Original Article

Study of visuospatial skill in patients with dementia

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Abstract

Objectives: To assess the visuospatial function in different types of dementia with the visual object and space perception (VOSP) battery and to relate the degree of visuospatial dysfunction with different types and stages of dementia. **Materials and Methods:** A sample of 53 participants with dementia and equal number of age-, sex-, and education-matched controls were recruited for the study. Participants were evaluated for visuospatial skill using VOSP test battery. The scores of dementia patients were compared with controls and within dementia cohort scores were compared based on stage of dementia. **Results:** The dementia group scored low in all of the subtests of the VOSP battery in comparison to controls. Alzheimer's disease (AD), dementia of Lewy bodies (DLB), and vascular dementia (VaD) patients performed more poorly than controls in all subtests examining object perception and space perception. The three semantic variants of frontotemporal dementia (FTD) patients scored low in all four subtests of object perception, whereas behavioral variant FTD (bvFTD) patients performed normally. The scores deteriorated with the advancement of dementia in all patients from the dementia groups. **Conclusions:** Visuospatial function is significantly impaired in dementia patients particularly in AD, DLB, and VaD patients from the beginning, and the impairment is severe in advanced disease stages.

Key Words

Alzheimer's disease (AD), clinical dementia rating (CDR), dementia of Lewy bodies (DLB), dementia, vascular dementia (VaD), visuospatial function, visual object and space perception (VOSP)

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Introduction

The visuospatial function involves identifying stimuli and their location in the environment. Studies indicate that the visuospatial tasks activate different cortical areas such as the Broadmann area V5, the superior parietal lobule, the parieto-occipital junction, and the premotor areas.[1-3] Visuospatial skills are the use of vision in the perception of objects in our environment and the spatial relationships between them. The pathways for processing visual information in the posterior cortex are segregated, such that the dorsal regions process space-based "where" information, and the ventral regions process object-based "what" information. The dorsal pathway projects rostrally via the superior longitudinal fasciculus from the dorsal occipital cortex to the posterior parietal cortex. The ventral pathway projects rostrally via the inferior longitudinal fasciculus from ventral occipital cortex into inferior temporal cortex.

Most of the commonly used neuropsychological tests assessing visual and spatial perception rely on additional cognitive abilities. Among these instruments is the visual object and space perception (VOSP) battery. This battery evaluates the space and the object perception and is based on the assumption that these perceptions are functionally independent. The subtests require very simple responses, each of which focuses on one component of visual perception while minimizing the involvement of other cognitive skills. The VOSP battery can be used to evaluate separately dorsal

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and ventral stream processing because it is divided into subtests that emphasize either object or space perception [4] Four visual object perception subtests evaluate the function and integrity of the ventral stream (what) from the ventral occipital cortex into the inferior temporal cortex and four visual space perception subtests evaluate functioning of the dorsal stream (where) from the dorsal occipital cortex to the posterior parietal cortex.

The VOSP battery seems to be sensitive to changes in visuospatial functioning in various diseases such as Alzheimer's disease (AD), posterior cortical atrophy (PCA),[5] dementia of Lewy bodies (DLB),[6] and vascular dementia (VaD). Additionally, VOSP has been reported to detect a lack of impairment in visuospatial functions in patients with Huntington's disease and atypical Parkinsonism.

In the present study, we aimed to evaluate visuospatial functioning with the VOSP battery in different types of dementia and to relate the degree of visuospatial dysfunction with different types and stages of dementia.

Materials and Methods

Participants

We evaluated 53 patients with dementia. Participants were enrolled consecutively from the Cognitive Disorder Clinic of our institute from January 2012 to June 2013. Before conducting the study, permission was obtained from the Institutional Ethics Committee. A detailed history was gathered from participants and their family members followed by a clinical examination that included neurological examination and assessment of cognitive functions as per protocol. We used the Mini Mental State Examination (MMSE) for the initial screening of the patients. Further, we used the Kolkata Cognitive Test Battery[7] and we also separately tested the language, praxis performance, executive functioning, and visuospatial and visuoperceptual functioning using standard methods. Each patient was then subjected to investigations including hematological, biochemical, and radiological tests. A cranial magnetic resonance imaging or computerized tomography scan was also performed. Some special investigations (e.g. electroencephalogram and cerebrospinal fluid analysis) were undertaken wherever investigators thought they were necessary. Dementia was diagnosed using Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM IV) criteria[8] (1994) and staging was done as per the clinical dementia rating (CDR) scale.[9] We used the National Institute of Neurological and Communication Disorders/Alzheimer's Disease and Related Disorders Association (NINCDS–ADRDA) criteria[10] for diagnosis of AD, Neary criteria for diagnosis of behavioral variant of frontotemporal dementia (bvFTD) and semantic dementia,[11,12] the Consensus criteria for diagnosis of DLB,[13] and NINDS-ARIEN criteria for diagnosis of VaD.[14] Healthy control participants were recruited from the healthy relatives of patients attending the outpatient departments of the hospital. Healthy participants had to report a normal neurological examination, a CDR score of 0, and an MMSE score equal to or greater than 28/30. All participants and, when applicable, their caregivers signed an institutional review board-approved research consent form before participating in the study. The illiterate participants and participants with visual impairment were excluded from both patient and control groups.

Instruments

Visuospatial skill was estimated using the VOSP test battery[4] that was composed of the following.

Screening test

The VOSP also contains a screening test that checks whether the participant's visual sensory capacities are sufficiently intact to permit further examination (Shape Detection Screening Test). The test consists of 20 stimuli: 10 of the stimuli contain an incomplete form of the letter "X," whereas the other 10 stimuli do not. The participant is required to determine whether an X is present. According to the test's manual, participants with a score of 15 or lower should not be further tested.

Visual object perception

Incomplete letters subtest

Within the objects perception part of the battery, the incomplete letters subtest consists of 20 letters that are 70% degraded. The participant has to identify the letters.

Silhouettes subtest

The subtest consists of 15 silhouettes of animals and 15 silhouettes of inanimate objects, drawn from an unusual perspective. Participants are required to identify the drawings.

Object decision subtest

For object decision, four figures are shown simultaneously to the participant and only one of these figures corresponds to a real object; the other three figures are nonsense form distracters. The participant is required to identify the real object, shown at a rotation of 75°.

Progressive silhouettes subtest

The progressive silhouettes subtest consists of two series of stimulus cards (depicting a gun and a trumpet), each one consisting of 10 silhouette drawings, with each successive drawing revealing progressively more details of the object. The participant is required to identify the object as early as possible (in this subtest, high scores imply poor performance).

Visual space perception

Dot counting subtest

Within the spatial perception part of the VOSP the first subtest is dot counting. This task consists of ten cards with five to nine dots on each card. The participant has to identify the number of dots presented on each stimulus card.

Position discrimination subtest

The position discrimination subtest consists of 20 cards. Each card shows two squares containing dots. The participant has to decide which square displays the dot in the center.

Number location subtest

The number location subtest consists of 10 cards. Each card shows two squares. The top square contains randomly placed numbers, whereas the lower square shows a black dot, placed in the same position as one of the numbers above. The participant

has to identify the card in which the position of the dot matches with the position of the number.

Cube analysis subtest

The last subtest, cube analysis, presents 10 stimuli where the subject is asked to determine the number of cubes shown on each stimulus card.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS) 13.0 software. The demographic variables were analyzed from a descriptive viewpoint. Nonparametric tests were used to compare VOSP result variables and non-continuous variables (Mann–Whitney and Kruskal–Wallis test). The chosen significance level was 5% ($P < .05$).

Results

The demographic and clinical data are given in Table 1. There was no difference between the dementia group and the control group with respect to gender, age, and education level. No difference was noted between various dementia subgroups and the controls.

Comparison of the scores of AD, VaD, FTD, and DLB patients with those of controls on the visuospatial evaluation (VOSP) is shown in Table 2. None of the participants failed on the screening test, which meant that all patients and controls were eligible to perform the other subtests.

The AD patients ($N = 31$) showed significant impairment in all subtest of visuospatial function in comparison to the controls. Similarly, the performance scores of the VaD group ($N = 11$) was poor on all subtests in comparison to the controls, indicating significant impairment in object perception and space perception of visuospatial function.

Owing to the small size of the FTD ($N = 8$) and DLB ($N = 3$) groups, we could apply the Mann–Whitney *U*-test. In the FTD group, we found significant differences in performance scores in comparison to the controls in the shape detection screening test, the incomplete letters test, and the object decision test. Two of our semantic variant patients scored low in space perception (one in number location and one in cube analysis) and one of the bvFTD patients scored low in number location. Within the FTD group, the bvFTD participants performed well on these tests of object performance, semantic dementia ($N = 3$) patients performed poorly and the semantic dementia patients made the overall scores of FTD group low as compared to controls. The DLB patients also performed poorly as compared to controls in all subtests of object perception and space perception ($P < .05$).

Table 3 shows that the mean performance scores on all of the VOSP subtests steadily declined with advancement of dementia in all subgroups. We performed a Kruskal–Wallis test to compare the performance of different dementia stages (CDR1, CDR2, CDR3) with respect to various VOSP subtests and found significant differences on all subtests and MMSEs. This result signifies that the performance worsens with the advancement of dementia. Comparing the performance of patients in mild (CDR1) versus moderate (CDR2) dementia and between mild (CDR1) and severe (CDR3) with the Mann–Whitney *U*-test, we found significant differences on all subtests. Although no differences were found for the moderate (CDR2) and severe (CDR3) groups, a difference was found for the MMSE scores across these groups.

Table 1: Demographic characteristics of patients of various types of dementia and comparison with control

Dementia type	Number (gender ratio)	Mean age and age range (*P* value)	Mean MMSE (*P* value)	Mean education (*P* value)
Control	53 (M=32, F=21)	66.83 [range]	28.28	11.01
AD	31 (M=17, F=14)	68.96 [59-80] (0.348, NS)	18.74 (<0.001)	11.54 (0.551, NS)
VaD	11 (M=8, F=3)	66.36 [55-75] (0.185, NS)	17.63 (<0.001)	9.70 (0.243, NS)
FTD	8 (M=6, F=2)	64.50 [52-72] (0.538, NS)	21.87 (<0.001)	12 (0.330, NS)
DLB	3 (M=2, F=1)	72 [68-78] (0.089, NS)	19 (<0.001)	10.66 (0.693, NS)
Total dementia	53 (M=33, F=20) NS	67.92 [range] NS	19 (*P*<0.001)	11.18 NS

AD = Alzheimer disease, VaD = Vascular dementia, FTD = Frontotemporal dementia, DLB = Dementia with Lewy bodies, MMSE = Mini Mental State Examination, M = Male, F = Female, NS = Not significant

Table 2: Comparison of performances of various dementia subgroups with control group

VOSP Test subgroup	Control mean (SD)	AD mean (*P* value)	VaD mean (*P* value)	FTD mean (*P* value)	DLB mean *P* value
Shape detection Screening test	19.33 (0.97)	16.12 (<0.001)	16.09 (<0.001)	17.25 (0.002)	16.00 <0.001
Incomplete letter	18.98 (0.93)	4.81 (<0.001)	12.72 (<0.001)	14.50 (0.049)	6.66 <0.001
Silhouette	16.45 (1.48)	7.64 (<0.001)	7.90 (<0.001)	12.00 (0.053)	7.33 (<0.001)
Object decision	16.58 (1.33)	8.19 (<0.001)	8.45 (<0.001)	11.25 (0.018)	7.00 (<0.001)
Progressive silhouette	13.30 (2.30)	18.16 (<0.001)	17.81 (<0.001)	16.75 (0.006)	17.00 (<0.008)
Dot counting	9.56 (0.63)	6.61 (<0.001)	8.27 (<0.001)	8.12 (0.094)	6.66 (<0.001)
Position discrimination	18.13 (1.20)	9.61 (<0.001)	12.54 (<0.001)	13.50 (0.055)	12.66 (<0.001)
Number location	9.03 (0.93)	4.67 (<0.001)	4.81 (<0.001)	6.50 (0.002)	4.66 (<0.001)
Cube analysis	8.32 (1.26)	3.58 (<0.001)	4.09 (<0.001)	6.62 (0.011)	5.00 (<0.001)

VOSP = Visual Object and Space Perception Battery, AD = Alzheimer disease, VaD = Vascular dementia, FTD = Frontotemporal dementia, DLB = Dementia with Lewy bodies, SD = Standard deviation

Table 3: Comparison of performance of patients in different stages of dementia

VOSP test subgroup	Control mean (SD)	CDR 1 mean (SD)	CDR 2 mean (SD)	CDR 3 mean (SD)
Shape detection Screening test	19.33 (0.97)	17.37 (1.54)	15.68 (1.07)	15.14 (0.37)
Incomplete letter	18.98 (0.93)	13 (4.54)	8.75 (4.12)	7.42 (1.61)
Silhouette	16.45 (1.48)	11.82 (4.18)	6.76 (1.93)	6.57 (2.76)
Object decision	16.58 (1.33)	11.52 (3.50)	6.96 (2.12)	7 (2.44)
Progressive silhouette	13.30 (2.30)	16.88 (1.96)	18.10 (1.75)	19.14 (1.57)
Dot counting	9.56 (0.63)	8.64 (1.45)	6.31 (2.05)	6.14 (2.54)
Position discrimination	18.13 (1.20)	14.41 (4.69)	8.68 (4.17)	9.71 (3.54)
Number location	9.03 (0.93)	5.76 (2.07)	4.68 (1.41)	3.71 (0.95)
Cube analysis	8.32 (1.26)	5.17 (1.97)	3.82 (1.69)	3 (1.00)

VOSP = Visual Object and Space Perception Battery, CDR = Clinical dementia rating, SD = standard deviation

Discussion

The aim of the present study was to evaluate the visuospatial skill of the patients with different forms of dementia and in different stages of dementia. We selected age, sex, and education matched dementia and control groups to nullify their possible influence on VOSP performance. Akin to many previous studies,[15,16] our AD patients performed poorly as compared to controls on all eight subtests (four object perception and four space perception) of VOSP.

AD can affect most aspects of visual processing with the impact on both dorsal and ventral stream areas. Patients are impaired in dorsal stream functions such as angle discrimination and motion perception,[17] and ventral stream functions such as the perceptual discrimination and recognition of faces, colors, and objects.[18] Contrast sensitivity deficits are also prominent in AD patients.[19] In AD patients, visuospatial functioning can be impaired in the beginning of the disease, and it gradually declines with deterioration of cognition over time. In two studies done by Quental *et al*. (2009, 2013)[15,16] on visuospatial skill with early AD patients and controls, it was found that controls outperformed AD patients on all neuropsychological evaluations, indicating different types of impairments of visuospatial functioning in AD patients. The subtests of the VOSP battery were found to be sensitive for detecting this impairment in mild cases.

Our DLB subgroup also performed poorly in all VOSP subtests in comparison to controls. The DLB patients showed more severe and pervasive visuospatial, attentional, and executive impairments compared to the AD patients, whereas the AD patients showed more severe memory impairment compared to the DLB patients. Visuospatial deficits are an important component for differentiating DLB from AD. Mosimann *et al*. (2004) found that DLB and Parkinson's disease dementia (PDD) patients showed more severe impairments compared to the AD patients on tests tapping both ventral stream functioning (tests of object and form perception) and dorsal stream functioning (tests of dot position and motion perception).[20] In a study by Calderon *et al*. (2001), the DLB group showed impaired performance on fragmented letters subtest, object decision subtest, and cube analysis subtest relative to both control patients and patients with AD.[21]

Our VaD cohort also performed poorly on the VOSP subtests in comparison to controls, indicating significant impairment in object perception and space perception of visuospatial functioning. In a study by Clague *et al*. (2005), the VaD group showed impairment on tests of attention and executive functions, naming, object decision, and cube analysis from the VOSP.[22] Thus, patients of AD, VaD, and DLB showed significant derangement of visuospatial skill including both object perception and space perception.

Our FTD patient had impaired object perception. Out of the eight FTD patients, three were of the semantic variant and five were of the behavioral variant (bvFTD). Whereas all three patients of the semantic variant produced low scores on all four subtests of the object perception test, patients of bvFTD performed well on the tests of object perceptions. The persons with semantic dementia showed poor semantic knowledge and usually experienced difficulty in naming visually presented objects or their pictures.[23] Therefore, impaired performance of our patients on all object perception tests may be attributed to impairment of their semantic knowledge (anterior temporal lobe), rather than object perceptual problems (ventral stream of visual processing).

Two of our semantic variant patients scored low in space perception subtest (one in number location and one in cube analysis) and one bvFTD patient scored low in number location subtest. Impaired space perception is not seen in FTD patients and this observation is difficult to explain. This might be due to attentional problem of bvFTD patients. Consistent with the relative preservation of the posterior cortex, mild bvFTD patients usually perform normally on tests that assess "bottom-up" visual spatial perception, such as the subtests of the VOSP battery.[24,25] In a study done by Rahaman *et al*. (1999) on eight patients with the frontal variant of FTD, all patients showed normal scores on all aspects of the VOSP tests, whereas other aspects of cognition were impaired.[25] In a study done by Snowden *et al*. (2004), 15 patients showing a semantic variant of FTD performed normally on subtests of the VOSP battery, with the exception of the silhouettes subtest, which requires recognition of pictures of animals and objects.[26]

The concept of visuospatial skill can be recast in terms of ventral (what) versus dorsal (where) visual processing streams. According to this widely accepted dichotomy, the ventral pathway, or stream of information, proceeds from the primary visual to the visual association areas in the inferior temporal region and underlies object recognition by the association of visual information with semantic knowledge about the perceived

objects. Components of VOSP, which depend primarily on ventral processing, are, therefore, the object decision subtest, the silhouette identification test and the fragmented letters subtest. The dorsal pathway projects rostrally via the superior longitudinal fasciculus from the dorsal occipital cortex to the posterior parietal cortex. The dorsal stream is responsible for computing the location of objects in space, the guidance of hand movements during grasping and complex visuospatial analysis. The cube analysis subtest and other subtests of space perception of VOSP draw heavily on the dorsal pathway. Based on the current findings and knowledge, it seems that our patients with AD, DLB, and VaD had severe deficits in both dorsal and ventral processing streams. In our dementia cohort, the performance of visuospatial skill deteriorated as the disease advanced progressively from mild through severe stages, which indicates that visuospatial functioning progressively deteriorated with the progression of dementia.

Normal visuospatial skill is extremely important for everyday activities. It is required in every moment of our life. Life becomes difficult when visuospatial functioning is significantly impaired, as is the case of dementia patients. The issue, however, is often neglected by the treating physicians. Not many studies have been done so far on this subject. Early institution of specific rehabilitation therapy can help, if the disease is detected in an early phase of dementia. According to some recent research, visuospatial tests have tremendous potential as effective and sensitive biomarkers for dementia, particularly in AD patients.[27]

The current study was limited in a few ways. For example, we used clinically probable cases based on the standard criteria for diagnosing various dementia subtypes. The pathological diagnoses of our patients are not available. Thus, the results of the current study need to be interpreted with the possible fallacies of diagnostic accuracies of various clinical criteria. The low number of patients of FTD and DLB in our study was another limitation.

In summary, the present study supports the assumption that visuospatial tasks are valuable for diagnosing AD and other dementias like DLB, and VaD. Several subtests of the VOSP battery proved effective for detecting visuospatial impairment in AD and different forms of dementia. Further studies on a larger sample and correlating visuospatial function with other cognitive and neuropsychological domain are now needed to confirm our preliminary findings.

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Conflicts of interest
All contributors receive salary from Government and nobody is getting any financial assistance from any commercial agencies. Thus, we declare that there is no competing interest involved in this study.

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