

## A 6-Year Study of Cognition and Spatial Function in the Demented and Non-Demented Elderly: The Sydney Older Persons Study

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### Key Words

Pentagon copying · Visuospatial impairment · Mini-Mental State Examination · Normal elderly

### Abstract

**Background:** Spatial function has been suggested to be disproportionately worse in people with dementia with Lewy bodies (DLB) than other dementia groups, and poor performance on the Mini-Mental State Examination pentagon copying (PC) task has been proposed as adequate for assessing this. We aimed to establish the prevalence of poor PC in the non-demented elderly; determine the validity of the use of PC as a spatial function test, and determine if poor PC is more common in DLB than non-DLB dementias. **Methods:** In a population-based sample of 299 participants, 126 were rated as being cognitively normal (clinical rating scale [CDR] = 0), 95 mildly cognitively impaired (CDR = 0.5), and 78 met criteria for dementia, 19 of whom met criteria for probable DLB (pDLB) and 25 with none of the core features of DLB (non-DLB). The accuracy of PC performance was determined across CDR groups, and the relationship of PC to performance on a broad range of cognitive tests

was evaluated. The dementia groups were compared cross-sectionally to determine differences in PC and other cognitive test performance, as well as 3 and 6 years earlier to determine cognitive differences at initial stages of cognitive decline. **Results:** Poor PC was common in the non-demented elderly (39% CDR = 0; 43% CDR = 0.5). In this non-demented group, PC was selectively related to tests of spatial function. Poor PC was not significantly different in the pDLB and non-DLB groups at any assessment time, however it became more prevalent as dementia severity increased. Memory function and verbal fluency were more impaired in the pDLB group in the early stages of the disorder. **Comment:** PC appears to be a good measure of spatial function in the elderly. However, in contrast to other findings of poor spatial skills in DLB when dementia is in the mild to moderate stages, poor PC performance has not been shown to be a good early marker of DLB and its clinical correlates are yet to be determined.

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1420–8008/03/0164–0181\$19.50/0

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## Introduction

Dementia with Lewy bodies (DLB) is reported to be the second most common cause of dementia in the elderly based on clinical and autopsy studies [1], yet accurate clinical diagnosis remains elusive [2] and epidemiological studies are lacking [3]. Proposed guidelines for the diagnosis of DLB include progressive cognitive decline of sufficient magnitude to interfere with normal social or occupational function [4]. These criteria note that impairment of attentional, fronto-subcortical, and visuospatial skills may be particularly prominent, however their respective presence is not reported as being core to the disorder.

More recently, it has been suggested that the spatial impairments evident in DLB may be of differential diagnostic significance [5], with one study showing patients with DLB having disproportionately severe impairments in this cognitive domain early in the course of their disease compared to Alzheimer's disease (AD) [6]. Cognitive testing has been asserted to be of considerable assistance in differentiating DLB from other forms of dementia, in particular AD.

The Mini-Mental Status Examination (MMSE) [7] is one of the most commonly used cognitive screening tests. Ala et al. [8] have suggested that the pentagon copying (PC) item from this test may be an adequate way of assessing spatial function in patients with dementia. These authors compared the PC performance of 17 patients with autopsy-proven DLB with that of 27 AD patients. The MMSE scores of these patients averaged 21.8 and 20.9, respectively. They found that only 2 of the DLB patients had acceptable PC performance, as opposed to 16 of the AD patients. They suggested their results supported the notion of spatial impairment distinguishing DLB from AD in the early stages of the dementing process.

The study of Ala et al. [8] had several limitations. First, PC performance was compared only between DLB and AD patients, and not with a broader non-DLB dementia category (which would offer greater clinical use diagnostically). Second, their participants were drawn from a clinical rather than population-based sample. Third, the absence of a control group (of non-demented individuals) precluded the identification of the prevalence of poor PC in the general population, which would be very important for interpretation and use in early diagnosis. Furthermore, whilst the authors speculated that spatial impairment might well be an early diagnostic feature of the disorder, they did not have longer term information available to test this at the milder stages of the disorder. Finally, apart from the MMSE, no other cognitive tests were

presented for comparison, thus leaving the validity of PC as a test of spatial function unclear.

The aims of this study were first to establish the prevalence of poor PC in the non-demented elderly, and in this group to determine the validity of the use of PC as a test of spatial function. Second, to determine if poor PC is more common in clinically diagnosed probable DLB (pDLB) than those with dementia and no DLB core features. Third, to follow the population-based dementia groups longitudinally in order to examine what cognitive measures, including poor PC, were associated with DLB.

## Subjects and Methods

The Sydney Older Persons Study (SOPS) is a longitudinal study following an initial random sample of 630 community dwellers from the inner west region of Sydney, Australia, and aged 75 years and over at the time of recruitment in 1991–1993. The background to SOPS has been published elsewhere [9, 10]. Dropout throughout this study was mainly due to death. Participants were clinically evaluated on three occasions over 6 years, with the third review carried out in 1997–1999. No a priori exclusion criteria were applied in order to maintain an accurate reflection of community-living people's abilities and deficits in this age band. For this study, continuing participants from wave 3 of SOPS were used.

Of the 347 remaining participants, 299 were reviewed at wave 3. On this occasion participants were interviewed in their homes and assessed on a large range of past and current health measures with structured questionnaires. In addition, they received a comprehensive medical examination and cognitive assessment by a trained and supervised psychologist. The medical data collected were reviewed by an experienced neurologist/geriatrician (H.C.) who subsequently made clinical diagnoses of systemic and neurodegenerative diseases and allocated all relevant diagnoses. The neurologist had access to MMSE results, however not those of the remaining cognitive tests. Dementia severity was established with the Clinical Dementia Rating scale (CDR) [11] based on information gathered from an informant nominated by each participant. For this scale, 0 represents normal cognition, 0.5 questionable dementia (or mild cognitive impairment not reaching criteria for dementia), and a score of 1 and above representing mild, moderate and severe dementia. Of the 221 who did not meet criteria for dementia, 126 were rated as having a CDR score of 0 and 95 a CDR score of 0.5.

At wave 3, 78 (26%) of the 299 available participants had a CDR score of >0.5 which is consistent with the prevalence found in other larger population-based studies [12, 13]. Fifteen participants met NINCDS-ADRDA [14] and Diagnostic and Statistical Manual of Mental Disorders – 4th ed (DSM-IV) criteria [15] for AD ( $n = 15$ ); 34 had possible DLB and 19 pDLB according to consensus criteria for DLB [4], and 10 participants met other dementia subtypes according to DSM-IV criteria [15]. For each participant, the presence of the three core features in the diagnosis of DLB was established from the medical examination (extrapyramidal syndrome: presence of either rigidity or bradykinesia from medical examination); and from informant information (visual hallucinations and fluctuating cognition).

For this study, the pDLB group (i.e. with two or three core features) was compared with a non-DLB dementia group (i.e. with no

core features). Participants with possible DLB (i.e. one core feature) were excluded from all analyses as the diagnostic clinico-pathological accuracy remains poor in this group [16], and their exclusion is likely to increase the diagnostic accuracy of the other dementia groups of interest. The non-DLB dementia group (n = 25) comprised subjects with a diagnosis of AD (n = 15), mixed dementia (n = 5), vascular dementia (n = 1), dementia due to other general medical conditions (n = 1), and unable to classify (n = 3).

Having identified the pDLB and non-DLB groups at wave 3 and evaluated aspects of clinical status as outlined in our aims, cross-sectional analyses between groups were performed on the wave 1 and wave 2 cognitive data in order to establish potential differences in the earlier, 'preclinical' stages of their respective clinical presentations.

This research project was approved by the Ethics Committee of Concord Hospital and written informed consent was obtained from all participants or their carers where appropriate.

#### *Cognitive Tests Evaluated*

The cognitive tests administered at wave 3 were grouped into five domains: language (subset of 24 items from the Boston Naming Test) [17]; spatial skills (copy of cube, coil, infinity loop, interlocking infinity loops, drawing of a clock to command [18, 19], and a subset of 20 items from Judgement of Line Orientation Test [20]); memory (Wechsler Memory Scale – Revised [21], Logical Memory I and Logical Memory Percent Retention [Logical Memory II/I × 100], and Visual Reproduction I and Visual Reproduction Percent Retention [Visual Reproduction II/I × 100], Reid Memory Test Trial 5 and Delayed Recall [18]); and executive function (Phonemic ['FAS'] and Semantic ['Animal Naming'] Verbal Fluency [22], Similarities from the Wechsler Adult Intelligence Scale – Revised [23]). MMSE was administered as a measure of overall cognitive performance. In addition to these wave 3 data, test scores from waves 1 and 2 were available on the MMSE, cube copying task, Phonemic and Semantic Verbal Fluency, and the Boston Naming Test (a subset of 11 items).

#### *Statistical Analysis*

$\chi^2$  statistics was used to evaluate differences in PC performance between the pDLB and non-DLB group at waves 1, 2, and 3 (dichotomous variable), and t tests were employed to analyze differences between groups for the remaining cognitive measures at each of the 3 waves, in addition to baseline demographic data (continuous variables). There were missing values for 16 of the subjects and 21 were unable to perform the task.  $\chi^2$  analysis was carried out to determine if there were significant differences in the accuracy of PC performance between groups at wave 3 based on CDR status (i.e. cognitively normal, mild cognitive impairment, and dementia), and analysis of variance was carried out to investigate the relationship of PC performance to performance on all other cognitive tests in the non-demented group, controlling for the effects of age, sex, education and MMSE score. The significance level was set at 0.05 for all analyses.

## **Results**

At wave 3, the dementia groups were well matched for age (pDLB = 87.9 ± 5.1 years; non-DLB = 87.3 ± 3.6 years) and education (pDLB = 10.2 ± 2.2 years; non-DLB = 10.4 ± 1.8 years). The 2 non-demented groups

were slightly younger than those with dementia, however between those with a CDR score of 0 and 0.5 there were no significant differences between age (CDR = 0: 85.3 ± 2.7 years; CDR = 0.5: 86.7 ± 3.9 years) and education (CDR = 0: 0.1 ± 1.9 years; CDR = 0.5: 9.95 ± 1.8 years).

At wave 3, examination of PC accuracy for each CDR category revealed that 42 (39%) of 110 participants with normal cognition displayed inaccurate PC; 32 of the 74 (43%) participants with mild cognitive impairment (CDR = 0.5) demonstrated poor PC; and 32 of the 51 (67%) with dementia (all groups combined) had poor PC. These differences across groups were statistically significant ( $\chi^2 = 11.704$ , d.f. = 2;  $p < 0.005$ ).

The validity of PC as a general measure of spatial skills was investigated by carrying out multivariate analysis of variance on the cognitive measures in the non-demented group at wave 3 based on PC performance. Given the known associations between age, sex, years of education, and performance on cognitive tests, all the analyses were performed controlling for these variables. We also controlled for total MMSE score to ensure that any identified relationship was selective to PC performance per se, rather than to overall cognitive status. These data, presented in table 1, show that PC performance in the non-demented elderly was selectively related to other tasks of spatial function (copied cube, coil, interlocking infinity loop, Judgment of Line Orientation Test), including spatial memory (Visual Reproduction I).

Based on wave 3-defined dementia groups, differences in the cognitive test performance at each time point (waves 1, 2, and 3) were examined. At wave 1, MMSE scores were not significantly different, both groups averaging scores in the range of what might be considered a 'preclinical' dementia phase. Significant differences were observed at waves 2 and 3 with the pDLB group performing more poorly than the non-DLB group (table 2). Significant differences between the 2 dementia groups were present for the Reid Memory Test (Trial 5 and Recall) at wave 1, that is, even when the mean MMSE scores were similar. Three years later at wave 2, further significant differences emerged for Cube Copying, Similarities, and for Semantic and Phonemic Verbal Fluency.

Examining PC performance, there were no significant differences between the two dementia groups at any wave (wave 1:  $\chi^2 = 1.555$ ,  $p = 0.212$ ; wave 2:  $\chi^2 = 0.486$ ,  $p = 0.486$ ; wave 3:  $\chi^2 = 2.936$ ,  $p = 0.086$ ) although an increasingly greater proportion of pDLB participants failed the task as MMSE scores worsened at each successive examination.

**Table 1.** Performance of non-demented elderly on cognitive tasks based on pentagon copying result controlling for age, sex, education, and MMSE score

	Incorrect PC (n = 66) mean (SD)	Correct PC (n = 106) mean (SD)	F	Significance of F
<i>Language</i>				
Boston Naming Test	6.0 (2.6)	7.7 (2.2)	2.705	0.102
<i>Perceptual and spatial skills</i>				
Cube	6.3 (2.2)	7.9 (1.3)	16.198	0.000
Coil	4.50 (0.8)	4.83 (0.4)	4.450	0.036
Infinity Loop	5.11 (1.1)	5.67 (0.7)	3.013	0.084
Interlocking Infinity	4.40 (1.4)	5.3 (0.93)	5.655	0.019
Clock Drawing	3.96 (0.97)	4.32 (0.759)	0.946	0.332
Judgment of Line Orientation	15.6 (3.0)	17.5 (2.0)	8.230	0.005
<i>Memory</i>				
Logical Memory I	17.0 (6.8)	19.5 (7.6)	0.286	0.593
Logical Memory (% loss)	38.0 (26)	33.0 (25)	0.652	0.420
Visual Reproduction I	16.0 (7.6)	22.5 (6.9)	11.534	0.001
Visual Reproduction (% loss)	53.0 (32)	44.0 (29)	0.001	0.970
<i>Executive functions</i>				
Phonemic Fluency	26.0 (11)	31.0 (12)	0.204	0.652
Semantic Fluency	11.7 (4.5)	13.8 (4.5)	0.170	0.681
WAIS-R Similarities	3.8 (2.7)	5.6 (2.6)	1.406	0.237

## Discussion

Our results demonstrate that in people without dementia, PC performance is indeed closely and specifically related to performance on other neuropsychological tasks used to assess spatial function [24, 25]. This finding has important clinical implications, as the PC task has many advantages over the other spatial tasks. It takes little time to give, is relatively easy to score, and requires minimal testing equipment for administration. Ala et al. [8] have been criticized for their use of a simple dichotomous scoring method for the PC task (i.e. as per original instructions) [26]. Our finding of an association of PC performance with other spatial tasks with more complex scoring systems supports its continued use. Additionally, the MMSE is often the only cognitive test that is carried out in the clinic as well as in the context of research, and support for the validity of PC as a specific spatial test is important.

PC has been suggested as a test that may potentially be used to differentiate patients with DLB from those with AD early in the disease course [8]. Our results do not support this position for two reasons. First, over one third of community-dwelling people without dementia (CDR = 0) had poor PC. This indicates that the task is a poor diag-

nostic marker for identifying any form of dementia. Second, at an earlier disease stage, when diagnostic precision is currently most difficult (average MMSE 23–25 or ‘pre-clinical’), there was no difference found in PC performance between pDLB and non-DLB participants. Our study did find a greater proportion of pDLB subjects performed poorly on the PC task in the later waves when the dementing process was well established. This is consistent with other studies which have identified faster cognitive decline in DLB as opposed to AD [27–29]. Poor PC, and thus spatial impairment, appears to be a distinguishing feature of people with DLB only once the dementing process is more advanced. The fact that poor PC is so common in the non-demented elderly further reduces its potential use as an early marker of dementia onset.

A limitation of this study is the small subject numbers within the dementia groups, and for this reason the study may not have had sufficient power to detect relationships that were genuinely present. This limitation is not uncommon in studies involving serial assessments of community-dwelling people at these advanced ages. For example, the nonsignificant result on verbal fluency might well be an early distinguishing feature in pDLB and indicate an impairment of frontal systems.

**Table 2.** MMSE and cognitive test performance at 3 waves for pDLB and non-DLB subjects

	Wave 1		Wave 2		Wave 3	
	mean	SD	mean	SD	mean	SD
<i>MMSE</i>						
Non-DLB	25.0	3.5	23.2	4.3	21.0	8.1
pDLB	23.2	3.4	18.3**	5.5	12.6**	8.0
<i>Cube Copy</i>						
Non-DLB	7.1	1.7	6.4	2.4	5.0	3.7
pDLB	6.7	2.1	4.2*	2.9	2.3*	2.9
<i>Phonemic Fluency</i>						
Non-DLB	29.1	10.9	23.1	12.0	17.9	14.7
pDLB	21.8	10.8	13.8*	8.6	7.1*	10.0
<i>Semantic Fluency</i>						
Non-DLB	13.1	6.1	9.6	3.9	8.4	6.2
pDLB	9.6	5.0	6.2*	3.7	4.1*	5.1
<i>Similarities</i>						
Non-DLB	5.1	2.5	4.1	2.5	2.9	2.4
pDLB	4.5	3.7	1.9*	2.3	1.4	2.7
<i>Boston Naming Test</i>						
Non-DLB	6.6	3.0	5.3	3.3	3.7	3.5
pDLB	6.6	2.4	3.5	2.4	1.9	2.4
<i>Reid trial 5</i>						
Non-DLB	5.9	1.2	5.3	1.5	3.8	3.1
pDLB	5.0*	1.1	3.5**	1.7	1.9	2.6
<i>Reid recall</i>						
Non-DLB	3.6	2.0	1.95	2.0	1.9	2.5
pDLB	2.1*	1.8	1.7	2.0	0.3**	0.8

\* p < 0.05; \*\* p < 0.01.

In our study, 80% of the non-DLB group were AD or mixed dementia sufferers, with the remainder suffering from other causes, three of whom we were unable to classify. Whilst this lack of homogeneity may be seen to be a limitation of the study, it reflects clinical reality and thus supports the clinical applicability of the findings. In this regard, the strengths of this study are its serial assessment design over time and representativeness of the broader community, being population-based. Arguably, the lack of autopsy data to confirm diagnosis remains a limitation (participants are still being studied). In order to minimize this limitation, we chose to only examine those patients who fulfilled criteria for pDLB. Neuropathological studies have reported around 80% diagnostic accuracy in this group when coming to autopsy [16].

Whilst we could not validate PC as a reliable discriminator for DLB, our preclinical DLB patients were already performing more poorly than our preclinical non-DLB patients on memory tasks, even at a time when they did not differ in MMSE scores. Over waves, a broader range of cognitive domains differentiated the pDLB group. Cross-sectional studies have suggested that early differences in the cognitive profiles of DLB groups are for perceptual skills [5] and for working memory and frontal executive function [30], although longitudinal studies are lacking.

Only one prospective study by Ballard et al. [29] has looked at the rate and specificity of cognitive decline across a range of cognitive domains in DLB. In their study of clinically diagnosed patients with DLB, they found a prominent decline in verbal fluency. This was interpreted as being consistent with a fronto-subcortical-type cognitive presentation [4]. Such a clinical presentation is consistent with neuropathological evidence of a greater extent of cell loss in the basal ganglia and basal forebrain regions of the brain, in addition to a higher burden of Lewy body pathology in the anterior cingulate cortex [31, 32]. In our study, whilst the differences in Verbal Fluency (phonemic) were not statistically significant initially (they were at waves 2 and 3), at wave 1 pDLB participants were only able to generate an average of 22 words as opposed to the non-DLB's average of 29, raising the possibility that a significant difference might have been found had our sample sizes been larger.

Our finding of early memory impairment in our pDLB patients contrasts with that of Ballard et al. [29] who identified better recent memory in their DLB than their AD group, with the different findings potentially due to the fact that a different type of memory task was employed. Ballard et al. [29] concluded that relatively better memory function in their DLB group was consistent with neuropathological data suggesting hippocampal sparing [33]. However, recent neuropathological reports of cell loss in the hippocampus [34] and Lewy body pathology in the parahippocampus and temporal cortices [32, 35] gives support to our finding of early memory impairment in DLB.

In conclusion, we found PC to be a valid and simple test of visuospatial function. However, there was a large proportion of the non-demented elderly who performed poorly on the task limiting its use as a sole screening tool to differentiate those non-demented from those demented. The suggestion that PC performance is able to differentially diagnose DLB from other dementia subtypes is not supported by this study, with our findings sug-

gesting that tests of fronto-subcortical function and memory may be more sensitive in the earlier stages of the disorder. Further investigation of the meaning of impaired PC performance in this group may best be understood within the rubric of current concepts of 'mild cognitive impairment', the significance of which remains incompletely understood.

## Acknowledgements

This research was supported in part by a grant from the National Health and Medical Research Council of Australia and an Infrastructure Stream C grant from the Department of Health of New South Wales, Australia.

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