Archives of Gerontology and Geriatrics 52 (2011) 153–158

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Differential effects of delirium on fluid and crystallized cognitive abilities

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ARTICLE INFO

Article history:
Received 2 November 2009
Received in revised form 1 March 2010
Accepted 3 March 2010
Available online 30 March 2010

Keywords:
Delirium
Dementia
Cognition
Attention
Reading
Psychogeriatrics
Neuropsychological tests

ABSTRACT

Patients with delirium (acute confusional state) show extensive cognitive deficits. These deficits have typically been measured using tests of fluid cognition, which involve the active processing of mental representations. However, the effects of delirium on stored, crystallized dimensions of cognition, such as well-learnt word pronunciation knowledge, are not known. In this study 37 patients (aged 60–85 years) without delirium were recruited before undergoing cardiac surgery. Cognitive assessments were performed 0–8 days before surgery and again 2–9 days after surgery in order to determine the effects of post-operative delirium (POD) on fluid and crystallized aspects of cognition. Crystallized cognition was tested with the National Adult Reading Test (NART). Fluid cognition was tested with digit span, verbal fluency and Stroop tests. Nine patients (24%) developed delirium post-operatively. Patients with delirium showed significant post-operative deficits on most tests of fluid cognition, but no change in the NART measure of crystallized cognition ($p = 0.95$). These results parallel recent findings in Alzheimer's dementia and suggest that, despite showing extensive deficits of fluid cognitive processing, crystallized cognition is preserved in delirium. The results also suggest that the NART may be a useful tool for assessing premorbid ability in patients with delirium.

1. Introduction

Delirium (or "acute confusional state") is an acute neuropsychiatric disorder characterized by impaired attention, disturbed consciousness and disorganized thinking. It is highly prevalent in the elderly hospitalized population (Siddiqi et al., 2006), and is particularly common following hip fracture (Edlund et al., 2001) or cardiac surgery (Rudolph et al., 2009). Delirium is independently associated with increased mortality, and is a strong risk factor for long-term cognitive decline (Rockwood et al., 1999).

Cognitive impairment is one of the core diagnostic features of delirium (American Psychiatric Association, 1994), although detailed characterization of this impairment is lacking (Bhat and Rockwood, 2007). What is known is that patients show marked attentional deficits (O'Keeffe and Gosney, 1997), and so are impaired on tasks that require 'fluid' cognitive processing; that is, tasks that involve active, flexible processing of neural information, such as retrieving, maintaining, or manipulating mental representations (Horn and Cattell, 1966; Craik and Bialystok, 2006). For instance, patients with delirium are impaired at remembering arrays of objects (Hart et al., 1996) or words (Brown et al., 2009); responding to repeated presentations of a given target (Hart et al., 1996; O'Keeffe and Gosney, 1997; Lowery et al., 2008); and repeating or reversing oral sequences of numbers or words (Christensen et al., 1994; O'Keeffe and Gosney, 1997; Simon et al., 2006).

Fluid cognition can be contrasted with crystallized cognition, which reflects the stores of knowledge that have been accumulated through the product of learning and experience, and which is not concerned with the dynamic processing of this content (Horn and Cattell, 1966; Craik and Bialystok, 2006). Crystallized cognition includes 'well-learnt' knowledge, such as vocabulary, grammar, procedural skills and general knowledge. Crystallized cognition is typically measured by assessing participants' ability to accurately pronounce irregularly spelt words, or to recognize pieces of information that have been learnt throughout the lifetime (Scott et al., 2006).

Fluid and crystallized dimensions of cognition are believed to utilize separate resources in the brain, and can be differentially

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doi:10.1016/j.archger.2010.03.005

affected by particular neural events. For example, patients with mild to moderate Alzheimer's dementia show a sparing of crystallized cognition despite having marked deficits in fluid cognitive processing (McGurn et al., 2004). Preserved crystallized cognition has also been shown in patients with depression (Crawford et al., 1987) and schizophrenia (O'Carroll et al., 1992), who also have known deficits in fluid cognition. Furthermore, these two dimensions of cognition show different developmental trajectories over time: fluid cognition develops rapidly until early adulthood and subsequently shows a steady decline, whereas crystallized cognition shows a more gradual pattern of growth but is then maintained or increases throughout older adulthood (Horn and Cattell, 1967; Craik and Bialystok, 2006). This stability of crystallized cognition in the face of declines in fluid processing abilities means that patients' performance on tests of crystallized cognition can be used to reliably estimate their premorbid levels of functioning (Crawford et al., 2001). Such estimates of prior ability are particularly useful when trying to assess the extent of decline in individuals presenting with cognitive difficulties.

Whilst delirium is known to have pervasive effects on fluid cognition, its effect on crystallized cognition is not known. This is important as a better understanding of the cognitive domains that are affected in delirium could provide insights into the pathophysiological mechanisms that underlie it. Furthermore, if crystallized cognition is found to be unaffected by delirium, then patients' performance on these tasks might be useful for estimating their premorbid level of functioning. We therefore addressed this issue by measuring aspects of fluid and crystallized cognition in older patients before and after they underwent cardiac surgery, and then comparing the degree of pre- to post-operative changes in cognition between patients who did and did not develop delirium post-operatively. We hypothesized that crystallized cognition would be preserved in delirium, as it is in Alzheimer's dementia, and that this would contrast with substantial deterioration in fluid cognition.

2. Subjects and methods

2.1. Participants

Thirty-seven patients of mean age 70.5 ± 7.3 years (±S.D.) 26 males, completed the study. All patients were aged over 60 years, and were recruited on an opportunistic basis prior to undergoing coronary artery bypass graft (CABG), aortic valve replacement (AVR), or combined CABG and AVR surgery. This population was selected due to the high incidence of POD that occurs in patients of this age group undergoing cardiac surgery (Rudolph et al., 2009). Patients with evidence of dyslexia, dementia, or severe visual or auditory impairment, or who did not speak English as a first language, were not recruited. Forty-eight patients initially provided written informed consent to take part in the study. However, 11 of these patients did not complete the study (five patients were discharged before being able to undergo both testing sessions, five patients withdrew from the study, and one patient experienced prolonged post-operative complications that prevented her from completing the study), resulting in the final sample size of 37.

2.2. Procedure

Patients' cognition and delirium status were assessed both pre- and post-operatively. Pre-operative assessments were conducted on hospital wards, 0–8 days (mean = 1.5 ± 1.6) before surgery. Post-operative assessments were carried out in hospital, 2–9 days (mean = 4.1 ± 1.7) after surgery. All cognitive and delirium assessments were conducted by two researchers (HF and JR) who had been fully trained by a senior geriatrician (AM) and a psychologist (LB). The study was approved by the Scotland A Research Ethics Committee.

2.2.1. Cognitive tests

The cognitive tests were administered in the same, fixed order for each patient and in each session. Crystallized cognition was assessed using the NART (Nelson, 1982). In this test, patients are asked to read aloud 50 English words with irregular grapheme–phoneme or stress patterns. The NART provides an estimate of crystallized verbal knowledge (Scott et al., 2006), and is relatively independent of fluid cognition (Crawford et al., 1989). Before beginning the test, patients were given a brief practice task to ensure comprehension of instructions. For this, patients were asked to read aloud five common, regularly spelled words (bag, car, shop, paper, toast) that were printed in black, 24 point, 'Times New Roman' font. All patients successfully completed this practice task in both sessions. The 50 words of the NART test, printed in a 26 point font, were then presented to the patient. The patient was asked to read each word aloud, making his/her best guess for any words they were unsure of. The patient was prompted by the experimenter to continue with the task, and to attempt each word, when necessary. The NART score was defined as the number of words correctly pronounced by the patient.

Fluid cognition was measured using tests of verbal fluency, Stroop and digit span. Verbal fluency was assessed by asking patients to produce as many words as possible (excluding proper nouns, numbers and derivatives of a previously given word) beginning with a target letter specified by the experimenter. Different target letters were used in the pre ("T") and post ("S") operative test sessions in order to minimize practice effects. Fluency scores were defined as the number of permissible words produced in 1 min. The test was preceded in both sessions by a non-scored 30 s practice session using the target letter "R".

Stroop performance was then assessed using the Victoria version of the Stroop test, which is particularly appropriate for older age groups with potential cognitive impairment (Spreen and Strauss, 1998). This test consists of three consecutive tasks: D, W and C. In task D, patients are asked to name aloud the colors of 24 dots (six each printed in red, blue, green and yellow ink), presented in a 4 × 6 array. Next, in task W, patients are asked to name the colors in which 24 words (six each of "hard", "when", "and", and "over", printed in the same colors as for task D) are printed. Finally, in task C, patients are asked to name the colors in which 24 further words (this time the words "blue", "green", "red" and "yellow") are printed. These words are also printed in the same colors as for task D, with the color of each word always being incongruous to the printed color name. Patients were instructed to name the colors as quickly as possible for each task. They were prompted to continue if they stopped or lost their place on any of the three tasks, and any errors made by the patient were corrected during the task by the experimenter, as per the standard test instructions. The time taken to complete each task was used to measure patients' performance. The times that each patient took to complete tasks D and C were also used to calculate a Stroop "interference" score using the formula $C - D/D$ (where C is the number of seconds taken to complete task C, and D is the number of seconds taken to complete task D).

Digit span was assessed using the forward and backward digit span tasks of the Wechsler Memory Scale III (Wechsler, 1998). The experimenter read a string of digits to the patient, who was then required to repeat the string back in either the same or the reverse order. The lengths of the strings started at two digits in each task, and were gradually increased to a maximum of nine digits in the forwards task and eight digits in the backwards task. Two trials of each span length were presented in each task, and the task was discontinued if a patient responded incorrectly to both trials of any