Visuo-Constructional Ability: a Solitary Brain Process or Part of a Complex System?

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Abstract

Aim: **To investigate the nature of Visuo-Construnctional Ability.**

Material and Methods: **We examined 302 people with cognitive disorders with two mental scales (MMSE and CAMCOG) that both include a simple constructional command: the two pentagons that their intersection forms a quadrilateral.**

Results: **There is a significant correlation between MMSE ($p < 0.001$), CAMCOG ($p =< 0.001$) and the performance in the constructional command, while there is no significant correlation of this performance with age ($p = 0.198$) and education ($p = 0.193$).**

Conclusion: **It seems that this function is far more complex and it requires the integrity of many mental systems such as memory, concentration and the speech perception.**

Keywords: Visuo-constructional ability, Cognitive disorders, Higher Cognitive Function, MMSE, CAMCOG.

Introduction

Constructional tasks, such as drawing or reproducing shapes and forms are particularly useful in order to reveal brain disorder and must be included in neuropsychological investigation. The Visuo-constructional ability can be defined as the ability to draw or reproduce 2-D and 3-D shapes or forms. It is an organised activity, during which the spatial perception in combination with the perception of the object that is the target, results in the final construction. The reproduction of a sketch is an example of routine examination to find any disorder of this ability. Kleist reports that patients with constructional apraxia suffer a damage at the posterior parietal lobe of the left hemisphere[1]. Nevertheless damages at the right hemisphere also sometimes cause even more serious constructional apraxia than the left hemisphere damages[2]. Today we believe that the parietal lobes are the primary cortical regions for the spatial-kinetic completion. The optical regions of the optical lobes and the kinetic regions of the frontal lobes are essential for the response to all the visuo-constructional tasks while the parietal cortex is responsible for the complex completion. The hypothetical circuit of the visuo-constructional ability begins with the acoustic stimulus (acoustic cortex) and the optical stimulus, that from the region 17 of the optical cortex, spreads to the regions 39 and 40 of the parietal lobe where an analysis and a synthesis of optical, auditory and kinaesthetic images occur[3]. The kinaesthetic images are finally translated into kinetic schemes at the kinetic cortex. The pre-kinetic frontal lobe seems to be very important for the specific kinetic acts, in spite of the fact that only a small percentage of patients with limited damages of the frontal lobe manifest malfunction at the visuo-constructional ability[4].

The purpose of the current study was to correlate the results of a small (MMSE) and a larger (CAMCOG) test and the ability of the elderly subject to draw a linear shape that is included in both the above tests.

Material and methods

The study includes 302 individuals. 58 of the subjects were normal controls (N), 83 were patients suffering from memory disorders (Age-Associated Memory Impairment – AAMI), 47 suffered from Alzheimer’s Disease (AD), 81 suffered from dementia of a different cause (vascular – VD, post injury etc. – OD) and 33 had depression (D). AD diagnosis was reached according to DSM-ÉV[5] and NINCDS - ADRDA[6] criteria. Dementia diagnosis was reached according to DSM-IV criteria. The Hachinski[7] Ishaemia Scale was

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used to assist in the differential diagnosis between AD and VD. The Geriatric Depression Scale – GDS[8], was used in the quantification of depression.

All subjects were administered two neuropsychological scales, MMSE[9] and CAMCOG[10], which both include a small constructive order which originally was part of the Bender-Gestalt Test[11,12]. This task asks from the person to copy two overlapping pentagons (Figure 1.). Both scales have recently been evaluated and applied in Greece[13,14,15].

The application of the neuropsychological tests was made by a trained psychologist, blindly to the final diagnosis of the patient. The psychologist presented the two pentagons to the subjects, and asked them to copy them without recognise them or name them. This procedure took place in the frame of CAMCOG and MMSE administration. Each subject could try more than once to draw if he felt that the result was not satisfactory and the time for this trial was unlimited.

The results were scored in a scale from 1 to 6:

1 for exact copy,
2 when one of the pentagons was correct,
3 when there were two shapes but they were not pentagons,
4 when there was one shape, which was not a pentagon,
5 when there were only lines and
6 when there was no copy at all.

Statistical analysis

Statistical Analysis has been performed with the use of Non-Parametric methods.

The Spearman's rho[16] non-parametric correlation coefficient between the score on the coping of the pentagons and MMSE and CAMCOG scores, age and education of the subjects has been calculated.

The comparison between the differences of the MMSE, CAMCOG and the pentagons at the specific disorders was done with Kruskal Wallis ANOVA)[17].

Discriminant Function Analysis[18] was used in order to test the power of the various neuropsychological scores (MMSE, CAMCOG and Constructional Ability score) in discriminating between demented patients and non-demented control subjects.

Finally, Sensitivity and Specificity of the constructional in the differentiating between demented patients and control subjects task has been calculated.

Sensitivity (Sn)[19], is the ability of the instrument to detect patients (diagnosed by an external criterion) and its value is given by the division of true positive cases (tp) to the total number of patients diagnosed by the external criterion.

Specificity (Sp)[19], is the ability of the instrument to detect normal subjects (defined by an external criterion) and its value is given by the division of true negative cases (tn) to the total number of subjects diagnosed as normal by the external criterion.

Results

The statistical analysis showed that there is a strong correlation between MMSE ($p < 0.001$) and the CAMCOG scores ($p < 0.001$) and the ability to reproduce the shape. On the contrary, there is no correlation between of the ability to reproduce the shape and age ($p = 0.198$) or education ($p = 0.193$) (Table 2.).

MMSE score of AD patients was significantly different from that of patients with Depression ($p = 0.0026$) and AAMI ($p = 0.0002$). Also, this was true between VD patients and AAMI patients ($p = 0.004$). It was not significantly different between the AAMI patients and the patients with Depression ($p = 0.91$) and between VD patients and patients with Depression ($p = 0.054$).

CAMCOG score of patients with AD was statistically different from that of patients with Depression ($p = 0.0014$) and AAMI ($p = 0.0059$). It was not statistically different between patients with AAMI and patients with Depression ($p = 0.21$) and between the patients with VD and patients with Depression ($p = 0.099$).

The constructional ability score was significantly different only between the patients with AD and AAMI ($p = 0.0069$) (Table 3).

In Table 2. the correlation between education, MMSE and constructional ability score is shown. It seems that education does not have a significant impact on constructional ability, however there is a strong correlation between the MMSE and the constructional ability.

The results of Discriminant Function Analysis are shown in Table 4. It seems that the testing of Constructional Ability alone has comparable power to total MMSE and CAMCOG score in discrimination between demented patients and non demented control subjects. According to these results, about 92-95 % of non-demented subjects will be correctly classified when we use the MMSE level 21/22, or the CAMCOG level 64/65, or the Constructional Ability score level 2/3 as cut-off. However, Constructional Ability score performs poor when used to diagnose demented subjects, as it can correctly classify only 55.81 % of these patients, in comparison to 69.77 % of MMSE and 74.29 % of CAMCOG.

Sensitivity and Specificity of all the neuropsychological tests are shown in Table 5. Constructional Ability seems to be equally powerful to MMSE, while CAMCOG fails to manifest a satisfactory combination of high Sensitivity and Specificity.

Discussion

The visuo-constructional ability is a function whose disorder can help us detect organic brain damages. The reproduction of forms and shapes demands except from the tactical movement of the hands, the perceptual completion at kinaesthetic images and the transformation of the kinaesthetic images into movements in order to perform the construction[20].

Despite its clinical importance, the visuo-constructional ability is not assessed in the everyday clinical practice. This happens partly because very few patients complain about a disorder of this ability. Architects or mechanics, whose profession demands high visuo-constructional ability, often report difficulty when they have to draw a watch or any other shape they are asked to draw.

Today, Clinical Neuropsychology places the visuo-constructional centre at the posterior parietal lobe bilaterally. That puts forward the question, whether this ability is an isolated brain function or a complex system.

To answer this question it is necessary to examine the cognitive status of the patients as a whole, to discover if it demands the integrity of many systems, such as memory, concentration or speech perception in order to perform the visuo-constructional tasks right.

Reports from certain researchers who applied specially designed scales for Alzheimer disease like ADAS[21,22] say that the visuo-constructional ability is affected at the late stages of the disease[23]. The present study reports a strong correlation between stages of the disease and visuo-constructional ability status. The fact that in AD we observe a participation of all the lobes of the brain, and, at the early stages, especially of the temporal and the parietal lobes, seem to support our findings.

As it has already been mentioned in the introduction section, if we accept that the posterior regions of the parietal lobes are mainly responsible for the visuo-constructional ability, then this cognitive function should be affected even in the early stages of the disease. On the other hand as the disease spreads, the decline of cognitive function brings an analogous malfunction in the everyday life, which is no more than constructive function decline (apraxia)[24]. There have been reported cases with posterior cortical atrophy, visuo-constructional apraxia, alexia, optical agnosia, agraphia, and asymbolia without disorders of memory, orientation and social activities[25].

The findings of the current study are important, because in order to perform a neuropsychological evaluation of all the cognitive functions we need a lot of time, which usually is beyond our potential at the everyday praxis. However, the simple knowledge of the relation between the visuo-constructional function and MMSE and therefore between visuo-constructional function and the stages of the disease can help minimising the time spent in the neuropsychological evaluation. The results of the current study support the theory that if the patient is not demented and has only depression the visuo-constructional ability is intact. Also, the results support the particular usefulness of the use of the visuo-constructional ability testing as a valuable and valid method to complement the effort to define the stage of the dementia since it appears to be equally powerful in the detecting of dementia, to other, larger neuropsychological tests.

Table 1.
The characteristics of the subjects (mean ± SD) that took part in the study are shown

Group	N	Age
AD	47	69.78 ± 6.69
VD	42	70.00 ± 8.56
OD	39	70.94 ± 7.51
AAMI	83	71.33 ± 7.56
Depression	33	66.40 ± 5.75
Normal controls	58	69.76 ± 7.38

Table 2.
Statistical analysis and correlation between the MMSE, CAMCOG, pentagons, the age and the education

Correlation	Spearman’s Rho	p
Age-MMSE	- 0.10	> 0.05
Age-CAMCOG	- 0.12	> 0.05
Age- Pentagons	0.11	> 0.05
Education-MMSE	0.16	> 0.05
Education -CAMCOG	0.15	> 0.05
Education -Pentagons	0.13	> 0.05
MMSE-CAMCOG	0.76	< 0.001
MMSE- Pentagons	- 0.78	< 0.001
CAMCOG- Pentagons	- 0.72	< 0.001

Table 3.
Mean scores and standard deviation of MMSE, CAMCOG, and Constructional Ability Score in the various diagnostic groups.

	AD	VD	OD	AAMI	Depression	Normal Controls
AAMI	15.20 ± 6.64	19.38 ± 6.37	22 ± 2.28	25 ± 2.56	23.5 ± 5.12	27.69 ± 2.07
CAMCOG	41.61 ± 20.4	67.70 ± 14.33	67.25 ± 12.4	84.66 ± 5.5	72.62 ± 21.9	88.6 ± 6.59
Constructional Ability Score	3.41 ± 1.76	2.61 ± 0.96	2.16 ± 1.47	1.75 ± 0.46	2.00 ± 0.75	1.15 ± 0.46

Table 4.

Discriminant Function Analysis results. Diagnosis (demented vs. non-demented) was the dependent variable and MMSE, CAMCOG and Constructional Ability were the independent ones.

Classification Matrix					**Classification Functions**		
Rows: Observed classifications							
Columns: Predicted classifications							
MMSE							
	Percent Correct	N	D				
		p = 0.537	p = 0.462			N	D
N	94.00	47.00	3.00				
D	69.77	13.00	30.00		MMSE	1.03	0.68
Total	82.80	60.00	33.00		Constant	-14.19	- 6.70
CAMCOG							
		p = 0.533	p =0.466				
N	95.00	38.00	2.00				
D	74.29	9.00	26.00		CAMCOG	0.26	0.16
Total	85.33	47.00	28.00		Constant	-11.39	- 4.97
Constructional Ability							
		N	D				
Correct	p = 0.537	p = 0.462			N	D	
N	92.00	46.00	4.00				
D	55.81	19.00	24.00		Constructional Ability	1.07	2.19
Total	75.27	65.00	28.00		Constant	-1.40	- 4.06

Table 5.

Sensitivity and Specificity of the Neuropsychological Instruments used in the current study

MMSE	**Sn**	**Sp**
20 / 21	58.14	96.00
21 / 22	69.77	94.00
22 / 23	***79.07***	***90.00***
23 / 24	***88.37***	***84.00***
24 / 25	95.35	78.00
CAMCOG		
60 / 61	48.84	96.00
61 / 62	51.16	96.00
62 / 63	53.49	96.00
63 / 64	55.81	96.00
64 / 65	60.47	96.00
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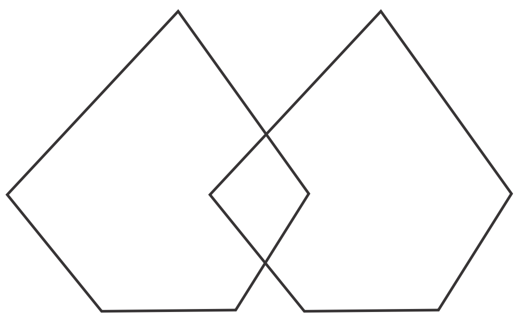
74 / 75	65.12	88.00
75 / 76	65.12	88.00
76 / 77	72.09	88.00
CONSTRUCTIONAL ABILITY		
1 / 2	91.18	62.00
2 / 3	***72.06***	***92.00***
3 / 4	51.47	100.00
4 / 5	50.00	100.00
5 / 6	45.59	100.00

Figure 1.

The two overlapping pentagons, which are included both in MMSE and CAMCOG. Originally this task was part of the Bender-Gestalt Test.



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