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NEUROPSYCHOLOGICA

EXECUTIVE DYSFUNCTION IN DEMENTIA OF THE ALZHEIMER TYPE

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SUMMARY

Objective. *Executive functions were assessed in a group of 30 patients with dementia of the Alzheimer type (DAT). The results were analyzed with reference to the severity of the dementia, the patients' age, and the results obtained from healthy controls.*

Background. *Executive functions are higher-order processes responsible for conscious and goal-oriented activity (both cognitive and behavioral). Their dysfunction is often diagnosed in DAT, but there are discrepancies regarding its severity and the symptoms at different stages of the dementia.*

Method. *The main methods used in the study were the ecological Clinical Test of Executive Dysfunction – Revised and the Mini-Mental State Examination.*

Results. *The performance of the demented patients was worse than that of the healthy controls in all of the tasks for executive functions. These results strongly correlated with the scores in MMSE but not with age.*

Conclusions. *Executive dysfunction is generally very prominent in DAT, though at the early stage a considerable diversity in its severity can be observed. Deterioration in the patients' mental state and executive deficits follow each other very closely in the course of the illness. Age does not seem to have a significant influence on executive functions either in healthy elderly or in DAT patients.*

INTRODUCTION

In relation to other cognitive processes in the brain, executive functions are on a higher level of processing, but they are not independent of the rest

(Pąchalska 2007a). They are responsible for the planning, coordination, sequencing and monitoring of cognitive processes. This allows a human being to perform a conscious and goal-oriented activity, instead of merely passively reacting to external or internal stimuli. Executive functions enable the person to acquire feedback on her actions and to shape her own behavior in accordance with the situational demands (Busch et al. 2005).

Coolidge and Wynn (2005) stress the importance of this fact. Executive functions have been essential for developing reasoning, language, and culture. They determine our abilities to adapt to the environment, to protect our resources, to avoid manipulation and – first and foremost – to build relationships with other people and to learn from each other.

The theory of executive functions originated in the works of Norman and Shallice on the Supervisory Attentional System, and Baddeley and Hitch on working memory (Pąchalska 2007a; Kensinger et al. 2003). The latter has drawn a substantial amount of attention among scientists. This model posited the existence of a Central Executive System that orchestrates the operations performed on information inside working memory. Its tasks included the coordination of the remaining subsystems of working memory (metamemory), attentional control, the inhibition of inadequate responses and the retrieval of information from long-term memory. In the 90s, the whole concept was redefined to encompass the entire conscious activity of the human being - including language, emotions, intellect and behavior (Pąchalska 2007b).

Persons whose executive functions work well are capable of setting goals, making plans and following them consistently, even in the presence of distraction (Pąchalska 2007b). Whenever situational conditions hamper the attainment of the goal, people modify their strategies, their plans and eventually their goals. They can also give up on their actions if any further persistence is futile. Such people are able to think and act creatively, without merely following fixed mental patterns, and that is one of the basic features of abstract thinking.

The cognitive and behavioral metaprocesses responsible for executive functioning are in constant interaction, and the transition from perception to behavior depends on their efficiency and coordination (Pąchalska 2007b; Calabrese 2005; Perry and Hodges 1999). Executive dysfunction can result from the disruption of just one of these involved processes. Their neural basis consists of circuits that link the prefrontal cortex areas with subcortical structures (mainly basal ganglia and thalamus), which in turn have a multitude of connections with many other cortical areas (Kensinger et al. 2003; Royal et al. 2002). It must be noted, however, that despite the role the executive functions play in controlling other cognitive domains, without the normal functioning of such mediating processes as attention, memory, or emotions, any efficient control of one's own complex cognitive activity would also be impossible.

Executive dysfunction results in the loss of spontaneity and planning, but also in the growth of impulsiveness (Herzyk 2005). Attention becomes dis-

tractible, and such processes as decision-making, introspection, abstract thinking and response inhibition are much more difficult to perform than they were before (Pąchalska 2007a). These symptoms are particularly noticeable in non-routine situations, especially social ones.

Dementia of the Alzheimer type (DAT) – an illness that is characterized by gradually progressing and very extensive degeneration of neural cells in cortical and subcortical areas - first damages the structures responsible for higher-order functions, which means executive functions as well (Sąsiadek & Turek 2003; Dobryszycka & Leszek 2003; Perry & Hodges 1999). Alzheimer's disease is a heterogeneous brain disease of complex and obscure etiology, first described by Alois Alzheimer in 1906 (Sobów et al. 2004). As a result of histopathological changes in the brain tissue (the appearance of so-called senile plaques and neurofibrillary tangles) neural cells undergo apoptosis. This is thought to lead to an inflammatory state, dysfunction in neurotransmission, and eventually to atrophy (Żekanowski et al. 2003). This whole process has been called the "amyloid cascade."

This type of dementia mainly afflicts persons over 60-65 years of life ("sporadic" DAT); however, a certain percentage of patients (5% in Poland) fall ill before the sixth decade of life ("familial" DAT, genetically conditioned). The progress of the disease is so far irreversible. The standard life expectancy of a person with DAT ranges between 2 and 10 years (Pąchalska et al. 2004).

The most typical symptoms diagnosed in DAT are breakdown in memory, attention, executive functions, visuo-spatial functions, orientation, language and intellect. There is also a higher level of anxiety, blunt affect, and behavioral disorders, such as agitation, psychosis, depression and apathy (Pąchalska 2007b; Chen et al. 1998).

Most patients (but not all – see Waltz et al. 2004) display their first deficits in executive functions in the early stage of dementia. According to Lafleche and Albert (1995), this is the most common symptom of the disease next to the deficits in memory and attention. It is often diagnosed before any breakdown in language and the visuo-spatial area becomes clear. In the first place it manifests itself by loss of cognitive flexibility. The concurrent manipulation of information begins to cause trouble. The modification of current patterns, self-monitoring and planning also become unstable and problematic. Research shows, however, that patients in early DAT are still able to perform simple or well-rehearsed tasks on a similar level to the healthy population.

Due to the reciprocal relationship between executive functions and other cognitive domains, executive dysfunction is also detrimental to their effectiveness. On the other hand it can sometimes be impossible to draw an exact distinction between primary and derivative symptoms, especially in the more severe stages of the disease. Contrary to the dysexecutive symptoms in fronto-temporal dementia, personality disorders are very rare in DAT, and if they do appear, it is usually in the advanced stage of the dementia (see Gustafson et al. 2004).

Studies that touch upon executive dysfunction in the course of DAT often mention that the first deficits can be observed in the early stage of the disease, but they do not explain how common (given the disease's heterogeneity) and severe they will be at the different stages.

The main purpose of our study was to evaluate and compare the level of executive dysfunction in patients who differed in dementia severity. Emphasis was placed on the ecological character of the study, which means that the tasks the participants were performing were as similar as possible to those of everyday life. Not only does such an approach deliver information about the person's deficits, but also about the remaining functions and the actual self-reliance level. The practical consequence of this is undeniable when it comes to – for example – care-giving issues. This provides such methods with a certain advantage over tests which are based on abstract tasks that have nothing to do with real life. On the other hand, these classic tests are often better standardized tools, which still allow for a more precise diagnosis of the disordered mechanism than ecological tools.

When using the ecological method for testing executive functions, one must check how the given test consists of tasks that require taking initiative, the modification of previous mental sets, planning, holding the instructions in working memory, self-monitoring and behavior adjustment.

MATERIAL AND METHODS

We recruited 36 women and 14 men for our study. Their age ranged from 64 to 86 years (x=77.1; SD=5.27). The sample consisted of persons consulted in the Reintegration and Training Center of the Foundation for Persons with Brain Dysfunctions in Cracow, Poland, between March and December of 2006. Persons under 60 or over 90 years old and those with physical, mental, cognitive or language difficulties that could influence the results of the test were excluded from the study.

The sample was divided into an experimental group ("group E") and a control group ("group C"). Group E was composed of people who were diagnosed with DAT (the diagnosis was performed by a psychiatrist or neurologist from six to eighteen months prior to this study). This group consisted of 30 people (22 women and 8 men). Group C was formed of individuals who had not been diagnosed with dementia of any kind or any other serious illness that could influence their cognitive state. This consisted of 20 persons (14 women, 6 men). The age difference between each group was statistically insignificant, as was the age difference between the men and the women inside each group.

Before commencing the experimental phase of the study, a thorough analysis of the participants' documentation and clinical interviews was carried out.

The main methods used in the experiment were:

– the Mini-Mental State Examination (MMSE);

– the Clinical Test of Executive Dysfunction – Revised (CTEF-R).

The Clinical Test of Executive Dysfunction – Revised (Pąchalska et al. 2004) is an ecological tool. It is based on seven tasks (*Making a sandwich, Filling a bottle with 1 liter of water, Buying a newspaper, Writing a letter, Addressing an envelope, Making a phone call, Finding a key*) of various levels of difficulty. All of them require the engagement of executive functions. For each task there have been established standardized steps that every person must follow in order to achieve the goal. Each task has also its individual time limit.

The subject can score between 28 and 112 points in the whole test. For each of the seven tasks a person can receive from 4 to 16 points. The scores are granted in four categories:

1. Self-reliance – the participant's ability to perform the whole task independently;
2. Performance time – the amount of time each participant needs in order to complete the task;
3. Effectiveness – whether or not the participant's performance follows the instructions;
4. Priming – the number of prompts a participant requires to achieve the goal (each task has its own prompt limit).

RESULTS

Since the selection to the groups was carried out using the matching method, Fisher's F-test was used to determine if the variances in the groups differed significantly from each other. They did, which is why a paired Student's t-test was used in order to determine the statistical significance of the differences between these two groups. This variant of the t-test does not assume the equality of sample variances.

For the following analysis the significance level was set at $p<0.05$.

The results obtained from the two groups on the MMSE (Table 1) differ from each other significantly ($p<0.0001$). All the participants from group C

Table 1. MMSE results

	Group C (N=20)	Group E (N=30)
Mean and SD* in MMSE	28,1 ± 1,32	19,4 ± 4,54
MMSE outcome (n)		
Norm	20	2
Cognitive Deficits without Dementia	0	2
Mild Dementia	0	11
Moderate Dementia	0	14
Severe Dementia	0	1

* SD – Standard Deviation

performed at a normal level, while in group E there were only 2 such individuals and 26 whose MMSE scores indicated dementia.

The differences between the results of these two groups in CTED-R were also significant (t=17.328, p<0.0001). The mean score in group E indicated moderate executive dysfunction. In turn, group C showed a normal level of executive functioning (Table 2).

One should note that variation in the experimental group was higher than in the control group, which showed their substantial diversity - from a very serious deficit to nearly normal.

The results in each of the parameters of the CTED-R in both groups can be found in Table 3 and Table 4. For a graphic presentation, see Figs. 1-4.

A statistical analysis of the average scores obtained by both groups in each of the CTED-R tasks shows that the differences between them are statistically significant. All the results in the DAT group were lower than in the group of healthy controls.

Table 2. Descriptive statistics for total scores from the CTED-R in both groups

Statistics	Group C	Group E
Mean	108,8	50,5
Standard error	0,71	3,29
Median	109,5	48,5
Mode	112	43
Standard deviation	3,19	18,01
Sample variation	10,17	324,33
Interval	12	76
Minimum score	100	29
Maximum score	112	105
Probability level (95,0%)	1,49	6,72

Table 3. Comparison of the average total scores on the CTED-R in group E

		Self-reliance		Performance time		Effectiveness		Priming	
No.	Task	x*	SD**	x	SD	x	SD	x	SD
I	Making a sandwich	3.1	0.55	2.7	0.67	3.0	0.73	2.3	0.86
II	Filling a bottle	2.6	0.69	2.2	0.59	2.1	0.79	2.8	0.64
III	Buying a newspaper	2.5	0.76	2.3	0.79	2.1	0.79	2.8	0.64
IV	Writing a letter	2.3	0.92	1.6	0.94	1.6	0.89	1.6	0.94
V	Addressing an envelope	1.7	0.92	1.5	0.83	1.4	0.68	1.4	0.68
VI	Making a phone call	1.6	0.82	1.6	0.83	1.3	0.66	1.6	0.83
VII	Finding a key	2.4	0.68	2.2	0.70	2.1	0.69	2.7	0.57
Total		13.8	4.92	12.2	4.61	11.8	4.40	12.8	4.83

* x - mean

** SD – Standard Deviation

Table 4. Comparison of the average total scores on the CTED-R in group C

No.	Task	Self-reliance		Performance time		Effectiveness		Priming	
		x*	SD**	x	SD	x	SD	x	SD
I	Making a sandwich	4.0	0.00	4.0	0.00	4.0	0.00	4.0	0.00
II	Filling a bottle	4.0	0.00	4.0	0.00	4.0	0.00	4.0	0.00
III	Buying a newspaper	4.0	0.00	4.0	0.00	4.0	0.00	4.0	0.00
IV	Writing a letter	3.9	0.31	4.0	0.00	3.5	0.69	3.8	0.41
V	Addressing an envelope	3.9	0.31	4.0	0.00	3.8	0.52	3.9	0.31
VI	Making a phone call	3.7	0.49	4.0	0.00	3.5	0.76	3.6	0.50
VII	Finding a key	3.8	0.44	4.0	0.00	3.8	0.44	3.8	0.41
Total		27.2	0.95	28.0	0.00	26.5	1.54	27.1	0.91

* x - mean

** SD – Standard Deviation

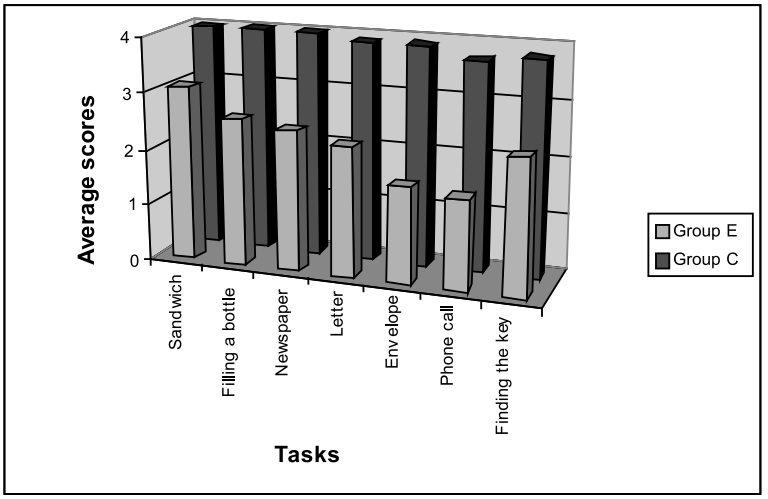

Fig. 1. Results on all tasks in the category Self-reliance

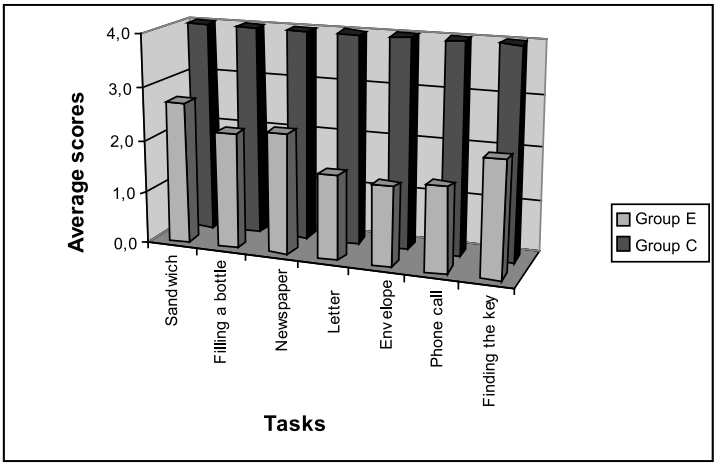

Fig. 2. Results on all tasks in the category Performance time

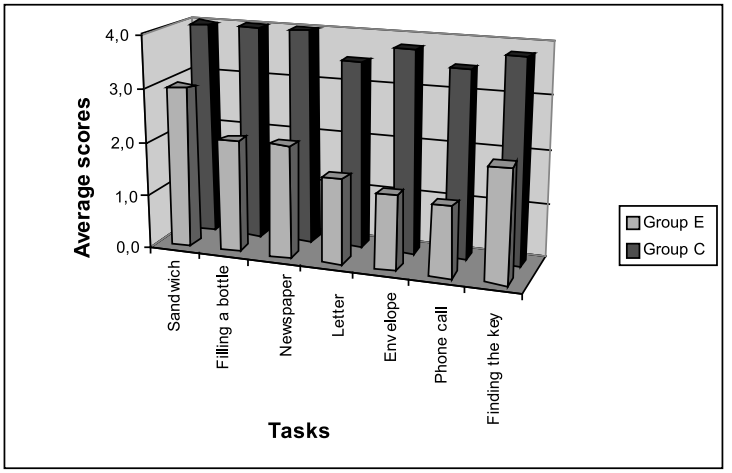

Fig. 3. Results on all tasks in the category Effectiveness

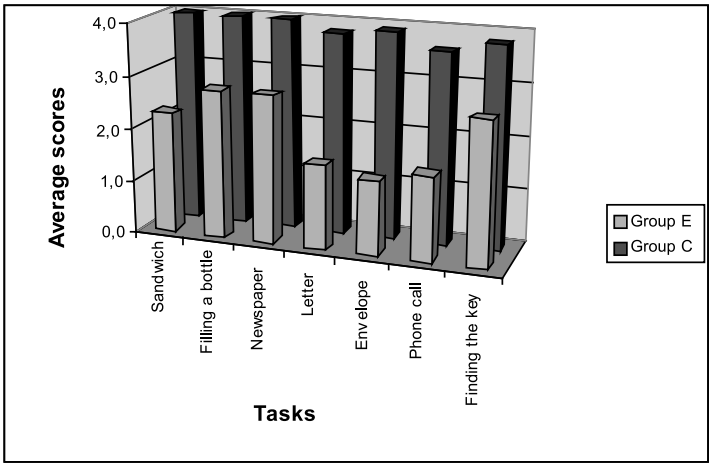

Fig. 4. Results on all tasks in the category Priming

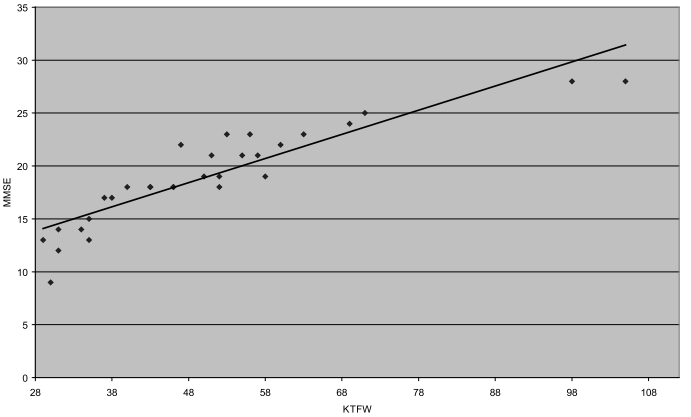

Fig. 5. Regression of the relationship between MMSE and CTED-R scores in group E

The Student's t-test scores for each task were as follows:
- Making a sandwich: t=12.809, p<0.0000;
- Filling a bottle: t=14.6863, p<0.0000;
- Buying a newspaper: t=13.9875, p<0.0000;
- Writing a letter: t=15.5535, p<0.0000;
- Addressing an envelope: t=20.4299, p<0.0000;
- Making a phone call: t=16.3235, p<0.0000;
- Finding a key: t=12.5239, p<0.0000.

Analysis of the differences between the groups in all four parameters of the CTED-R also showed them to be statistically significant. Group E scored lower than group C in each parameter (self-reliance, performance time, effectiveness, priming).

The Student's t-test scores for the CTED-R parameters were as follows:
- Self-reliance: t=14.5582, p<0.0000;
- Performance time: t=18.8141, p<0.0000;
- Effectiveness: t=16.8287, p<0.0000;
- Priming: t=15.8270, p<0.0000.

In order to verify the hypothesis of a possible relationship between executive dysfunction and the global level of cognitive deterioration, a regression analysis was conducted using Pearson's r coefficient. To avoid a ceiling effect, it was performed on the scores of group E only (Figure 5). The computed value of the r coefficient was r=0.9023.

Another regression analysis was conducted to see whether there was any relationship between the level of executive functioning and the participants' age. Pearson's r coefficient was used again. The results were:
- in both groups: r=-0.2118;
- in group C: r=-0,2735;
- in group E: r=-0,2067.

None of these correlations was statistically significant.

DISCUSSION

Our study showed that persons with DAT were significantly worse than healthy controls in tasks that required correct executive functions. They more often resorted to assistance, they needed more time to perform the tasks, they made more mistakes, and more often asked for further instructions or seemed to forget what they had been asked to do. The most demanding tasks were Addressing an envelope and Making a phone call. Both of these strongly engage cognitive resources, the ability to plan and organize one's own behavior, and some prior knowledge that may be missing in some people – for example, in Poland many older people from both groups might have had relatively little contact with a telephone in their lives. The least demanding task was making a sandwich, an activity often well rehearsed and routine.

Most of the published studies have touched very generally upon the relationship between the severity of dementia and the level of executive functions. While the late phases of the illness are characterized by very serious dysexecutive symptoms, the early stage is very diverse in that respect. The current study performed this often-neglected analysis, which showed that the relationship between the deterioration of mental state and deficits in executive functioning was very strong (r=0.9).

It appeared, however, that age does not in itself influence the decrease in the scores achieved in the executive functioning test. While in old age some natural deterioration in executive functions might take place, it is usually not severe enough to cause a loss of ability to cope on the part of persons in old age, even those with DAT. It can be assumed that the breakdown in most cognitive functions caused by the disease is so serious that the age factor cannot and does not play any important role in and of itself.

To sum up: executive dysfunction is definitely one of the most typical symptoms observed in DAT. Patients show deficits in cognitive flexibility, overcoming habitual reactions, planning, self-monitoring or maintaining information in working memory. On the other hand, not every patient with DAT will present the same exact combination of dysexecutive symptoms, especially in the early stage of the disease.

The ecological approach of this study allowed for a multifaceted and more practical observation of the patient's predicaments. Whereas healthy people found all the CTED-R tasks relatively simple, for the patients certain tasks were clearly more difficult than others. These differences, which are untraceable in healthy people, could - if thoroughly analyzed - enable a more specific description of the dysfunction, and could become a supportive element in the diagnostic process.

CONCLUSIONS

In our research, subjects with clinically diagnosed dementia of the Alzheimer type (DAT) in the early stage of the disease, in comparison with healthy individuals of the same age:

1. showed less ability to cope with the entirety of the ecological tasks requiring a good command of executive functions. This is borne out by the fact that the results obtained by those in the experimental group, both in the whole test and in its individual task components, were significantly lower than was the case for the control group. Accordingly, dysexecutive syndrome belongs, next to cognitive disturbance, to the most typical symptoms observed in Alzheimer's disease. This does not mean, however, – and it is essential to emphasize this – that every patient who suffers from DAT will necessarily have the same problems.
2. when confronted with tasks demanding a high level of executive ability, required a greater degree of help from another person, i.e. in other words

they presented a markedly lower degree of independence during the realization of the tasks. This tendency concerned equally individual tasks, as well as the test as a whole.

3. devoted considerably more time to the completion of these same tasks, and made a significantly larger number of mistakes, even though they were given the very same instructions, i.e. their effectiveness in the realization of tasks was less.
4. more often showed that they were lost during task performance, being unaware of what they were to do next, and thus requiring far more information about the subsequent steps that they needed to take in order to complete the task they had been given.

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