Clustering and Switching in Verbal Fluency in Parkinson's Disease

Kelly Donovan, Richard Siegert, & John McDowall
School of Psychology, Victoria University of Wellington,

David Abernethy
Wellington School of Medicine, University of Otago

Thirteen patients with non-dementing Parkinson's disease (PD) were compared with 11 healthy controls on a semantic and a phonemic verbal fluency task. Analysis of the data examined total words produced as well as two additional components of verbal fluency: Clustering (generating words which share a semantic or phonemic similarity), and switching (the ability to shift between clusters). Overall, PD patients generated fewer words than the controls, and made less use of switching both in the phonemic and semantic fluency tasks. They did not differ from the controls in the amount of clustering. The results are consistent with the notion that patient groups in which the frontal lobes are compromised will perform poorly on switching tasks.

Verbal fluency tasks are a standard part of the neuropsychological assessment of many neurological and neuropsychiatric disorders. Typically the participant is asked to name as many words beginning with a particular letter of the alphabet (phonemic), or to name as many examples of a specific category such as *vegetables (semantic)*, in a fixed time period (Lezak, 1995). However, while it is generally accepted that fluency may suffer as a consequence of a range of different neuropathological conditions, it remains uncertain exactly which anatomical structures, and which cognitive processes, might underlie such deficits. One approach to clarifying these issues has been to study fluency deficits across different neurological conditions. For example, researchers have examined verbal fluency in patients with Alzheimer's disease (Hart, Smith, & Swash, 1988), Parkinson's disease (Hanley, Dewick, Davies, Playfer, & Turnbull, 1990), mild traumatic brain injury (Raskin & Rearick, 1996), and depression and schizophrenia (Crowe, 1992). This comparative approach has been useful in helping to reveal the differences in fluency that can arise with different diseases and their implications for our understanding of the brain structures involved. For example, researchers typically report a deficit on tasks of semantic (category) fluency amongst patients with Alzheimer's disease where the temporal lobes (and semantic memory stores) are likely to be compromised (e.g., Randolph, Braun, Goldberg, & Chase, 1993; Mickanin, Grossman, Onishi, Auriacombe, & Clark, 1994). By contrast, researchers studying Parkinson's disease (PD), where cortical impairment most likely involves the frontal lobes with consequent compromise of retrieval processes, typically report impairment on tasks of phonemic fluency but less so on tasks of semantic fluency (e.g., Bayles, Trosset, Tomoeda, Montgomery, & Wilson, 1993).

Research on verbal fluency has also concentrated on the specific cognitive processes that might underlie verbal fluency, and that may be impaired when there is brain pathology. The most popular strategy has been where researchers have compared their participants' performances on phonemic and semantic fluency tasks. The assumption here is that the two tasks are qualitatively different and that performance differences may give clues about cognitive processes involved. Probably the most frequently reported finding here is that participants can produce fewer words on the semantic version of the task than the phonemic. For example, Troyer, Moscovitch, & Winocur, (1996,1997) reported this with younger and older healthy adults, and Raskin, Sliwinski and Borod (1992) with patients with PD and also their control participants.

Auriacombe, Grossman, Carvell, Gollomp, Stern, and Hurtig (1993) have suggested four specific cognitive processes that could be involved in verbal fluency tests. These are: (a) attention and vigilance, (b) a lexical or semantic store, (c) a retrieval mechanism, and (d) a working memory that monitors items already produced. However, while these four putative component processes fit well with contemporary information processing accounts of human cognition, most neuropsychological studies on verbal fluency have only measured the final output, or total number of words produced. Given that the cognitive processes involved are not directly observable this is perhaps not

surprising. However, recent work by Troyer et al. (1997) and Troyer, Moscovitch, Winocur, Leach, and Freedman (in press), suggested a new method for analysing the spoken responses of participants at a more molecular level that may yield new insights into covert cognitive processes. Troyer et al. (1997) suggested that performance on verbal fluency tasks could be analysed in terms of two components they called *clustering* and *switching*. Clustering has been previously used to analyse verbal fluency data (eg. Raskin et al., 1992) and involves counting the number of successive words that share a semantic or phonemic similarity. Thus, in a phonemic cluster successive words may begin with the same two letters (e.g., apple, ape, appear), be homonyms (e.g., main, mane), rhyme (e.g., same, shame) or share other phonemic characteristics. The second component, switching, is a new concept to the literature and refers to the ability to shift efficiently to a new subcategory. These two simple concepts combined allow for a straightforward and quantifiable method for analysing individual responses to both semantic and phonemic fluency tasks. While they do not specifically relate these two concepts to the four component processes suggested by Auriacombe et al. (1993), Troyer et al. do suggest that clustering will involve accessing a word store and switching will involve search processes.

In the present study we set out to use the Troyer et al. (1997), method of analysing fluency data to clarify the nature of verbal fluency deficits in a group of PD patients. Verbal fluency deficits are well documented in people with PD although the precise nature of these deficits remains controversial. A common finding has been that PD patients demonstrate a selective deficit for semantic but not phonemic fluency (eg. Miller, 1985; Raskin, Sliwinski & Borod, 1992; Auriacombe et al., 1993). However, this differential impairment is not always observed. For example, Gurd and Ward (1989) reported that their PD subjects were impaired on both types of fluency task. By contrast, Hanley, et al. (1990) found no significant deficits on either task. They explained this finding in terms of a general impairment of verbal skills and not a specific retrieval deficit. Randolph, et al. (1993) who administered only a semantic fluency task, reported an impairment which was not evident on a cued version of the task, and interpreted this as evidence for a retrieval deficit. They suggested the retrieval functions involved might depend upon the prefrontal cortex. More recently, Troyer et al. (in press), observed people with PD with dementia to be impaired on both phonemic and semantic fluency, whereas non-demented people with PD were not impaired on either. In summary then, a number of studies have reported people with PD to be impaired on semantic fluency tasks but not phonemic tasks although, as noted, this is not a consistent finding. This differential impairment, where it has been demonstrated, has usually been explained in terms of a retrieval deficit associated with a dysfunction of the prefrontal cortex which is common in PD.

In the present study we employed the clustering and switching method, recently advanced by Troyer et al. for analysing verbal fluency data, to clarify the nature of verbal fluency deficits in PD. Specifically, we wished to test the following hypotheses:

(a) that participants with PD will produce fewer words than healthy controls on the semantic fluency task;

(b) that participants with PD will perform as well as healthy controls on the phonemic fluency task;

(c) that participants with PD will display less use of the switching component of fluency, relative to the control group, but that the use of clustering will be mediated by task type.

Method

Participants

Participants were 13 PD patients recruited from Neurology outpatients at Wellington Hospital, and 11 volunteers who served as healthy controls. In the PD group, nine were male, four were female, and all were aged between 45 and 85 years (mean = 68.15 years). The control group comprised four males and seven females, aged from 46 to 81 years (mean = 63.81). A chi-square test (Fischer's exact test) revealed no significant differences in the sex ratios of these two groups (chi square = 2.60, d.f. = 1, p=.11). None of the participants reported a history of head injury in the preceding ten years or had a history of alcohol abuse, stroke or epilepsy. All had normal or corrected to normal vision. One PD patient had received a diagnosis for mild depression, but was included as this had been some years earlier. Participants with other age-related medical problems (e.g. arthritis, osteoporosis, glaucoma) were not excluded from the study.

Each of the 13 PD patients was rated by a consulting neurologist on the Hoehn and Yahr (1967) degree of clinical disability scale for PD and all were judged to be in either the early or middle stage of the disease. Four people were in stage 1, six in stage 2, and three in stage 3. Duration of disease ranged from just less than one year to 18 years with a median of six years. At the time of testing 10 out of 13 patients exhibited bradykinesia, 9 had an apparent tremor, and a majority were on anti-parkinsonian medication. A summary of the characteristics of both groups are displayed in Table 1.

The Mini-Mental Status Examination (MMSE: Folstein, Folstein, & McHugh, 1975) was used as a screen for dementia and no participant scored below the cutoff of 24 points. The Wechsler Adult Intelligence Scale - Revised (WAIS-R: Wechsler, 1981) Vocabulary subtest revealed no significant group differences on estimated verbal intellectual ability. There were no significant group differences shown by t-tests on the variables age, or MMSE. There was a significant difference between the groups on years of formal education. The mean years of formal education reported by the PD participants was 12.38 years compared with 15.09 years for controls.

Table 1. PD and control group characteristics according to mean age, sex, education, MMSE and WAIS-R. Standard deviations are presented in parentheses.

	PD	Control	*t*	p =
Subjects	13	11		
Sex: Males	9	4		
Females	4	7		
Age	**68.15** (9.71)	**63.18** (11.91)	1.127	0.27
Education	**12.38** (3.43)	**15.09** (2.55)	2.159	0.04
MMSE	**27.23** (1.79)	**28.28** (2.27)	1.148	0.26
WAIS-R (Vocabulary raw scores)	**49.92** (7.70)	**56.45** (8.63)	1.96	0.06

Materials

The phonemic fluency test used was the Controlled Oral Word Fluency Test from the Multilingual Aphasia Examination (Benton & Hamsher, 1976) which requires the naming of words that begin with the letters F, A, and S, for 60 seconds each. The semantic naming task was the Animal Naming subtest from the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972) requiring the naming of animals in 90 seconds. However, this was adapted for the present study allowing participants 60 seconds rather than 90 seconds to make the scores more directly comparable with scores on the phonemic task. A practice trial involving the naming of vegetables over 60 seconds was included prior to this task. The results from this practice trial were not included in the final analyses.

Procedure

Prior to commencing this study, all procedures were first approved by the Ethics Committee of Capital Coast Health. Each participant was first administered the MMSE, and the WAIS-R in that order. Next the verbal fluency tasks were administered. For the phonemic fluency task, participants were instructed to generate as many words as possible beginning with F, A, or S. They were told that proper nouns, or the same word with a different suffix (e.g. *jump* and *jumping*), were not allowed. For the semantic task participants were instructed to generate names of vegetables in the practice trial followed by the naming of animals in the trial proper. The order of presentation of the tasks was randomised across participants.

Participants' responses were written down by the experimenter and also tape-recorded. The tape recording allowed an assessment of interrater reliability. Pearson correlation coefficients revealed that interrater reliabilities were high for phonemic cluster size (r = .98) and switching (r = 0.99), and for semantic fluency cluster size (r = 0.99) and switching (r = 0.97). For each participant, three scores were generated for each of the four relevant tests. These three scores were: the number of words generated (total verbal output), the mean cluster size, and the number of switches.

Total verbal output. The total number of words generated was obtained by counting the number produced by each participant excluding perseverations, errors, and proper nouns. For the semantic task, the total number of words produced in 60 seconds constituted the score, and for the phonemic task it was the total produced on the three letter trials. The salient phonemic measure was the average of these three trials.

Clustering and Switching. Instructions for scoring phonemic and semantic clustering were as described in Troyer et al. (1997). In brief, for the phonemic task, clusters included two or more successive words that rhymed (e.g., same, shame), words that began with the same two first letters (e.g., apple, appear), differed only by a vowel sound (e.g., foot, fit, fat), or were homonyms which the participant identified as two different words (e.g., some, sum). Semantic clusters were defined as two or more successively generated words that belonged to the same semantic subcategory, such as farm animals, zoo animals, pets, African animals, water animals etc. Cluster size was counted as beginning with the second word in each cluster. So "fit, fat, foot", for example, would be counted as a cluster size of two, and "same, shame" as one. The variable of interest here was the mean cluster size for the phonemic and semantic tasks. Switches were calculated as the number of transitions or shifts between clusters including single words. For both the mean cluster size and the total number of switches, errors and repetitons were included, because as Troyer et al. (1997) argue, these still provide information about the cognitive processes underlying verbal fluency tasks regardless of whether or not they are included in the total number of words produced.

Results

All data were entered on to a VAX mainframe computer and analysed with the Statistical Analysis System (SAS). Preliminary analyses revealed no significant difference between the two groups on the total number of repetitions made on the fluency tasks. The number of errors made was negligible with only five errors in total over 120 test trials (i.e. 5 trials x 24 participants). The means for both groups, on total words generated, number of switches, and cluster size, for both the phonemic and semantic tasks, are displayed in Table 2.

A 2 (Group: Parkinson's disease, Controls) X 2 (Task type: Phonemic, semantic fluency) ANCOVA on total scores with education as a covariate revealed a main effect of Group, $F(1, 21) = 9.83$, $p<.01$. Patients with PD generated

Table 2. Mean Fluency Performance by PD and Control Participants. Standard deviations are shown in parentheses

	Phonemic Fluency (average of F, A, S)		Semantic Fluency (animals)	
Variable	Parkinson's	Control	Parkinson's	Control
n	13	11	13	11
Words generated	**11.87** (3.96)	**15.85** (3.59)	**12.38** (3.66)	**16.77** (4.27)
Switches	**8.72** (2.28)	**11.36** (1.91)	**5.54** (2.37)	**9.18** (3.06)
Cluster Size	**1.39** (0.32)	**1.51** (0.39)	**2.98** (2.77)	**1.65** (0.45)

fewer words than controls for both the phonemic and semantic fluency tasks. There was no main effect of Task Type, F (1,22) = 1.21, p = .28, nor any interaction (F<1). Because of the relatively small number of subjects in this study a power analysis was conducted on the group differences. This revealed that power was high with regards to the detection of between group differences (.84).

A 2 X 2 ANCOVA on switching scores with education as a covariate revealed a main effect of Group, F (1, 21) = 28.40, $p < 0.001$. Patients with PD generated less switching overall than the control group. There was a main effect of Task Type , F (1, 22) = 14.12, $p < 0.01$, with more switching occurring in the phonetic fluency task than in the semantic fluency task. There was no interaction between Group and Task Type, (F<1). A power analysis revealed that power was high with regard to detection of Group differences (.99).

Finally, a 2 X 2 ANCOVA on clustering scores found no main effect of Group, F (1, 21) = 1.35, $p > 0.05$, no main effect of Task Type, F (1, 22) = 4.47, $p > 0.05$, nor any interaction (F<1). A power analysis on between group differences revealed a relatively low level of power (.20). All means are shown in Table 2. An identical pattern of results was observed when using WAIS-R Vocabulary score as a covariate.

In view of the significant difference observed between the two groups in the variable years of education, we then performed a multiple regression analysis to determine precisely how much years of education influenced verbal and semantic fluency. Using stepwise multiple regression, phonemic and then semantic fluency scores were regressed on the linear combination of Age, Gender, Years of Education, IQ (NART) and Group. The results of these two separate stepwise regression analyses are summarised in Table 3. Inspection of Table 3 reveals that for both phonemic and semantic fluency Group emerges as the single best predictor of variance. Moreover, for both the dependent variables, Years of Education did not significantly add to the overall proportion of variance accounted for.

Correlations between total verbal output and clustering and switching, for all 24 participants combined, were calculated to determine the relative contributions of these two components to fluency. On the phonemic fluency task the total number of words generated correlated positively with both the number of phonemic clusters (r = .47, p<.01)

Table 3. Summary of Stepwise Regression Analyses of Phonemic Fluency and Semantic Fluency with Age, Gender, Years of education, I.Q. (NART), and Group.

Dependent Variable: Phonemic Fluency

Step	Predictor*	R^2	df	F	p=
1	Group	.28	23	8.50	.008
2	I.Q.	.36	23	2.91	.10
3	Age	.43	23	2.26	.15

Dependent Variable: Semantic Fluency

Step	Predictor*	R^2	df	F	p=
1	Group	.25	23	7.20	.01

NOTE: No other variables met the 0.15 significance level for entry into the model.

and the number of switches, ($r = .78$, $p < .001$). On the semantic fluency task, the total number of words produced was correlated with the number of semantic switches ($r = .58$, $p < .01$), and negatively correlated with the number of clusters, ($r = -.14$, $p < .05$).

Discussion

The present findings do not support the notion that PD patients are typically impaired on semantic fluency tasks but not on phonemic tasks. Rather, we observed PD patients to be impaired on both tasks when compared to healthy controls. In this regard, the present study adds to a number of recent studies which have not found PD patients to be impaired only on the semantic fluency task (e.g., Gurd & Ward, 1989; Hanley, et al., 1990; Randolph, et al., 1993; Troyer, et al., in press). As predicted, participants with PD demonstrated significantly less use of the switching component of fluency on both types of tasks. Troyer et al. (1997a, 1997b) have provided evidence that switching relies on intact frontal lobe functioning (see also Owen, Roberts, Polkey, Sahakian, & Robbins, 1991; Vilkki & Holst, 1994). The observation in the present study that PD subjects performed poorly and demonstrated less switching on both tasks is consistent with suggestions that a retrieval deficit resulting from dysfunction of the prefrontal cerebral cortex is common in PD.

It also suggests that an important element of the retrieval process is the ability to monitor the words produced, to quickly assess when a specific category, or letter, is largely exhausted, and to disengage from that category or letter and shift to a different one.

By contrast with the switching data, there was (as predicted) little difference between the two groups in mean cluster size. In fact, on the semantic task the PD group actually generated a larger mean cluster size than the controls, reflecting perhaps their greater difficulty in switching or shifting set. This does not mean, however, that clustering is a less useful concept than switching, as it is likely to be more salient with patients with an Alzheimer's dementia where a deficit in semantic memory is evident (e.g., Troyer, et al., in press). The finding in the present study that cluster size did not differ between the PD group and the healthy controls is also consistent with other studies (Auriacombe et al., 1993; Troyer et al., in press).

One notable issue in the present study was the less than perfect matching of the two groups. The two groups were well matched in terms of age and MMSE scores, but the control group did report significantly more years of education. Also, the difference between the two groups on WAIS-R Vocabulary scale raw score approached significance. However, ANCOVA's which included each of these two variables as the covariate, indicated that Group was the influential independent variable while, Years of Education and WAIS-R Vocabulary were not. Similarly, a multiple regression analysis demonstrated Group to be the best single predictor of variance in both verbal and semantic fluency. Once again, Years of Education and WAIS-R Vocabulary were, by comparison, of relatively minor importance.

There are a number of interesting questions that arise from the results of the present study which future research might address. One question, is to what extent can performance be improved on the fluency task by "coaching" people in the uses of clustering and switching? In particular, it would be of interest to see whether PD patients, in whom the deficit is presumably "hard-wired", benefit from such instruction relative to healthy controls. In this regard Nisbet, Siegert, Hunt and Fairley (1996) demonstrated that the performance of patients with schizophrenia on a card-sorting task, widely regarded as a "frontal lobe" task, could be improved with a simple training procedure. One further direction for future research would be to examine the extent to which switching and clustering are affected by different neuropathological conditions that are considered to impair executive functions. For example, one might compare PD patients with closed head injury patients, or with patients with more focal frontal lesions as can arise with tumours. Another subject of interest would be to examine whether switching can actually provide a more sensitive index of frontal dysfunction, than just relying upon the total number of words generated.

Overall, the results of the present study support the value of Troyer, et al.'s analytic method of comparing clustering and switching in understanding performance on verbal fluency tasks. In addition they support the claim that clustering and switching are dissociable fluency components and that clustering depends upon intact temporal-lobe functioning, whereas switching relies on intact frontal-lobe functioning, typically impaired in PD patients.

References

Auriacombe, S., Grossman, M., Carvell, S., Gollomp, S., Stern, M., & Hurtig, H. (1993). Verbal fluency deficits in Parkinson's disease. *Neuropsychology, 7,* 182-192.

Bayles, K., Trosset, M., Tomoeda, C., Montgomery, E., & Wilson, J. (1993). Generative naming in Parkinson disease patients. *Journal of Clinical and Experimental Neuropsychology, 15,* 547-562.

Benton, A., & Hamsher, K. (1976). *Multilingual Aphasia Examination.* Iowa City: University of Iowa.

Crowe, F. (1992). Dissociation of two frontal lobe syndromes by a test of verbal fluency. *Journal of Clinical & Experimental Neuropsychology. 14,* 327-339.

Folstein, M., Folstein, S., & McHugh, P. (1975). Mini-Mental State: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189-198.

Goodglass, H. & Kaplan, E. (1972). *Assessmant of Aphasia and Related Disorders.* Philadelphia: Lea & Febiger.

Gurd, J. & Ward, C. (1989). Retrieval from semantic and letter-initial categories in patients with Parkinson's disease. *Neuropsychologia, 27,* 743-746.

Hanley, J., Dewick, H., Davies, A., Playfer, J., & Turnball, C. (1990). Verbal fluency in Parkinson's disease.

Neuropsychologia, 28 , 737-741.

Hart, S., Smith, C.M., & Swash, M. (1988). Word fluency in patients with early dementia of Alzheimer's type. *British Journal of Clinial Psychology, 27,* 115-124.

Hoehn, M. M., & Yahr, M.D. (1967). Parkinsonism: onset, progression, and mortality. *Neurology, 17,* 427-442.

Lezak, M.D. (1995). *Neurological Assessment.* (3rd ed.). NY: Oxford University Press.

Mickanin, J., Grossman, M., Onishi, K., Auriacombe, S., & Clark, D. (1994). Verbal and nonverbal fluency in patients with probable Alzheimer's disease. *Neuropsychology, 8,* 385-394.

Miller, E. (1985). Possible frontal impairments in Parkinson's disease: A test using a measure of verbal fluency. *British Journal of Clinical Psychology, 24,* 211-212.

Nisbet, H., Siegert, R., Hunt, M. & Fairley, N. (1996). Improving schizophrenic in-patients' Wisconsin card-sorting performance. *British Journal of Clinical Psychology, 35,* 631-633.

Owen, A.M., Roberts, A.C., Polkey, C.E., Sahakian, B.J., & Robbins, T.W. (1991). Extra-dimensional versus intra-dimensional set shifting performance following frontal lobe excisions, temporal lobe excisions or amygdalo-hippocampectomy in man. *Neuropsychologia, 29,* 993-1006.

Randolph, C., Braun, A., Goldberg, T., & Chase, T. (1993). Semantic fluency in Alzheimer's, Parkinson's, and Huntington's disease: dissociation of storage and retrieval failures. *Neuropsychologia, 7,* 82-88.

Raskin, S. A., & Rearick, E. (1996). Verbal fluency in individuals with mild traumatic brain injury. *Neuropsychology, 10,* 416-422.

Raskin, S., Sliwinski, M., & Borod, J. (1992). Clustering strategies on tasks of verbal fluency in Parkinson's disease. *Neuropyschologia, 30,* 95-99.

Troyer, A., Moscovitch, M., & Winocur, G. (1996). Clustering and switching on verbal fluency tests: Evidence from healthy controls and patients with Alzheimer's and Parkinson's disease [Abstract]. *Journal of the International Neuropsychological Society, 2,* 11.

Troyer, A., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. *Neuropsychology, 11,* 138-146.

Troyer, A. K., Moscovitch, M., Winocur, G., Leach, L., & Freedman, M. (in press). Clustering and switching on verbal fluency tests in Alzheimer's and Parkinson's disease. In press with *Journal of the International Neuropsychological Society.*

Vilkki, J., & Holst, P. (1994). Speed and flexibility on word fluency tasks after focal brain lesions. *Neuropsychologia, 32,* 1257-1262.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale - Revised: Manual.* New York: The Psychological Corporation.

Address for correspondence:

Richard Siegert
School of Psychology
Victoria University of Wellington
P.O.Box 600
Wellington, New Zealand.

e-mail: richard.siegert@vuw.ac.nz