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The Effect of Organization on Working Memory in Left and Right Frontal Lesion Patients

KEYWORDS: Prefrontal cortex, working memory, organizational strategy, encoding.

Bangalore N Roopesh
Assistant Professor
Department of Clinical Psychology
National Institute of Mental Health and Neurosciences (NIMHANS)
Bangalore 560 029, India

Renu E George
Clinical Psychologist
55, Type IV, Block IV
BRC Campus, NIMHANS
Bangalore 560 029, India.

C. R. Mukundan
Former Head & Professor
Department of Clinical Psychology
National Institute of Mental Health and Neurosciences (NIMHANS)
Bangalore 560 029, India.

ABSTRACT *Patients with lesion in the prefrontal cortex perform poorly on these planning, working memory and organization strategy. Studies highlight that the left prefrontal cortex as compared to the right prefrontal cortex is more involved in encoding. As efficient organization improves encoding, this study looked at the effect of organization inherent in the working memory tasks on the performance of 10 left and 14 right frontal lesion patients and compared their performance with 17 group matched community controls. Neuropsychological tests used were Last Word Recall Test (LWRT), and Complex Figure Test (CFT). Results showed that left frontal lesion group performed poorly as compared to the other two groups. All the three groups benefitted from the organization that is inherent in LWRT; however, this did not reach significance level in right frontal lobe lesion patients. This study has important implication for the cognitive retraining of brain lesion patients.*

INTRODUCTION

Working memory refers to the temporary online storage of information required for on-going cognitive processes. This is considered as a tripartite system, which comprises an attentional control system called the Central Executive, which operates in conjunction with two subsidiary systems. The two subsystems are the Phonological Loop and Visuo-Spatial Sketchpad (Baddeley, 1998). Recent advances in working memory research suggest it being central to various aspects of human cognition, including language and comprehension (Daneman & Carpenter, 1980; Frisk & Milner, 1990). Among the components of the working memory, the central executive is emphasized because of its crucial role in processing, which may include problem solving and encoding.

Encoding is one of the initial steps in the memory process, where an existing organizational structure is used to classify and store all new incoming information. This classification is the function of the central executive, which selects relationship and meaning from the existing organizational structures and uses it to classify the incoming neural signals. It has been found that the central executive engages itself to optimize the performance in search of organizational strategy that may be inherent in all newly learnt information (Diamond, DeLuca, & Kelley, 1997; Owen, Downes, Sahakian, Polkey, & Robbins, 1990). Organization of information during encoding has shown to aid in better memory performance and decrease the difficulty of the task while learning (Bor, Cumming, Scott, & Owen, 2004; Bor, Duncan, Wiseman, & Owen, 2003).

Neuroimaging studies show bilateral prefrontal cortex involvement in tasks that involve central executive component of the working memory (D'Esposito, et al., 1995; Fletcher, Shallice, Frith, Frackowiak, & Dolan, 1996). In a lesion study (Gershberg & Shimamura, 1995), the authors found that free recall was impaired in frontal lobe lesion patients. When instruction was given about organization strategy, their performance improved. However, this study did not try to analyze the difference between left and right frontal lobe lesions in the performance.

Studies have shown that left prefrontal cortex is involved in encoding (Demb, et al., 1995; Fletcher, Shallice, Frith, Frackowiak, & Dolan, 1998; Shallice, et al., 1994; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994), and right prefrontal cortex is involved in retrieval (Fletcher, et al., 1996, 1998). However, there is no consensus with regard to the above findings.

To summarize, studies in this area have shown how lesions affect working memory. Research has shown the importance of organization in encoding, but these are mainly of neuroimaging studies. According to the available knowledge, there are no studies that have looked into at how the organization that is inherent in working memory tasks will affect the encoding of the material learnt by left and right frontal lesion patients separately and compared the results with community controls.

METHODOLOGY

The design of the study was cross-sectional and case-control comparison, where the Left-frontal lesion, Right-frontal lesion and Community Control groups were compared with each other on two neuropsychological tests. The Left-Frontal lesion group had 10 patients and the Right-Frontal lesion group had 14 patients. Community Control consisted of 17 subjects, who were group matched on age, education, sex and handedness with the patient population. Edinburgh Handedness Inventory (Oldfield, 1971), was administered to select only the right handed subjects. Patients for both the groups were selected based on purposive sampling, from the Neurosurgery in-patient units of National Institute of Mental Health and Neuro Sciences (NIMHANS), Bangalore, India. CT scan reports were used to arrive at the localization of the lesion site. Only those patients who had localized lesion in either left or right frontal cortex were selected for the study. Community Control group was selected from the community controls, based on snowball sampling. Patients were excluded if they had any primary sensory deficits, mental retardation, history of alcoholism and/or drug dependence and/or any co-morbid psychiatric disorder. Community Control group was screened on General Health Questionnaire – 12 (Goldberg & Williams, 1988), and those found to have more than the cutoff of 2 points were excluded. In addition to the above, Community Control subjects who had any history of psychiatric, neurological and/or neurosurgical disorders were excluded from the study. Written informed consent was obtained from all the subjects. After this the subjects were administered the Last Word Recall Test (LWRT) and Complex Figure Test (CFT). Each of these tests contained two versions. LWRT had Related-Last-Words and Unrelated-Last-Words versions. CFT had Intact-Figure and Separate-Parts versions. The administration of the tests as well as the versions were counter-balanced.

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Description of the neuropsychological tests

Last Word Recall Test

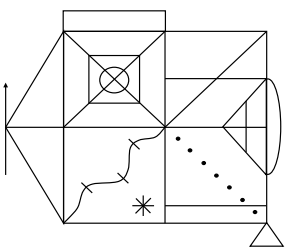
This test has been adapted from Daneman and Carpenter (1980). In the original version the subject is read out a series of sentences one by one, and is asked to tell whether the sentence is generally true or false, while having to maintain the last word of each sentence, which is to be recalled at the request of the examiner. This test is said to measure the working memory capacity for words. For the current study, this procedure has been modified, i.e. the task was made into two versions, each having two levels. In one version, the last word of each sentence together form a sentence (related last words version). In the other version, the last word of each of the sentence do not form a sentence (unrelated last words version). Each version has two levels, with the first level having 3 sentences and the second level having 6 sentences (Please refer Table 4). In addition, in the current version, instead of answering true or false, the subjects had to repeat the sentence (after the examiner reads it out) and remember the last word for later recall. No points were given for repeating the sentence while mistakes made in the repetition were noted. A score of 1 point is given for each correct recall of the last word, in both the related words and unrelated words condition. Level 1 and Level 2 scores were combined to get the total score. The maximum score is 9 each for related words as well as unrelated words condition.

Table 4: Last Word Recall Test

Version	Level	Sentences	To be recalled words
Unrelated last words	I	Yesterday there was no supply of ELECTRICITY Monkeys are sitting on the branch of a TREE Madhuri is considered as very BEAUTIFUL	Electricity Tree Beautiful
	II	There is a great demand for civil SERVICES Rich people buy tickets of first CLASS Because of violence match was called OFF The father of the nation was very TRUTHFUL The train was late by thirty MINUTES Shankara considered everything as an LLUSION	Services Class Off Truthful Minutes Illusion
Related last words	I	Govinda's sister's name is SANDHYA He was alone and decided to get MARRIED Last year gold medal was won by RAMESH	Sandhya Married Ramesh
	II	It is easy to convince CHILDREN Eating chocolates is something we LOVE In beaches we see boys PLAYING Alcoholics are difficult to adjust WITH My friend's house is quite SMALL Abroad we get expensive TOYS	Children Love Playing With Small Toys

Complex Figure Test

This test had two versions; one was the Intact-Figure and the other was the Separated-Figure version. The Intact-Figure version involved Rey-Osterrieth Complex Figure Test – Taylor Alternate Version (Spreen & Strauss, 1998) with a small modification. In this version the subject was shown the complete figure for 40 seconds, after which the subject was asked to draw the figure from memory (Please refer Figure 1).



In the Separated-Figure version, the complex figure was adapted from NIMHANS Neuropsychological Test Battery (Mukundan, Rao, Jain, Jayakumar, & Shailaja, 1991). In the original, the complex figure is displayed to the subject in its entirety (Please refer Figure 2e). For the present study, the complex figure is divided into 4 parts and printed on a transparency sheet (Please refer Figure 2a, 2b, 2c, 2d). The subject is shown the first part for 10 seconds and the subsequent parts are superimposed on the earlier ones, allowing 10 seconds after each superimposition. The presentation builds up to a complete figure (Please refer Figure 2e). On the whole, the total time the subject will be viewing the figure would be 40 seconds. After the display of the 4th part, the subject is asked to draw the complete figure from memory. Both the figures are scored based on the number of elements drawn, with maximum score being a 20 for each sub test.

"Figures 2a, 2b, 2c, 2d, 2e about here"

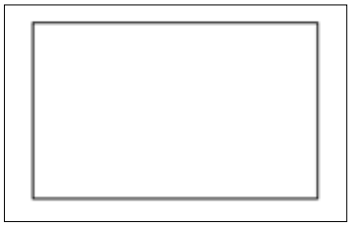


Figure 2a:

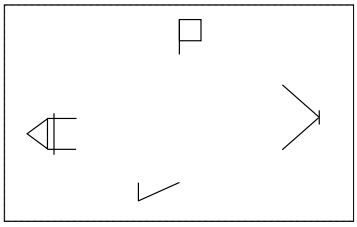


Figure 2c:

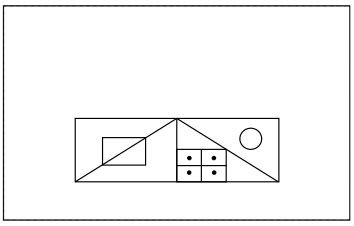


Figure 2d:

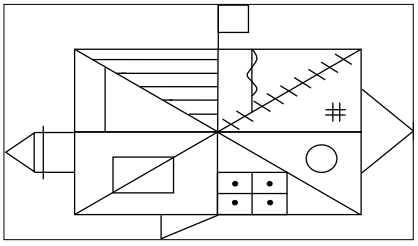


Figure 2e:

STATISTICAL ANALYSIS

Analysis was done using SPSS-10 software. ANOVA was used to test the significance of difference among the three groups, and Post-hoc test (Bonferroni) was used whenever the ANOVA showed significant differences. Similarly, to compare between the two subtests within each group, t-tests has been used.

RESULTS AND DISCUSSION

The three groups did not differ with each other in terms of age and number of years of education (Table 1). Both the lesion groups had more number of males compared to females.

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Table 1: Socio-demographic characteristics of the sample

	Left Frontal Mean (SD)	Right Frontal Mean (SD)	Community Controls Mean (SD)	F	Sig
Age	34.10 (7.46)	34.07 (8.69)	34.82 (7.97)	0.041	n.s
Education	11.80 (3.64)	10.14 (2.41)	11.23 (3.19)	0.93	n.s
Gender	7 Males	12 Males	14 Males	---	---

n.s. = not significant

In the Last Word Recall Test, the three groups did not differ significantly in the unrelated-last-words trial. In the related-last-words trial, the results showed significant difference among the three groups. However, post-hoc test revealed the significant difference was only between left frontal lesion and the community control group (Table 2).

Table 2: Results of the three groups on the Last Word Recall Test

	Left Frontal Mean (SD)	Right Frontal Mean (SD)	Community Controls Mean (SD)	F Ratio	Sig.	Multiple Range
Unrelated-Last-words	2.80 (2.15)	3.85 (1.70)	4.70 (1.86)	3.24	0.05	-
Related-Last-Words	3.70 (2.0)	4.64 (1.69)	6.00 (1.54)	6.54**	0.004	L & CC
't' value	2.08*	1.71	3.10**	-	-	-
Significance	0.03	0.055	0.003	-	-	-

*P ≤ 0.05 **P ≤ 0.01 L = Left, R = Right, CC = Community Controls

On the other hand, the left frontal lesion and the community control group performed significantly poorly in unrelated-last-words trial compared to related-last-words trial. The right frontal lesion group showed a tendency towards significant difference. This indicates that all the groups performed better when organization was introduced within the stimuli. However, the benefit was more for the community control group and the right frontal lesion group benefitted least. On the whole, this indicates that lesion either in left or right frontal region impairs encoding in working memory, where the effect is pronounced if the lesion is on the left hemisphere. As this being the verbal test, this result can be expected.

Introduction of the organization strategy within the stimulus improved performance in both the lesion groups as well as in the community control group. Surprisingly, the increase in the scores in right frontal lesion group in related-last-words trial matched the unrelated-last-words trial of community controls. This indicates that at least with increased organization, right frontal lesion patients can perform almost equal to that of community controls. However, this phenomenon was not observed with respect to the left frontal lesion group, where the increase in the scores for related-last-words trial was still far below that of unrelated-last-words score of community controls. This indicates that even after introducing organization in the stimulus, working memory of the left frontal lesion patients still showed deficits compared to the community controls.

All the three groups did not show any significant differences among each other either in Intact-Figure version or in the Separated-Figures version. Similarly, none of the groups showed any significant difference between Intact-Figure version or in Separated-Figure version (Please refer table 3). This is in contradiction to the results obtained by Lange et al. (2000), where the results showed greater organizational impairment in the right hemisphere lesion patients.

Table 3: Results of the three groups on the two subtests of Complex Figure Test

	Left Frontal Mean (SD)	Right Frontal Mean (SD)	Community Controls Mean (SD)	F Ratio	Sig.
Intact figure	7.60 (5.92)	7.57 (5.09)	8.88 (4.63)	0.32	0.72
Separate figure	6.40 (3.56)	7.07 (3.36)	8.70 (3.30)	1.50	0.23
't' value	1.38	0.70	0.32	-	-
Significance	n.s	n.s	n.s	-	-

On the whole, though not reaching significance difference the mean of the Intact-figure version was higher in all the three groups. This might be due to the fact that intact figure itself acts as a 'gestalt' and might aid in providing organization for the figure, thereby enabling better performance. Further, the intact-figure might have helped the subjects to make their own organization strategy, rather than depending on the strategy presented by the authors. On the other hand, though the results did not reach any significance level, it is interesting to note that left-frontal lesion patients performed poorer than the right-frontal lesion patients in Separate-figure version. The figure in this version are presented sequentially and as the left hemisphere is more involved in serial processing (as against 'parallel processing of the right hemisphere), this results can be expected.

The study has important implications for cognitive retraining after the neurotrauma. Patients can be retrained on cognitive functions using principles of organization, such as making the task more meaningful, organized and with more strategies, which might increase the working memory capacity of the patients. As working memory is central to many of the cognitive process, increasing the efficiency of the working memory in turn might improve the other cognitive functions of the patients with brain lesion. This might increase their functional skills, quality of life and wellbeing in general.

Limitations and suggestions:
Though it is usual for the lesion studies, the study involved small sample size. In addition, recognition trials would have been used to differentiate whether the deficit was in encoding and/or retrieval. However, the objective of the study was more to find the differences between the left and right frontal lesion patients on the working memory performance, rather than the encoding – retrieval distinction. The localization of the lesions was done based only on the CT scan report and no pixel or volumentric analysis has been done. Future studies can look into this aspect.

SUMMARY AND CONCLUSIONS:
Verbal working memory performance is poor in left-frontal lesion group compared to the right-frontal lesion group. Introducing organization into the verbal working memory task has increased performance and the capacity of the working memory in both the lesion groups. Performance of both lesion groups does not differ for Intact-figure and Separate-figure presentations. Increasing organization of the cognitive retraining tasks might improve the working memory capacity of the patients who are suffering from neurotrauma, thereby increasing their overall cognitive functioning. This might help them to reach closer to the premorbid level of cognitive functioning.

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