International Journal of
Physical Medicine & Rehabilitation

Kawamura and Morioka, Int J Phys Med Rehabil 2013, 1:4
http://dx.doi.org/10.4172/2329-9096.1000130

Research Article Open Access

How Useful Word Fluency Tasks Will be in the Case of Reduced Working Memory Capacity and Impaired Attention Functions

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Abstract

In the present study, we investigated the Word Fluency Functions when reduced Working Memory (WM) capacity and impaired Attention Functions are recognized. We imposed the Japanese version of the reading span test (RST) and 3 types (category, letter, and verb) of word fluency tasks (WFTs) on 14 patients with attention disorder recognized as reduced WM capacity and 28 normal subjects. In the WFTs, 4 trials with a time limit of 60 s were conducted in each condition. The numbers of words generated in the WFTs were compared between the groups, and the correlation coefficient between the proportion of correctly recalled words in the Japanese RST version and the number of words generated in each WFT was calculated. Comparison of the numbers of generated words between the groups resulted in significantly more words by the normal subjects in all 3 conditions. Regarding the correlation between the proportion of correctly recalled words and number of generated words, a positive correlation was observed in the 3 conditions for normal subjects and category and verb conditions for patients with attention disorder. These results reveal that difference in WM capacity exerts influences on word fluency functions of patients with attention disorder. They also indicate that when using the letter fluency task as an assessment battery for fluency functions of patients with attention disorder, we need to fully consider the relationship between fluency and WM functions.

Keywords: Working memory capacity; Word fluency task; Attention disorder

Introduction

Today, word fluency tasks are widely used for neuropsychological investigations of the patterns of word generation. The most well known types of these are category fluency and letter fluency tasks. A category fluency task comprises the production of as many words as possible that belong to a given category within a time limit. This task requires searching accumulated vocabulary and categories of meaning from formed concepts that are consistent with the instruction, and efficiently using semantic memory to generate words that belong to that category. Letter fluency tasks comprise the production of as many words as possible that begin with a particular letter within a time limit. This type of task requires employing the cognitive flexibility to search for words beginning with the same letter while suppressing the normal method of using a language (i.e. searching for words according to their meanings) [1]. Letter fluency tasks are believed to reflect executive and inhibition functions, which are controlled by the frontal lobe [2]. In recent years, increasing knowledge has been obtained from verb fluency tasks that require verb generation. Verb fluency tasks require the production of verbs associated with a noun (the stimulus word); however, many points regarding this generation process remain unclear. The strategy used in the process of word generation, thus, differs depending on the nature of the stimulus word.

Kawamura et al. [3] imposed the above-mentioned 3 word fluency tasks (WFTs) on normal subjects to show that those with higher WM capacity generated significantly more words in a time limit. In addition, in WFTs with a time limit of 60 s, those with lower WM capacity showed significantly lower word number ratios in the latter 45–60-s period. Based on these results, they concluded that differences in WM capacity caused individual differences in word fluency through the significant involvement of fluid intelligence such as cognitive flexibility and emergent property [3].

The development of technology in recent years that has enabled visualization of brain activity via brain-imaging devices has also led to numerous studies showing detailed information on the relationship between language and the brain, including functions for which the language-related regions are believed to be responsible [4-8].

Moreover, there is growing awareness of highly graded language functions because of the functional connectivity of language-related regions with the surrounding regions. Among these, Hulme et al. [9] and Kaneda and Osaka [10] stated that WM is closely related to linguistic long-term memory information and that WM is involved in the semantic encoding of language (i.e. the task of "imparting meaning to language information"). It is also believed that an area surrounding the language-related regions (the inferior frontal gyrus) is the dominant region corresponding to central executive functioning, which is at the core of WM [11]. Thus, the understanding of the roles of brain function in human language operations is gradually being transformed and it has become clear that a close functional connectivity exists between WM and language-related regions.

Hence, in the case that reduced WM capacity is observed due to the after effects of stroke, word fluency functions are most likely to be problematic. In the present study, in order to verify word fluency functions, we imposed 3 types of WFTs on the patients with higher brain dysfunction showing impaired attention functions due to the effects of stroke [3]. It has been made clear that attention functions have close functional connectivity with WM function [12], but the Assessment and Rehabilitation of the patients with both functions impaired or reduced due to brain stroke have not yet been established. Therefore, in this study we verified the usefulness of the Word Fluency Tasks with different strategies as an assessment of the patients with

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Received April 26, 2013; **Accepted** May 18, 2013; **Published** May 20, 2013

Citation: Kawamura M, Morioka S (2013) How Useful Word Fluency Tasks Will be in the Case of Reduced Working Memory Capacity and Impaired Attention Functions. Int J Phys Med Rehabil 1: 130. doi:10.4172/2329-9096.1000130

WM capacity reduced and Attention functions impaired due to brain stroke.

Methods

Subjects

Subjects included 14 patients with attention disorder showing no aphasia (9 subjects with cerebral infarction and 5 subjects with cerebral hemorrhage; age, 52.50 ± 11.07 years, with 18.71 ± 10.82 months of illness) as well as 28 normal subjects without a history of illness in the brain, in visual or auditory senses (age, 24.46 ± 3.26 years). Table 1 shows details of the attributes and attention functions of subjects of the attention disorder group. The subtests of clinical assessment for attention [13] reflect sustained, selective, divided, switching, and control attentions. Thus, attentions scored above or below the cut-off value assigned to each age range based on the subtest results. Moreover, the attention disorder group consists of those who were recognized to have reduced WM capacity based upon Japanese Version of Reading Span Test. In addition, more than 90% of all the subjects were judged to have right hand dominance based on the Edinburgh handedness inventory [14].

Japanese Version of Reading Span Test (RST)

This test was conducted according to the procedures of Osaka and Osaka (1994) and Osaka (2002) to calculate the proportion of correctly recalled words for all subjects [15,16]. The proportion of correctly recalled words is the average percentage of correct recall calculated from the percentages of all the sets [17,18].

Word Fluency Task

Procedure

The experimental protocol is shown in figure 1. Category, letter, and verb were set as the 3 conditions, and 4 stimulus words were used for each condition. Subjects were asked to say aloud as many words related to the stimulus word as they could within a time limit of 60 s. After the 60-s time limit, a 10-s rest period was allowed before the next stimulus word was displayed. Stimulus words were displayed in Japanese on the screen of a personal computer (NEC LaVie LM530/W). In the verb condition, in addition to the above procedure, the subjects were asked to express the verbs that could be related to the stimulus word, which was a highly familiar noun (e.g. cup° drink, hold, and wash)

Posture and view point

Subjects were seated in chairs with their heads positioned 60 cm from the computer screen. They were instructed to look at either a fixation cross or a stimulus word displayed on the computer screen continuously during the tasks. A digital voice recorder (ICD-UX513F, Sony) was used for voice recording of the experimental sessions.

Material

For the category condition, highly familiar words of word familiarity levels 5.001–7.000 from the Nippon Telegraph and Telephone Corporation database series "Lexical Properties of Japanese" [19] were classified by category. The 4 categories containing the largest numbers of words (foods, clothing, occupations, and transportation) were used as the stimulus words. For the letter condition, highly familiar words investigated for use as the stimulus words in the category condition were classified according to their initial syllables. The 4 syllables with which the highest number of words begin (*ka*, *o*, *a*, and *ki*) were used as the stimulus words. For the verb condition, the 4 most familiar words—one from each of the 4 categories were used in the category condition (*udon* [wheat noodles], *skaato* [skirt], *pairotto* [pilot], and *torakku* [truck]) were used as the stimulus words.

Data analyses

Student's *t* tests were applied to the comparison between groups by using the number of words generated in WFTs as dependent variables and group factors as independent variables, with a significance level of 5%.

Next, Mann-Whitney U Test with a significance level of 5% was applied to compare the proportion of correctly recalled words (%) in the RST and the number of words generated in each WFT in between the impaired two hemispheres of the attention disorder group.

Moreover, Pearson's Correlation Coefficient Test was applied with a significance level of 5% to evaluate the correlation between the proportion of correctly recalled words (%) in the RST and the number of words generated in each WFT.

						Clinical assessment for attention				
	Gender	Age	Months	Disease	Lesion	Sustained	Selective	Divided	Switching	Control
A	Men	55	33	CI	L/P	X	O	X	X	X
B	Women	32	24	CI	L/F	X	X	X	X	X
C	Women	38	12	CH	R/F	O	O	X	X	X
D	Women	52	5	CH	L/T	O	O	O	X	O
E	Men	69	9	CI	L/T	X	X	X	O	X
F	Men	57	8	CI	L/T	O	O	X	X	X
G	Men	57	28	CI	L/B	X	O	X	X	X
H	Women	41	17	CI	R/B	O	X	X	O	X
I	Men	42	8	CH	R/F	X	O	X	X	X
J	Men	58	10	CI	L/F	O	O	X	X	X
K	Men	50	16	CH	R/B	X	X	O	O	X
L	Men	56	35	CI	R/P	X	X	X	X	X
M	Men	56	38	CH	R/C	X	X	X	X	X
N	Men	62	27	CI	R/F	O	O	X	O	O

Note: The subordinate tests of clinical assessment for attention [14] reflect sustained, selective, divided, switching, and control attentions. Thus, attentions scored above or below the cut-off value assigned to each age range based on the subordinate test results, which are, respectively, shown by using a circle or cross.
Abbreviations: Months→Disease duration, CI→Cerebral infrarction, CH→Cerebral hemorrhage, L→Left hemisphere, R→Right hemisphere, F→Frontal area, T→Temporal area, P→Parietal area, C→Cerebellum area, B→Basal ganglia

Table 1: The attributes and attention functions of the attention disorder group.

Results

Japanese version of reading span test

The mean and standard deviations of the proportion of correctly recalled words were 48.83 ± 16.26% and 75.90 ± 8.97% in the attention disorder and normal groups, respectively.

Word fluency task

Table 2 shows the results of WFTs from the attention disorder and normal groups. The number of words generated was significantly higher in the normal group than in the attention disorder group in the category (t=7.95, p<0.01), letter (t=4.29, p<0.01), and verb (t=5.15, p<0.01) conditions.

Table 3 shows the results of RST and WFT from each impaired hemisphere of the attention disorder group. Any significant difference between right and left hemispheres could not be recognized in the proportion of correctly recalled words (p=0.95 n.s.) in the RST and the number of words generated in each WFT (Category: p=0.78, Letter: p=0.78, Verb: p=0.83, all n.s.)

Table 4 shows the results of the correlation evaluation between WM capacity and WFTs. In the category condition, a significant positive correlation was observed in both the attention disorder (r=0.56, p<0.05) and normal (r=0.51, p<0.01) groups. In the letter condition, a weak negative correlation (r=0.16, p=0.58) and a significant positive correlation (r=0.60, p<0.01) were observed in the attention disorder and normal groups, respectively. In the verb condition, a positive correlation (r=0.47, p=0.09) and a significant positive correlation (r=0.57, p<0.01) were found in the attention disorder and normal groups, respectively.

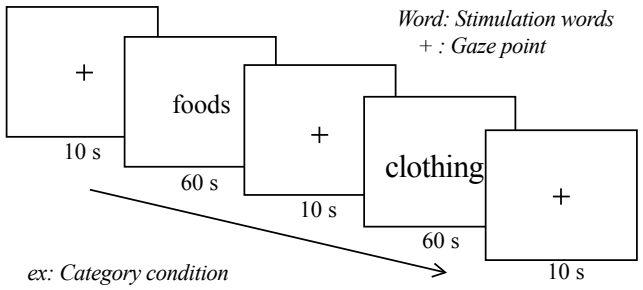

Figure 1: Experimental protocol.

Word fluency task				
Group	**N**	**Category**	**Letter**	**Verb**
Attention Disorder	14	9.14 (1.88)**	8.79 (2.87) **	5.66 (2.66) **
Normal	28	15.22 (3.05) **	13.88 (4.03) **	11.59 (4.97) **

Note: The value of each condition is the average of the number of words generated within 60 s. The value in parentheses represents the standard deviation. **p < 0.01

Table 2: Numbers of generated words in the 3 conditions.

Reading span test			Word fluency task (words)		
Lesion	**N**	**Proportion Word (%)**	**Category**	**Letter**	**Verb**
Left Hemisphere	7	48.13 (13.35)	9.04 (2.06)	8.75 (3.37)	5.86 (2.81)
Right Hemisphere	7	49.54 (19.83)	9.25 (1.83)	8.82 (2.53)	5.46 (2.71)

Note: The value in parentheses represents the standard deviation

Table 3: The Results of each impaired hemisphere of Attention Disorder Group.

Attention disorder					Normal			
Condition	**N**	**r-value**	**t-value**	**p-value**	**N**	**r-value**	**t-value**	**p-value**
Category	14	0.56	2.33	0.01*	28	0.51	3.00	0.006**
Letter	14	-0.16	-0.58	0.58	28	0.60	3.84	0.001**
Verb	14	0.47	1.84	0.09	28	0.57	3.50	0.002**

Note: *p < 0.05, **p < 0.01

Table 4: Correlation evaluation of the 3 conditions of word fluency task.

Discussion

First, we showed significant differences in the number of generated words between the attention disorder and normal groups. The present study indicated that impairment in attention functions due to the after effects of stroke might lead to impaired word fluency functions. In addition, although WFTs are used in clinical sites as tests to measure the frontal brain lobe functions, in the present study, brain damage sites of the attention disorder group were found not to be limited to the frontal lobe. Moreover, as the results of this study indicate, there could not be found any significant difference in each impaired hemisphere of the attention disorder group. Therefore, this study indicates that word fluency functions are composed of a network of a wide range of sites in the brain. However, the average ages are significantly different between the 2 groups. Regarding this, there are reports that the performance of normal subjects in WFTs declines when the subjects are over 80 years of age [20], and age difference exerts no influence on the number of generated words when the subjects are aged 16–70 years [21]. Therefore, we consider that the age difference between the groups affecting the number of generated words is rather small.

Next, we correlated the proportion of correctly recalled words, which is an indicator of WM capacity, and WFTs. The results in the present study showed a positive correlation in the 3 conditions in the normal group and the category and verb conditions in the attention disorder group. However, the Letter Fluency Task, which is considered to reflect the Executive Function and Inhibition Function, i. e. the Celebral frontal lobe functions [2], showed the negative correlation with WM capacity. Therefore, this study has made it clear that that WM capacity has a small-scale involvement in word generation in the attention disorder group during the letter condition task. Osaka et al. [12] clarified the presence of a firm neural network between WM function and attention function [12] and reported that the difference in the strength of the network results in individual difference in WM capacity. Hence, the results of the present study indicate that when using the Letter Fluency Task as an assessment battery for patients with higher brain dysfunction, sufficient considerations must be paid to Attention function and WM function, especially in the case of both of them being impaired or reduced.

Conclusion

The present study investigated the relationships between WM capacity and word fluency functions based upon 3 types of Word Fluency Tasks. The results indicate that there is a close relationship between WM capacity and Word Fluency functions. However, only in the Letter Fluency Task could not be found any positive correlation with WM capacity. Although the WFTs are widely used as an assessment battery of frontal lobe function in clinical practice, the final analysis of our study results indicates that we need to give full considerations to interpreting the results of WFTs respectively, because they involve the functioning of a wide range of brain networks.

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This article was originally published in a special issue, **Special Issue on Stroke Rehabilitation** handled by Editor. Dr. Shu Morioka, Kio University, Japan

Citation: Kawamura M, Morioka S (2013) How Useful Word Fluency Tasks Will be in the Case of Reduced Working Memory Capacity and Impaired Attention Functions. Int J Phys Med Rehabil 1: 130. doi:10.4172/2329-9096.1000130