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Qualitative Analysis of Clustering on Verbal Fluency in Young Adults

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Introduction

Tests of verbal fluency or word list generation are frequently used in clinical and experimental research of cognitive function. In general, these are operationalized as the number of words produced, usually within a restricted category and within a given time limit (Spreen & Strauss, 1998). There are several types of tasks that measure verbal fluency. It is typically tested in letter and category domains. The most common tasks used are letter or phonemic fluencies**,** where participants need to generate as many words as possible beginning with a specified letter such as F, A, or S in a limited time (Raskin, Sliwinski, & Borod, 1992; Troyer, Moscovitch, Winocur, Alexander & Stuss, 1998), and semantic fluencies, where words must belong to a specified semantic category like "Animal" , "Fruit" or "Supermarket" (Beatty, Monson, & Goodkin, 1989; Troyer, 2000).

Successful performance on verbal fluency is thought to depend on the ability to initiate, search and retrieve data from the lexicon or the semantic memory system and on efficient executive functioning, including attention (Rosser & Hodges, 1994). These tasks, therefore assess language function (vocabulary size, naming), speed of response, mental organization, search strategies & long-term memory (Ruff, Light, Parker & Levin, 1997).

Although the instructions for both these tasks are the same, there is a difference in their performance. This difference in performance is due to the variation in the hierarchical organization of the two categories (letters vs. semantic category) in the brain. The retrieval of letters requires exploration of more subsets of categories than the retrieval of names of a specified semantic category (e.g. animals) (Riva, Nichelli, & Devoti, 2000). Performance on these tasks is dependent upon a number of variables including age, gender, education, literacy level, ethnicity and intelligence (Kempler, Teng, Dick, Tuassig & Davis, 1998; Ratcliff, Ganguli, Chandra, Sharma, Belle, Seaberg & Pandav, 1998; Mathuranath, George, Cherian, Alexander, Sarma & Sarma, 2002).

The most commonly used score from verbal fluency test is the total number of words generated. However, this score provides little information about the cognitive processes underlying fluency performance and does not answer the question as to why a particular patient group or experimental manipulation is associated with reduced test performance. Additional information is needed to examine the behavioral components that determine fluency performance. Quantifying the qualitative aspects of verbal fluency performance has been studied extensively in the past few decade by many researchers (Troyer, 2000; Abwender, Swan, Bowerman & Connolly, 2001).

Analysis of verbal fluency production by breaking the list of verbal output into clusters of words that share similar properties could shed light on the ability of the participant to recall associated words and ability to switch to new categories when necessary. Clustering involves phonemic analysis on phonemic fluency and semantic categorization on semantic fluency, and is thought to be a relatively automatic process. It involves, searching sequentially for categories of associated words, retrieving items from category and then switching into a new category when retrieval from the previous category fails (Troyer, Moscovitch & Winocur, 1997).

A phonemic cluster consists of words starting with the same letter /sounds or that rhymes; semantic cluster consists of words with associated meaning. It has been argued that semantic clusters are more automatic relying on the common rules of categorization (e.g.: jungle animals, farm animals, pets, water animals, etc.), whereas phonemic clusters are more laborious relying on the frontal lobe (Ho, Sahakian, Robbins, Barker, Rosser & Hodges, 2002). Therefore, in semantic fluency, both semantic and executive abilities are equally important whereas in phoneme fluency task in which few semantic cues are available, executive abilities are more important.

As the method of analysis of clustering is not standardized, many methods have been used in research (Raskin et al., 1992; Troyer et al., 1997; Abwender et al., 2001). Though the approach for coding clustering has been put forth differently, these studies in the area of clustering have calculated mainly the following measures of clustering: number of clusters, cluster ratio, cluster size and mean cluster size. Using these measures, it has been revealed that clustering is related to temporal lobe functioning as indicated by impaired performance among patients with temporal

lobectomy, patients with Alzheimer's disease and unaffected by focal frontal lesions (Troyer et al., 1998). Thus, it shows that measures of clustering may provide useful information about the ongoing cognitive processes during performance on tests of fluency, including information for differential diagnosis in the brain damaged.

Need for the Study

Verbal fluency tasks have been commonly used for evaluating the semantic memory in clinical practice and research. Literature reflects a lot of inconsistency regarding the complex relationship between brain damage and verbal fluency. The lack of certainty regarding the proper interpretation of poor verbal fluency scores in clinical population could be occurring as a result of overreliance on the quantitative traditional assessment procedure, wherein, only the overall number of acceptable responses within a category is calculated. In Indian context, studies (Ratcliff et al., 1998; Mathuranath et al., 2003; Kar, Rao & Chandramouli, 2008) focusing on verbal fluency have restricted analysis of verbal fluency to quantitative analysis of total number of words produced on verbal fluency task alone.

However, in brain research, there is a need not just to understand how well an examinee performs in a task but also how one goes about in performing the task. It is in this context that examination of qualitative output using measures of clustering can serve as a window to clarify the precise nature of performance in normal population as well as clinical population. It also increases the usefulness of this measure of fluency index in clinical and research settings. This justifies the need for research on data from a group of healthy adults on clustering on verbal fluency task.

Aim

To analyze word clustering in healthy, young adult participants.

Objectives

To compare the performance of healthy adult participants on verbal fluency measures across verbal fluency tasks, gender and fluency measures.

Method

Participants

Participants were 30 healthy adults recruited from University-based participant pool from two gender groups: 15 males and 15 females. The age of participants from both genders ranged from 18 to 25 years with a mean of 21.5 years.

All participants were fluent in Malayalam, which belongs to the family of Dravidian languages. Those right handed adults between 18 to 25 years, born and brought up in Kerala and with Malayalam as mother tongue and who could read and write Malayalam were selected.

Those individuals with any sensory deficits like hearing loss and with history of any neurological disorder / psycho affective / language difficulties / substance abuse / drugs were excluded. All participants tested were included in the analysis.

As would be expected in the general population, all the participants in the younger group were equally educated since all of them were university students. They provided voluntary informed consent to participate in the study.

Procedure

All testing was conducted in Malayalam. No training trials were provided. Each participant was given two verbal fluency tasks, that is, one semantic fluency task and one phonemic fluency task. Consistent with the standard instructions (Spreen & Strauss, 1998), participants on phonemic fluency were asked to generate as many words as possible in 60 seconds that began with the letter /p/, excluding proper names, numbers, verbs and variants of the same word, that is words with different suffixes (e.g., pen, pens). On animal fluency, participants were instructed to name as many different animals as possible in 60 seconds. Sixty seconds was allotted for each of the phonemic and semantic trial.

Analysis

Recording of each task was done for a minute using an audio recorder. After recording, offline analysis was done by transcribing the words. For both tests of phonemic and semantic fluency, all errors, including repetitions and intrusions, were recorded along with correct words in the order in which they were generated. Four scores were obtained from each fluency task, including the number of clusters, cluster size, mean cluster size, and the total number of correct words generated, based on Troyer (2000). All correct scores were given a score of one and incorrect, a score of zero.

Cluster refers to generation of successive words within a subcategory. Number of clusters (NC) was calculated by calculating the number of phonemic & semantic clusters.

Phonemic clusters were defined as successively generated words that began with the same first two letters (e.g., pot, pocket), differed only by a vowel sound (e.g., pen, pin) or rhymed (e.g., sand, stand).

Semantic clusters were defined as successively generated words belonging to the same semantic sub categories, such as Pet animals, Farm animals, Wild animals, Water animals and belonging to individual zoological categories, such as birds, canine, insects, primates, and so on.

Phonemic & semantic clusters were counted on both phonemic and semantic fluency. Thus, number of clusters refers to the total number of clusters in each task. Cluster size (CS) is used as a measure of retrieval. It is counted from the second word of each cluster (e.g. a 3-word cluster was counted as a cluster size of 2), so that a single word has a cluster size of 0. Mean cluster size (MCS) is calculated by dividing cluster size by the total no of clusters. Total number of correct words (TW) were also calculated by excluding proper names, numbers, verbs and repetitions of the same word with different endings and those words which did not start with the particular phoneme in case of phonemic fluency. In case of semantic fluency, it's the number of correct words uttered after excluding the repetitions plurals, synonyms and other incorrect utterances.

For the purpose of analysis, statistical relation between total number of words generated and clustering measures on both phonemic & semantic fluency test was determined on correlation measures. Gender differences on these variables were also explored using Independent T test using SPSS 16 version.

Results

Table 1 depicts the performance of the participants (mean and standard deviation) on verbal fluency measures of total number of words (TW), Number of clusters (NC), Cluster Size (CS) & mean cluster size (MCS) across the semantic and phonemic fluency task and across gender.

Table: 1 Fluency performance by healthy adults across tasks and across gender

	Semantic fluency				**Phoneme fluency**			
Males n=15	TW	NC	CS	MCS	TW	NC	CS	MCS
	20.66 (4.89)	5.06 (1.57)	12.8 (5.2)	2.75 (1.50)	15.33 (2.05)	4.13 (1.12)	7 (2.59)	1.75 (.76)
Females n=15	19.40 (4.28)	4.60 (1.29)	11.6 (3.24)	2.78 (1.49)	15.73 (2.52)	4.53 (1.84)	7.4 (1.80)	2.08 (1.40)

Across Gender

On semantic fluency, mean total number of words across males is 20.66 with a S.D. of 4.89 and that of females, 19.40 with a S.D of 4.28. The mean difference of 1.26 and standard error difference of 1.68 was not found to be statistically significant (t = .754, p = .457) on Independent t test. Similarly, on measures of clustering, the mean number of clusters in males and females was 5.06 (1.57) and 4.60 (1.29) respectively with mean difference of .466 and standard error difference of .527. However, no significant difference was seen between the two groups (t= .884, p = .384). No gender differences were observed on cluster size (t= .798, p = .432 with mean difference of 1.26 and standard error difference of 1.58) or mean cluster size (t= -.043, p = .966 with mean difference of -.02 and standard error difference of .546).

On phonemic fluency, the mean total number of words across males is 15.33 with a S.D of 2.05 and that of females 15.73 with a S.D of 2.52. The mean difference of -.40 and standard error difference of .840 was not statistically significant (t = -.476, p = .638). Similarly on measures of clustering, the mean number of clusters in males and females is 4.13 (1.12) and 4.53 (1.84) respectively with mean difference of -.40 and standard error difference of .558. No significant difference was obtained between the two groups (t= -.716, p = .480). Further, no gender difference was observed on cluster size (t= -.572, p = .572 with mean difference of -.466 and standard error difference of .815) or mean cluster size (t= -.806, p = .427 with mean difference of -.332 and standard error difference of .412).

Across Tasks

On comparison between the two tasks, statistically significant difference was found between semantic and phonemic fluency on total number of words (t=4.832, p=.000), cluster size (t=5.72, p=.000) & the mean cluster size (t=2.55, p=.013). However, no significant difference was obtained for number of clusters (t=1.31, p=.19) on both the tasks.

Across Fluency Measures

Table: 2 Correlation coefficient for fluency variables

	Semantic fluency		
	CS	CN	MCS
TW-Semantic fluency	.782**	.646 **	.173

	Phoneme fluency		
	CS	CN	MCS
TW- Phoneme fluency	.698**	.483**	-.319

****p<.01**

Table 2 reflects statistically significant positive associations between total number of words and number of clusters and cluster size in both fluency tasks. However, essentially no meaningful relationships were found between total number of words and mean cluster size.

Discussion

The present study aimed at comparing verbal fluency measures across verbal fluency tasks & gender in young healthy adults. The results revealed that: (a) semantic fluency was better than phonemic fluency (b) verbal fluency scores did not vary with gender and (c) there existed a

positive correlation between the total number of words generated and two of the clustering measures.

The results indicated that across both types of fluency, significantly fewer words, cluster size and mean cluster size were produced in phoneme fluency as compared to semantic fluency; however, there was no significant difference between tasks on number of clusters.

Rende, Ramsberger & Miyake (2002) in their study, suggested that letter fluency performance relies on the phonological loop of the working memory whereas, category fluency relies on the visuospatial sketch pad, therefore enabling participants to effectively implement visualization strategies. Therefore, semantic fluency depends strongly on access to and integrity of semantic stores, where activation of an initial and highly prototypical exemplar leads to automatic activation of closely related semantic neighbours (Rosser & Hodges, 1994).

By contrast, phonemic fluency requires the processing of the phonemic characteristics of words according to a given rule (i.e., same first letter). The search process is less automatic and necessitates the active generation of a new strategy. Martin, Wiggs, Lalonde & Mack (1994) reported that more than semantic fluency task, the phonemic fluency task requires participants to make correct selections, to inhibit intrusions, and to keep a constant level of focused attention. This difference in verbal fluency performance found in the present study on both the tasks supports the findings that phonemic verbal fluency and semantic verbal fluency are distributed and partially distinct functions that rely on different component processes of the word retrieval system.

Gender differences in cognitive abilities have long been hypothesized with women performing better on tasks involving receptive and productive language and men excelling in visual–spatial abilities. A female superiority for phonemic verbal fluency has often been reported in studies carried out in normals (Bolla, Lindgren, Bonaccorsy & Bleecker, 1990; Crossley, D'Arcy & Rawson, 1997) whereas in semantic verbal fluency, available data does not suggest a female advantage (Capitani, Laiacona & Basso, 1998).

Weiss, Kemmler, Deisenhammer, Fleischhacker & Delazer (2003) found women to have a significant advantage in the lexical condition with no significant difference in the categorical task. However, some other studies failed to find gender differences regardless of task type (Cohen & Stanczak, 2000; Kempler et al, 1998; Tombaugh, Kozak, & Rees, 1999) or only found sex differences in specific categories that may reflect socio cultural factors (Kosmidis, Vlahou, Panagiotaki & Kiosseoglou, 2004).

Consistent with the previous reports of no significant gender differences in fluency performance across younger adults, the participants of the present study also generated equal number of words, number of clusters, cluster size and mean cluster size. This indicates that processing strategies used by men and women for phonemic and semantic verbal fluency tests to optimize verbal fluency task performance are not different.

In the present study, for both types of verbal fluency, there was a positive correlation between clustering measures of cluster size and number of clusters and total number of words generated on semantic & phoneme fluency. However, no positive correlation was observed between mean cluster size and total number of words. This indicates that clustering measures, specially cluster size and number of clusters are important for optimal performance on fluency task. This finding contrasts with studies in adults showing an equal contribution of all components of clustering in semantic fluency (Troyer et al., 1997).

The performance of the participants also revealed shorter intervals between uttering words within clusters compared to the interval between non-clustered words in the semantic task, confirming the notion that fluency production occurs in bursts of associated words, with more effortful switches between clusters (Gruenwald & Lockhead, 1980). This indicates that the process of clustering performance involves a search for fields within the same subcategories for semantic fluency task which corresponds to the pause between clusters and also a search for and production of words within the subcategories or semantic fields once these are identified resulting in spurts of words belonging to the same category.

The aforesaid findings have critical implications for clinical practice and research on executive functions & semantic memory. Since clustering appears to predict organizational strategies, use of this analysis can detect executive function problems in neurological disorders. Studies done on Alzheimer's afflicted have revealed that mean semantic cluster size was smaller in comparison to patients with Parkinsons disease or for normal controls (Troyer, Moscovitch, Winocur, Leach & Freedman, 1998). In a similar study, patients with left temporal lobe lesions produced smaller cluster sizes on semantic fluency than did their normal counterparts (Troyer et al., 1998).

In such a situation, analysis of the verbal fluency output using the methods described in this study could provide evidence for different patterns of deficits in organizational or retrieval or switching. Thus, this data on healthy adults can therefore serve as a baseline while evaluating patients with focal / diffuse brain injury, in the Indian context.

Conclusion

Although verbal fluency is a frequently used test in clinical population, little is known about the underlying cognitive processes. The findings of this study imply that one of the important components of fluency performance that determines the output quantity is clustering measures, specifically, number of cluster and the cluster size. This measure should be considered as a part of routine clinical evaluation in order to help us understand the brain- behavior relationship. Findings of the study show a significant relationship between verbal fluency and types of task, wherein better performance is observed on semantic fluency task compared to phonemic fluency task. The lack of significant relationship between gender and verbal fluency supports the findings that clustering is not confounded by differences in gender. Future research needs to focus upon

other confounding factors and their effects on verbal fluency performance for widening the knowledge base in this area.

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