Non Verbal Sequential Memory in Broca's Aphasia

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Abstract

Memory problems can result from head trauma, stroke, anoxia, tumors, infections and vitamin B1 deficiency or from excessive use of alcohol. Stroke or Cerebro Vascular Accident (CVA) is one of the most prevalent causes of aphasia. Although stroke is a major neurological disorder often leading to serious and long lasting sensorimotor, language and behavioral disabilities, little is known about severity and frequency of memory impairment following stroke. Impairments of both working memory and long-term memory have been observed in patients with aphasia. Most of the recent psycholinguistic research on the nature of normal linguistic storage has utilized verbal learning experimental procedures. The use of traditional verbal learning experimental procedures to assess memory in aphasics is likely to yield contaminated data as these materials seem to require direct utilization of mental processes which are presumably impaired in aphasics. It has also been suggested that the kind of stimulus employed and type of response required from the participants for assessment of memory may also affect the performance of both normals as well as aphasics. The present study was taken up to address such issues.

Introduction

Cognition refers to all the mental processes by which information is transformed, reduced, elaborated, stored, recovered and used (Neisser, 1997). The relation between aspects of cognition and language status of individuals with aphasias is not well established. Out of all the cognitive processes involved in normal language functioning memory is one of the most important aspects. Memory can be defined as stored representation and process of encoding, consolidation and retrieval through which knowledge is acquired and manipulated (Bayles & Tomoeda, 1997).

Memory impairment associated with aphasia has been predominantly characterized as a reduction of immediate serial recall or span memory (Albert, 1976; De- Renzi & Nichelli, 1975).

Types of Memory

A major division of memory is based on the duration for which information is retained. It can be divided into:

1. Long Term Memory (LTM)
2. Short Term Memory (STM)

According to Baddeley (1992) short-term memory is composed of a central executive and a number of material specific slave systems. The central executive is a set of executive control

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processes responsible for selection and execution of strategies for maintaining and shifting attention when appropriate and for coordinating and manipulating information from a range of sources. Separate slave systems are dedicated to storing and maintaining different types of information.

Based on these slave systems short-term memory can be further divided as:

i Verbal memory-It tends to refer to performance on measures of new learning of material that is symbolic, meaningful and conducive to semantic mediation. It may involve processing of material in the auditory sensory modality although it is clear that material that is visually presented may be verbally mediated.

ii Non-Verbal memory: It tends to include learning of material that has been variously described as visual, visual-spatial, perceptual, figural, unfamiliar, difficult to verbalize and difficult to encode verbally (Moye, 1997).

There has been a long-standing interest in the relation between linguistic and short-term memory systems (Vallar & Shallice, 1990). Evidence from both normal (Hulme, Maughan & Brown, 1991) and impaired population (Martin & Saffran, 1997) suggests that the two systems share some underlying processes. Span size varies depending on the nature of items to be recalled. For e.g., in normals digit span is greater than for words and span for words is greater than for non-words (Hulme et al, 1991; Martin & Ayala, 2004).

Baddeley (2003) proposed that short-term memory could be divided into 4 sub systems:

1. Phonological loop: concerned with verbal and acoustic information.
2. Visuospatial sketchpad: involves visual or non-verbal equivalent of phonological loop.
3. Central executive: assumed to be responsible for attentional control of working memory.
4. Episodic buffer: serves the function of combining information from different modalities into a single multi-faceted code.

It was proposed that phonological loop could be broken into two sub-components, a temporary storage system which held memory traces over a matter of seconds, during which they decayed, unless refreshed by the second component. This involved a sub-vocal rehearsal that not only maintained information within the store but also served the function of registering visual information within the store provided the items can be named.

A study on participants with lesions resulting in phonological loop deficits and neuro-imaging studies support the hypothesis of separable storage and rehearsal systems with Brodmann area 44 being the cortical area associated with storage while sub-vocal rehearsal appears to be associated with Broca's area (Brodmann areas 6 and 40).

Memory has been viewed as a multifaceted system dependent on many cortical and sub-cortical structures and pathways. Memory impairments may negatively influence the functional communication abilities and response to treatment of adults with neurogenic communication disorders. Thus speech language pathologists and health care professionals must be cognizant of the types of memory problems that may occur in patients (Murray, Ramage & Hopper, 2001)

Impairments of both short-term and long-term memory have been observed in patients with aphasia. There is some evidence to suggest that there is a relation between aphasic patients working memory and language abilities (Caspari, 1998).

Although investigators have long pondered the role of cognitive functions such as memory in aphasia, empirical evidence has been slow to accumulate. Advancements on the area of memory and aphasia no doubt have been hindered, at least in part, by the challenge of developing reliable and valid assessments of aphasic memory deficits. For e.g., many commonly used memory tasks (e.g. digit span) are inappropriate because of their heavy linguistic demands (Murray, Ramage & Hopper, 2001).

Long-term memory (LTM) often has been described as being intact in individuals with aphasia because of their relatively preserved autobiographical memory (Schuell, Jenkins & Jimenez-Pabon, 1964). Milner (1982) found that individuals with excisions within the left frontal lobe, excluding Broca's area were impaired on verbal and non-verbal LTM tasks that require a serial recall strategy.

The selective deficits of short-term memory are usually accompanied by difficulty in processing longer sequences of words. Because word processing and short-term memory deficits are so pervasive in aphasia, this population offers an excellent opportunity to identify patterns that reflect links between the two systems. Caspari, Parkinson, La Pointe and Katz (1998) found a relation between WM capacity as measured by modified listening and reading versions of the Reading Span Test (RST). They concluded that language comprehension abilities in aphasia could be predicted by WM capacity.

By contrast Caplan and Waters (1994) pointed out that aphasic patients who do poorly on WM span tests often do well at comprehending sentences with complex syntactic structures and so there must be a memory system specific to syntactic processing and separate from a general WM. It was also found that on word list recall tasks aphasic patients with phonological deficit showed a robust primacy effect (i.e. recall of words from the beginning of list thought to be based on storage at semantic levels) whereas aphasic patients with semantic deficits had an enhanced recency effect (i.e. recall of words from the end of a list thought to be based on storage at phonological levels (Martin & Saffaran, 2001).

Researchers (Capitani, Sala, Logie & Spinnler, 1992; Raymonds, 1964) have suggested that primacy effect is influenced by presentation rate, item frequency, stimulus type and by semantic similarity. On the other hand recency effect is affected by a filled delay and by phonological similarity. Atkinson and Shiffrin (1968) interpreted primacy effect that in the beginning of the list where participants were able to rehearse items and successfully transfer them to long-term memory. This process became increasingly difficult as the list progressed. Ostergaard and Meudell (1984) and Martin and Ayala (2004) have also suggested that sub-vocal rehearsals or covert rehearsals are important for the maintenance of information in short-term memory.

To establish the memory functions a thorough assessment is required. Unfortunately many commonly used tests have linguistic processing and/or production demands that make them largely invalid for use with aphasic individuals. Thus studies on cognition in people with aphasia typically have employed cognitive tests with no obvious linguistic demands. Wickelgren (1965) has shown that non-verbal visual stimuli are stored in memory in an auditory-linguistic form.

It is not only the memory but also the ability to process order or sequential information which is an essential aspect of human cognition and normal language functioning (Lewandosky, Brown, Wright & Nimmo, 2006). Non-verbal sequential memory has been less researched despite its demonstrated role in various cognitive tasks (Heathcote, 1994). Thus assessment and management of memory is required while dealing with individuals with aphasia. However it is difficult to establish whether the observed impairments in aphasics reflect memory deficits or are secondary to linguistic disturbances. Hence memory assessment protocols with minimal language processing requirements may provide a better knowledge of memory impairments in individuals with aphasia.

There is dearth of studies in Indian context with respect to memory impairments and aphasia. Given the relative importance of memory in normal language functioning, assessment of memory has far reaching implications for planning an effective rehabilitation program for individuals with Broca's aphasia. Moreover it is not clear whether language abilities and memory span in individuals with aphasia are inter related or independent.

Aims of the study

1. To compare the non-verbal sequential memory span of individuals with Broca's aphasia and normal individuals.
2. To compare the effects of stimulus characteristics on quantitative and qualitative aspects of non-verbal sequential memory.

Method

Inclusionary criteria for experimental group:

a) A total of nine participants having aphasia voluntarily participated in the study
b) Participants were diagnosed as having Broca's aphasia by a speech-language pathologist and/or neurologist
c) Participants with history of a single episode of brain attack due to cerebro vascular accident (CVA) only were included in the study
d) Participants were at least 3-6 month post onset at the time of testing with an average time post stroke being 13; 5 months
e) Participants had no significant history of pre-morbid neurological, psychological or any other organic deficit
f) Selected participants did not have any sensory deficits such as visual (e.g., visual neglect, visual agnosia) and/or auditory deficits
g) All the participants included for the study were pre-morbidly right handed

Control Group

Nine normal participants matched with the aphasic group for age, gender, education, dexterity and language were included for the study.

Tools

1. Western Aphasia Battery (Kertesz & Poole, 1974; Kertesz, 1979)
2. The stimuli for the experimental task included:

a) Digits: Ranging from 2-7 units per presentation. e.g., the first trial involved presentation of the digits 3 and 8 one after another. The length of the digit string was gradually increased till the presentation of 7 digits in final trial.
b) Meaningful units: Frequently occurring nouns ranging from 2-7 units per presentation e.g. cup and bus were presented one after another for the first trial. The length of the meaningful unit string was gradually increased till the maximum 7 units.
c) Non-meaningful units: It consisted of geometrical patterns ranging from 2-7 units per presentation (taken from Raven's Progressive Matrices).

Power Point presentation was prepared to present the stimuli. All the stimulus categories had colored photographs. Along with slides flash cards of the size 3"x 4" were made for the stimuli across all categories.

Procedure

The participants were seated comfortably in front of the computer screen placed one and a half feet from the eye level. The presentation of the stimulus was as follows:

a) Digits: Starting from 2 units per presentation followed by 3 units per presentation and similarly till 7 units of presentation.
b) Meaningful units: For this stimulus also the experimental task started with the presentation of 2 units and continued till 7 units per presentation.
c) Non-meaningful units: In this domain also the experimental task started from 2 units per presentation and proceeded till 7 units per presentation.

Each stimulus item appeared on the screen for 2 seconds (approximate scanning time for aphasics, Swinney & Taylor, 1975) with an inter stimulus interval of 0.7 seconds. The flash cards were placed in the visual vicinity of the participants. The numbers of flash cards were always two more than the number of stimuli appearing on the screen.

Instructions

The subjects were instructed in their native language to point in the same order as the stimuli appeared on the computer screen.

Scoring

A score of 1 each was given for pointing the presented unit at the correct position. Thus maximum score of 2 was possible for trial 1 across different domains while maximum score of 7 was possible for trial 6 for all the tasks. A score of 0 was given for each incorrect response. The scores were appropriately tabulated.

Statistical Analysis: SPSS software (version 10) (Garrett & Woodworth, 1979) was used

Results and Discussion

The results are discussed under the following sub-sections.

- Memory span of individuals with Broca's aphasia and normals for digit task
- Memory span of individuals with Broca's aphasia and normals for meaningful stimuli

- Memory span of individuals with Broca's aphasia & normals for non-meaningful stimuli

The memory span of individuals with Broca's aphasia and normal participants across various trials of digit task were tabulated using the raw scores. The raw scores of both individuals with Broca's aphasia and normal participants were further converted into percentage. Table 1 furnishes the mean and S.D values for percentage scores for aphasics and normal groups across trials of digit task.

Table 1: Mean and S.D of percentage scores of digit task for aphasics and normals

Groups	M/SD	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Aphasics	Mean	100	100	66.67	51.11	51.85	46.03
	S.D	-	-	33.07	20.28	13.03	9.524
Normals	Mean	100	100	100	97.78	72.22	71.43
	S.D	-	-	-	6.67	33.3	22.59

Table 1 represents the mean percentage values across different trials for the digit task. Further the results show that the performance decreases from 100% to 46.03% (SD=9.52) for the aphasic group and for the control group the digit span decreased from 100% to 71.43% (SD=22.59) from trial 1 to trial 6 thus indicating that performance of both aphasics and normal participants decline as the number of items increases, the reduction in the memory span is more in aphasics compared to the normal participants. The results of the study are also in accordance to the reports stated by Baddeley and Hitch, (1974) who also found that as the digit load increases there was a decline in the memory span.

The results thus give an idea that insult to the anatomical regions which form the basis of language will not only affect the language abilities of aphasics but will also influence the memory span. The performance of individuals with Broca's aphasia and normal subjects was compared for each trial using t-test. Results of t-test showed statistically significant difference in the scores of two groups for trial 3, trial 4 and trial 6 at 0.05 levels ($p<0.05$). This difference in trial 5 may be attributed to high standard deviation observed in normals for this trial. Thus the results show that insult to brain results in decline in the performances. These results are in agreement with the study of Swinney and Taylor (1971) who found that aphasics performed poorly on memory task.

Serial curves were drawn for each trials and it was evident that a strong primacy effect was present for both individuals with Broca's aphasia as well as normal participants. It has been suggested that primacy effect is mainly because the participants are able to rehearse the items and maintain them in memory (Capitani et al, 1992). Additionally the primacy effect has been observed to be affected by word frequency (Raymonds, 1969). As digits are frequently used and highly redundant it is possible that as in normal participants sub-vocal rehearsals are also present in individuals with Broca's aphasia but with less efficiency.

1. Memory span of individuals with Broca's aphasia and normals for meaningful stimuli

The raw scores of both individuals with Broca's aphasia and control groups were converted into percentage. Mean and S.D values for percentage scores for individuals with aphasia and normals across trials of meaningful stimuli task is presented in table 2.

Table 2: Mean and SD of percentage scores of meaningful stimuli task for aphasics and normals.

Groups	M/SD	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Aphasics	Mean	100	100	88.89	68.89	57.41	53.97
	S.D	-	-	18.16	22.60	31.30	18.59
Normals	Mean	100	100	100	95.56	75.93	61.90
	S.D	-	-	-	8.82	18.84	12.37

It can be encapsulated from table 2 that the mean percentage values across different trials for the meaningful stimuli task decreases from 100 % to 53.97% (SD=18.59) for individuals with aphasia and from 100% to 61.90 % (SD=12.37) for the control group from trial 1 to trial 6. This is similar to the trend observed earlier for mean digit span. These findings also draw support from earlier findings (Martin & Ayala, 2004; Swinney & Taylor, 1971).

Further t-test was used to compare the performance of Broca's aphasia group and normal subjects for each trial of meaningful stimuli. There was no statistically significant difference observed for trial 3, trial 4 and trial 6 ($p<0.05$). The results can be attributed to the fact that all the tokens used in this task were semantically loaded stimuli, thus even a brief presentation of the linguistic stimuli would have activated underlying semantic concepts and thus resulting in better retrieval abilities in both the groups. This effect can again be ascribed to word frequency, familiarity and semanticity (Capitani et al, 1992; Raymond, 1969).

2. Memory span of individuals with aphasia and normals for non-meaningful stimuli

A percentage score was derived from the raw scores of both individuals with Broca's aphasia and normal participants. The mean and SD values for percentage scores in aphasics and normals across trials of non-meaningful stimuli task are presented in table 3.

Table 3: Mean and S.D of percentage scores of non-meaningful for aphasics and normals

Groups	M/SD	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Aphasics	Mean	100	100	63.89	57.78	57.41	42.86
	S.D	-	-	30.90	12.02	20.60	20.20
Normals	Mean	100	100	91.67	73.33	61.11	41.27
	S.D	-	-	17.68	28.28	16.67	28.07

As evident from table 3 the mean percentage values across different trials for the non-meaningful stimuli task reduced from 100% on trial 1 to 42.86% (SD=20.20) on trial 6 for aphasic group while for normals the meaningful memory span reduced from 100% on trial 1 to 41.27% (SD=28.07) on trial 6.

The other information which can be summarized from table 3 is that the mean of non-meaningful stimuli memory span decreased from trial 1 to trial 6 for both the Broca's aphasics and normals. This is in parallel to the trend observed earlier for mean digit span and mean span for meaningful stimuli. Also the rate of decline in both the groups was highest when non-meaningful stimuli were used. Martin and Ayala (2004) also reported that individuals with Broca's aphasia performed worst on non-meaningful stimuli as compared to digits and meaningful stimuli.

To compare the performance of Broca's aphasia group and normal subjects on each trial of non-meaningful stimuli a paired t-test was used. There was a statistically significant difference observed only for trial 3 at 0.05 levels and as the complexity of the task increased both the groups showed similar trends. These findings support the fact that although language and memory are separately represented they are interconnected.

The results of the study are in accordance to the reports stated by Ostergaard and Meudell (1984) where they found that verbal mediation play a significant role in memory for visually presented non-verbal material and this could account for the deficit in both the groups but more so in Broca's aphasia. Perhaps these patients' deficiencies in rehearsal of verbally encoded materials put them at a disadvantage even in the non-verbal task.

A primacy effect was observed for non-meaningful stimuli also but it was not as robust as for digits and meaningful stimuli. This can be due to the fact that stimuli used for this task were not familiar and lacked any semantic load.

3. Comparison of performance of participants using repeated measures ANOVA

A repeated measure of ANOVA was done to study the interaction between tasks and groups and a significant interaction was found between the tasks (digits, meaningful stimuli and non-meaningful stimuli) and the two groups (2, 32) = 6.460, $p<0.05$.

The next analysis was undertaken to study whether there was a significant difference across various tasks when all the participants were taken as a single group. There was a significant difference in the performance of participants between digit task and non-meaningful task and also between meaningful stimuli and non-meaningful stimuli task ($p<0.05$). This is in accordance with the findings of Martin and Saffran (1997) and Martin and Ayala (2004). The various stimuli used in the present study differed in terms of semanticity, familiarity and redundancy which could have differentially affected both the memory span as well as the primacy effect in the serial position curve.

It was also examined that whether there was a significant difference between the two groups (aphasics and normals) for the three tasks. When the data was subjected to Bonferroni test statistically significant difference was found between the two groups [$F(1, 16) = 13.05$ ($p<0.05$)].

Further analysis was undertaken to study the difference between the tasks across different groups. For normals a significant difference was found across various tasks as digits, meaningful stimuli and non-meaningful stimuli [$F(2, 16) = 22.285$ ($p<0.001$)]. Additionally Bonferroni analysis was done to examine difference between different tasks for normals.

A statistically significant difference was found for the normals between digit spans and non-meaningful stimuli span and also between meaningful stimuli span and non-meaningful stimuli span at $p<0.05$. This difference can be attributed to the fact that both digits and meaningful tokens employed for this task occur frequently and were redundant. This would have facilitated strong sub-vocal rehearsals which in turn would have led to better retrieval of these stimuli. On the other hand non-meaningful stimuli lacked any semanticity, this attributed to poor sub-vocal rehearsals and hence, poor performance on this task. Research findings (Capitani et al, 1992; Martin & Ayala, 2004) have stated that sub-vocal rehearsals strengthen an individual's ability to retain stimuli. In aphasics also statistically significant difference was noticed across different tasks [$F= (2,16)=3.091$, $0.05<p<0.1$]. Subsequently Bonferroni analysis was undertaken to study the difference between the tasks across the aphasic group.

A statistically significant difference was found between meaningful stimuli span and non-meaningful stimuli span (i.e. for task 2 and task 3) at 0.05 levels ($p < 0.05$). This difference again suggests that language and memory are discrete and individuals with Broca's aphasia might be using their intact comprehension skills to supplement the memory deficits.

Conclusions

Thus it can be concluded that there is a significant difference between normals and individuals with aphasia in memory span. The results have strongly suggested that there are obvious observable memory deficits in individuals with Broca's aphasia. Further the results of the study also advocate that the stimuli employed for assessing the memory can influence non-verbal sequential memory span. In order to generalize these results in other types of aphasia similar studies should be conducted.

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