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# A Developmental Study of Working Memory in Relation to Individual Differences

**Sushma Pandey**
Associate Professor,
Deptt. of Psychology (D.S.A.),
D.D.U. Gorakhpur University,
Gorakhpur

**Priti Tamta**
Assistant Professor,
Deptt. of Psychology,
S.S.J. Campus Almora,
Kumaun University,
Nanital

**Niharika Tripathi**
Research Scholar,
Deptt. of Psychology,
D.D.U. Gorakhpur University,
Gorakhpur

**Abstract**

This study intended to analyze the influence of age, gender and verbal ability of children on development of working memory. A 2×2×2 factorial design, with two age groups, (younger & older group) × gender (boys & girls) × verbal ability level (high & low) was used in present study. Verbal Ability Test (VAT) was applied to identify the level and form of verbal ability in children. Working Memory tasks were exercised to assess three components of working memory i.e., Phonological Loop, Visuo-Spatial Sketch Pad and Central Executive.

Results revealed the significant effects of age and verbal ability on working memory. However, the role of gender in working memory was partially supported. More specifically, elder children performed better on different components of working memory as compared to younger children. Gender differences were identified only on central executive working memory. Moreover, high verbal ability in children facilitated proper development of working memory. Regression results proved the contributing role of age, gender and various forms of verbal ability in the development of working memory. Findings have been discussed.

**Keywords:** Central Executive, Individual Differences, Phonological loop, Verbal Ability, Visuo-Spatial Sketch Pad and Working Memory

**Introduction**

Working memory, our ability to process and remember information, is linked to a range of cognitive activities from reasoning tasks to verbal comprehension. Working Memory (WM) refers to the temporary storage and manipulation of information. It is involved in information processing during the performance of a wide range of everyday tasks, as well as in laboratory studies of short-term storage.

Working memory grew out of dissatisfaction in the early 1970s with the idea of a single short-term storage and processing system, characterized most notably in the Atkinson and Shiffrin (1968) model. This led Baddeley and Hitch (1974) to propose a Working Memory (WM) which comprised a number of components. One component, the central executive, was proposed as the system responsible for reasoning, decision making, and coordinating the operation of subsidiary specialised "slave" systems. Two slave systems were proposed initially, namely the visuo-spatial sketch-pad, or VSSP, and the articulatory loop. The visuo-spatial sketch-pad was considered to be responsible for the temporary storage and manipulation of visuo-spatial material, while the articulatory loop provided a similar function for verbal material. Later Baddeley (2000) developed a model of working memory which suggested that WM is a domain-general component responsible for the control of attention and processing that is involved in a range of regulatory functions, including the retrieval of information from long-term memory. This model also includes two domain-specific stores responsible for the temporary storage of verbal and visuo-spatial information and has been supported in studies of children, adults, and neuron imaging research (Jonides, Lacey, & Nee, 2005).

Although, working memory can be tested reliably from as young as 4 years of age yet, performance on working memory tasks is subject to large degrees of individual variation. Individual differences in working memory capacity have important consequences for children's ability to acquire knowledge and new skills (Cowan & Alloway, 2008). In typically developing children, scores on working memory tasks predict reading achievement independent of measures of phonological skills. Working memory is also linked to math outcomes; low working memory scores are closely related to poor performance on arithmetic, word problems and poor computational skills. This capacity has a significant impact on learning in various developmental disorders such as reading disabilities (Gathercole, et.al; 2006), language impairments (Alloway & Archibald, 2008), and motor difficulties. In addition, Working Memory is related to academic achievement in the domain of reading writing, mathematics, and science. As Working Memory plays an important role in cognitive activity, researchers are exploring ways of applying WM research to improve abilities such as fluid intelligence–the ability to understand complex relationships and solve new problems and science achievement (Martinez, 2000).

The neural processes sub-serving working memory and brain structures underlying this system continue to develop during childhood. The prefrontal cortex is one of the last brain regions to mature and it has been suggested that developmental changes in this brain area parallel the cognitive development during childhood (Luna et.al; 2001). Researchers evinced that the development of working memory processes is tied to the maturation of the frontal lobes in childhood years. By studying school-age children differing in age by 2 or 3 years, experimental and neuro-imaging studies offered important information on the developmental progresses of the different processes throughout childhood ; (1) verbal storage processes developed substantially throughout early and middle childhood, with peaks at 7 and 10 years of age; (2) Visuo spatial storage processes developed more prominently before the age of 9 years; and (3) interference control processes emerged between middle to late childhood, usually around the age of 9 or above years due to the late development of higher cognitive abilities in frontal lobes maturation (Pickering et al; 2001), and (4) The development of interference control processes might best be reflected by cross-domain interference control processes.

Developmental studies conducted with the n-back task have shown that visuo-spatial working memory (VSWM) performance improves throughout childhood and adolescence into young adulthood (Kane et al; 2004). Developmental changes in knowledge and strategy use are very complex and must involve the acquisition of additional information in older children. Thus, the development of working memory follows increasing pattern however, the rate and quality of development have also been influenced by a number of variables like language comprehension, gender and mental status. There is a literature, suggesting that Visuo Spatial Working Memory (VSWM) is affected more by age than performance on verbal tasks. Jenkins, et.al; (2000) found older adult's performance on VSWM tasks was poorer than their performance on verbal WM tasks, whereas Myerson et al; (2003) found evidence for greater interference on a visuo spatial compared with a verbal span task.

Although, studies mentioned earlier indicate age-related variations in the development of cognitive functions however, on some domains, like verbal fluency, girls were found better than boys and therefore, the role of gender in working memory was also identified another interesting research area for psychologists. Earlier studies document gender and age differences in the profile of cognitive abilities, especially among children and adolescents (Hyde & Linn 1988). Men outperformed women on space and number factor, whereas, women did better than men on verbal fluency (Pandey & Tamta, 2013). Several studies have demonstrated greater performance in women in certain tasks that involve verbal memory tasks of verbal learning, associated verbal pairs or logical memory (Lewin et al; 2001). One working memory task that has shown sex differences favouring women is the Digit Symbol subtest from the Wechsler Adult Intelligence Scales (WAIS) battery.

When working memory is deconstructed into spatial and verbal components, evidence suggests that behavioural disparities emerge between genders. Research has shown that from a behavioural performance perspective, males demonstrate greater mathematical, spatial (Lejbak, et al; 2011), and object working memory (Lejbak et al.; 2011) compared to females, and females display greater verbal and writing skills than males. The discrepancy in male and female spatial ability appears to begin as early as preschool and then becomes even more significant as males and females enter adulthood, whereas the female superiority in verbal facts tends to appear slightly later, peaking in early adulthood.

A bulk of studies suggests that working memory is involved in a broad range of cognitive abilities. In addition, individual differences in the functioning of working memory have been found to be related to important cognitive abilities such as reading skills, reading ability, arithmetic, reasoning and language acquisition (Baddeley, 1986 et al.). Daneman and Carpenter's (1980) study provides support for a memory capacity in adults using simple and complex span test. Swanson (1993) reports a similar distinction in children. Readers who have large working memory span can quickly process ambiguous sentences. In addition, researches have demonstrated that people with large working memory span are especially skilled in guessing the meaning of unusal word on the basis of sentences context. Working memory also helps to understand complicated sentences. People who can maintain many items in memory while they unravel sentences are more accurate and more rapid in understanding complex sentences. Adams and Gathercole (2006) indicate that working memory played a role in productive vocabulary, sentence length and sentence complexity.

In earlier studies, many issues concerning individual differences in working memory have been primarily examined on adult population. However, in the present study, researcher has adopted individual differences approach i.e., age, gender, and verbal ability to pursue several issues of working memory in children i.e., development of working memory and its components, working memory in boys and girls and the influence of verbal ability on development of working memory.

**Objectives & Hypothesis**

Against this backdrop, present study was planned to investigate the influence of individual differences on working memory and its components. Following hypotheses were made;

1. In the context of findings of earlier developmental studies (Alloway & Gathercole, 2006) exerting facilitative effect of age on memory processes, it can be hypothesized that a developmental pattern in different components of working memory would be found. Therefore, older age children would perform better on working memory and its domains as compared to younger group of children.
2. In the backdrop of earlier researches on the role of gender in memory and other cognitive functions (Lejbak, et.al; 2011) showing gender differences in memory due to gender based socialization which shapes different pattern of development of memory, it would be hypothesized that male and female would differ on experience of working memory as a whole and its domains.
3. Researches indicate that numerous cognitive factors i.e., language, comprehension, reasoning etc facilitate development of working memory (Alloway & Archibald, 2008). Thus, it is hypothesized that Verbal Ability of children would exert facilitative role in working memory. Therefore, children with high verbal ability would show better working memory than low verbal ability level of children.
4. Individual differences would be found strong predictors of working memory and it various components.

**Method**

**Participants**

A total of 120 children, age ranged 11-16 yrs. (mean age 13.39 yrs) grade 6 to 10th standard, enrolled in different schools of Gorakhpur city, (U.P, INDIA) participated in present study. Stratified random sampling technique was used for sample selection. No children were known to have any sensory or educational difficulty. On the basis of median score obtained on verbal ability test (mdn=23), children were divided into high and low verbal ability groups. Thus, 15 children participated in each of the eight cells.

**Measures**

**Verbal ability test (VAT)**

In order to assess the level of verbal ability in children, Verbal Ability Test was devised and standardized. Items for this test were selected from specific areas of verbal ability i.e. word meaning, opposites, analogy, word classification and sentence completion.

A comprehensive list of 90 items related to different dimensions of verbal ability was prepared. Data on these items were obtained from a total of 350 children age ranged 10-18 yrs. residing in different areas of Gorakhpur city. Scoring was done according to defined rules and scores were treated for standardization of the measure using item analysis. On the basis of results obtained and insight gained in this study, some items were found ambiguous and inappropriate, so these items were excluded. Finally, 50 items were retained in the final list of the test. The reliability and validity of the test were determined. The Alpha of this scale was found to be high (r=0.82) and the item- total correlation ranged between (r=0.17 to 0.46). Finally, this test was found appropriate to determine the level of verbal ability in children.

**Working Memory Task**

Three sets of working memory tasks were devised. These tasks were used to assess the level and form of working memory.

1. **Reading Span Task (RSPAN):** Based on Reading Span Task (Chiappe, Hasher & Siegel 2000), RSPAN was designed to measure the combined processing and storage capacity of working memory Reading span task contains 30 sentences each one written on a separate card. These cards were categorized under five sets based on increasing the number of sentences. The length of each sentence given in card is 8 to 12 words. Every card is presented for 0.5 second. Respondent read each sentences aloud and determined whether it made sense or not, and at the same time remembering the Red word (as one word was written with red color) of that sentence. After the presentation of each set, respondents were asked to recall the red word in correct order. Aggregate of correctly recalled items denoted the level of memory span (RSPAN) in children.
2. **Visual Pattern Recall (VSPAN**): The Visual Pattern Recall Task consisted of 25 Geometric designs. The participant was instructed to look carefully at the pattern and try to remember where the blank parts were. The design was presented on the card and there was a half second delay before presentation of an empty geometric design of the same size of recall. The participants were asked to correctly recall the pattern by putting (√) mark at the same part. After the presentation of card assigned immediate memory test was done. The correct responses on geometric design were added together, which denoted the level of VSPAN in children.
3. **Operation Span Task (OSPAN):** This task is based on Operation Span Task (Turner & Engle 1989). OSPAN task consisted of 30 math equations. Each card contained one word. These cards were categorized under five sets based on increasing the number of Math equation with words. For instances, $1^{st}$ set of the task includes 2 cards and 2nd set of task contains 4 cards and so on. Immediate memory test was done. The participants were given a set of equation and accompanying with words. They read the equation aloud as soon as it appeared. Then, they were asked to solve a series of math equations while, trying to remember a sets of unrelated words. Lastly, they were asked to recall all words in the proper order. The total of correctly recalled items denoted the level of memory span (OSPAN) in children. Finally on the basis of total scores obtained on three types of

task, the level of overall working memory in children was determined.

**Procedure**

In this study, participants (children) were contacted individually at school setting and they were introduced about problem of the study. After receiving the initial willingness, their background information was collected on the basis of Personal Data Sheet (PDS). Then Verbal Ability Test (VAT) was administrated one by one and they were requested to respond carefully. Children were assured that their response would be kept confidential. This test was used to identify level of verbal ability in children. On the basis of median score on verbal ability test, children were divided between high and low verbal ability groups. In the 2nd phase of the study, the working memory task containing three types of measures i.e. RSPAN, VSPAN and OSPAN were administered to participants one by one and instructions were given for each task. They were requested to respond carefully. As soon as they completed these tasks, data were collected and they were thanked for their cooperation. Data were scored and subjected to computer analysis using SPSS -17th version.

**Results**

Obtained scores were treated statistically in term of both Univariate and Multivariate analysis. ANOVA results have been reported first then, results obtained from multivariate analysis have been reported and interpreted.

**Interpretation of Univariate Analysis**

In order to assess the effect of verbal ability, age and gender on working memory and its components, 2×2×2 factorial analysis of variance were computed. Results displayed in Table-1 shows Mean, S.D. and significant F values for overall working memory and its components by age, gender and level of verbal ability.

**Table-1 Mean, S.D. and significant F values of Working Memory and its Dimenssions by Age, Gender and Verbal ability**

| Working Memory (WM) | | | Younger Children | | | | Older Children | | | | Significant F-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | High Verbal Ability | | Low Verbal Ability | | High Verbal Ability | | Low Verbal Ability | | A= Age B= Gender C= Verbal Ability |
| | | | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls | |
| Components of Working Memory | Working Memory (Over All) | Mean | 38.15 | 38.33 | 35.55 | 36.58 | 48.33 | 44.82 | 37.97 | 41.83 | A= 20.219** |
| | | (S.D.) | 6.61 | 8.91 | 7.95 | 7.74 | 6.23 | 6.28 | 5.82 | 7.69 | C= 10.690** |
| | Phonological Working Memory | Mean | 12.02 | 12.6 | 10.24 | 11.07 | 16.33 | 13.94 | 12.61 | 13.53 | A= 19.754** |
| | | (S.D.) | 3.81 | 4.51 | 3.47 | 3.41 | 1.97 | 2.43 | 3.78 | 2.65 | C=7.737** |
| | Visuo-spatial working memory | Mean | 15.53 | 13.0 | 14.53 | 14.38 | 18.0 | 17.45 | 15.31 | 15.58 | A= 9.004** |
| | | (S.D.) | 4.50 | 4.11 | 4.24 | 4.57 | 3.87 | 3.36 | 3.09 | 3.83 | |
| | Central Executive Working Memory | Mean | 10.73 | 13.20 | 10.87 | 11.13 | 13.88 | 13.45 | 10.15 | 12.47 | A=3.929* B=5.049* |
| | | (S.D.) | 2.31 | 3.33 | 2.89 | 2.66 | 3.19 | 3.05 | 1.91 | 3.41 | C=8.637** A×B×C=5.763** |

**N= 240, **=P<.01, *=P<.05**

It is apparent from table-1, working memory (overall) was significantly influenced by age and level of verbal ability of children. Significant main effect of age denoted that younger children performed poor on working memory as compared to older children. It is also clear from graphical representation (Fig.-1) that older children were found superior than younger children on over all working memory. Further, main effect of verbal ability was found significant (Fig-2) which denotes that children with high verbal ability made superior performance on working memory as compared to low verbal ability group of children.

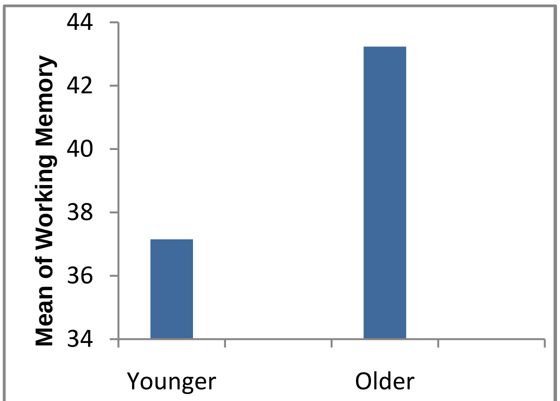


**Fig-1: WM (over all) as a function of Age**

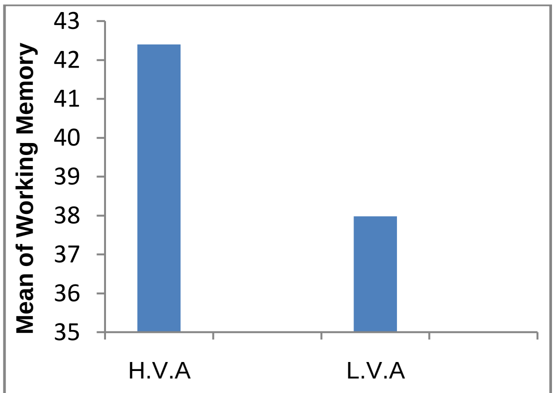


**Fig-2: WM (over all) as a Function of Verbal ability**

Component wise ANOVA were also computed. Results displayed in Table-1 indicate that main effect of age on phonological working memory was found significant which suggests that younger children performed poor on phonological component of working memory as compared to older children.

Further, significant main effect of verbal ability reveals that high verbal ability group of children were found superior on phonological working memory than low verbal ability group. On visuo-spatial component of working memory main effect of age was found significant which revealed that younger children performed very poor on visuo-spatial working memory as compared to older children.

Results, further suggests that Central Executive domain of WM was significantly influenced by age, gender and verbal ability of children. Significant main effect of age evinced that younger group performed poor on Central Executive Working Memory as compared to older children. Further main effect of gender indicates that girls showed better performance on Central Executive WM than boys. Similarly, main effect of verbal ability evinced that high verbal ability group showed better performance on central executive WM than low verbal ability group. Further, significant age × gender × verbal ability interaction effect denotes that in case of younger group girls with high verbal ability performed far better on central executive than those of low verbal ability group. However, in case of boys no difference on central executive was found between high and low verbal ability children of younger age. Despite this, a reserve pattern was found in case of older children. Boys with high verbal ability performed far superior on central executive as compared to low verbal ability group. But no clear cut difference was found between high and low verbal ability groups in case of girls. An overview of ANOVA results suggests that working memory develops with growing age. Moreover, verbal ability facilitates proper development of working memory.

Correlations were computed to determine the relationship between various components of working memory and verbal ability. Results show that verbal ability as a whole was found positively correlated with Working Memory (overall) (r=.336). Further, dimensions of verbal ability were also found positively correlated with various components of working memory. More specifically, Word Meaning was found positively correlated with working memory (as a whole) (r=.228). Similarly, Opposite was also found positively correlated with working memory (overall) (r=.181) and central executive WM (r=.231). Analogy was found positively correlated with working memory (overall) (r=.330) and its various components i.e, phonological WM (r=.199), visuo-spatial WM (r=.270) and central executive WM (r=.252). Word Classification was found positively correlated with working memory (overall) (r=.191) and phonological (r=.186) and central executive component of working memory (r=.213). Further, fill in the blanks was found positively correlated with central executive component of working memory (r=.186). The review of correlation results proves the positive and strong association between verbal ability and WM.

**Multivariate Analysis**

Significant correlation results suggest going for step wise multiple regression analysis (SMRA), to determine the predicting roles of different forms of verbal ability in working memory and its domains. Summary of regression results are displayed in table-2.

**Table-2: Step Wise Multiple Regression Analysis for Working Memory and its Components on to the Age, Gender and Verbal Ability**

| Predictor Variables | Criterion Variable | | | | |
|---|---|---|---|---|---|
| | R | $R^2$ | $R^2$ change | β (Beta) | F Value |
| **Working Memory (as a whole)** | | | | | |
| **Age** | .367 | .142 | .142 | .367 | 19.459** |
| **Verbal ability as a whole** | .507 | .257 | .116 | .340 | 20.256** |
| **Phonological Working Memory** | | | | | |
| Age | .380 | .145 | .145 | .380 | 19.951** |
| Verbal ability as a whole | .453 | .205 | .060 | .246 | 15.083** |
| Word classification | .484 | .234 | .029 | .172 | 11.891** |
| **Visuo-spatial Working Memory** | | | | | |
| Age | .383 | .073 | .074 | .272 | 10.071** |
| Analogy | .270 | .147 | .073 | .270 | 9.291** |
| **Central Executive Working Memory** | | | | | |
| Verbal ability as a whole | .350 | .123 | .123 | .350 | 16.4777** |
| Gender | .407 | .165 | .043 | .208 | 11.595** |
| Age | .444 | .197 | .031 | .177 | 9.469** |

N=240, **=P<.01, *=P<.05

As regression results denote that Working Memory (working memory) was positively predicted by age and verbal ability. Though, independently age has contributed 14.2%, and verbal ability (as a whole) 11.6% variance in criterion variables. But the composite contributions of these factors were found 25.7% variance in the overall working memory. Phonological working memory was predicted by three factors. Age explained maximum positively followed by Verbal Ability (as a whole) and Word Classification. Though, independently age has contributed 14.5%, verbal ability 6% and word classification 2.9% but composite contribution of age, verbal ability and word classification were 23% variance in the phonological working memory.

Further, Visuo-Spatial WM was predicted by age and analogy. Though, independently age has contributed 7.4% and analogy contributed 7.3% but the composite contributions of these factors were found 14.7% variance in the visuo-spatial WM. Similarly, Central Executive WM was strongly predicted by Verbal ability (as a whole) maximum positively, followed by gender and age. Though, independently verbal ability (as a whole) has contributed 12.3%, gender has contributed 4.3% and age contributed 3.1% variance in Working Memory, but the composite contributions of these factors were found 19.7% variance in the central executive working memory.

Thus, present findings have proved the pervasive impact of individual differences on the development of working memory.

**Discussion**

Finding of present study have proved the hypothesis that changes in different components of working memory were found to be very similar showing linear increases in performance from younger to older age group of children. Verbal ability also played significant role in development of working memory. More specifically, children with high verbal ability displayed superior on phonological, visuo-spatial sketch pad, central executive and over all working memory as compared to those having low verbal ability level. Gender difference in working memory is partially supported.

Present finding have ample empirical and theoretical supports. Gathercole et al. (1994) reported that the developmental increase in memory capacity appear to be due to increase in speed and efficiency of the sub vocal rehearsal process. There is close association between the speed with which children and adults can articulate words and their phonological loop capacity (Baddeley et al., 1975). This association is thought to reflect the fact that the faster articulation allows faster sub-vocal rehearsal. Thus, as children grow older and their rate of speaking increases, their sub-vocal rehearsal rate also increases allowing more material to be continuously recycled without decay, resulting in greater phonological loop capacity (Roodenrys et al., 1993).

Moreover, results revealed that difference between boys and girls on working memory was found non-significant except, on central executive WM, in which girls did better than boys. A number of studies also report no clear cut gender difference on working memory capacity (Tende et al., 2012; Vuonteal et al., 2003). Harness et al. (2008) found that on verbal working memory task men and women were not significantly different but on visual working memory task, women showed better performance than men, whereas, Minor and Park (1999) found no gender differences in spatial working memory function. Contrary to this, subsequent research has elucidated that sex difference in cognition are well established, with a male advantage found for spatial measures and a female advantage found for many verbal measures (Weiss et al., 2006) and object location memory measures (Silverman & Eals, 1992). Vuontela et al., (2003) found that boys having shorter reaction times were less accurate and made more multiple responses than girls. These gender differences were more prominent in the group of younger children.

Another important finding of present study is that verbal ability exercised important role in proper development of working memory. As findings indicate that children with high verbal ability showed higher WM capacity, better phonological working memory and central executive WM than children with low verbal ability. On the basis of findings of the present study it is explained that high verbal ability made children more capable for storing and maintaining information. Regression results have also proved the positive contribution of age gender and verbal ability in proper development of W.M.

Present results have ample empirical evidences. Carpenter et al. (1995) found that working memory plays an important role during reading, especially because working memory span can quickly process ambiguous sentences. A number of studies have shown a strong relation between working memory and children's reading comprehension (Leather & Henry, 1994). This relationship between working memory and reading comprehension has been found to hold with tasks that require the processing and storage of words and sentences. Bayliss et al. (2003) explores the relation between working memory and reading comprehension in children, using a sentence comprehension test. They found moderate correlation between reading and both verbal and visuo-spatial tasks. Adams and Gathercole (1995) showed in children of 4 and 5 years of age that differences in phonological memory abilities were associated with difference in spoken narrative skills. In addition, the phonological memory skills of 3-year-old children were also found to be related to the extent of their productive vocabulary, the length of their utterance in term of grammatical morphemes, and the range of syntactic constructions that they employed in their spontaneous speech. Working memory has been commonly proved to have a great contribution to reading comprehension. Swanson and Howell (2001) asserted that working memory shows particular importance in handling high level cognitive tasks such as reading comprehension whereas short-term memory plays a minor role in this area.

The findings of present study as well as other researches proved that age and verbal ability exercise strong impact on development of working memory. Findings can be supported by Neo Piagetian views that egocentric ability develops steadily in the growing age, however individual differences (verbal ability) etc. facilitate the proper development of cognitive functioning (Working Memory).

**Conclusion:**

This study aimed to investigate the developmental changes in working memory as a function of individual differences i.e., age, gender and verbal ability in children. Both univariate and multivariate analyses were exercised. Findings of the study confirm the hypothesis that working memory develops with growing age. More specifically, a developmental trend with growing age was found. Older children performed better on working memory than younger children. Since older children have broader knowledge about the world and improved cognitive ability therefore, they were found superior on working memory as compared to younger children (Kempe, 2000). Findings of present study further evinced that working memory and its components are strongly influenced by verbal ability. More specifically, children with high verbal ability showed better working memory than low verbal ability group of children.

Present study provides valuable data, which focus on some of the unexplored area of individual differences in working memory. There are few limitations of this study. First, generalization of the results from this study is limited as the sample size is small and limited to one region of Uttar Pradesh. Secondly, researchers should implement some situational test in addition and exercise other qualitative analysis to support present findings.

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