INTACT SHORT-TERM MEMORY AND IMPAIRED EXECUTIVE FUNCTIONS IN OBSESSIVE COMPULSIVE DISORDER

Gyula DEMETER[1], Mihály RACSMÁNY[1], Katalin CSIGÓ[2], András HARSÁNYI[2], Attila NÉMETH[3], László DÖME[2]

[1]Department of Cognitive Science, Budapest University of Technology and Economics, Budapest
[2]Department of Psychiatry, Gyula Nyírő Hospital, Budapest
[3]Semmelweis University, Clinic of Psychiatry, Budapest

ÉP RÖVID TÁVÚ MEMÓRIA ÉS KÁROSODOTT VÉGREHAJTÓ FUNKCIÓK KÉNYSZERBETEGSÉGBEN
Demeter Gy; Racsmány M, PhD; Csigó K, MD; Harsányi A, MD; Németh A, MD; Döme L, MD
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Background and purpose – Previous neuropsychological studies produced inconsistent results with tasks tapping short-term verbal and visual-spatial memory and executive functions in obsessive compulsive disorder (OCD). The aim of this study was to investigate the presence of deficits in these cognitive domains. A further goal was to describe the distribution of patients in different impairment ranges for all functions, and clarify the relationship between symptom severity and cognitive impairments.
Methods – Thirty patients with OCD (DSM-IV) and 30 healthy volunteers were compared using well-known neuropsychological tasks. We assessed short-term verbal memory with the Digit Span Forward and Digit Span Backward Tasks, short-term visual-spatial memory with the Corsi Block Tapping Task, while we measured the level of executive functions with the StroopTask and the Wisconsin Card Sorting Test (WCST).
Results – Compared with a matched healthy control group, the performance of OCD patients was in the impaired range only in the two executive tasks. We find a significant positive correlations between the Y-BOCS (Yale-Brown Obsessive Compulsive Scale) total scores and the number of perseverative responses ($r(28)=0.409$, $p<0.05$) and perseverative errors ($r(28)=0.385$, $p<0.05$) in the WCST.
Conclusion – Our results gave evidence that executive functions are impaired while short-term memory is intact in OCD. This is in line with neuropsychological model of OCD that the deficit of cognitive and behavioral inhibition are responsible for the main cognitive findings of this disorder, most prevalently the deficit in set shifting and prepotent response inhibition.

Keywords: *executive function, inhibition, neurocognitive deficit, obsessive-compulsive disorder, short-term memory*

A kutatatás célja – A korábbi neuropszichológiai kutatások a rövid távú verbális és vizuális emlékezet, valamint a végrehajtó funkciók terén ellenmondásos eredményeket hoztak kényszerbetegségben (obsessive compulsive disorder, OCD). A jelen kutatás célja a deficitek meglétének vizsgálata ezeken az alapvető kognitív területeken. További cél a betegek eloszlásának bemutatása a különböző sérült övezetek mentén, valamint a tünetek súlyossága és a kognitív sérülések közötti összefüggés tisztázása.
Módszerek – Harminc kényszerbeteg és 30 egészséges személy teljesítményét hasonlítottuk össze jól ismert neuropszichológiai feladatokban. A rövid távú verbális emlékezetet a Számterjedelem Előre, illetve Számterjedelem Fordított Sorrendben feladatokkal, a téri vizuális emlékezetet a Corsi-kockák feladattal, míg a végrehajtó funkciókat a Stroop és a Wisconsin Kártyaszortírozási Feladatokkal (WCST) végeztük.
Eredmények – Az egészséges kontrollcsoport teljesítményéhez hasonlítva a kényszerbeteg teljesítménye csak a két végrehajtó feladatban volt a sérült övezetben. Szignifikáns pozitív korrelációt találtunk a Y-BOCS (Yale-Brown Obsessiv Compulsiv Skála) -összpontpontszámok és a WCST-tesztben kapott perszeverációs válaszok [$r(28)=0{,}409$; $p<0{,}05$], valamint a perszeverációs hibák [$r(28)=0{,}385$; $p<0{,}05$] száma között.
Következtetések – Eredményeink a végrehajtó funkciók sérülése és a rövid távú emlékezeti funkciók intaktsága mellett szólnak. Ez összhangban van az OCD neuropszichológiai modelljével, mely szerint a kategóriaváltási nehézségekért és a prepotens válasz gátlásának zavaráért a kognitív és viselkedésbeli gátlás sérülése felelős.

Kulcsszavak: *végrehajtó funkciók, gátlás, neurokognitív deficit, obszesszív-kompulzív zavar, rövid távú emlékezet*

Correspondent (levelező szerző): Gyula DEMETER, Department of Cognitive Science, Budapest University of Technology and Economics, Egry József u. 1, T/511, H-1111 Budapest, Hungary. Phone/fax: (06-1) 463-1273. E-mail: gdemeter@cogsci.bme.hu

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Obsessive-compulsive disorder is a highly debilitating neuropsychiatric condition characterized by intrusive unwanted thoughts and/or repetitive, compulsive behaviours, or mental rituals[1]. Recent research has produced compelling evidence for orbitofrontal- and basal ganglia-related neuropsychological dysfunctions[2-5]. According to recent findings the primary cognitive deficit contributing to the OCD profile is dysfunction of the executive system[6]. However, many studies have found less impaired or intact performance in traditional executive neuropsychological tasks for OCD patients[7-10]. The executive system is not unitary and different researchers understand different cognitive mechanisms on it[11-13]. The picture is more confusing if we take into consideration that the different methods used to evaluate executive functions require different cognitive processes. According to *Miyake* et al.[14] traditional neuropsychological executive tasks depend on three main central executive components: inhibition, modality-specific updating/monitoring and shifting. Inhibition here refers to one's ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary. One of the most commonly used tasks to investigate inhibitory processes in OCD patients is the Stroop Task, in which subjects have to inhibit a dominant response (i.e. reading the name of the colour as written) and produce an adequate response (i.e. naming the ink colour). The results of this task with OCD patients are contradictory. Some studies have found impairment in this task[15] and others have reported a similar performance by a matched healthy control group[16-18]. These differences could reflect the different methodology used and the heterogeneity of the OCD population.

Updating and monitoring in *Miyake* and his colleauges' model refers to refreshing the content of the working memory[14]. Maintenance of task-relevant information is accomplished by monitoring and coding relevant incoming information, and replacing old information that is no longer task-relevant[19]. Updating refers to the active manipulation of the content of working memory[14]. The tasks that are most commonly used to test this function in the OCD literature are the Letter Fluency Task[15], the Letter Memory Task[19], and the N-back Task[20]. The OCD patient performs poorly in the latter two tasks. There are a number of studies that shows that working memory is impaired in OCD, and is associated with symptom severity, and more importantly improves with treatment and is associated to frontal-striatal-thalamic activation[21-23].

The third component of the executive system is shifting, which is responsible for coordinating the change between relevant and irrelevant sets[14]. The task that is most often used to study the set-shifting abilities of OCD patients is the Wisconsin Card Sorting Task (WCST)[24]. Some studies have described set-shifting deficits in OCD using the WCST[25, 26], while others have not[27-30]. WCST is a complex task and depending on the structural equation modeling analyses used it mainly reflects the shifting component of the executive system[14].

Only a few studies have reported deficits in both verbal and spatial short-term memory, but most of the studies have failed to find verbal memory deficit in OCD[8]. OCD group seem to perform in the Digit Span Forward and Backward Task at the level of the healthy control group[17, 26, 31-34]. Most of the studies reported poor performance for OCD in tasks involving spatial working memory functions[21, 35-37].

The aim of the present study was to assess the level of short-term memory and executive functions in OCD compared to healthy control subjects. A further goal was to describe the distribution of patients in different impairment ranges for all functions, and clarify the relationship between symptom severity and cognitive impairments.

Methods

SAMPLE

Thirty patients diagnosed with OCD who satisfied the diagnostic criteria in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)[1] were examined at the Nyírő Gyula Hospital, Psychiatry II, Budapest, Hungary. A psychiatrist confirmed the diagnosis following the Structural Clinical Interview for DSM-IV Axis I Disorders (SCID-I)[38]. The severity of OCD symptomatology was assessed using the Yale Brown Obsessive-Compulsive Scale (Y-BOCS)[39, 40]. We excluded subjects who met the criteria for severe depression and who had histories of alcohol/substance abuse or neurological disorder, and subjects with any concurrent comorbidity or lifetime history of schizophrenia and tic disorders. With regards medication, five patients had been unmedicated for at least three months, seven were taking selective serotonin reuptake inhibitors (four citalopram, three sertraline), twelve were taking double action noradrenaline and serotonin agents (seven clomipramine, four venlafaxine, one duloxetine) and one was taking a dopaminergic agent (amfebutamone). Thirty healthy volunteers were selected for the control group, which was matched according to age and education to the OCD group. None of the control subjects had

a history of neuropsychiatric illness or were taking psychopharmacological medication. The research project has been approved by the Ethics Committee of the Budapest University of Technology and Economics. Written informed consent was obtained prior to the study (see **Table 1.**).

Table 1. *Clinical characteristic of the patients*

Characteristics	OCD (n=30)		Healthy Control (n=30)		ANOVA	
	Mean	SD	Mean	SD	F	p
Age (years)	32.43	10.88	33.00	12.15	0.01	n.s.
Education (years)	13.66	1.82	14.13	2.47	0.41	n.s.
Sex (M/F)	14/16		14/16			
Y-BOCS Total	26.16	5.7				
Y-BOCS ORS	13.03	3.4				
Y-BOCS CRS	13.03	5.2				
HAM-D	10.56	6.16				

Note. OCD, obsessive-compulsive disorder; M, male; F, female; Y-BOCS Total, Yale Brown Obsessive Compulsive Scale Total score, Y-BOCS ORS, Yale Brown Obsessive Compulsive Scale, Obsessions-Severity Score; Y-BOCS CRS, Yale Brown Obsessive Compulsive Scale, Compulsions Severity Score; HAM-D, Hamilton Depressive Rating Scale, n.s., not significant.

PROCEDURE

All OCD patients received the following evaluations: a psychiatric interview by an experienced clinician (MD); an assessment by trained raters that included the Structured Clinical Interview for DSM-IV to confirm current Axis I DSM-IV disorders[38], the Y-BOCS[39, 40], the Hamilton Rating Scale for Depression (HAM-D, 21-item)[41, 42], and a neuropsychological assessment performed by a trained neuropsychologist.

ASSESSMENT OF SHORT-TERM MEMORY AND EXECUTIVE FUNCTIONS

The neuropsychological test battery was designed to assess short term verbal-, visual-spatial memory and executive functions.

Digit Span Forward and Digit Span Backward

We used the Digit Span Forward and Digit Span Backward Tasks as measures of verbal memory. In both tasks trials consisting of a series of increasing numbers are presented orally by the examiner at a rate of one digit per second, and have to be repeated by the subject in the same (forward span) or in the reverse order (backward span). These tasks were mainly administered to OCD patients as part of the Wechsler Adult Intelligence Scale – Revised in earlier studies, in contrast, we have followed a more rigorous performance evaluation. Each trial consisted of four series of equal length, and we considered a trial completed if the subject reproduced at least two correct series. The number of correctly recalled trials for forward and backward span was counted[43].

Corsi Block Tapping Task

This has been used for a variety of purposes, including the assessment of deficits in short term non-verbal memory[44-46], investigating developmental changes and gender differences in spatial skills[47-49], and more recently, for clarifying theoretical conceptions of visual-spatial memory[50].

We used the original Corsi apparatus and placement to measure the capacity of the visual-short-term memory, which consisted of nine, irregularly arranged, 2.5 cm blocks[51]. The examiner tapped the blocks in randomized sequences of increasing length. The subject's task was to reproduce each sequence immediately after presentation. Our trials consisted of four series of equal length, and we considered a trial completed if the subject reproduced at least two correct series. The number of correctly recalled trials for visual-spatial span was counted.

Stroop Colour Word Interference Test

This task measures the inhibition component of the executive system[14]. In part 1 the subject has to name the appropriate colour (red, green, blue or yellow) of printed Xs, and to press the designated answer key on a keyboard as quickly as possible. In part 2 the subjects have to read the names of colours printed in black ink and press the appropriate answer key. In part 3, the colour names are printed in incongruent ink colours, and the subject's task is to name the colour of the ink and press the correct answer key instead of reading the name. In this created interference situation the subject is required to inhibit a prepotent response in favour of an unusual one. We measured the reaction time and the errors committed in the three parts of the test. Following the presentation of the task a practice trial was employed to ascertain that the subject understood the task. The items remained visible on the computer screen until the subject pressed one of the possible answer keys. A total of 90 items were grouped into two blocks. There were 15 items in each block as printed coloured Xs, 15 items as colour names printed in black ink, and 15 items as colour names printed in different colours.

Wisconsin Card Sorting Test

The Wisconsin Card Sorting Test (WCST) is one of the most frequently used neuropsychological tests of executive functions[24]. The correct resolution of the test invokes abilities such as: abstract reasoning, concept formation, decision-making, set shifting, and planning of behaviour. According to *Miyake* et al.[14] structural equation modeling (SEM) analysis, this complex task taps the executive functioning related to shifting.

We administered a computerized version of the test (WCST computer version 4, Research Edition) using the standard instructions.

Results

The data were tested for normative distribution using the Shapiro-Wilk test and this analysis revealed that neuropsychological variables were not normatively distributed, and therefore the Mann-Whitney U non-parametric test was carried out. The correction for planned group comparisons is based on the domain-wise Bonferroni adjusted p value; with two domains (short-term memory, executive functions) the p value required for significance is 0.025 (0.05/2)[21]. Values <0.05 were considered as trend towards significance. Pearson's correlation analysis was employed to examine the relationship between the scores on neuropsychological tests and symptom severity. All the reported p values are two-tailed except that reported for error inhibition index, which is one-tailed.

OCD patients performed similarly to the healthy controls in the Digit Span Forward (DSF) ($z=-0.86$, $p>0.05$, $r=0.11$) and Digit Span Backward (DSB) ($z=-0.56$, $p>0.05$, $r=0.07$) tests. In the Corsi Block Tapping Task (CBTT) the OCD group completed fewer series than the healthy control group ($z=-2.23$, $p=0.026$, $r=0.28$). Patients performed more poorly in the Stroop Task, were significantly slower in the colour naming condition (SRTC) ($z=-3.65$, $p<0.001$, $r=0.47$), in the colour reading condition (SRTR) ($z=-3.5$, $p<0.001$, $r=0.45$) and in the interference condition (SRTI) ($z=-2.98$, $p<0.01$, $r=0.38$). It is important to highlight that the OCD group committed higher number of errors in the interference condition (SEI), although this was only a tendency like effect ($z=-2.11$, $p=0.035$, $r=0.27$). We also calculated the so-called *error inhibition index* (SEII) (Errors Interference Condition – Errors Colour Naming Condition), and there was a tendency like difference between the two groups, the OCD group achieving higher score ($z=-1.59$, $p=0.05$, $r=0.2$).

OCD patients committed a higher number of total errors in the WCST (WCST-TE) ($z=-3.25$, $p<0.01$, $r=0.41$), showed more perseverative (WCST-PE) ($z=-3.1$, $p<0.01$, $r=0.41$) and non-perseverative errors (WCST-NE) ($z=-2.9$, $p<0.01$, $r=0.37$), more trails were administered (WCST-TA) ($z=-3.23$, $p<0.01$, $r=0.41$), completed fewer categories (WCST-CN) ($z=-2.83$, $p<0.01$, $r=0.36$), required more trials to complete the first category (WCST-NT) ($z=-2.24$, $p<0.025$, $r=0.28$) and committed more failures in order to maintain a set (WCST-LS) ($z=-2{,}33$ $p<0.025$, $r=0.3$) compared to healthy controls. The main findings on short-term memory and executive function tasks are summarized in **Table 2**.

Analysis of the relations between the Y-BOCS scores and the neuropsychological results revealed significant positive correlations between the Y-BOCS total scores and the number of perseverative responses [$r(28)=0.409$, $p<0.05$] and perseverative errors [$r(28)=0.385$, $p<0.05$] in the WCST.

Average differences are not the most informative data for any cognitive impairment in such a heterogeneous disorder as OCD, due to the large numbers of outliers. Therefore, we analyzed the percent of OCD patients performed within one standard deviation (normal performance), within (moderately impaired), and above (seriously impaired) two standard deviation of the average healthy adult group scores. This analysis revealed that merely the scores of executive tasks are in the severely impaired range see **(Table 3.)**.

Discussion

Previous neuropsychological studies produced inconsistent results with tasks tapping short-term memory and executive functions in OCD. Our goal was to investigate the level of these cognitive functions in the same sample diagnosed with OCD. According to our results, OCD group performed within the healthy adults range in the short-term memory tasks, while they produced severely impaired performance in executive tasks. Although, a strong tendency group difference was found for Corsi Block Tapping Task, the percent distribution analysis revealed that none of the OCD patients performed in the seriously impaired range (above two standard deviations of the average healthy control group scores). Each OCD patient in our sample performed within the normal range (one standard deviation of the average control scores). Based on this, despite the average group difference in the

Table 2. *Results of short-term memory and executive tasks in the two groups*

	OCD (n=30)		Healthy control (n=30)		Test of independence	Significance	Effect size
	Median	Percentiles (25^{th}-75^{th})	Median	Percentiles (25^{th}-75^{th})	Mann-Whitney U test	p	r
DSF	6	5.75-7	6.5	6-7	U = 394.5 z = 0.86	n.s.	0.11
DSB	5	4-5	5 4-6		U = 414 z = 0.56	n.s.	0.07
CBTT	5	4-6	5 5-6		U = 308 z = -2.23	0.026	0.28
SER	0	0-0	0 0-0		U = 434.5 z = 0.6	n.s.	0.07
SEC	0	0-0	0 0-0		U = 360 z = -2.55	n.s.	0.32
SEI	0.5	0-2.25	0 0-1		U = 324 z = -2.11	0.035	0.27
SRTR	1308	1166.75-1557.25	1025	948.75-1154.25	U = 213 z = -3.5	0.000	0.45
SRTC	1251.5	1023-1381	940.5	881.75-1092.75	U = 203 z = -3.65	0.000	0.47
SRTI	1580	1344.25-2019.75	1196	1059.5-1425.25	U = 248 z = -2.98	0.002	0.38
WCST-TA	112	81.25-128	75.5	70-92.5	U = 233.5 z = -3.23	0.001	0.41
WCST-TE	26	13.5-48.75	9.5	8-21.25	U = 230 z = -3.25	0.001	0.41
WCST-PE	13	7-23.75	5	4.75-10	U = 241 z = -3.1	0.002	0.4
WCST-NE	13	6.5-23.25	4.5	3-11.25	U = 254 z = -2.9	0.003	0.37
WCST-CL	64.5	58.75-73.25	64	61-67.25	U = 436.5 z = 0.2	n.s.	0.02
WCST-CN	6	3-6	6	6-6	U = 304.5 z = -2.83	0.003	0.36
WCST-NT	16	11-24	12	11-16.25	U = 299.5 z = -2.24	0.024	0.28
WCST-LS	1	0-1.25	0	0-1	U = 308 z = -2.33	0.02	0.3

OCD: obsessive-compulsive disorder, DSF: Digit Span Forward, DSB: Digit Span Backward, CBTT: Corsi Block Tapping Task, SER: Stroop Test Errors Reading Condition, SEC: Sroop Test Errors Color Naming Condition, SEI: Stroop Test Errors Interference Condition, SRTR: Stroop Test Reaction Time Reading Condition, SRTC: Stroop Test Reaction Time Color Naming Condition, SRTI: Stroop Test Reaction Time Interference Condition, WCST: Wisconsin Card Sorting Test, WCST indices: TA: Trials administered, TE: total errors, PE: perseverative errors, NE: nonperseverative errors, CL: conceptual level response, CN: number of categories completed, NT: number of trials to complete first category, LS: failure to maintain set, n.s.: not significant. WCST scores represent raw scores. Reaction time on the Stroop Task was measured in msec.

Table 3. *The distribution of OCD patients in terms of average healthy adult group scores (the data represent percent scores)*

Task	Functions measured	1 SD+	1 SD-	2 SD+	2 SD-
DSF	short term verbal memory	36.66	50	6.66	3.33
DSB	short term verbal memory	60	40	0	0
CBTT	short term visuo-spatial memory	30	70	0	0
SEII	inhibition	53.33	13.33	0	33.33
WCST-PE	shifting	26.66	36.33	0	30

OCD: obsessive-compulsive disorder, SD: standard deviation, 1 SD+/-: percent of patients are within 2 SD of the healthy adults mean, 2 SD+/-: percent of patients are above 2 SD of the healthy adults mean, DSF: Digit Span Forward, DSB: Digit Span Backward, CBTT: Corsi Block, SEII: Stroop Error Inhibition Index (Errors Interference Condition – Errors Colour Naming Condition), WCST-PE: Wisconsin Card Sorting Task perseverative errors.

Corsi scores there is no sign of impairment of spatial short-term memory functions in our OCD sample.

The OCD patients were significantly slower in all three conditions of the Stroop Task, and there was a tendency toward significance at the level of committed errors in the interference condition. We suggest, that the inability to inhibit a prepotent response in the Stroop task is a consequence of the impairment of inhibitory executive functions in OCD.

Our study confirms earlier results wich showed that OCD patients produced impaired performance in the WCST[25, 26] in almost all aspects of the task: OCD patients committed significantly more total errors, perseverative errors and non-perseverative errors, completed fewer categories, required more trials to complete the first category, and showed

more failures to maintain set compared to healthy control group.

The higher number of perseverative errors in WCST is a good index of a shifting deficit, which could also be the consequence of impaired inhibitory mechanisms, consistently linked to dorsolateral prefrontal deficit[27, 28]. We argue that set-shifting also requires the ability to inhibit previously acquired rules, a process mediated by the orbitofrontal cortex, an area which might be impaired in OCD[9]. In sum, inhibitory failures caused by the abnormalities of orbitofrontal and dorsolateral prefrontal cortex are likely to play a crucial role in the appearance of perseverative errors in the WCST.

The presence of perseverative responses correlated with the severity of symptoms, patients with higher Y-BOCS scores committed more perseverative errors.

Our findings are also in line with results showing that patients in the recovered phase of the illness had significant impairments in set-shifting tasks, which is a possible candidate for endophenotypic marker for OCD[52].

The significantly more errors in the failure to maintain set indices could be interpreted as an attention deficit impairment[53], which might be a consequence of the hyperactivity of the anterior cingular cortex in OCD[20, 54].

Based on the results of the short-term memory tasks, we can conclude that updating component of the working memory system seems to be intact in OCD[14]. short-term memory scores of the OCD group were in the healthy range. Note, that Digit Span Backward Task, which requires a constant updating of the contents in short-term memory, is a more difficult probe then the Digit Span Forward Task, and the performance of the patients is not impaired.

Our results support the view that executive functions are altered in OCD. The general executive function deficit could be explained by the failures of inhibition mechanism. These results support the neuropsychological model of OCD wich proposes that the deficit of cognitive and behavioral inhibition are responsible for the main cognitive findings of this disorder, most prevalently the deficit in set shifting and prepotent response inhibition[9].

There were some limitations to our study. First we used a heterogeneous group of patients and did not use subgroups. Second, the majority of the patients were under medication during the study. Third, we based our conclusions on the few neuropsychological tasks selected for this study.

Further research is needed to clarify the exact nature of inhibitory executive processes and their contribution to the cognitive neuropsychological profile and symptoms of the disorder.

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