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Short-term, Long-term and Order Memory as a Function of Ageing

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***Abstract**: Age-related changes in short-term, long-term and order memory were studied in three groups of normal adults (young, middle-aged and old) to determine the age of onset of decline in these memories and the nature of such decline. Group difference in test performance determining the effect of age was analyzed by means of one-way MANOVA which was found to be significant for all these memories. Post-hoc comparison revealed marked difference between young and middle-aged groups as well as young and old groups but not between middle-aged and old group in respect of short-term and long-term memory, whereas, the young group differed significantly from the middle-aged group and both the groups differed significantly from the old group in respect of order memory. The results have been discussed in terms of variation in the rate of decline in these memories at different age levels unraveling the possible neurological, psychological and genetic factors as well as changes in specific cortical structures underlying the same and suggestions have been made for its prevention.*

***Keywords:** Short-term memory, Long-term memory, Working memory, Order memory, Ageing, Cognitive training.*

I. Introduction

Memory as a process involves several stages, i.e., encoding (acquisition), storage (consolidation) and retrieval and takes many different forms depending on what that information is and how long one retains it. From this perspective, the most influential and enduring theory of memory developed by Atkinson and Shiffrin (1968) explains the process in terms of three systems or stages, namely, sensory memory, short term memory (STM) and long term memory (LTM) and is considered to be a useful framework for understanding how information is recalled and how it is forgotten.

Sensory memory provides a temporary storage of information received through our senses from the environment in a moderately unprocessed way, whereas short-term memory is the capacity for holding a small amount of information with little processing, but in an active and readily available state for a short period of time, that is, a few seconds. Long-term memory, where association among information are stored, on the other hand, stores a seemingly unlimited amount of information for an indefinite period. STM is further divided into primary memory and working memory, whereas, LTM is divided into declarative (explicit) and procedural (implicit) memory with declarative memory further having two subdivisions, namely, episodic memory and semantic memory. The prefrontal areas of the cortex are quite activated during STM storage, while the hippocampus, the limbic system as well as the cerebral cortex are involved in LTM.

Both STM and LTM are capable of storing the information as per their temporal order or sequence which is known as order memory and is barely essential in many cases of learning. The underlying cognitive process is successive processing as is viewed by the proponents of PASS (planning, attention, simultaneous, successive) theory of intelligence (Naglieri & Das, 1988,1990).

The PASS theory explains all cognitive functioning in terms of three systems and four interrelated processes that are carried out in three blocks of human brain and operate on a knowledge base. The first system is the planning system that involves executive functions responsible for controlling, organizing, searching, goal-setting, selecting constructing and executing plans or strategies, monitoring performance, evaluating the course of action and decision making. Planning is a higher order cognitive process, a synthesizer of all intellectual operations and the essence of human intelligence (Das, 1984). It is carried out in the frontal, especially, the pre-frontal areas of the cortex.

The second system is the attention system, which is responsible for maintaining arousal levels and alertness and ensuring focus on relevant information to the exclusion of irrelevant ones. It is the function of brainstem, diencephalon and the medial regions of the brain.

The third system is the information processing system which employs simultaneous and successive processing to encode transform and retain information. Simultaneous processing organizes information in a relational manner and underlies activities like comprehending the text, solving arithmetic problems and relational thinking etc. Successive processing, on the other hand, organizes information in a sequential manner and underlies activities like word reading, order memory (serial recall), and narrative speech etc. Simultaneous processing is carried out in the occipito-parietal areas, whereas, successive processing is carried out in the fronto-temporal areas of the cortex. The four processes are closely related to each other and operate on a knowledge base.

The important point of concern, however, is that the various systems and forms of memory undergo marked changes with progressing age, a phenomenon known as age-related memory impairment (AMI) or age associated memory impairment (AAMI). Results of both cross-sectional and longitudinal studies suggest that the ability of encoding, storage and retrieval of information or events, particularly of new ones decline with age and some types of STM and LTM like working memory and episodic memory are especially impaired in the normal process of aging (Bender, Naveh-Benjamin, & Raz, 2010 ; Chen & Naveh-Benjamin, 2012; Fournet et al., 2012, Hedden & Gabrieli, 2004, Ishihara, Gondo, & poon, 2002, Nilsson, 2003). Similarly studies reveal that memory of context is more vulnerable to ageing than memory for content. Moreover, order errors, omissions as well as intrusions are seen more in older adults compared to younger ones (Maylor, Vousden, & Brown, 1999, Spencer & Raz, 1995).

Decline in memory is closely linked to the biological changes associated with ageing. For example, changes have been found to occur with age in specific brain structures like the frontal cortex and the hippocampal regions which play significant role in memory. With increasing age the functions of these structures are compromised leading to memory impairment. However, none of these studies reveal the age of onset of decline in various types of memory and the nature of such decline, i.e., whether the rate of decline is consistent across the age. The present study is an attempt in this direction.

Objective: The objective of the present study was to examine the age at which short-term, long-term and order memory begin to decline and the nature of this decline with increasing age in each case. On the basis of previous studies it was hypothesized that all the three types of memory would decline with increasing age, but the rate of decline would be found to be more at a later age. The age of onset of decline in the three types of memory was to be seen.

II. Method

2.1 Sample: The sample consisted of 150 healthy normal adults chosen from three different age groups, i.e., 20-35 years, 40-55 years and 60-75 years constituting the ‘young’, ‘middle-aged’ and ‘old’ groups respectively with 50 participants in each group. Out of these 150 participants, 145 were graduates. The remaining 5 were Higher Secondary pass outs of whom three belonged to the ‘middle-age’ group and two, the ‘old’ group. The participants were from both the sex groups.

Most of the participants in the young group were continuing their studies, whereas some were in jobs and few were housewives. Among the middle-aged, majority were in jobs, few were businessmen, and the remaining few were housewives. In old group, on the other hand, majority were retired persons, few were housewives and very few were either continuing in some jobs or looking after their business. The participants were selected from among a population of 500 adults covering three different districts of Odisha, namely, Balasore, Balangir and Jajpur and had no report of any serious or chronic illness.

2.2 Test: All the participants were administered the Hopkins Verbal Learning Test – Revised (Brandt & Benedict, 2001) in order to assess their strength in STM and LTM. Order memory, on the other hand, was measured by Sentence Repetition and Sentence Questions, the two tests chosen from the Standard Battery of Cognitive Assessment System (Naglieri & Das, 1997) designed to measure the PASS (Planning – Attention – Simultaneous – Successive) processes. Sentence Repetition and Sentence Questions are typically designed to measure one’s strength in successive processing, a mode of information coding involving sequential memorization or processing of information as conceptualized by the PASS theory of intelligence. All these tests, their administration and scoring procedures are described below.

Hopkins Verbal Learning Test-Revised (HVLT-R)

This is the most recent version of the verbal learning and memory test which allows the psychologist to learn a great deal of useful information about the status of an individual’s memory functioning quickly, easily and repeatedly. The test offers six alternative forms, of which the Form No. 5 was used in the present study. Each form contains 12 words, with four from each of three semantic categories (e.g., articles of clothing, vegetables, musical instruments etc.) The list is presented at the rate of approximately one word in every 2 seconds and the words are learned over the course of three learning trials. The learned items are reproduced immediately after each presentation and the average of correct responses in the three trails are taken into consideration for scoring purpose. Approximately 20-25 minutes later, a delayed recall trial is completed and the responses are recorded. Each correct response carries a score of ‘1’ with the maximum possible score for the test being 12.

Sentence Repetition

This test which is designed to tap successive processing is a test of memory for word order but the words are arranged within a syntactic frame. The participant is read 20 sentences aloud and is asked to repeat each sentence exactly as presented. The sentences are composed of colour words (e.g. “The blue is yellowing”) instead of content words so as to reduce the influence of semantic processing. The subtest is discontinued after 4 consecutive errors. The raw score is the total number of sentences repeated correctly.

Sentence Questions

This test of successive processing consists of 21 sentences that are of the same type as those used in the Sentence Repetition test. But here, the participant is read a sentence and asked a question about it. For example, the examiner reads "The blue yellows the green" and asks the participant, "who yellows the green?". Successful completion of the task demands comprehension of the sentence based on the serial relationship among the words.
The raw score is the total number of questions answered correctly. The test is discontinued after 4 consecutive errors (i.e., incorrect answers).

2.3 Procedure

The test was administered individually to the participants. Those who were students, received it in their respective colleges/universities where they were studying, and those in jobs, in their respective job places, whereas, those who were retired or housewives were tested at their own residence. But in each case, a separate room was used for the purpose. However, before administering the tests to any participant, the examiner asked a few formal questions to obtain the required demographic information and ascertain the participant's ability to hear spoken language at a conversational volume.

Form No. 5 of Hopkins Verbal Learning Test-Revised (HVLT-R) was used in the present study, the words of which belonged to three semantic categories, i.e., occupation/profession, sports, vegetables. The instructions as given in the test manual were read aloud and repeated wherever needed to make sure that the subject understands the task properly. To measure the strength of STM, immediate recall of the list of words in the Form were taken thrice, once after each presentation and the average of correct recalls was calculated and scored. A time of gap of 25 minutes was then given during which the participant either did his/her own work or was engaged in conversation with the Examiner. Following this the participant's delayed recall of the same list of words was tested to ascertain his/her strength in Long-term memory. The responses of the participant in both the conditions were recorded and scored to carry out the desired statistical analyses.

For measuring the participants' strength in order memory each of them was administered the two tests of successive processing, i.e., Sentence Repetition and Sentence Question as per the rules given in the test manual developed for the same. The responses of the participants were recorded and raw scores were obtained which were further converted into their corresponding scaled and standard scores for the statistical analyses of the results. The participants fully cooperated with the Examiner during the administration of the tests and also enjoyed the tasks at hand.

III. Results

Keeping in view the objective of the study, the data were analysed by means of one-way multivariate analysis of variance (MANOVA) followed by post-hoc comparison, the result of which are presented in different tables in this section.

Table 1 Means and Standard Deviations for Short-term, Long-term and Order Memory Scores of Participants of Three Age Groups (N=50 in each group)

Type of Memory	Young		Middle-aged		Old	
	Mean	SD	Mean	SD	Mean	SD
Short-term	6.26	1.44	4.88	1.49	4.54	1.50
Long-term	7.00	2.12	5.32	1.77	4.88	1.63
Order	117.76	20.28	99.00	19.76	73.68	12.77

Table 1 presents the means and standard deviations of the three groups of participants – young (1), middle-aged (2) and old (3) in respect of their performance on Hopkins Verbal Learning Test-Revised measuring their strength in short-term memory and long-term memory and tests of Sentence Repetition and Sentence Questions measuring their strength in order memory. It may be seen from the table that the mean score was highest for the young group and lowest for the old-group, but in-between for the middle-aged group in each case. The difference among the three groups in respect of the three types of memory was tested by means of one-way MANOVA, the results of which are presented in table 2.

Table 2 Summary of One-Way MANOVA Results for Short-term, Long-term and Order Memory (N = 50 in each group)

Source	Dependent Variable	Sum of Squares	df	Mean Square	*F*	
Age	Short-term memory	83.04	2	41.52	18.70**	
	Long-term memory	126.88	2	63.44	18.45**	
	Order memory	48934.77	2	24467.39	76.06**	
Error	Short-term memory	326.47	147	2.22		
	Long-term memory	505.36	147	3.44		
	Order memory	47286.00	147	321.67		
Total	Short-term memory	409.52	149			
	Long-term memory	632.24	149			
	Order memory	96220.77	149			

**P< .01

It may be seen from Table 2 that the participants of the three age groups, i.e., young, middle-aged and old, differed significantly from one another with respect to each of the three types of memory, i.e., short-term, long-term and order memory that suggests a significant age effect on these memories ($p<.01$). However in order to know about the pattern of differences among the group means, post-hoc comparison was made through Tukey's HSD test. The *q* value (.05 level) being 3.31, *n* being 50, and s^2w being 2.22, 3.44 and 321.67 for short-term, long-term and order memory respectively, the HSD critical value was found to be 0.70 for short-term memory, 0.87 for long- term memory and 8.40 for order memory. These values were compared with the mean differences obtained for pairs of groups in the three types of memory to test their significance. These results have been presented in Table 3.

Table 3 Results of Tukey's HSD Test for Short-term,Long-term and Order Memory (N=50 in each group)

Type of memory	HSD (critical value)	Mean Differences		
		M_1-N_2	M_2-M_3	M_1-M_3
Short-term memory	0.70	1.68*	0.44	2.12*
Long-term memory	0.87	1.38*	0.34	1.72*
Order memory	8.40	18.76*	25.32*	44.08*

*P < .05

As is seen from Table 3 the mean score of young group (M1) differed significantly from that of middle-aged (M2) and old groups (M3) with respect to both STM and LTM, whereas, mean score of middle-aged group did not differ significantly from that of old group in either case. On the other hand, young group differed significantly from middle-aged group and both the groups differed significantly from old group in order memory. The results, thus, suggest that, all the three types of memory gradually decline with increasing age, but the rate of decline slows down at the middle age in case of both STM and LTM, whereas, in case of order memory marked deterioration occurs across the age groups.

IV. Discussion and Conclusion

The objective of the present investigation was to study the age-related changes in short-term, long-term and order memory so as to know the age at which they start declining and the nature of such decline. It was hypothesized that all these memories would decline with increasing age, and the rate of such decline would be more at a later age. The age of decline in each case was to be seen. Participants from three different age groups, i.e., 20-35 years (young), 40-55 years (middle-aged) and 60-75 years (old) were tested for their STM and LTM by means of Hopkins Verbal Learning Test-Revised and order memory, by means of the successive processing tests chosen from CAS. The results revealed a gradual deterioration in both STM and LTM with increasing age and the difference among the groups was statistically significant. However in both STM and LTM significant difference could be noticed between young and middle-aged adults and between young and older adults, but, not between middle-aged and older adults. The deterioration in these memories, thus seems to begin at around 40 years of age that proceeds at a faster rate until 55years of age, i.e., the stage of middle adulthood but slows down thereafter, i.e., in late adulthood or old age. The hypothesis framed in this connection, therefore, is partially supported. In case of order memory, on the other hand, young adults not only differed significantly from the middle-aged adults, but, both the groups differed significantly from the older adults also. In other words, deterioration in order memory which begins at around 40 years of age seems to proceed further in a progressive manner till one reaches the stage of late adulthood or old age. This part of the result supports our hypothesis fully.

Studies reveal that short-term memory is impaired in normal ageing process because of the impairment in the ability of older people to refresh recently processed information. (Johnson et al., 2002, Nilsson, 2003). Long-term memory, on the other hand, is impaired because in old age people often forget the source and the context of acquired information, and become deficient in associative learning, i.e., a deficiency in creating and retrieving links among separate units of information (Light, 2011, Provyn et al., 2007) which makes new learning difficult for them. In other words, older people have limited resources available with them for encoding new information into and retrieving them from memory. Moreover, the associations regarding contiguity become weaker with increasing age (Kahana et al., 2002). We may explain these impairments to be the consequences of diminished attentional capacity, lack of inhibitory control, diminished working memory capacity, i.e., failure in clearing the working memory of information that is no longer relevant to the current task, and reduced processing speed, decreasing speed of executing cognitive operations, impairment in access to stored information, lesser use of effective memory strategies and above all, very poor self-confidence regarding the memory performance in older adults. (Hartman and waren 2005; Maylor,1999).

Biologically, STM is a temporary potentiation of neural connections occurring through depletion of neurotransmitters and can become LTM through the process of rehearsal and meaningful association. LTM, on the other hand, is a long-term potentiation involving a physical change in the structure of neurons through which short-term memories move into long-term storage. Constant stimulation, therefore, is needed to maintain this functional condition of the cells and preserve the learnt information through repeated recall and recapitulation so as to enable one to form an association among the information and retain them in an ordered manner so that the executive functioning of the brain like planning, behavior monitoring and decision making can be maintained. These functions are affected adversely due to ageing because of reduced functional efficiency of frontal lobes and ineffective frontal-medial temporal lobe interactions leading to memory impairment (Denburg, Tranel, & Bechara, 2005). Memory loss is also caused due to myelin loss for which neurons conduct more slowly and interfere with each other's activity (Jensen, 1998). Additionally, deficits occur at molecular level also. For example, genes in the dentate gyrus of the hippocampus undergo changed levels of expression with ageing that results in less abundant production of the protein RbAp48 in humans which is important for memory. As is known, hippocampus plays a crucial role in both consolidation and retrieval of learnt information. Genes involved in synaptic functioning and plasticity, including those responsible for glutamate and GABA receptors and for synaptic vesicle release and recycling, are also affected due to ageing . As the findings of the present study suggest, all these changes seem to occur at a rapid rate in one's 40s and 50s provided precautionary measures are not taken against the same. However, once the major impairment has taken place, there may be found little addition to it with further advancement of age as has been found in case of STM and LTM, whereas in other cases the impairment may be progressive in nature till the end as is seen in case of order memory in the present study.

4.1 Cognitive training and improvement in memory

Over the past several years, researchers have focused on how performance gets affected by age-related changes in memory, because, it affects not only the person concerned, but also his/her near and dear ones. However, memory decline in elder hood can be prevented by staying active both physically and mentally throughout one's 40's and 50's. It is clear that for older adults acquiring new skills and information is difficult for which they are advised to focus on the domains of intellectual expertise that they have developed over their life time. But, by performing new tasks and learning new skills during middle adulthood one can exercise his/her brain and maintain its functional efficiency. There have also been found some promising results using cognitive training to improve working memory for example, elementary and middle school children improved on a version of Raven's Progressive Matrices after training on a video game that required recalling where an object appeared on the screen a few trials earlier (Jaeggi, Buschkuekhl, Jonides and shah, 2011). Similarly elderly individuals who were trained on a game that required steering a car on winding roads and responding to various signs along the way gained in working memory and attention and showed increased prefrontal activity (Anguera et al., 2013). Besides training in multiple cognitive domains produced improvement in memory, attention and reasoning in a group of elderly Chinese (Cheng et al., 2012).

Brain changes also occur with certain interventions. For example, working memory training increased dopamine binding (McNab et al., 2009) and functional connectivity in the frontal-parietal network (Jolles, van Buchem, Crone, and Rornbouts, 2013). Similarly, adults who took 70 hours of intensive reasoning instruction in preparation for Law School Admissions Test showed increased frontal-parietal connectivity and connectivity between parietal and striatal areas (Mackey, Singley, and Bunge, 2013). But, equally important are a healthy diet, regular socialization and management of chronic conditions. Scientists, today, even claim that specific impaired neurons within the human brain can be recovered when stimulated. If that happens, and memories lost with age are rescued, probably we will move into a healthier and happier old age.

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