be done utilizing different cues for designing AAC systems that facilitate the latency and accuracy of symbols. The findings need to be investigated further in larger samples and extend the participants with disabilities (CP and ASD) who might benefit from AAC interventions. Similar studies can be carried out on high-tech devices with more picture symbols, and other arrangements such as corner and widely spaced can be explored. Similar studies can be conducted in other languages and with children of different age ranges.

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APPENDIX I

Consent form

All India Institute of speech and Hearing,

Naimisham Campus, Manasagangothri, Mysore

Dissertation on

"Closed Set versus Perimeter Spatial Arrangement on Symbol Identification in Children with Down's syndrome"

You are invited to participate in the study titled "Comparison of closed set versus perimeter spatial arrangement on symbol identification in children with Down's syndrome". This study is conducted by Ms Noora Mol. K, a postgraduate student of the All India Institute of Speech and Hearing, under the guidance of Dr. Reuben Thomas Varghese, Scientist, Department of Speech-Language Sciences and Co-guidance of Dr Jayakumar. T, Associate Professor, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysore.

The study aims to evaluate whether changes in the spatial arrangement (closed set versus perimeter) of symbols influence the symbol identification skills in children with Down's syndrome using communication board. Participants and caregivers will be interviewed to obtain demographic details and necessary information prior to confirming eligibility for the study. Once eligible, the communication board will be presented in closed set and perimeter spatial arrangement to the participant, and the responses will be recorded for further reference.

The identity of the participant will not be revealed at any time, and the information and videos will be maintained confidential. The data obtained will not be disclosed, and access will be limited to individuals working on the study. Participation in this study is voluntary. You can refuse to participate or withdraw at any point in the study without penalty or loss of benefits to which you are otherwise entitled. The procedures of the study are non-invasive, and no risks are associated.

Informed consent

I have read the preceding information or read it to me in the language I understand. I have had the opportunity to ask questions about it, and any questions I have asked have been answered to my satisfaction.

I, ___________________________, give consent on behalf of my child to be a participant of this investigation/study/program.