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CONSTRUCTION AND VALIDATION OF WORKING MEMORY SCALE

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Abstract: The principle objective of the study is to standardize the working memory scale and find out its reliability and content validity. Actually the tool has been administered by the investigator individually to 50 adolescents. Alpha reliability and reliability by test-retest method were found out and content validity was also accessed by giving the assessment for content validity to 25 experts in the field of educational psychology. The reliability values of alpha and test-retest method are 0.8270, 0.764 respectively and content validity values is 0.874.

Key Words: Recall, Rehearsal, Reliability, Validity, Working Memory.

I. INTRODUCTION

Working memory comprises multiple specialized components of cognition that allow humans to comprehend and mentally represent their immediate environment, to retain information about their immediate past experience, to support the acquisition of new knowledge, to solve problems, and to formulate, relate and act on current goals [1]. Working memory is generally used synonymously with short term memory, but this depends on how the two forms of memory are defined [17]. Working memory includes subsystems that store and manipulate visual images or verbal information, as well as a central executive that coordinates the subsystems. It includes visual representation of the possible moves, and awareness of the flow of information into and out of memory, all stored for a limited amount of time [50]. Short-term memory is also called working memory, is our very limited ability to remember new information without storing in long-term memory [52]. The amount of memory available at the present time to do a task plays a vital role in outcome of performance. Information organized in small quantities, practiced, learned at the beginning or end of lists, and studied recently, is remembered longer [11]. Many studies indicate that working memory capacity varies among people, predicts individual differences in intellectual ability, and changes across the life span [16]. In this paper we discuss the standardization of working memory scale.

A study done by [26 a] assessed the psychometric properties of several commonly used verbal working memory measures among one hundred thirty-nine individuals. All the measures had adequate internal consistency. The magnitude of the correlations was similar across the age groups and ranged from 0.52 to 0.81. Confirmatory factor analysis suggested that six of the seven tasks reflected a common factor. Both test retest reliability and stability of classification improved when a composite measure reflecting performance on several tasks was used. [32 a] reported data from a longitudinal study that addresses the relations between working memory Kate Cain capacity and reading comprehension skills in children aged 8, 9, and 11 years. Analyses of their study revealed that the relations between reading comprehension and both inference making and comprehension monitoring were not wholly mediated by working memory. Rather, these component skills explained their own unique variance in reading comprehension. [25 a] examined the construct validity, internal consistency, and test-retest reliability of several working memory tasks and determined which tasks were feasible to use with people with a wide range of aphasia severities. Controls showed ceiling effects on 1-back and people with aphasia showed floor effects on listening span. Both the square span tasks and n-back showed poor internal consistency for people with aphasia and age-matched controls. A composite score based on the forward and backward versions of picture span provided a measure of verbal working memory with acceptable construct validity, internal consistency and test-retest reliability and can be completed by non-brain-damaged adults

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and people with aphasia. Based on these studies the investigators have decided to construct and standardize the working memory scale.

A. *Memory and recall*

Psychologists test these forms of recall as a way to study the memory processes of humans [49]. Recall tasks makes the participants to retrieve the information which are learned by them. The recall limit is important because it measures what is termed working memory [5], [41]. One of the important processes of working memory which is known as free recall and it describes the process in which a person is given a list of items to remember and then is tested by being asked to recall them in any order [10]. In the present study the item numbers 1, 4, 5, 7, 8, 9 the free recall concept is used. Serial recall is the ability to recall items or events in the order in which they occurred. For example in our scale item numbers 2 and 6 the concept of serial recall has been given prime importance. Serial-order also helps to remember the order of events in our lives, our autobiographical memories. Our memory of our past appears to exist on a continuum on which more recent events are more easily remembered in order [28]. Rehearsal involves repeating information over and over in order to get the information processed and stored as a memory [27]. Rehearsal is helpful in maintaining information in working memory. So that recall could be done perfectly.

B. Memory and repetition

Many theories were proposed to account for spacing and repetition effects [21], [29], [30] usually based on either some notion of consolidation (e.g., Landauer, 1967, 1969) or encoding variability [37], [39]. They tested whether a reversal of the list-strength effect in recognition occurs if repetitions are presented in such a way that they are likely to be encoded in separate images. In our study all the questions has the repetition parameter in terms of numbers, letters or words. It was found that repetitions of words in different sentences produced a list-strength effect whereas repetitions of entire sentences did not [45]. Working memory ability explained unique variance for both levels of Intervening Task Difficulty (ITD) even after controlling for single-presentation trial performance (i.e., working memory and the benefits from repetition learning were positively correlated). Secondly there was a crossover interaction between working memory ability and Intervening Task Difficulty (ITD) such that for low working memory individuals, repetition benefits were greater following an easy intervening task than following a difficult intervening task, where as the opposite was true for those with high working memory ability [23]. Another study conducted by [9] suggested that a more difficult intervening task leads to more variable encoding across study repetitions. Intervening tasks are incorporated in the present study in item numbers 4 and 8.

II. OBJECTIVE OF THE STUDY

The main objective of the study is to standardize the working memory scale.

1. To find out the alpha reliability of the working memory scale.
2. To calculate the test-retest reliability of the working memory scale.
3. To measure the content validity of the working memory scale.

III. DESIGN OF THE STUDY

In order to conduct the present study on working memory scale, there were 9 questions related to working memory tasks, developed and were administered on a sample of 50 average intelligence learners with the age range of (15-18 years) who were selected according to their Intelligence Quotients (IQ). Working memory tests were conducted individually for each student according to the criteria of each individual test. In order to conduct the retest one month interval was given to avoid the influence of the previous test. After one month retest was conducted on the same scale with the same students. Alpha reliability, test-retest reliability and content validity values were calculated for standardization of the working memory scale.

IV. ITEMS IN WORKING MEMORY SCALE

- Forward Digit Recall
- Backward Digit Recall
- Paired Association

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- Complex Span
- Simple Span
- Recall of Acoustically Similar Letters
- Word List Recall
- Recall of letters with distracting task
- Listening Recall

A. Forward Digit Recall

The students were given a series of 8 numbers for rehearsal in a stipulated time period and were asked to repeat only the prime numbers in the series. The repetition time and the number of correct answers were noted. The test-retest correlation is ($r=0.718$; $p<0.01$, $N=50$). Studies have shown both primacy (advantage for early list items) and recency (advantage for late list items) effects for forward recall but minimal primacy and steeper recency for backward recall [8], [36]. Recall direction also interacts with the prevalence of traditional short-term memory effects, including those of word length, irrelevant speech, phonological similarity, and concurrent articulation [8]. Both forward and backward recall employs short-term phonological storage (i.e., short-term memory).

B. Backward Digit Recall

A series of 10 numbers were given to students for memorization with the interval of time period and asked to repeat them immediately. The time period for repetition was recorded along with the correct answers. The test- retest correlation of backward digit recall is calculated as ($r=0.805$; $p<0.01$, $N=50$). The primacy effect, however, is not affected by the interference of recall. The elimination of the last few items from memory is due to the displacement of these items from short term memory, by the distracting task. As they have not been recited and rehearsed, they are not moved into long-term memory and are thus lost. A task as simple as counting backwards can change memory recall; however an empty delay interval has no effect [13]. This is because the person can continue to rehearse the items in their working memory to be remembered without interference. Digits Backward is thought to be a more complex span task, requiring information storage as well as concurrent processing essential to mentally reordering the information [55]. The more complex task of recalling digits in the reverse order is assumed to rely more heavily on working memory processing [55]. Evidence suggests that the effects are either absent or greatly attenuated when participants are asked to recall items in reverse order [8], [38], [54]. There is also neuro-imaging evidence for the involvement of visuo-spatial processes in backward recall [26]. Backward recall is also considered to require an attention-demanding transformation of the digit sequence, thus classifying this task as a complex span measure of working memory [2]. Because of the above mentioned reason we have incorporated backward digit recall in the item number 2.

C. Paired Association

Eight pairs of unrelated words were given for a period of 5 seconds each during that time period the students should try to learn the pairs. After finishing all the pairs the students were asked to recall the list by giving all the first words in a fixed column and a separate card for the matched pairs were given to fix it with the correct words on the left hand side. The test retest correlation was noted as ($r= 0.554$; $p<0.01$, $N=50$). Working memory and associative learning rely on different regions of the Pre Frontal Cortex [47 a].

D. Complex Span

Two category of word list was given to the pupil and were asked to read the first word in category 1 and were asked to do the first mathematical operation and finally they were asked to read the first word in the category 2. Like wise it was repeated till the last row. The students were asked to recall the last two words in each column and the number of correct words and number of correct mathematical operations were noted with time period. The test-retest correlation was noted as ($r=0.476$; $p<0.01$, $N=50$). The reading span task was the first instance of the family of complex span tasks, which differ from the traditional simple span tasks by adding a processing demand to the requirement to remember a list of items. In complex span tasks encoding of the memory items (e.g., words) alternates with brief processing episodes (e.g., reading sentences). For example, the operation span task combines verification of brief mathematical equations such as "2+6/2 =?" with memory for a word or a letter that follows immediately after each equation [56]. Complex-span tasks have also been shown to be closely related to many other aspects of complex cognitive performance besides language comprehension, among other things to measures of fluid intelligence [32].

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E. Simple span

Six numbers of Words with two letters were given to the students for rehearsal and were asked to repeat the last four words in the series. The test-retest correlation was ($r=0.672$; $p<0.01$, $N=50$). Scientists found that working memory task performance (recall of series of digits or spatial locations) was affected by domain specific interference in both children and adults and these simple working memory tasks involve central executive processes and attention more in young children than in adults [27 a].

F. Recall of Acoustically similar letters

Acoustically similar 6 letters were given and the recall capacity was recorded with the number of correct letters. The test-retest correlation was ($r=0.443$; $p<0.01$, $N=50$). Short-term memory is believed to rely mostly on an acoustic code for storing information, and to a lesser extent a visual code. It was found that test subjects had more difficulty recalling collections of letters that were acoustically similar (e.g. E, P, D) [15]. Confusion with recalling acoustically similar letters rather than visually similar letters implies that the letters were encoded acoustically. One of the study [14] deals with the encoding of written text, thus while memory of written language may rely on acoustic components, generalizations to all forms of memory cannot be made.

G. Word List Recall

Ten numbers of unrelated short single words were presented to an individual to memorize them with time interval scale. Immediately after memorizing the individual was asked to recall the items. The time taken for recall and the number of correct words were noted. The test-retest correlation of the word list recall was ($r=0.563$; $p<0.01$, $N=50$). The words should be unrelated and categorical groupings should be avoided so that verbal working memory and long-term representations have less impact on performance. Also, the words should be relatively short, typically one or two syllables in length [42].

H. Recall of Letters with Distraction

Five non-acoustically similar letters were shown to the student with an auditory distraction of probing a normal day today activity questions in between each letter. Finally the student was asked to recall the last 4 letters in a sequential order. The test-retest correlation was ($r=0.352$; $p<0.01$, $N=50$). While most theorists focus on the allocation of working memory resources to processing and storage activities [31], some take the position that capacity is really about controlled, sustained attention in the presence of interference or distraction [19].

I. Listening Recall

The students were presented a series of five sentences and at the end of listening to all the five sentences the students were asked to recall the last word in each sentence. The time taken by the students for recall and the number of correct answers were considered for the scoring. The test-retest correlation was noted as ($r=0.592$; $p<0.01$, $N=50$). Working memory ability was assessed using listening span in which the participant must both process and store new information [22 a].

V. RELIABILITY

Reliability is said that the scale which yields the same score for the same person in different administrations. Because of the inclusion of two or more different processes of the present working memory scale, the obtained values were converted into z-score in order to avoid the dominance of the high values in the single process of the scale. Then the values were subjected to reliability analysis. Alpha reliability and test-retest reliability were selected for the reliability analysis of working memory scale which measures the available memory for performance.

A. *Alpha Reliability-Internal Consistency*

Alpha reliability takes all possible halves and computes a reliability estimate for each possible split and then averages all those reliability estimates. If different tests or different parts of a test correlate highly with each other, then that means they would be likely to correlate higher with themselves.

$$\text{Standardized alpha of whole test} = \alpha = \frac{K * \text{r-bar}}{1 + (K-1) * \text{r-bar}}$$

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K is the number of items on the test

B. Test-Retest Reliability

Test-retest reliability is the degree to which scores are consistent over time. It indicates score variation that occurs from testing session to testing session as a result of errors of measurement.

VI. CONTENT VALIDITY

It is the degree to which the elements of an assessment instrument are relevant to and representative of the targeted construct for a particular assessment purpose. Content validation is applicable across assessment methods because it addresses the inferences that are based on the obtained data (Stephen et al., 1995). We developed 11 questions based on the elements of the scale and it was given to 25 experts in the same area of research (Appendix 1). Their opinion about the scale was collected and the values were taken for calculating content validity. The content validity was found out as 0.874.

TABLE I

CORRELATION MATRIX

	Q1	Q2	Q3	Q4	Q5
Q1	1.0000				
Q2	0.4870	1.0000			
Q3	0.1472	0.3971	1.0000		
Q4	0.3972	0.4427	0.3652	1.0000	
Q5	0.3991	0.4903	0.4299	0.4586	1.0000
Q6	0.2504	0.3610	0.2955	0.5024	0.4953
Q7	0.3083	0.4324	0.3002	0.5279	0.4535
Q8	0.2458	0.4509	0.2609	0.2045	0.1258
Q9	0.4026	0.3435	0.3014	0.1997	0.3454

	Q6	Q7	Q8	Q9
Q6	1.0000			
Q7	0.3745	1.0000		
Q8	0.2305	0.1660	1.0000	
Q9	0.1696	0.3029	0.4217	1.0000

TABLE II

RELIABILITY ANALYSIS SCALE- (ALPHA)

Question Number	Scale mean if item deleted	Scale variance if item deleted	Corrected item total correlation	Squared multiple correlation	Alpha if item deleted
Q1	0.0000	16.2435	0.4969	0.3717	0.8019
Q2	0.0000	15.6143	0.6716	0.4974	0.7820
Q3	0.0000	16.3574	0.4701	0.2999	0.8051
Q4	0.0000	16.5706	0.5863	0.4595	0.7941
Q5	0.0000	15.6642	0.6029	0.4850	0.7890
Q6	0.0000	16.4066	0.4990	0.3643	0.8016
Q7	0.0000	16.3530	0.5336	0.3753	0.7979
Q8	0.0000	15.8036	0.3968	0.3435	0.8211
Q9	0.0000	16.1452	0.4863	0.3513	0.8034

Reliability Coefficients for 9 items; Alpha = 0.8178 Standardized item alpha = 0.8270

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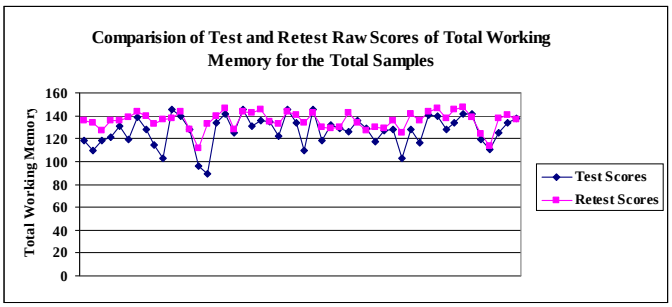

Fig 1: Comparison of Test and Retest Raw Scores of Total Working Memory for the Total Samples

TABLE III
TEST-RETEST CORRELATION

Questions	Test-Retest 'r'
1	0.718**
2	0.805**
3	0.554**
4	0.672**
5	0.476**
6	0.443**
7	0.563**
8	0.352*
9	0.592**
Total Working Memory	0.764**

****p<0.01; *p<0.05; N=50**

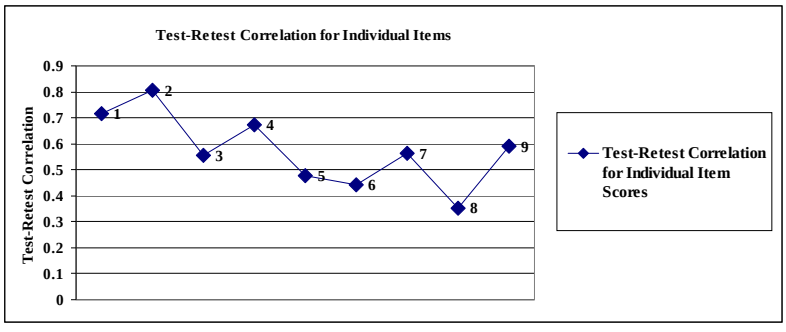

Fig 2: Test-Retest Correlation for Individual Items

VII. FACTORS RELATED TO WORKING MEMORY

Studies of [12] and [43] showed that differential mood states can influence cognitive processing. A recent study demonstrated that psychosocial stress induces working-memory impairment in healthy subjects [51]. [3] suggests that a positive mood increases the release of the neurotransmitter dopamine in the prefrontal cortex. Higher levels of dopamine directly enhance the performance of working memory. [25] showed that if a child is distracted or interrupted

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while using working memory the process is lost and the child cannot resume from where they were interrupted. Keeping this point in mind the investigator has incorporated only one item with distraction task. Individual differences in working memory capacity predict general intelligence, reading comprehension and ability to learn [6], [7]. In the present study intelligence of the students were first measured and then the scale was given to the students. Since the study of [40] showed that a seminal paper claiming a limit of 7 +/- 2 chunks as the capacity of working memory, a significant amount of work has attempted to determine the units of storage in working memory. Keeping this view in mind in the present study item numbers 2 and 7 are incorporated in the study. [40] showed that seven is the capacity limit often found for storing single digits, letters or spatial positions. [18] showed that the passive storage capacity is closer to four when active rehearsal is prevented. The researchers varied maintenance load by changing the number of items to be either maintained in the originally presented order (maintenance-only), or alphabetized during the maintenance period (maintenance-plus-manipulation) [22]. When emotional processing systems are activated (e.g., by viewing a fearful stimulus), additional inputs would likely be received by the working memory system [35]. Working memory refers to a mental workspace that is involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks [44]. Verbal–numerical working memory and visual–spatial working memory contributed unique variance to mathematical performance, independent of chronological age, short term memory, reading and processing speed [57]. In the present study these factors might also have an impact on the students' performance but it is not controlled or limited according to the selected sample.

VIII. CONCLUSION

The working memory scale developed for adolescence age group yielded alpha reliability of 0.8270 and test-retest reliability value of 0.764. Acceptable test-retest reliability shows that the scale is not showing much variation in different testing times and the alpha reliability value shows that the items are internally consistent with each other and the total items. The acceptable level of content validity (0.874) shows that the scale is valid based on its content according to the report given by the experts.

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APPENDIX 1

S.No	Elements of Content Validity	Yes	No
1.	Do the item of the questions arrange in an order?		
2.	Do subtest of the items relate to working memory?		
3.	Do the process items of working memory satisfy students' needs?		
4.	Are the sequencing of items arranged?		
5.	Are the instructions to the participants given correctly?		
6.	Do the temporal parameters of the responses satisfy the individuals?		
7.	Are the methods and the standardization of administration performed correctly?		
8.	Are scoring, data analyses and item weightage done correctly?		
9.	Does the definition and domain of the construct match the main variable?		
10.	Does the method of administration match the working memory?		
11.	Does the function of working memory match its instrument?		

BIOGRAPHY

The first author of this paper Dr.K.Sarladevi, M.Sc., M.Phil., M.Ed., Ph.D., PDF., Associate Professor in Physical Science Education, Meston College of Education, Chennai-600014, Tamilnadu, India. She is a practitioner of NLP and Cognitive Behaviour Therapy. Her biographies has been published in the books of Asian admirable achievers, Men and Women achievements in Asia, Asia ' s WHOs WHO, National ' s WHOs WHO and also received awards such as Bharath Excellence Award, Best Citizens of India, 2011, Best Personalities of India, Adhunik Prasati Award, Inspiring Pillars of India, Golden Personalities of India, Bharat Mahila Award, Rajiv Gandhi Arch Excellence Award. She is a research awardee from University Grants Commission for doing Post Doctoral Fellowship during 2009-2011. She has 32 years of teaching experience and more than 16 years of research experience. She has published 12 research papers in national and international research journals, 13 papers presented at state, national and international seminars in India. She has published 25 research articles in the conference proceedings at international venues. She is member of TASC Chennai, ITAA, USA, NFNLP, U.S.A, STAR, Germany (National Representative), META NEXUS, U.S.A., APA, U.S.A, EHPS, UK. She guided 58 M.Ed, 56 M.Phil projects. 5 Ph.D scholars have been awarded under her supervision and guiding 9 students at present. She has earned 85 international CE credits.

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