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Original Article

Auditory Memory and Visual Memory in Typically Developing Children: Modality Dependence/Independence

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BACKGROUND: The study aimed to determine whether there was a difference or an association between auditory memory and visual memory in typically developing children.

METHODS: Eighteen children, aged 8 to 12 years, with normal hearing and visual acuity, were evaluated using the Children's Memory Scale (CMS) to determine their auditory and visual memory performance. Using the core subtest battery of the CMS, auditory/verbal (immediate and delayed), visual/nonverbal (immediate and delayed), and general memory index scores were assessed.

RESULTS: No significant difference was found between auditory/verbal memory and visual/nonverbal memory scores for both immediate and delayed recall. Likewise, no correlation between auditory/verbal memory and visual/nonverbal memory scores was found. However, there was a significant correlation between immediate and delayed recall scores within each modality.

CONCLUSIONS: The non-significant difference between the two modalities for both immediate and delayed recall gives the impression that memory is modality independent. However, the lack of any correlation between the two suggests there was no association between them. The absence of a significant difference between modalities can be attributed to the auditory and visual test material used in CMS not being analogous. It can thus be inferred that the auditory and visual modalities are independent. While the visual material evaluates simultaneous/concurrent perception, the auditory material assesses sequential perception.

KEYWORDS: Modality dependence, modality independence, immediate memory, delayed memory, children's memory scale

INTRODUCTION

Assessment of memory in children is essential as it is known to be a precursor for the development of complex skills such as learning, reasoning, and problem-solving.[1] These skills have been found to be important for academic achievement.[2-5] However, there is considerable debate as to whether memory is modality-dependent or independent. Such information has implications for diagnosis and the teaching methods used for children. If memory is modality-independent, it would not matter whether information that needs to be remembered is provided through the auditory or visual modality. However, if memory is modality-dependent, analogous tests, wherein the stimuli for each modality are matched in terms of the way they are processed, would be needed. This is required to determine the functioning of the two modalities to decide which of them is more conducive to retaining information. This would help design effective therapy/training programs. The need for using analogous test materials has been emphasized to differentially diagnose auditory modality-specific disorders from other overlapping conditions.[6]

A few studies have found memory to be modality-dependent, as the auditory modality was observed to be superior to visual memory.[7-12] The reason given by Dornbush and Basow[11] for the superior performance of auditory memory over visual memory is that auditory stimuli are processed sequentially, where the stimuli are perceived one after the other. On the other hand, visual stimuli are processed simultaneously, where the signals are perceived in a concurrent manner or globally. They observed that if

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both modalities were given sequential stimuli, the auditory modality would outperform the visual modality, as the presentation would favor recall in the auditory modality. Pillai and Yathiraj[10] also noted that the presentation of sequential stimuli resulted in better auditory memory than visual memory. Studies have also reported that literacy training enhances the dominance of auditory memory over visual memory in children.[8,9]

In contrast to the above studies, researchers have also reported that visual memory was superior to auditory memory.[13-16] Foos and Goolkasian,[14] using verbal and nonverbal stimuli, observed that visual stimuli have direct access to semantic memory and possess finer details, leading to better long-term representation in memory when compared to auditory stimuli. Further, Cohen et al[13] opined that the capacity of the auditory modality may be limited to process and store information, unlike the visual modality, leading to the better performance of the latter modality. Gloede and Gregg[15] also found visual memory to be better than auditory memory while assessing same-day immediate memory. They noted that more detailed information was encoded in the visual modality than the auditory modality while encoding of memory in the auditory modality was reported to be coarse. They also ascribed the better performance of the visual modality compared to the auditory modality due to simultaneous processing in the former modality.

It has also been found that memory is modality independent, as studies have found scores on both auditory and visual modalities to be similar.[15,17-19] Ward et al[17] reported that short-term auditory and visual memories are functionally equivalent. However, they stress the need to control methodological differences when investigating if memory is modality-specific. For the visual material they used unfamiliar faces, while for the auditory material they used nonwords. Likewise, Visscher et al,[18] who found no significant difference in auditory and visual memory, accredited their results to similar mechanisms being employed during memory processing in the two modalities. Additionally, Gloede and Gregg[15] who reported of differences across the modalities for immediate recall, found no such differences for delayed recall. They ascribed this difference in immediate and delayed recall to the auditory modality being more resistant to information loss over time as it is stored in a conceptual-based way.

Thus, there is no consensus on whether memory is modality-independent or not. As mentioned earlier, such information has implications for the diagnosis of memory problems and the techniques used in their rehabilitation. Further, studies that evaluated the impact of auditory and visual modalities on memory have mainly done so using immediate memory tasks. It has been observed that the effect seen during immediate memory tasks may not be the same as that seen for delayed memory tasks. Hence, the study aimed to assess whether auditory and visual memory are different in typically developing children when evaluated using immediate and delayed recall tasks. It has been hypothesized that there will be no significant difference in the memory processed in the auditory and visual modalities.

MAIN POINTS

- It is inferred that memory is modality-dependent.
- Memory needs to be evaluated separately in the auditory and visual modes.
- Implications for managing children with neurodevelopmental disorders.

MATERIALS AND METHODS

The study was carried out utilizing a cross-sectional research design, with the participants selected through a convenience sampling technique. The required sample size was found to be ~16, which was determined using G-Power software, version 3.1[20] The sample size was estimated using the values given by Riccio et al.[21] The study adhered to the Declaration of Helsinki and its modifications, and ethical clearance for bio-behavioral research was obtained from the institutional review board (JSSMC/IEC/070324/01 NCT/2023-24).

Participants

Eighteen children (10 females and 8 males), aged ≥ 9 to ≤12 years (mean age = 10.82; SD = 0.80) and educated in English, were evaluated. The details of the age and gender distribution of the participants of the study have been provided in Table 1. The children had normal hearing sensitivity (≤ 15 dB HL from 250 Hz to 8 kHz) as determined using a screening audiological test. Normal visual acuity was confirmed using a Snellen chart placed at 20 feet. They were reported to have no history of otological and neurological problems. Only children with no academic difficulties, as per the report of class teachers who had taught the children for more than 2 years, were selected. The Screening Checklist for Auditory Processing,[22] answered by the class teacher who had taught the children for at least a year, was utilized to rule out the risk for auditory processing deficits. Informed consent was obtained from the parent or caregiver.

Table 1. Age and Gender Distribution of the Participants of the Study

Participant	Age (in years)	Gender
1	12	F
2	10	F
3	11	F
4	11	M
5	12	M
6	12	M
7	12	M
8	9	F
9	10	F
10	11	M
11	11	F
12	11	F
13	10	F
14	10	M
15	11	M
16	11	M
17	11	M
18	11	M

F, females; M, males.

MATERIAL

The Children's Memory Scale (CMS), developed by Cohen[23] was administered to measure the auditory and visual memory abilities of the children. The CMS examined declarative memory and learning functions in 3 broad domains (auditory/verbal, visual/nonverbal, and working memory that included attention and concentration), with each domain having multiple indices. Only the two "core subtests" of each domain were used for the study and not the "supplementary subtests." Both immediate memory and delayed recall were evaluated. The CMS "core subtest battery" consisted of several subtests in the auditory/verbal domain (stories, word pairs) and the visual/nonverbal domain (dot locations, faces). Five index scores were derived after the administration of the "core subtest battery,"" which included "auditory/verbal immediate," "auditory/verbal delayed," "visual/nonverbal immediate," and "visual/nonverbal delayed." From these, the global memory index was calculated by combining the auditory/verbal and visual/nonverbal immediate recall and delayed recall scores.

The auditory/verbal domain of the "core subtest" included stories and word pair subtests that evaluated both immediate and delayed memory. The stories were used to assess a child's ability to recall meaningful and semantic content. The "word pairs" subtest assessed the ability of a child to learn a list of novel word pairs. The visual/nonverbal domain included "dot locations" and "faces" subtests. The ability of a child to learn the spatial locations of a set of dots over three successive learning trials and the ability to remember and recognize a series of faces were measured in this domain, respectively. The auditory and visual stimuli used in the CMS test are non-analogous.

Before administering CMS, it was cross-culturally adapted for Indian children with the help of 3 speech and hearing professionals. Infrequently used names of girls ("Lisa," "Melissa," and "Jessica") were replaced with Indian names ("Leela," "Megha," and "Sangeeta"), which were chosen from grade-equivalent school textbooks. Further, unfamiliar words/phrases ("lifeguard class," "steering," and "got mad at") were replaced with more familiar phrases ("expert swimming class," "driving," and "got angry at") from the Oxford dictionary. All the modifications were done in the story description section of the test.

Procedure

Once it was ascertained that each child had normal hearing and was not at risk for an auditory processing disorder, a structured interview was conducted with the class teacher as well as the children to obtain information about their educational history and handedness. Following this, the children were made to sit comfortably, and the CMS was administered in a quiet, well-lit classroom, free from distractions. Only tasks that had both auditory and visual subsections were measured. The order in which the test items were administered was as given in the test manual and was identical for all the participants. The "dot locations" test was administered initially, followed by "stories," "faces," "numbers," and "sequences," respectively. It was ensured that the delayed recall portions of the subtests were administered 30 min after the administration of the immediate recall subtests. The children were instructed on how to respond before the commencement of each subsection, and it was repeated if they asked for it or were unsure of what to do.

The responses were scored in terms of accuracy, as given in the original test. For calculating accuracy, every correct response was awarded a score of "1", and an incorrect response was scored "0." Response accuracy was scored for all the domains evaluated in the current study. The raw scores were converted to index scores to equate the maximum possible scores across the subsections and age groups. All the responses were noted on response sheets and analyzed later. The scores obtained for all the 8 indices in the "core subtest battery" were summed to arrive at the "general memory index score." To determine the auditory/verbal memory index scores, the scores obtained in the "verbal immediate" and "verbal delayed" were summed. Likewise, to determine the visual/nonverbal memory index, the scores of the "visual immediate" and "visual delayed" were summed. The children were given a break if they showed signs of restlessness.

Analyses

As the Shapiro–Wilk test of normality indicated that the data were normally distributed ($p < .05$), parametric tests were used. Both descriptive as well as inferential statistics were carried out. Statistical analyses were performed using the Statistical Package for Social Sciences software (IBM, version 20, Chicago, Illinois).

RESULTS

The significance of the difference between the scores of the auditory/verbal and visual/nonverbal domains, as well as between the immediate and delayed recall subtests, was checked using a repeated measures analysis of variance (ANOVA), after checking for an age effect. Further, the association between the auditory/verbal and visual/nonverbal memory indices, as well as between the scores of the immediate and delayed subtests within each modality, was determined using Pearson's correlation and Bland–Altman plots.

The mean and standard deviation for the auditory/verbal (immediate and delayed), visual/nonverbal (immediate and delayed), and general memory indices are presented in Table 2. It can be observed that the scores for the auditory/verbal material were higher than those obtained for the visual/nonverbal material. This was seen for both immediate recall scores as well as the delayed recall scores. Also, the immediate memory scores were higher than the delayed recall scores for both the auditory and visual memory indices.

The participants were divided into two groups (9 to < 11 years and 11 to 12 years) to determine if there is an age effect. A one-way ANOVA, with Welch correction for unequal number of participants, revealed no significant differences between the age groups for auditory

Table 2. Mean and Standard Deviation of the Indices of the Children's Memory Scale (CMS) Test Battery

CMS Index	Mean* (n = 18)	Standard Deviation
Auditory/Verbal immediate response	103.16	18.35
Auditory/Verbal delayed response	100.66	17.30
Visual/Nonverbal immediate response	93.11	9.46
Visual/Nonverbal delayed response	90.83	11.73
General memory	95.33	12.75

*Maximum possible score = 150; CMS, Children's Memory Scale.

immediate ($F(1, 17) = 2.98$, $p = .10$), auditory delayed ($F(1, 17) = 3.98$, $p = .07$), visual immediate ($F(1, 17) = 0.69$, $p = .43$), visual delayed ($F(1, 17) = 0.43$, $p = .84$), and general memory ($F(1, 17) = 0.03$, $p = .86$) scores. Hence, the remaining analysis was done with all the participants combined.

A repeated measure ANOVA (2 auditory/verbal x 2 visual/nonverbal) was conducted to check for the significance of the difference between the auditory/verbal scores (immediate and delayed) and the visual/nonverbal scores (immediate and delayed). No significant main effect was obtained ($F(3, 15) = 3.19$, $p = .07$, $\eta_p^2 = 0.16$), indicating that there was no difference between the auditory and visual memory as well as between the immediate and delayed scores.

To determine the relationship between the 4 measures of CMS (auditory/verbal immediate and auditory/verbal delayed, visual/nonverbal immediate, andvisual/nonverbal delayed), a Pearson's correlation test was performed. No significant correlation was found between the two modalities for the subtests evaluating either immediate memory ($r(18) = 0.33$; $p = .18$) or delayed memory ($r(18) = 0.28$; $p = .24$). However, within the auditory/verbal domain there was a significant strong correlation ($r(18) = 0.784$; $p = .00$) between immediate and delayed memory scores. Similarly, a significant moderate correlation ($r(18) = 0.46$; $p = .05$) was found between the immediate and delayed memory scores for the visual/nonverbal domain.

Additionally, Bland–Altman plots were obtained to determine the agreement between the immediate and delayed memory scores within each of the modalities (Figure 1a and b) and between the two modalities (Figure 2a and b). The bias, computed by subtracting the immediate and delayed auditory memory scores (Figure 1a) was 2.50, while the bias for the immediate and delayed visual scores (Figure 1b) was 2.28, indicating that the latter was closer to the line of identity. However, the bias values calculated from the difference between the auditory and visual immediate memory scores (Figure 2a) as well as the auditory and visual delayed memory scores (Figure 2b) was −10.1 and −9.83, respectively, demonstrating that they were further away from the line of identity compared to the within-modality scores. For all 4 comparisons, most of the data points were within the 95% confidence interval.

DISCUSSION

The findings of the significance of the difference between the 4 index scores ("auditory/verbal immediate," "auditory/verbal delayed," "visual/nonverbal immediate," and "visual/nonverbal delayed") as well as the correlation/association between them are discussed. The lack of a significant difference between the auditory and verbal memory scores seen in the present study for both immediate and delayed recall gives the impression that memory is modality-independent. These results are in agreement with the findings of Gloede and Gregg,[15] Ward et al,[17] Visscher et al,[18] and McFarland and Cacace,[19] who also reported that memory is processed in a similar way in both the auditory and visual modalities. However, these studies, including the current study, did not use analogous material to evaluate the two modalities. Hence, the absence of a difference between memory assessed in the auditory and visual modalities could be influenced by the stimuli used. Ward et al[17] also ascribed the similarity

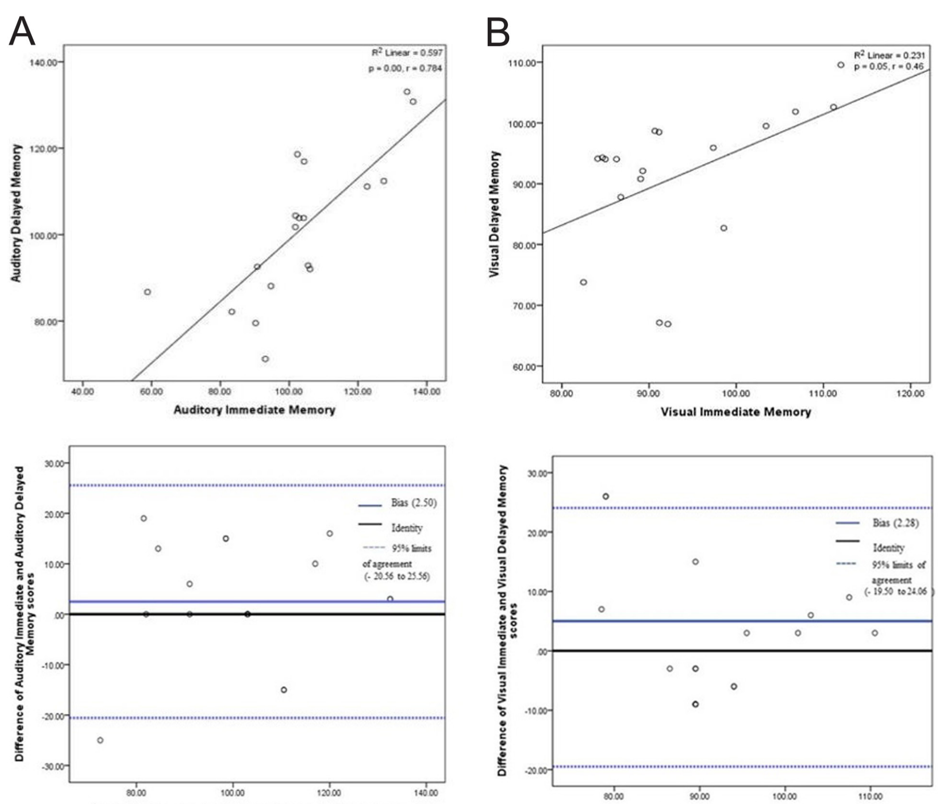

Figure 1. Bland–Altman "scatterplots" and "difference plots" for immediate and delayed auditory/verbal memory index scores (A) and immediate and delayed visual/nonverbal memory index scores (B) for the Children's Memory Scale.

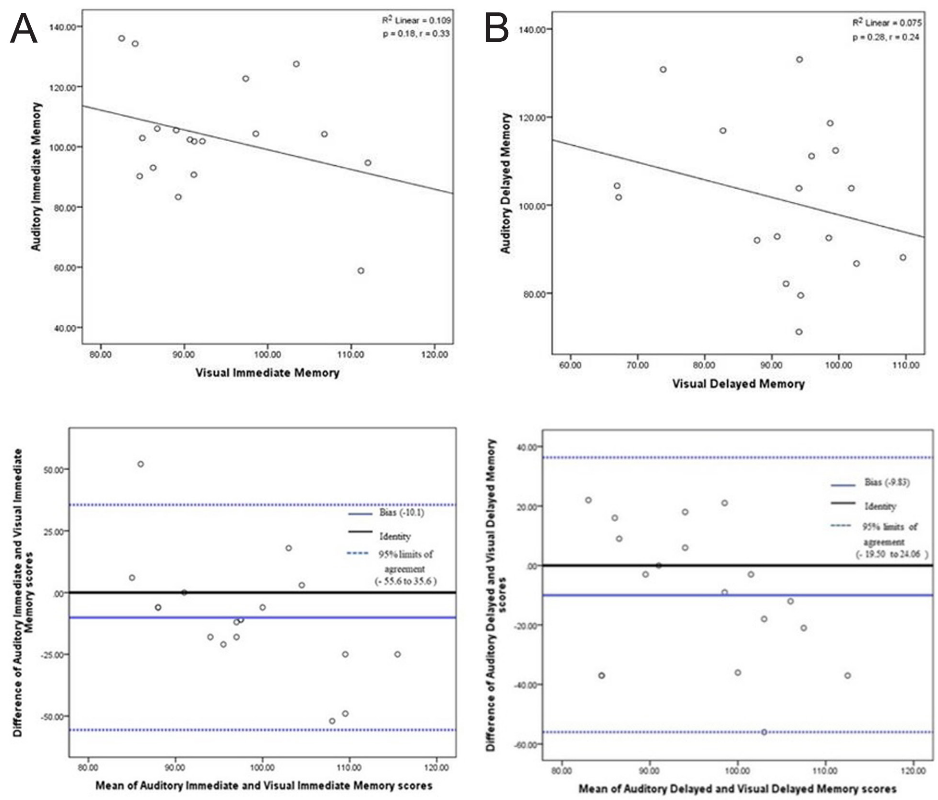

Figure 2. Bland-Altman "scatterplots" and "difference plots" for the auditory/verbal and visual/ nonverbal immediate memory index scores (A) and auditory/ verbal and visual/ nonverbal delayed memory index scores (B) for the Children's Memory Scale.

in performance across the auditory and visual modalities to differences in stimuli used by them rather than actual memory processing. Likewise, in the test used in the present study that was developed by Cohen,[23] the visual stimuli assessed simultaneous perception, while the auditory stimuli assessed sequential memory. This difference in the material used to assess memory in the two modalities could have been a covariable that would have influenced the results of the current study.

Unlike the current study, where no difference was seen between the two modalities during immediate memory and delayed memory, Gloede and Gregg[15] reported that the two modalities were significantly different for immediate memory, but not for delayed memory.

In the literature, a significant difference between the two modalities has been found in studies that have used analogous material to assess auditory and visual memory.[7,10,18,24] However, no significant difference in memory processing between the modalities was found by Visscher et al[18] despite using analogous stimuli. Unlike the studies done by Logie,[7] Lohithakshan and Nataraja,[24] Pillai and Yathiraj,[10] they utilized nonverbal stimuli to assess memory. It is likely that nonverbal analogous stimuli are processed differently compared to verbal analogous stimuli across the two modalities.

Further, the absence of a significant difference between immediate and delayed memory within each modality in the current study indicates that the tasks were simple enough to enable typically developing children to recall the stimuli after a gap of 30 min. This was similar to what Cohen[23] noted in the norms provided in the test, where the difference in scores of immediate and delayed memory varied marginally or overlapped. It requires to be studied whether those with an auditory processing problem would show a difference between immediate and delayed recall for any specific modality when analogous material is used.

Additionally, in the present study, no significant correlation was found between the auditory and visual memory scores of the typically developing children. Thus, it can be inferred that the two modalities assess different aspects of memory. However, a significant correlation within modality was found for the immediate and delayed auditory and visual memory scores. This substantiates that the lack of difference seen between the auditory and visual memory seen in the study at hand could be due to covariables influencing the results. On the other hand, the correlation between the immediate and delayed memory scores suggests that the two are associated with each other and are probably not influenced by other covariables. The findings of the correlation were also reflected in the association measured using Bland–Altman plots. The association between the two modalities was considerably lesser for both immediate and delayed memory, as the bias values were high. Likewise, as seen in the correlation, the association was stronger between immediate and delayed memory within each of the modalities. These results highlight that the way memory is processed in the auditory and visual modalities is not similar. As the results were compared with the findings of Pillai and Yathiraj[9] and Lohithakshan and Nataraja,[24] participant variabilities could have influenced the conclusions. However, as the earlier studies used similar inclusion criteria, it is unlikely that this variability would have influenced the conclusions.

CONCLUSION

The absence of a significant difference between the auditory and verbal memory scores for both immediate and delayed recall in the current study is attributed to the non-analogous stimuli used in CMS and does not indicate that memory is modality independent. To confirm that memory is modality-independent or dependent it is essential to use analogous test material. The lack of correlation and association between the scores of the two modalities for immediate as well as delayed recall also substantiates that the auditory and visual modalities are modality independent.

The outcome of the study has implications for designing assessment and treatment protocols for children exhibiting deficits in either auditory, visual, or both modalities. This may include children with auditory processing disorder, specific learning disorder, and/or children with memory deficits secondary to neurodevelopmental disorders.

Ethics Committee Approval: This study was approved by the Ethics Committee of JSS Academy of Higher Education and Research University, (Approval No: JSSMC/IEC/070324/01 NCT/2023-24, Date: 09.03.2024).

Informed Consent: Informed consent was obtained from the parents or caregivers of the participants who agreed to take part in the study.

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REFERENCES

1. Cowan N. Working memory underpins cognitive development, learning, and education. *Educ Psychol Rev*. 2014;26(2):197-223. [CrossRef]
2. Maehler C, Schuchardt K. The importance of working memory for school achievement in primary school children with intellectual or learning disabilities. *Res Dev Disabil*. 2016;58:1-8. [CrossRef]
3. Blankenship TL, O'Neill M, Ross A, Bell MA. Working memory and recollection contribute to academic achievement. *Learn Individ Differ*. 2015;43:164-169. [CrossRef]
4. Bergman Nutley S, Söderqvist S. How is working memory training likely to influence academic performance? Current evidence and methodological considerations. *Front Psychol*. 2017;8:69. [CrossRef]
5. Roberts G, Quach J, Gold L, et al. Can improving working memory prevent academic difficulties? a school based randomised controlled trial. *BMC Pediatr*. 2011;11(1):57. [CrossRef]
6. Jerger J, Musiek F. Report of the Consensus Conference on the diagnosis of auditory processing disorders in School-aged children. *J Am Acad Audiol*. 2000;11(9):467-474. [CrossRef]
7. Logie RH. *Visuo-spatial Working Memory*. Mahwah, NJ: Lawrence Erlbaum Publishers Ltd; 1995.
8. Boivin MJ, Bangirana P, Shaffer RC. The relationship between visual-spatial and auditory-verbal working memory span in Senegalese and Ugandan children. *PLoS One*. 2010;5(1):e8914. [CrossRef]
9. Conant LL, Fastenau PS, Giordani BJ, Boivin MJ, Opel B, Dia Nseyila D. Modality specificity of memory span tasks among Zaïrian children: a developmental perspective. *J Clin Exp Neuropsychol*. 1999;21(3):375-384. [CrossRef]
10. Pillai R, Yathiraj A. Auditory, visual and auditory-visual memory and sequencing performance in typically developing children. *Int J Pediatr Otorhinolaryngol*. 2017;100:23-34. [CrossRef]
11. Dornbush RL, Basow S. The relationship between auditory and visual short-term memory and reading achievement. *Child Dev*. 1970;41(4):1033-1044. [CrossRef]
12. Gadzella BM, Whitehead DA. Effects of auditory and visual modalities in recall of words. *Percept Mot Skills*. 1975;40(1):255-256. [CrossRef]
13. Cohen MA, Horowitz TS, Wolfe JM. Auditory recognition memory is inferior to visual recognition memory. *Proc Natl Acad Sci U S A*. 2009;106(14):6008-6010. [CrossRef]
14. Foos PW, Goolkasian P. Presentation format effects in a levels-of-processing task. *Exp Psychol*. 2008;55(4):215-227. [CrossRef]
15. Gloede ME, Gregg MK. The fidelity of visual and auditory memory. *Psychon Bull Rev*. 2019;26(4):1325-1332. [CrossRef]
16. Moulton JM. Auditory and visual memory skills in normal children. 1977. University of Montana. Available at: https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=5991&context=etd. Accessed October 12, 2023.
17. Ward G, Avons SE, Melling L. Serial position curves in short-term memory: functional equivalence across modalities. *Memory*. 2005;13(3-4):308-317. [CrossRef]
18. Visscher KM, Kaplan E, Kahana MJ, Sekuler R. Auditory short-term memory behaves like visual short-term memory. *PLoS Biol*. 2007;5(3):e56. [CrossRef]
19. McFarland DJ, Cacace AT. Modality specificity of auditory and visual pattern recognition: implications for the assessment of central auditory processing disorders. *Audiology*. 1997;36(5):249-260. [CrossRef]
20. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-191. [CrossRef]
21. Riccio CA, Cash DL, Cohen MJ. Learning and memory performance of children with Specific Language Impairment (SLI). *Appl Neuropsychol*. 2007;14(4):255-261. [CrossRef]
22. Muthuselvi T, Yathiraj A. Utility of the screening checklist for Auditory Processing (SCAP) in detecting (C) APD in Children. dissertation article done at AIISH, VII, Student research at AIISH, Mysore*;* 2009.
23. Cohen MJ. *Children's memory scale. Administration manual*. San Antonio, Texas: The Psychological Corporation; 1997.
24. Lohithakshan NM, Nataraja NP. Effect of stimulus modality on the performance on working memory tasks in children. *Int J Health Sci Res (*www.ijhsr.org*)*. 2020;10(12):247-251.