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Research Paper

Cognitive Map Formation: A Comparative Study

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ABSTRACT

Cognition is a mental process in the brain that helps to gain knowledge and understanding. The mental processes involved are such as thinking, knowing, remembering, judging and problem solving. Language, imagination, perception and planning are some of these high-level mind functions. This study has investigated if there is difference in the ability of cognitive map formation in normal children when compared to children who are Deaf or hard of hearing (DHH). A matched group design was used in which each participant initially underwent a common task assessment. Participants (both normal and deaf or hard of hearing) were grouped based on the score in the IQ test, ensuring comparable IQ levels. The sample included 120 adolescents aged between 14 and 16; 60 DHH children and 60 children with normal hearing. From the results it was seen that the two groups differed significantly in their cognitive map formation ability. That is, contrarily to their normal-hearing peers, DHH children exhibited more facilitation during the learning phase of cognitive maps building, as indicated by less trials made and shorter time duration. Additional analyses showed no significant influence of socio-demographic variables between the two groups.

Keywords: *Cognitive map, hearing impairment, higher-order functioning*

Cognition, defined as the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses, encompasses perceiving, conceiving, remembering, reasoning, judging, imagining, and problem-solving (APA,2023). In psychology, cognition relates to both conscious and unconscious processes involved in thinking, reasoning, perception, intelligence, and learning.

A cognitive map is a mental representation of spatial and physical relationships in one's environment, an internalized map used for navigation, prediction, and interaction. These maps result from cognitive processes such as perception, memory, and attention, integrating sensory experiences and observations into a comprehensive framework. Cognitive maps include physical layouts, landmarks, travel times, distances, and even abstract concepts associated with locations.

They are crucial for decision-making, enhancing spatial memory, and effective problem-solving. The formation of cognitive maps poses unique challenges for children with hearing

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impairments, as their visual and auditory cues for spatial orientation and navigation are altered or limited. Hearing loss can affect psychomotor, communication, and language-acquisition abilities, impacting psycho-affective balance and time-space structure (Nasralla et al., 2014). Early hearing loss can substantially influence how children understand and navigate their environment, affecting their ability to cope with social demands and acquire skills.

Despite these challenges, studies show that children with hearing impairments can develop effective word-learning strategies and unique gesture languages, reflecting speech properties learned by hearing children (Lederberg et al., 2000). However, they may make errors in identifying social gestures, emotions, and facial expressions (Omerovic, 2023). Understanding how children with hearing loss form cognitive maps using limited cues is crucial for developing educational, rehabilitative, and inclusive strategies.

Objectives

1. To investigated if there is difference in the cognitive map formation ability in normal children when compared to children who are Deaf or hard of hearing (DHH)

Hypothesis

1. There is a significant difference in the cognitive map formation ability in children when compared to children who are deaf or Hard of hearing (DHH)

METHOD

Design and Sample

Using a matched group design, 120 adolescents aged 14 to 16 were recruited, including 60 DHH children and 60 children with normal hearing from Thiruvananthapuram district, Kerala, India. Participants were fluent in Malayalam, their native language. Informed consent was obtained, and all participants were school-going teenagers.

Participants were categorized into groups based on their performance on a common task, using Raven's Standard Progressive Matrices to match groups based on general intellectual functioning. Children scoring above the 75th percentile were included in the study.

Table 1 Sample Distribution

Age category	Male (N)	Female (N)	Male (D)	Female (D)	Total
14-16	30	30	30	30	120

*N: Normal; D: Hearing Impaired

Tools

Following were the tools used for collecting the data

1. Personal data sheet
2. Raven's Standard Progressive Matrices (SPM)
3. Finger maze

1. Personal data sheet

A Personal Data Schedule collected relevant socio-demographic information.

2. Raven's Standard Progressive Matrices

Nonverbal test for assessing general intellectual functioning, was used as a common task for categorizing the sample. Intelligence tests provide a standardized measure of cognitive abilities, allowing for the comparison of participants on a common ground. By using Raven's Standard Progressive Matrices, the study ensured that all participants had a comparable level of general intellectual functioning, which is crucial for isolating the effects of hearing impairment on cognitive map formation. To be included in the study, children had to score above the 75th percentile on this test. This criterion ensured that only those with a higher-than-average intellectual functioning were included, thereby focusing the study on the impact of hearing impairment rather than variations in general intelligence.

3. Finger maze
The finger maze apparatus was used to assess learning and cognitive map formation. The time taken and the number of trials required for successful completion were recorded. The participant was seated comfortably and allowed a 5-second glance at the maze before being blindfolded. Precautions included using only the dominant hand's index finger to trace the maze and no disclosure of results until the experiment's completion.

Data analysis
Data analysis was conducted using IBM SPSS 21, employing t-test and two-way ANOVA as the statistical techniques

RESULTS

The study aimed to identify significant differences in cognitive faculties between normal children and children who are deaf or Hard of Hearing specifically focusing on time and trials.

Comparison of Cognitive Map Formation
A cognitive map is a mental representation of spatial and physical relationships in one's environment, an internalized map used for navigation, prediction, and interaction. These maps result from cognitive processes such as perception, memory, and attention, integrating sensory experiences and observations into a comprehensive framework. Cognitive maps include physical layouts, landmarks, travel times, distances, and even abstract concepts associated with locations.

Hypothesis: There is a significant difference in the cognitive map formation ability in children when compared to children who are deaf or Hard of hearing (DHH)

Table 2 Comparison of Cognitive Map Formation

Variable	Group	N	df	Mean	SD	t-value	Sig
Time	1	60	118	13.1	30.5	-36.940	0.000
	2	60		42.72	5.41		
Trials	1	60	118	2.00	0.00	-6.1667	0.000
	2	60		8.17	1.96		

Both comparisons yielded p-values of 0.000, indicating statistically significant differences in time and trials between children hard of hearing and normal. The negative t-values suggest that the DHH group had significantly lower means for both time and trials.

DISCUSSION

The findings of this study reveal significant differences in cognitive map formation abilities between children who are hard of hearing or deaf and those with normal hearing.

Specifically, DHH children exhibited superior performance by taking fewer trials and less time to complete the maze, indicating more efficient cognitive processing in spatial tasks.

Several factors might contribute to this enhanced performance. One plausible explanation is the compensatory mechanism that develops in DHH children. According to the sensory compensation hypothesis, when one sensory modality is impaired, other senses may become more attuned to compensate for the loss. This phenomenon has been observed in various studies. For instance, Bavelier et al. (2006) found that individuals with hearing impairments often develop enhanced visual processing abilities. This heightened visual attention may enable DHH children to form cognitive maps more efficiently (Dye et al. 2007).

Furthermore, cognitive flexibility might play a role in the superior performance of DHH children. Cognitive flexibility refers to the ability to switch between different concepts or adapt to new situations quickly. Enhanced cognitive flexibility has been observed in individuals who have undergone extensive practice in navigating their environment without relying on auditory cues (Dye & Hauser, 2014). This ability to adapt and reorganize cognitive strategies could explain why DHH children performed better in the maze task.

Another aspect to consider is the potential use of distinct cognitive strategies. DHH children might rely more heavily on visual and spatial memory, as well as on other non-verbal cues, to navigate their environment. Studies have shown that DHH individuals often excel in tasks requiring visual-spatial processing, such as mental rotation and spatial memory tasks (Arnold, 1978; Auer & Bernstein, 2007). This proficiency in visual-spatial skills likely contributes to their ability to form cognitive maps more efficiently.

Contrary to some literature that suggests cognitive deficits in DHH children (Almomani et al., 2020; Kral et al., 2016), our findings highlight their strengths in specific cognitive domains. This discrepancy may be due to differences in the nature of the tasks used in various studies. While some tasks may emphasize language-based or auditory processing, others, like the maze task used in this study, rely more on visual-spatial skills, where DHH children tend to excel.

The findings also align with the theory of neuroplasticity, which posits that the brain can reorganize itself in response to sensory deprivation or training. Neuroimaging studies have shown that individuals with early-onset deafness exhibit structural and functional changes in brain regions associated with visual processing (Simon et al., 2020). These changes may underlie the enhanced visual-spatial abilities observed in DHH children.

In addition to cognitive factors, environmental influences such as educational methods and parental support play a crucial role in the cognitive development of DHH children. Hamanjilla et al. (2024) emphasize that supportive environments can significantly enhance cognitive outcomes in children with hearing impairments. The participants in this study may have benefited from specialized educational programs and familial support, contributing to their superior performance.

Despite these strengths, it is essential to acknowledge the study's limitations. The relatively small sample size and the specific geographic location may limit the generalizability of the findings. Additionally, while general IQ was controlled, other variables such as previous experience with similar tasks were not accounted for. Future research should aim to include larger, more diverse samples and consider additional factors that may influence cognitive map formation.

Major Findings

1. Significant Difference in Time: The ANOVA results indicate a significant difference in the time taken to complete the maze between DHH and normal-hearing children, with DHH children taking less time on average.
2. Significant Difference in Trials: There is a significant difference in the number of trials required to complete the maze, with DHH children needing fewer trials on average.

Limitations of the study

1. Sample Size: The study's sample size was relatively small, which may limit the generalizability of the findings.
2. Geographical Limitation: The sample was drawn from a specific region in India, which may not represent the broader population.
3. Control of Variables: While general IQ was controlled, other variables such as prior experience with similar tasks were not accounted for.
4. Assessment Tools: The finger maze and Raven's Standard Progressive Matrices may not fully capture all aspects of cognitive map formation.

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Conflict of Interest

The author(s) declared no conflict of interest.

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