

## Review Article

# Predictors of Verbal Fluency Decline in People with Cognitive Dysfunctions

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## Abstract

**Background:** Verbal fluency impairment is a prospective risk for dementia and conversion from Mild Cognitive Impairment (MCI) to dementia. In elderly may be related to the deficits in other cognitive domains and also with age and duration of cognitive decline.

**The AIM:** The purpose of this study was to analyze the results of Verbal Fluency Tests (VFT) in people with cognitive decline in relation to age, duration of the cognitive decline and the level of cognitive dysfunction.

**Methods:** 279 (177 females and 102 males) people with cognitive decline (MCI and dementia), aged 50-91 years were included in the study. For the evaluation of general cognitive abilities Mini Mental State Examination (MMSE) and for assessment of verbal fluency– Verbal Fluency Test (phonological and categorical) was applied. Statistical analysis was performed using nonparametric tests. Factor analysis of the main components of Verbal Fluency Test and MMSE were used and one-way ANOVA test in the prediction analysis was applied.

**Results:** All dimensions of verbal fluency subscales and MMSE are explained by one factor, which indicate their similar etiological mechanism. The longer duration of the cognitive impairment the worse results in VFT and MMSE. Worse results of MMSE were associated with worse performance on VFT, the most important critical moment of deterioration was associated with scores in the range of 25-23 and 17-18 MMSE points, however there are some differences between verbal fluency categories. The most significant periods of duration of the disease for VFT performance were months 6 and 9, and for the category of categorical fluency months 6,9, as well as 26, 31-32 and 36. No significant associations between the age and VFT and MMSE results were observed.

**Conclusions:** Verbal fluency decline is related to global cognitive functioning. Longer duration time of the disease was associated with the level of verbal fluency and cognitive decline, while the age of patients is not an important factor. The verbal fluency deterioration occurs in leaps and bounds, the critical moments for verbal fluency decline may be established based on the duration of the illness and global functioning measured by MMSE.

**Keywords:** Cognitive decline; Verbal Fluency Tests; MMSE

## Introduction

VFT is a neuropsychological tool commonly used in diagnosis of cognitive decline and risk of dementia. Efficient word exchange relies on semantic networks and basic skills like understanding verbal messages. In older adults, word comprehen-

sion disorders can reduce word use and verbal fluency ability [1,8]. The quality of linguistic processes and semantic memory is influenced by how verbal fluency tasks are performed, considering factors like the number of generated concepts, their

compliance with criteria, errors, and word clusters. Current research shows many factors that affect verbal fluency, including age, gender, education, cognitive abilities, and personality disorders. Verbal fluency impairment may predict the conversion from MCI to dementia, especially in MCI with severe memory decline [3,4,6].

Semantic verbal fluency involves adapting words from broad or narrow categories, while phonemic fluency involves generating words starting with specific letters, commonly F, A, and S or K L M in Polish literature. The test usually lasts 60 seconds, with different letter sets used across variations [1,8]. A systematic review of data obtained from Verbal Fluency Tests in different countries shows minimal difference in testing procedure, however the diagnostic accuracy does not change [2,5].

The aim of the study is to analyze the results of VFT (phonological and categorical) in people with cognitive decline MCI in relation to the age, duration of the cognitive decline and the level of cognitive abilities measured by MMSE, and to check the critical moments for cognitive and verbal fluency decline.

## Methods

### Subjects

279 people with cognitive decline (MCI and dementia) were included in the study. Subjects were aged 50-91 (average 72.00 ± 10.47) years. The study included data obtained from 177 women and 102 men. The scientific material was collected in the Department of Clinical Neuropsychology at Ludwik Rydygier Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University in Toruń, approved by the Bioethics Committee (KB105 / 2021).

### Neuropsychological Tests

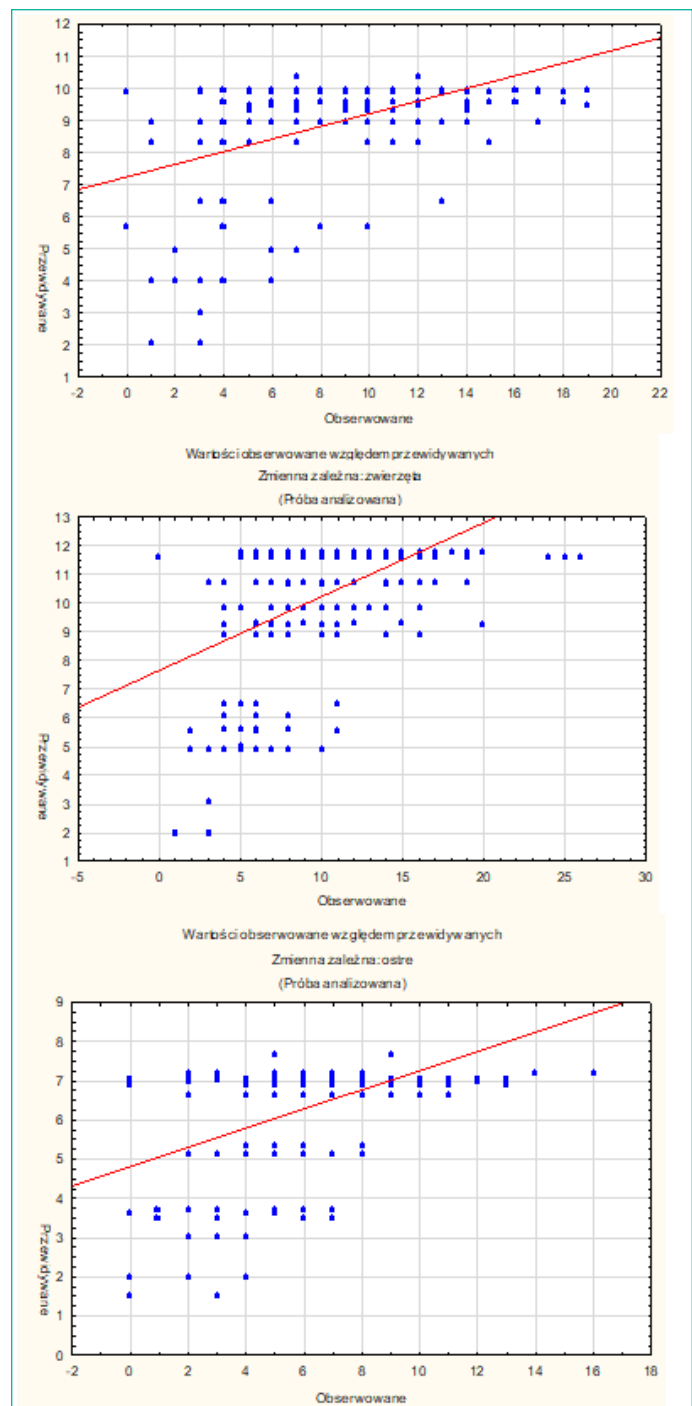
For the evaluation of general cognitive abilities MMSE- the screening tool for dementia was applied. For assessment of verbal fluency, the VFT - a version using the phonological and categorical criteria was applied. In the phonological fluency the letter version – (words beginning for the letter “K”), and in categorical criterion “animals” and “sharp objects” were used. Subjects are asked to produce as many words as possible for given category within 60 seconds.

Statistical analysis was performed using nonparametric tests because of nonparametric variable distribution. Factor analysis of the main components of Verbal Fluency Test and MMSE was applied. One-way ANOVA test was used in the prediction analysis.

### The Results

The age of the respondents and the result of the MMSE test did not differentiate between groups of men and women. Mean scores of MMSE which is 23,4 points indicate a significant cognitive decline (border MCI and dementia). The results on Verbal Fluency Test show a significant decline, range 0-26 spelled words given to current category (table 1). Figure 1 presents the distribution of normality of predicted vs. expected residuals in the three parts of Verbal Fluency Test in studied group.

In the first phase of the analysis, the internal consistency of the verbal fluency scale was analyzed. The significant internal correlations were observed: the letter test correlated with the animal test ( $R=0.48$ ,  $p<0.001$ ) and the sharp objects test ( $R=0.56$ ,  $p<0.001$ ), the animals test also correlated with the



C

**Figure 1:** Distribution of predicted versus expected residuals in the Verbal Fluency Tests. A: phonological fluency test, B: categorical fluency test – animals, C: categorical fluency test - sharp objects.

sharp objects test ( $R=0.56$ ,  $p<0.001$ ). Table 2 presents the results of factor analysis of the main components of Verbal Fluency Test and MMSE test. All dimensions of verbal fluency subscales and MMSE are explained by one factor. This means that the studied parameters have a similar etiological mechanism.

Table 3 presents the results of the correlation analysis between the age of respondents and the duration of cognitive impairment, as well as the results of the MMSE test and their performance of the VFT. There were no significant correlations between the age and VFT performance and MMSE results. Duration the cognitive impairment correlated negatively with the performance of VFT and positively with the results of MMSE. This means that the longer duration of the disease the worse verbal abilities and worse cognitive functions measured by

**Table 1:** Age and MMSE scores of the respondents. Comparison of women's and men's results.

	Whole group	Females	Males	Z statistic (with Liferson correction)	Significance (U-Mann Whitney test)
Age	72,00± 10,47	72,18 ± 10,52	71,67 +10,41	-0,38	0,71
MMSE	23,39±3,41	23,34± 3,61	23,49+ 3,04	-0,07	0,94

**Table 2:** Factor analysis of the main components of the Verbal Fluency Test and MMSE.

	Labeled principal components significant at the alpha level >0,7
letter test	0,80
animals	0,82
sharp objects	0,82
MMSE	0,73
output variance	2,46
contribution	0,61

**Table 3:** Spearman's rank correlations between Verbal Fluency Tests performance and age, duration of cognitive impairment and the performance of the MMSE.

Verbal Fluency Test	Age	Duration of cognitive impairment	MMSE
Letter	0,00	-0,36*	0,29*
Animals	-0,10	-0,34*	0,44*
Sharp objects	0,02	-0,21*	0,35*

MMSE. The positive correlation between MMSE and VFT scores were observed.

In further analyses, it was decided to check whether the value obtained by the respondents in the MMSE test is significant for the level of results obtained by the respondents in the VFT. The analysis of collinearity coefficients with sigma-constraints was conducted here, and the results of these analyzes are presented in table 4.

The obtained results show that cognitive impairment at the level of 25-23p in the MMSE test were the most important for the performance of the phonological VFT, followed by the score of 21p in the MMSE, and a clear weakening of the results was recorded from 17 p in MMSE. As can be seen, for the performance of the categorical fluency test in the "animals" category, the performance of the test was associated with scores in the range of 25-23 and 17 points in the MMSE. For the results in the "sharp objects" categorical test, the most significant were scores of 25-23 p in MMSE, as well as scores of 21 and 18 points. These results show that the weakening of verbal fluency in the

**Table 4:** Results of univariate ANOVA analysis - prediction of the performance of the fluency test (letter test, animals and sharp objects) based on the MMSE score in the study group.

Effect	SS	Degrees of freedom	MS	F	p
Verbal fluency –letter "K" test. Standard assessment error 3.67					
Intercept term	2405.26	1	2405.26	178.58	0.0000
MMSE	858.66	16	53.67	3.98	0.0000
Error	3515.32	261	13.47		
Verbal Fluency Test- animals. Standard assessment error 3.73					
Intercept term	2872.69	1	2874.69	206.21	0.0000
MMSE	1273.34	16	79.58	5.71	0.0000
Error	3680.34	264	13.94		
Verbal Fluency Test – sharp objects. Standard assessment error 2.36					
Intercept term	1093.50	1	1093.50	196.28	0.0000
MMSE	478.28	16	29.89	5.37	0.0000
Error	1476.355	265	5.57		

**Table 5:** The relationship between the results of the MMSE test and the performance of the fluency test in the study group. The collinearity coefficients with sigma-constraints analysis.

MMSE effect (scores)	Variance (infl. factor)	R <sup>2</sup>	Beta (w)	Semi - part	t	p
The phonological fluency test - the letter test (K)						
17	8.02	0.88	-0.35	-0.12	-2.21	0.03
21	7.57	0.87	0.37	0.14	2.44	0.02
23	5.13	0.80	0.45	0.20	3.56	0.00
24	4.83	0.79	0.37	0.17	3.05	0.00
25	4.75	0.79	0.60	0.27	4.95	0.00
The categorical fluency test - animals						
13	28.90	0.97	-0.59	-0,11	-2.08	0.04
23	5.13	0.81	0.18	0.16	3.07	0.00
24	4.80	0.79	0.27	0.24	4.57	0.00
25	4.76	0.79	0.37	0.34	6.45	0.00
The categorical fluency test - sharp objects						
18	20.30	0.95	0.58	0.13	2.42	0.02
21	7.64	0.87	0.54	0.19	3.65	0.00
23	5.17	0.81	0.49	0.22	4.03	0.00
24	4.83	0.79	0.60	0.27	5.12	0.00
25	4.87	0.79	0.67	0.31	5.77	0.00

**Table 6:** The relationship between the Duration of the Cognitive Decline (DCD) and the performance of the fluency test in the study group. The collinearity coefficients with sigma-constraints analysis.

DCD effect (months)	Variance (infl. factor)	R <sup>2</sup>	Beta (w)	Semi - part	t	p
The phonological fluency test - the letter test (K)						
6	1.17	0.14	0.24	0.22	3.98	0.00
8	1.18	0.15	0.12	0.11	1.98	0.05
9	1.17	0.14	0.26	0.24	4.25	0.00
The categorical fluency test - animals						
6	1.17	0.14	0.17	0.15	2.82	0.01
8	1.17	0.15	0.16	0.15	2.72	0.01
9	1.17	0.14	0.17	0.25	4.50	0.00
12	1.18	0.15	0.19	0.17	3.17	0.00
26	0.01	0.31	-0.15	0.00	-2.29	0.02
31	1.61	0.38	-0.14	-0.11	-2.03	0.04
32	1.46	0.31	-0.15	0.00	-2.29	0.02
36	1.91	0.48	-0.16	-0.12	-2.10	0.04
The categorical fluency test - sharp objects						
5	1.25	0.20	0.17	0.15	2.77	0.01
6	1.17	0.14	0.21	0.19	3.49	0.00
9	1.17	0.14	0.13	0.12	2.12	0.03
21	1.17	0.15	0.12	0.11	2.04	0.04
22	1.46	0.31	0.15	0.12	2.20	0.03
26	1.46	0.31	-0.14	-0.12	-2.10	0.04
31	1.61	0.38	-0.17	-0.14	-2.48	0.01
32	1.46	0.31	-0.14	-0.12	-2.23	0.04
35	1.91	0.48	-0.17	-0.12	-2.23	0.03
36	1.91	0.48	-0.17	-0.12	-2.23	0.03

examined people with cognitive disorders does not occur uniformly, and there are probably critical moments affecting the deterioration of verbal fluency abilities during the course of cognitive disorders. This mechanism, however, requires a detailed explanation, perhaps on neurobiological grounds.

A similar analysis of relationships was conducted in the case of the importance of the duration of cognitive impairment for the efficiency of maintaining language skills. The results of univariate analysis are presented in the table 6. As can be seen, the duration of the disorders was significant in the performance of all types of VFTs. Therefore, an analysis was made of the duration of cognitive impairments that is the most significant in the observed changes in the performance of the VFT. Table 6 presents collinearity coefficients with sigma-0 constraints for specific months of the duration of cognitive impairment. These results indicate that for phonological fluency the most significant were months 6, 8 and 9, for categorical fluency in the category "animals" there were many more time points and these were the months: 6, 8-9, 12, 26, 31-32 and 36. For categorical fluency in the "sharp objects" category, the following months were significant: 5-6, 9, 21-22, 26, 31-32, 35-36. Analyzing all the significant periods most significant for cognitive changes, for all categories these were months 6 and 9, and for the category of categorical fluency months 6, 9, as well as 26, 31-32 and 36.

## Discussion

In the first phase of the analysis, the usefulness of research tools for elderly people was assessed using the Alpha-Cronbach index for the VFT and the MMSE. An alpha index of 0.70 or higher indicates high internal consistency. The analyses showed high internal consistency for the subscales, with Cronbach's alpha ranging from 0.73 (MMSE) to 0.82 (VFT). Factor analysis revealed that all subtests of VFT and the MMSE result are explained by one factor, suggesting a similar mechanism of measured cognitive abilities. This approach is common in modern research on elderly people with cognitive disorders [9].

The analyzed group of elderly people was homogeneous. In terms of age and MMSE test results, the group of men and women did not differ at all. In the VFT, women scored higher than men in the letter test, while in the categorical tests (animals and sharp objects) the results were similar. However, this result should be considered only in relation to the study group, as not all world studies are unambiguous in this respect. In the elderly in the Spanish-speaking population, there were no significant differences in the performance of VFTs depending on gender, except for the "animals" subtest [10], and in another study of this language group such significant differences were not found [11]. In the study of Polish authors, significant differences were found in the performance of VFT in young people. Men scored slightly better in the semantic fluency test in this study, but there were no differences in verbal strategy. The authors hypothesized that these results may indicate differences in the lexical system in connection with social roles. However, this is an unconvincing hypothesis, especially since the study was not conducted on a representative group that would allow generalizations [7,12].

One of the recent meta-analyses showed that the most significant variable affecting the level of VFT performance in the elderly is age, while gender is not significant here [13]. The results of the correlation analysis carried out in this paper do not fully correspond to this observation. No significant correlations were found between the age of the respondents and the perfor-

mance of the VFT and the MMSE test. Only the duration of neurocognitive dysfunction negatively correlated with the number of generated words in the VFT. Thus, it can be concluded that the overall result of the VFT deteriorates with the duration of cognitive impairment. This result is consistent with the results of American studies, which clearly indicate that the deterioration of verbal fluency, especially in the test of phonemic and semantic fluency, is a predictor of general cognitive deterioration over time [14]. Similarly, in this study, a clear relationship was found between the efficiency of cognitive functions measured by the MMSE test and the performance of VFT. The greater the decrease in cognitive functions observed in the MMSE, the worse the results in all parameters of VFT were obtained by the respondents.

Contemporary research results indicate that higher verbal fluency proficiency is associated with a 60% reduction in the risk of dementia and about a 25% reduction in the conversion from MCI to dementia. It has been shown to be independent of age, gender, race, ethnicity, and APOE-4 polymorphism. This highlights the immense importance of Verbal Fluency Testing in groups of individuals at risk of dementia [15].

Interesting data, confirming the above-mentioned worldwide research, was obtained through prediction analysis. Prediction analysis of VFT performance was conducted based on the MMSE score obtained by the subjects. The data showed a very strong predictive power of the MMSE score on the results of all dimensions of VFT. However, the most interesting analysis in this regard was to determine whether a specific MMSE score can be associated with a sudden deterioration in VFT results and may even indicate the intensification of Central Nervous System (CNS) pathology responsible for decreased verbal fluency. This is, of course, an attempt, the results of which cannot be overinterpreted, but may constitute an interesting area of exploration in interdisciplinary neurolinguistic research. The results of the analysis (table 5) confirms that the most significant periods of verbal fluency decline during cognitive impairments occur at specific levels of global cognitive decline. The most essential moment was the level 23-25 in MMSE and then 17p.

Similarly, time of the cognitive disorder is vital for verbal fluency decline. The longer time of disorder the worse verbal fluency abilities. Our data showed that the first critical moment essential for deterioration of verbal fluency is 5-6 months and then the number of critical moments increases. These results indicate the need for analysis on large groups of older people with cognitive disorders to enable a wider interpretation of the clinical significance of this phenomenon. The decrease in verbal fluency performance probably occurs in jumps, and the results obtained in this analysis may indicate the existence of critical stages during progressive cognitive changes. It would be interesting to learn about the neurobiological mechanisms underlying this phenomenon.

Works in this field are being undertaken worldwide, one of which indicates a relative relationship between brain vascular changes and cognitive impairment, including the worsening of verbal fluency abilities. Perhaps the vascular mechanism or the intensification of neurodegenerative changes would be describable at different stages of cognitive impairment, including CNS disorders resulting in weakened verbal fluency [16].

Recent neuroimaging studies shed some light on this problem and indicate the significant role of changes in brain structures and blood vessels in predicting the severity of cognitive



changes. On the other hand, the intensification of cognitive changes suggests the intensification of brain changes. This approach is very important in the search for cognitive markers of dementia. Jokinen et al. (2020) described changes in small blood vessels in the brain that can be considered neuroimaging markers of cognitive decline. Other authors have described biochemical (metabolic) changes as markers of cognitive impairment in Alzheimer's disease [5,17].

At the same time, there is a growing trend in research that reinforces the approach treating cognitive dysfunction as biomarkers of brain damage in dementia. Therefore, the results obtained in this work fit into the stream of global research on the significance of cognitive impairment in relation to various brain changes in diseases associated with dementia. The identification of time points of weakening of verbal fluency in this research case may probably indicate disturbances in the functioning of neuronal connections responsible for verbal fluency performance (the so-called verbal fluency brain network). Studies published in 2021 indicate that the neuronal connections system associated with semantic fluency involves brain structures related to language processes, which are located in the frontal regions (including Brodmann areas 6, 9, 45, and 47) and the anterior part of the cingulate gyrus. They are associated with semantic processes, word generation, and speech programming, and the functional connections between these structures create the main neuronal network available in neuroimaging studies. Changes in these areas can result in disturbances of neuronal network function, verbal processing, as well as impairments of verbal fluency measured by neuropsychological tests [14,16].

The results obtained in this study are therefore very significant from a clinical and cognitive point of view, as disruptions in verbal fluency are likely cognitive markers of deeper structural and functional changes in the brain.

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