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The Short-term Effects of Coronary Artery Bypass Graft (CABG) Surgery on Cognitive Performance

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Declaration:

This work has not been submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

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Abstract

Considerable research evidence suggests that post-operative cognitive impairment is a common complication of coronary artery bypass graft (CABG) surgery. This study evaluated the short-term effects of CABG surgery on cognitive performance one to two days prior to surgery (baseline) and one-month post-surgery (follow up). 40 CABG surgical patients and 40 healthy, nonsurgical control participants were assessed with a standard neurocognitive battery that evaluated seven areas of cognitive functioning. Visioconstruction, visual memory, verbal memory, attention, psychomotor speed, executive functioning and language were measured. Additionally, the Beck Depression Inventory (BDI-II) and State-Trait Anxiety Inventory (STAI) were included to assess mood and anxiety states pre- and post-operatively. Demographic data pertaining to participants' general medical conditions were also collected. The repeated measures ANOVA with mixed designs procedure showed cognitive improvement on the domains of visioconstruction (p = 0.017), visual memory (p = 0.001), psychomotor speed (p = 0.001), executive functioning (p = 0.012) and language (p = 0.001). Significant cognitive decline on the domain of verbal memory (p = 0.026) was also found in both control and surgical groups. Furthermore, changes in mood and anxiety states did not influence post-operative changes in neurocognitive performance. The results yielded in the present study are mixed and confirm the multifactorial problem of studying cognitive functioning post-CABG surgery.

Introduction

Coronary artery disease (CAD) is the most common cause of heart disease as well as the most important single cause of death in developed countries all over the world (Julian, Cowan & McLenachan, 2005). It has been estimated that CAD will be the largest single cause of death causing disease burden worldwide by the year 2020 (World Health Organisation, 1999).

CAD is a cardiovascular disorder caused by a build-up of a mass of fat (atheroma) in the wall of the coronary arteries, hence partly blocking the vessel transporting blood to the heart muscle or myocardium limiting blood flow, thus resulting in a painful discomfort in the chest (angina pectoris) or a heart attack (myocardial infarction) – this occurs when the coronary artery has been completely blocked, causing heart muscle death (Phibbs, 2007).

Symptoms which coronary artery disease (CAD) patients may have include breathlessness and chest pain during times of physical exertion and emotional stress. The cause of atherosclerosis or hardening of coronary artery walls is unknown. However, Timmis, Nathan and Sullivan (1997) have argued that reducing potentially reversible risk factors are important as it protects against development or further CAD progression. Modification in lifestyle is usually required through changing diet by controlling cholesterol and fat intake, reducing weight if the patient is obese, lowering blood pressure, maintaining good glycaemic control in diabetes and quitting smoking. Engaging in regular exercise and reducing mental stress through utilising relaxation techniques are also thought to prevent CAD.

Timmis, Nathan and Sullivan (1997) propose some irreversible risk factors which contribute to CAD progression. Such factors include: (1) age – the risk of coronary artery disease increases progressively with increasing age; (2) male sex – men are at greater risk than women of comparable age to develop CAD; (3) family history – genetic predisposition to hypertension, Diabetes Mellitus and hypercholesterolaemia (high cholesterol level) all contribute to an increased risk; (4) personality type – whether one is Type-A (chronic sense of time urgency) or Type-B (more placid and relaxed). Type-A personalities have been associated with increased risk; however, evidence remains inconclusive (Timmis, Nathan & Sullivan, 1997; Phibbs, 2007).

Patients can also be adequately treated with medication (Mullany, 2003). Medication is often used to widen coronary arteries, thereby increasing the oxygen intake of the heart muscle (Phibbs, 2007). Nevertheless, some individuals will require surgical treatments to relieve them of chronic symptoms of CAD.

There are various surgical procedures that patients suffering from CAD can undergo, such as Percutaneous Transluminal Coronary Angioplasty (PTCA) with Intra-coronary Stenting and Off-pump Cardiopulmonary Bypass Graft Surgery (OPCAB). PTCA is a non-invasive surgical technique for opening obstructed coronary arteries through the use of inflating special balloons in the blocked artery. OPCAB is a form of open-heart surgery, similar to that of traditional Coronary Artery Bypass Graft Surgery (CABG), but performed on a beating heart (patient is not connected on the cardiopulmonary bypass unit) (Pillai & Wright, 1999).

This research is specifically concerned with the traditional Coronary Artery Bypass Graft Surgery (CABG) procedure as mentioned above, as it has become a primary treatment option for CAD (Blumenthal, Mahanna, Madden, White, Croughwell & Newman, 1995; Hunt, Hendrata & Myles, 2000). While it is commonly believed that CABG surgery benefits patients physically, much debate has surrounded the topic of whether it may affect patients cognitively. This research is a continuation of an earlier study which aims to examine the short-term effects of CABG on cognitive performance in a South African context.

Coronary artery bypass surgery (CABG)

Mason Sones laid the foundation for the development of coronary artery bypass surgeries in the 1960s when he discovered coronary cineangiography (Sabik, 2007). The practice of coronary artery bypass procedures since then has been widely adopted throughout the world. CABG is an effective procedure known to prolong survival, relieve angina, and improve quality of life. It is estimated that more than 800 000 bypass procedures are performed each year worldwide (Hunt, Hendrata & Myles, 2000; Selnes & McKhann, 2001; Estrada, Young, Nifong & Chitwood, 2003; Potter, Plassman, Helms, Steffens & Welsh-Bohmer, 2004; Sabik, 2007).

During coronary artery bypass surgery, the heart is stopped and connected to a heart-lung machine which does the work of both the heart and lungs. The machine removes blood from the superior and inferior vena cavae, bypassing the heart and lungs. It then oxygenates the blood and returns it back to the arteries. This is known as cardiopulmonary bypass (CPB) (Phibbs, 2007). Surgeons then either harvest saphenous veins from the legs, radial arteries from the forearm, or internal thoracic arteries from the chest of a patient as conduit veins for the bypass procedure. Depending on the number and location of blockages, multiple bypasses may be done (Sabik, 2007). The surgeon sutures cannulae into the heart and CPB is started. Once CPB begins, the aorta is cross-clamped and cardioplegia (paralysis of the heart) is induced. The conduit vein is sewn on, to replace the old, blocked section of coronary artery (Mullany, 2003). Once the new grafts are in place, the aortic clamps are removed, allowing blood to flow freely to the myocardium (heart). The heart is slowly weaned from cardiopulmonary bypass, and the cannulae are removed.

It is of great concern that while CABG surgery reduces physical symptoms of chest angina post-operatively, peripheral and central nervous system complications arise, which cause morbidity after surgery. Caplan, Hurst and Chimowitz (1999) note that cerebral dysfunction is attributed to air embolization and inadequate cerebral blood flow during CPB. Brain imaging studies have shown brain swelling, reduced regional blood flow, and decreased neuronal cell populations after CPB, therefore implicating CPB in post-operative cognitive dysfunction (Tardiff *et al.*, 1997; Kilo *et al.*, 2001). There is also evidence that the brain is bombarded with microemboli during CABG surgery. Brown, Moody, Challa, Stump and Hammon (2000) found that microemboli were more numerous in patients who underwent longer durations of cardiopulmonary bypass. While Borger, Peniston, Weisel, Vasiliou, Green and Feindel (2001) found that patients with longer cardiopulmonary bypass times tended to perform worse on performance tests of learning, memory, attention and concentration post-operatively.

Post-operative neurological and neuropsychological dysfunctions are considered to be important complications of CABG surgery (Roach *et al.*, 1996; Tardiff *et al.*, 1997; Selnes, Goldsborough, Borowicz, Enger, Quaskey & McKhann, 1999; Kilo *et al.*, 2001; Gao, Taha, Gauvin, Othmen, Wang & Blaise, 2005). However, despite the large body of literature documenting the presence of cognitive decline in mental abilities, concentration, attention, short-term memory as well as speed of cognitive processing after CABG (Ahlgren, Lundqvist, Nordlund, Aren & Rutberg, 2002), there is little consensus in regard to incidence and extent of cognitive impairment. Short-term cognitive changes (especially in memory) post-CABG surgery have been recognised, and incidences have been reported to vary widely from 33 to 83 percent (Newman *et al.*, 1995; Andrew, Baker, Bennetts, Kneebone & Knight, 2001; Selnes & McKhann, 2001; Kadoi & Goto, 2006).

Various researchers argue that there are seeming disparities in the literature on the incidence of adverse cognitive outcomes (Selnes *et al.*, 1999). Stroobant, Van Nooten, Van Belleghem, and Vingerhoets (2002) found no significant difference in post-operative neuropsychological performance after CABG surgery, as did Taggart, Browne, Halligan and Wade (1999). On the other hand, Selnes, Grega, Borowicz, Royall, McKhann and Baumgartner (2003) found cognitive improvement in CABG and control participant groups from their pre-operative baseline assessment to three months post-surgery. A greater improvement in verbal memory was also found in the CABG group (Selnes *et al.*, 2003). In concordance with these findings, other authors also found cognitive improvement in patients after CABG surgery on domains of attention, verbal memory and word fluency (Dupuis *et al.*, 2006).

Mahanna *et al.* (1996) argue that a possible reason for these differences is because there are no uniform criteria for assessing cognitive decline, while Van Dijk, Keizer, Diephuis, Durand, Vos and Hijman (2000) point out that this variability is caused in part by a number of methodological factors, as well as limitations. These will be outlined below:

Definitions of cognitive decline

It has been argued that variability in the incidence of neuropsychological deficits depends on the statistical criteria used (Kneebone, Andrew, Baker & Knight, 1998). Conventional methods of looking at neurocognitive decline has been to use the downward change in one standard deviation (1 SD) in a domain of cognition, or 20 percent or more decline on test scores (Blumenthal, Mahanna, Madden, White, Croughwell & Newman, 1995; Newman *et al.*, 2001; Slade, Sanchez, Townes & Aldea, 2001). Although this method of determining cognitive decline has been widely used, it also has been criticised heavily as researchers argue that this method may lead to arbitrary conclusions.

Collie, Darby, Falleti, Silbert and Maruff (2002) and Taggart and Westaby (2001) highlight that *true* change in cognitive test scores may be obscured by increased performance, owing to practice effects and other factors. Kneebone *et al.* (1998) criticise the use of the 1 SD method claiming that it has no theoretical underpinning and is an arbitrary approach in assigning deficit to those that have declined 1 SD or more. These researchers further contend that this approach is unable to detect whether "real" change has occurred or not. Furthermore, it has been observed that using this type of arbitrary cut-off method may over- or under-estimate incidence of neuropsychological dysfunction post-CABG surgery (Blumenthal *et al.*, 1995; Kneebone *et al.*, 1998). An example demonstrating this is a study done by Keizer, Hijman, Kalkman, Kahn and Van Dijk (2005). Their results illustrate how cognitive decline post-CABG surgery may previously be over-estimated as "incidence of postoperative cognitive decline changed dramatically from 31% to 8% after a different criterion for decline and inclusion of control subjects was applied" (Selnes & Zeger, 2007, p. 374).

Inclusion of baseline assessments

Many previous studies did not employ pre-operative neuropsychological testing to evaluate change in patients post-operatively (Van Dijk *et al.*, 2000). At a consensus meeting in 1994, it was recommended that neuropsychological testing be performed prior to CABG surgery so that accurate baseline information could be collected (Murkin, Newman, Stump & Blumenthal, 1995). Selnes and Zeger (2007) further suggest that pre-operative testing is important and has now become the established norm for measuring impact of CABG surgery on cognitive performance.

Control groups and sample size

Many studies also did not include control groups in their research. Slade *et al.* (2001) emphasise that control groups need to be implemented to separate cognitive performance owing to practice effects from real physiological improvement. These authors suggest implementing a friend control group to control for factors such as gender, age, and education background. Borowicz, Goldsborough, Selnes and McKhann (1996) maintain that it may also be necessary to include another surgical group in CABG studies to control for other crucial variables such as distress, anxiety, anaesthetic effects. Utilising small sample sizes of surgical participants poses as another methodological limitation, thus creating an inability to make generalisable conclusions of true incidence of cognitive decline (Borowicz *et al.*, 1996).

Use of neuropsychological tests

Van Dijk *et al.* (2000) point out that large numbers of neuropsychological tests have been used to assess various cognitive domains in a number of studies. However, owing to differences in the cognitive domains studied, comparisons of results are hampered. Therefore it has been suggested that tests used should assess a number of cognitive domains and conform to consensus guidelines as stipulated. It is further noted that "because of the multifocal nature of the potential lesion locations, no single test will always detect postoperative neurobehavioral dysfunction" (Murkin *et al.*, 1995, p. 1289).

Learning effects

Improvement in performance after exposure to the same neuropsychological tests is known to occur (Selnes *et al.*, 1999). Repeat testing leads to an increase in learning effects, hence using tests which are resistant to learning effects and well-established alternate forms of tests which assess the same cognitive domains is necessary in eliminating bias toward being less able to detect cognitive change in CABG patient populations (Van Dijk *et al.*, 2000; Andrew *et al.*, 2001; Slade *et al.*, 2001).

Changing patient populations

Borowicz *et al.* (1996) report that the patient population undergoing CABG is increasingly becoming older. The authors observe the average age of CABG patients to be 52 years in 1974, increasing to 64 years in 1994, and is currently 65 years of age. It has been further noticed that one third of patients undergoing CABG surgery are over 70 years of age. Increasing age has been thought to be a risk factor for cognitive decline, particularly if patients are over 70 years of age, as older patients present with more chronic disease risk factors (Borowicz *et al.*, 1996; Potter *et al.*, 2004; Selnes, McKhann, Borowicz & Grega, 2006); thereby causing problems of quantifying degrees of cognitive change and difficulty in attributing cause-effect relationships.

Differing methodologies

From the literature reviewed, various independent research studies seem to differ enormously in their methodology and approach to investigating cognitive dysfunction in surgical groups post-CABG surgery. Mahanna *et al.* (1996) used five sets of criteria to define cognitive decline on the same patient sample in their study, and concluded that the large variation in reported incidences of cognitive decline after CABG can be attributed to the different criteria used to define cognitive impairment. Ahlgren *et al.* (2002) on the other hand, used a neuropsychological battery of tests as well as a standard on-road driving test to measure cognitive performance after CABG. The results of their study indicated that cognitive functions important for safe driving might be influenced after cardiac surgery.

Silbert *et al.* (2004) employed a computerised battery of neuropsychological tests for measuring cognitive change after CABG surgery and concluded that computerised tests may be more suitable for measuring cognitive change after CABG than conventional neuropsychological tests. Potter *et al.* (2004) administered brief assessments of cognitive status to CABG patients telephonically. Researchers in this study utilised epidemiological datasets, no medical data regarding techniques employed and equipment used in individual surgeries was collected, and self-reports from patients were used. Results from this study suggest that timing of CABG surgical procedures may be an important predictor of positive cognitive outcomes. These differing methodologies create a multitude of possible outcomes and therefore act as a factor in itself – complicating interpretation of incidence data.

Aetiological factors relating to cognitive decline

Various authors in this field have identified differing aetiological factors as sources of neuropsychological dysfunction after cardiac operations. It is well recognised that emotional states such as depression and anxiety affect neurocognitive test performance on domains of attention and memory (Blumenthal *et al.*, 1995; Murkin *et al.*, 1995; Borowicz *et al.*, 1996; Andrew, Baker, Kneebone & Knight, 2000). Previously, it was believed that short-term cognitive decline after CABG surgery was attributable to depression (Magni *et al.*, 1987; Strauss *et al.*, 1992).

Studies done by McKhann, Borowicz, Goldsborough, Enger and Selnes (1997) and Tsushima, Johnson, Lee, Matsukawa and Fast (2005) found no relation between depression and anxiety on neuropsychological tests after CABG surgery. Even though low levels of depression and anxiety do not seem to affect neuropsychological test performance, it is yet to be demonstrated that moderate levels of depression and anxiety can affect cognitive functioning in CABG patients (Tsushima *et al.*, 2005). It has been found that CABG patients' pre-operative depression status is a good predictor of post-operative depression scores. Patients that were depressed before the operation were also depressed afterwards (McKhann *et al.*, 1997; Andrew *et al.*, 2000; Millar, Asbury & Murray, 2001; Rymaszewska, Kiejna & Hadrys, 2003).

Social support

From another perspective, it has been argued that patients with chronic, disabling neurological illnesses and limited social support are at risk for cognitive decline after CABG surgery (Ho *et al.*, 2004). It has been hypothesised that the size of one's social interactions and networks is linked with shielding against cognitive decline as patterns of social interaction are associated with engaging aspects of cognitive function (Seeman, Lusignolo, Albert & Berkman, 2001). Therefore, it can be further suggested that social support may act as a protective factor, curbing mortality for those with cardiovascular disorders (Connerney, Shapiro, McLaughlin, Bagiella & Sloan, 2001).

Education

Dupuis *et al.* (2006) and Taggart and Westaby (2001) maintain that baseline intellectual function is a good predictor of severity of neurocognitive decline. Education level, therefore, is an important factor in cognitive functioning and needs to be included in studies of cognitive performance, as it is important to control for the effects of education in group comparison scores before and after surgery. Some investigators have found that patients with higher levels of education were associated with less cognitive decline post-CABG surgery (Millar *et al.*, 2001; Ho *et al.*, 2004). This finding is in accordance with previous results from Newman *et al.* (1995) who noticed that increase in years of education was associated with a significant decrease of cognitive decline in eight of nine cognitive measures studied. Researchers note that a possible explanation for this is that patients with higher levels of education may have more neurocognitive reserve and can therefore adequately compensate for acquired cognitive problems (Newman *et al.*, 2001). In contrast to this finding, other authors found no significant effects of education on mental decline post-operatively (Selnes *et al.*, 1999; Smith *et al.*, 2000).

Medical and surgical factors

As an alternative explanation, it has been argued that change in cognition after CABG is associated with both medical and surgical variables and that the spectrum of cognitive change observed after CABG has multiple determinants (Newman *et al.*, 1995; Selnes *et al.*, 1999; Royter, Bornstein, & Russell, 2005). Such contributing parameters have been underlined to be anaesthesia, hypoperfusion, hypothermia, microemboli, comorbidity and disease severity, which may all have an impact on cerebral integrity of the post-operative patient as cognitive dysfunction has been reported to persist for several months or even years after CABG (Bendszus *et al.*, 2002; Stroobant *et al.*, 2002).

Patient-related factors

Several patient-related factors such as gender, older age and diabetes have been highlighted to impact on the neurologic outcome after CABG procedures (Diegeler *et al.*, 2000; Gao *et al.*, 2005; Kadoi & Goto, 2006). These factors will be further outlined below:

Gender

Although men are more likely to have CABG surgeries, it has been noticed that an increasing number of women are undergoing bypass surgeries to treat CAD (Hogue *et al.*, 2001; Keresztes, Merritt, Holm, Penckofer & Patel, 2003). Some researchers have found that female patients have more cardiovascular risk factors at the time of surgery such as older age, diabetes and hypertension, leading to higher rates of mortality, post-CABG surgery (Artinian & Duggan, 1995; Selnes *et al.*, 1999; Hogue *et al.*, 2001). While other studies have reported that in-hospital mortality is similar in men and women after CABG surgery (Jacobs *et al.*, 1998; Jacobs, 2003). Following this, it has been established that gender was not found to predict cognitive outcome post-CABG surgery (Du Puis *et al.*, 2006; Selnes *et al.*, 2006).

Older age

A number of investigators have identified older age as a possible factor for post-operative neurocognitive dysfunction (Roach *et al.*, 1996; Taggart & Westaby, 2001; Selnes *et al.*, 2006). It has been suggested that an increase in atherosclerosis with occult cerebrovascular disease, and increase in risk of embolisation are most commonly accepted explanations for post-operative cognitive decline associated with increasing age (Newman *et al.*, 1995). In a study done by Newman *et al.* (1995), age was shown to predict cognitive decline in seven of nine measures, with short-term memory showing the greatest effect of age.

However, a study done by Smith *et al.* (2000), found that age was not a significant predictor of cognitive decline, although a trend was observed with patients older than 65 years. The researchers propose some possible confounding variables between age and the likelihood of developing neuropsychological deficits to be "the prevalence of a preoperative history of cerebrovascular disease, pulmonary disease, and CHF as well as intraoperative palpable aortic atherosclerotic plaque" (Smith *et al.*, 2000, p. 431).

Gao *et al.* (2005) further notes that "the aged brain is different from younger brains in several important aspects, including size, distribution and type of neurotransmitters, metabolic function, and capacity for plasticity" (p. 3665). For this reason, the elderly may be more susceptible to post-operative cognitive dysfunction after major surgery, compared to middle-aged patients.

Diabetes

Previous research has shown that patients with diabetes mellitus (DM-II) undergoing CABG have an increased risk of morbidity and mortality post-operatively, with greater risk for cardiovascular and septic complications (McAlister, Man, Bistritz, Amad & Tandon, 2003); hence diabetes remains a powerful predictor of adverse outcomes after CABG surgery (Casserly & Moliterno, 2004). In a study by Selnes *et al.* (1999), having a history of DM-II was significantly associated with decreased psychomotor speed at one-month post-CABG surgery. Kadoi and Goto (2006) explain that possible mechanisms for diabetes mellitus and adverse cerebral outcomes post-CABG surgery may be due to deficiencies in cerebral autoregulation during CPB.

Post-surgical cognitive decline continues to be a major concern for many patients undergoing CABG with CPB. Therefore, it has been further suggested that identification of additional factors may help clinicians to select more suitable modes of revascularisation and to better counsel patients about the risks and benefits of surgery (Ho *et al.*, 2004; Royter, Bornstein & Russell, 2005).

CABG surgery is the most common cardiac operation in the world with the number of procedures performed on patients older than 65 years of age rising dramatically (Harrison, Schneidau, Ho, Smith, Newman & Treasure, 1989; Bendszus *et al.*, 2002; Pierson *et al.*, 2003; Dupuis *et al.*, 2006). Studies have shown this procedure to be effective in improving blood supply to the heart, relieving symptoms of angina or chest pain, and in some instances prolong life. However, CABG surgeries with the use of cardiopulmonary bypass (CPB) are associated with significant cerebral morbidity; mainly, stroke and cognitive decline (Van Dijk *et al.*, 2000). While various authors have identified differing short-term aetiological deficits after CABG procedures using sensitive tests of cognitive function, many of such aetiological models are plagued by methodological factors and limitations as already mentioned. Therefore, further research on cognitive outcome post-CABG surgery is needed. It has been proposed that efforts need to be made to provide research that overcomes any methodological issues. For this reason, core neuropsychological test batteries to accommodate for special conditions such as cardiac surgeries, as well as more standardised methodological approaches need to be agreed upon, so as to facilitate comparisons between researchers and investigative teams.

Significance of this study

Research documenting cognitive decline after CABG assumes considerable importance as it has been suggested that the cognitive abilities of people may be affected by the CABG procedure. According to a preliminary study done on patients undergoing CABG surgery, neurocognitive improvement was found postoperatively on the cognitive domains of visual memory, psychomotor speed and dorsolateral functioning (Chiang, 2005). In light of these mixed results, further investigation into this type of CABG research is crucial. This study attempts to overcome previous methodological limitations as mentioned above, thereby aiding in the identification of possible additional factors relating to cognitive decline, ultimately contributing to clinicians providing CAD patients with improved knowledge about the risks and benefits of CABG surgery.

Aim of Study

Considerable research evidence suggests that coronary artery bypass grafting surgery may result in short-term cognitive impairment (Van Dijk *et al.*, 2000). The aim of this study is to investigate the short-term effects of CABG surgery on cognitive performance, while overcoming current methodological limitations in the existing literature. The aim is therefore to assess neurocognitive functioning of patients prior to surgery (one to two days earlier) and again, approximately one-month after surgery, to determine whether a significant difference exists in cognitive performance. Consensus guidelines for assessing neurocognitive outcomes after cardiac surgery will be observed to overcome previous methodological limitations.

Method

Participants

Patients

43 eligible CABG patients participated in this study initially, of which 29 were male and 14 were female. Owing to attrition and death soon after surgery, three female participants were not included in the final sample of 40 CABG patients (29 males and 11 females). The following criteria were utilised in selecting the patient sample:

- English or Afrikaans home language speakers,

- symptomatic heart disease,
- able to sit up-right,
- no history of previous coronary artery procedures,
- no extensive non-cardiac impairments,
- readily available for pre- as well as post-operative assessments and interviews, and
- able to give his or her informed consent.

These criteria were chosen for the purposes of aiming to limit any other extraneous factors, which could possibly influence data collected.

Exclusion criteria

Participants enrolled in the surgical group were excluded if they were scheduled for further surgical procedures in addition to CABG surgery. Patients who underwent emergency bypass surgeries were also excluded as pre-operative data was difficult to obtain.

Control group

40 individuals participated in this study in a non-surgical control group. The individuals that were selected were required to fulfil the following criteria:

- English or Afrikaans home language speakers
- no medical conditions or previous cognitive disorders which may directly or indirectly affect current cognitive functioning (e.g. Alzheimer's Dementia)
- available for interviewing around the same time that patients were interviewed, and
- capable of giving informed consent.

These criteria were specifically employed to ensure that the sample of control participants could be matched as closely as possible to the surgical group in terms of demographic variables such as age, gender, language, and education level. Furthermore, it has been suggested that a suitable control group also allows the possibility of determining whether significant observed changes in cognitive test scores resulted from normal ageing in populations with cardiovascular risk factors, from practice effects or simply from the cardiac procedures themselves (Borowicz *et al.*, 1996; Selnes *et al.*, 1999; Slade *et al.*, 2001).

Materials

Neuropsychological testing

All participants in the surgical group and matched control group were administered a standardised neuropsychological battery of tests one to two days before surgery (baseline) as well as one month afterward (follow up).

It has been recommended that to introduce uniformity into neuropsychological testing and defining of postoperative cognitive decline, specific sets of neuropsychological tests need to be used to evaluate performance in all major areas of cognitive functioning (Murkin *et al.*, 1995; Van Dijk *et al.*, 2000). Silbert *et al.* (2004) suggested that the following tests are needed to evaluate such cognitive functioning; thus, these tests were used in this study to assess participants:

Visioconstruction:

- Rey Complex Figure – Copy trial

Visioconstruction abilities of participants are assessed in this task by asking them to copy a complex visual design.

Visual memory:

- Rey Complex Figure – Immediate and delayed recall trials

Participants were required to recall a complex visual design previously copied immediately after copying the figure, and again at a later time frame during the assessment.

Verbal memory:

- Rey Auditory Verbal Learning Test (RAVLT)

This word-list learning task consists of two 15-word lists which are presented to participants over a span of eight trials and assesses participants' verbal learning.

Attention:

- RAVLT (Trial 1)
- Digit Span – forward and backward

Participants were asked to repeat an increasing series of random digits. Participants first repeated the numbers forward, and then another series of digits were recalled backwards.

Psychomotor speed:

- Digit Symbol – Coding

This timed task requires participants to reproduce a series of geometric symbols that are paired with numbers using a coding scheme. Participants were asked to draw each symbol underneath its corresponding number within a 120-second time limit.

Executive functioning:

- Delis Kaplan Executive Functioning System (D-KEFS) Colour-word Interference (or Stroop Test)

This timed task examines ventromesial functioning. Participants were shown words in various colours. A number of these words were randomly typed in different colours to what the words actually read. For example, the word *blue* may be typed in red ink and later re-appear in green ink. In this task, participants were required to say the colour which a word is typed in, and not what the word actually read.

- Similarities Subtest of WAIS III

This task investigates the dorsolateral functioning of participants. Participants were given two words, for example, socks and shoes. They were then required to state what was alike or similar between the two objects or concepts. For example, socks and shoes are wearing apparel or clothing. The pairs of words then become increasingly abstract and difficult (for example, what is similar between a fly and a tree?).

Language:

- Boston naming test (short version)

Participants were asked to name a series of 30 line drawings

In addition to these tasks, all participants were administered the Beck Depression Inventory (BDI-II) (short version) at baseline and one-month follow up assessments. The BDI-II scale consists of 13 items, which assesses the intensity of depression in clinical and normal patients; thus, allowing the researcher to investigate the possibility of depression as a predictor of cognitive decline.

Furthermore, the Spielberger State-Trait Anxiety Inventory (STAI-S and STAI-T) was also given. This instrument is utilised in measuring anxiety in adults. The qualities evaluated by this scale are feelings of apprehension, tension, nervousness and worry. By using an anxiety scale, it further enabled the researcher to control for anxiety as a possible extraneous variable in affecting performance on neuropsychological testing.

All participant groups were also administered the Information Subtest of WAIS III at baseline to establish a level of prior cognitive functioning as it is resistant to change.

This test has been normed for the South African English and Afrikaans population group.

Silbert *et al.* (2004) notes that the above-mentioned tests show sensitivity to post-operative cognitive decline because they are able to detect change. Additionally, it can be emphasised that most of these tests have high test-retest reliability, are relatively easy to administer and have little or no practice effects. However, as a precaution to avoid learning effects, alternate forms for visual memory (Taylor Complex Figure), as well as different word lists for the Rey Auditory Verbal Learning Test (RAVLT) were used on follow up assessments. The tasks which participants were required to perform therefore enabled the researcher to distinguish whether cognitive decline was of a functional or an organic origin.

Procedure

The present study is part of a larger research study looking into the effects of three cardiac procedures on cognitive performance. Cardiologists and cardiothoracic surgeons in Groote Schuur Hospital and Gatesville Medical Centre were approached with criteria lists for surgical and control groups for the study at large. Post-graduate students in the field of Psychology were trained in administering and scoring the neuropsychological tests outlined above, and were randomly assigned eligible individuals for neuropsychological assessment. Although there were only three independent raters to score the assessments, the tests used in this battery are shown to have high inter-rater reliability (Lezak, Howieson & Loring, 2004), therefore consistency is maintained.

Ethical considerations

To uphold principles of ethical research, eligible participants took part in this study of their own free will. Participants that decided to take part were given an information sheet, which explained the overall purpose of the research – that of investigating cognitive performance prior to, and following cardiac procedures. Individuals were then asked to give informed consent with the understanding that confidentiality of information provided, as well as their identity would be safeguarded. Participants partook in two assessments at different time frames. The first time frame was established to assess baseline cognitive performance of participants either from the control group or surgical group, and the second time frame being the one-month follow up evaluation. Before any neuropsychological assessments began, participants were adequately informed about the study as well as the procedures that were involved. They were then given an opportunity to ask any questions pertaining to the study (for participant information sheet and consent form, see Appendix A).

Neuropsychological assessments

Assessments consisted of a broad 1.5 hour long neuropsychological evaluation that begun with measures of mood and anxiety; namely the Beck Depression Inventory (BDI-II), and the State-Trait Anxiety Inventory (STAI-S and STAI-T). Participants were then assessed on cognitive domains of language, visuoconstruction and visual memory, verbal memory, attention, psychomotor speed, dorsolateral functioning, and executive functioning, using the above-mentioned tests. Surgical patients were assessed one to two days before surgery and again approximately one month post-surgery, while the control group was assessed at mirroring intervals.

Before the study began, the researcher was informed that approximately five to ten cardiac procedures were performed every week at Groote Schuur Hospital and Gatesville Medical Centre. Therefore, the researcher had sufficient access to a cardiac patient sample.

Research design and statistical methods

The design implemented in this study was quantitative and quasi-experimental. Quasi-experiments are a type of comparative research that allow for experimental and control groups to be closely matched in terms of relevant characteristics, that is, characteristics that could provide a plausible rival explanation of any observed effects (Terre Blanche & Durrheim, 1999).

The primary data analysis in this research involved a two-way (2 X 2) repeated measures analysis of variance (ANOVA) with mixed designs performed using STATISTICA 7. The independent variable included one between-subjects variable, namely *Cardiac Procedure*, with 2 levels (surgical and control) and one within-subjects variable, *Time*, with 2 levels (baseline and follow up). This two-way repeated measures ANOVA was done 13 times on STATISTICA 7 for the seven cognitive domains that were tested. Assumptions of normality tests were run to ensure that variances for the two data groups were relatively similar. Of the 13 analyses done, 5 analyses violated the Levene's homogeneity test. However, ANOVA is relatively robust against violations of this assumption (Howell, 2002), and as the sample sizes were equal, the repeated measures procedure could be carried out accordingly. It has been cautioned that running multiple analyses increase the likelihood of Type I errors. Results were interpreted with caution regarding this note.

Results

Of the 83 participants that were fully assessed at baseline, only 80 completed the one-month follow up evaluation. 2 CABG patients died shortly after surgery, while the third patient was not available for a follow up assessment, owing to post-surgical complications. Of the remaining 80 participants, 40 were CABG patients with a mean age of 58.5 years, while the other 40 were control participants with a mean age of 59.05 years. Participants were closely matched in terms of age and education. However, it was difficult to match gender owing to a greater number of men undergoing CABG surgery in this sample. Demographic details of patients and controls are shown in Table 1.

Table 1

Demographic data of participants

Variable	CABG (n = 40)	Controls (n = 40)
Mean age (years)	58.5	59.05
Age range (years)	41 – 73	36 – 77
Sex (%)		
Female	27.5	50
Male	72.5	50
Mean education level (years)	9.325	10.675

Of the repeated measures ANOVA analyses that were done 13 times, 12 analyses appeared significant (see Table 2). Factor A (Cardiac Procedure) had two levels – CABG group and control group, while Factor B (Time) also had two levels, namely baseline and follow up.

On the domain of visioconstruction, the Rey Complex Figure (Copy trial) was found to have a significant main effect on Factor B [$F_{(1, 80)} = 5.98$; $p = 0.017$] with 2% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.02$). Upon inspecting the means in the descriptive statistics table (see Table 3), it can be seen that mean of follow up ($M = 33.994$) is higher than that of baseline mean ($M = 33.106$), thus showing improvement in both groups (CABG and control) on this domain over time.

On the domain of visual memory, the Rey Complex Figure (immediate and delayed recall) trials were both found to have significant main effects on Factor B [$F_{(1, 80)} = 82.033$; $p = 0.001$] with 15% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.150$), and [$F_{(1, 80)} = 76.108$; $p = 0.001$] with 11% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.113$) respectively. Baseline means ($M = 16.237$ for immediate recall and $M = 16.331$ for delayed recall) were also found to be significantly lower than follow up ones ($M = 22.325$ for immediate recall and $M = 21.294$ for delayed recall) in both cases, showing significant improvement in both groups on this cognitive domain at the one-month level.

The Rey Auditory Verbal Learning Test (RAVLT) total recall score, measuring verbal memory, was found to have significant main effects on both Factor A [$F_{(1, 80)} = 5.414$; $p = 0.023$] with 5.6% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.056$), and Factor B [$F_{(1, 80)} = 5.174$; $p = 0.026$] with 0.9% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.009$) respectively. When inspecting the means, it can be seen that regardless of time, the control group ($M = 8.887$) performed significantly better than the CABG surgical group ($M = 7.150$). However, the follow up mean ($M = 7.675$) is lower than that of the baseline mean (*M* = 8.363), thereby demonstrating significant decline in both groups at the one-month level.

Attention, measured using the RAVLT (Trial 1) and the Digit Span scores were both found to have significant main effects on Factor A [$F_{(1, 80)} = 8.674$; $p = 0.004$] with 7.7% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.077$), and [$F_{(1, 80)} = 10.537$; $p = 0.002$] with 11.2% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.112$) respectively. Upon looking at the means closely, it can be noticed that for these two tests, the control group (*M* = 5.713 for RAVLT [Trial 1], and *M* = 16.663 for Digit Span) performed significantly better than the CABG group (*M* = 4.650 for RAVLT [Trial 1], and *M* = 13.863 for Digit Span) on this cognitive domain.

The Digit Symbol test, a measure of psychomotor speed, was found to have significant main effects on Factor A [$F_{(1, 80)} = 16.208$; $p = 0.001$] with 16.2% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.162$), and Factor B [$F_{(1, 80)} = 51.936$; $p = 0.001$] with 2.4% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.024$). On comparing means of the two groups, it is noticed that the control group (*M* = 59.250) performed significantly better than the CABG surgical group ($M = 46.650$) regardless of time. The follow up mean ($M = 55.362$) is higher than that of the baseline mean ($M = 50.538$), thereby showing significant progress in both groups at the one-month level on this particular domain.

Executive functioning, as measured by the Stroop Test (Time score) yielded significant main effects on Factor A [$F_{(1, 80)} = 13.534$; $p = 0.001$] with 13.2% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.132$), and Factor B [$F_{(1, 80)} = 6.648$; $p = 0.012$] with 0.8% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.008$). On examining the group means, it can be observed that the CABG group ($M = 99.250$) took a significantly longer time period to complete the task than the control group ($M = 75.450$). However, upon inspection, baseline means ($M = 90.31$) were significantly higher than follow up means ($M = 84.388$) showing that both groups improved significantly over time by taking a shorter time period to complete the task.

The Similarities test, another measure of executive functioning, was also found to have significant main effects on Factor A [$F_{(1, 80)} = 11.048$; $p = 0.001$] with 11.6% of the variability in cognitive performance explained by the factor of cardiac procedure

($\eta^2 = 0.116$), and Factor B [$F_{(1, 80)} = 11.245$; $p = 0.001$] with 0.8% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.008$). Overall, it can be observed that regardless of time, the control group (M = 21.825) performed significantly better than the CABG group (M = 17.450). Upon examining the means of baseline (M = 19.075) and follow up (M = 20.200), it was found that both groups performed better over time.

The Boston Naming Test was utilized to investigate the domain of language, and was found to have significant main effects on Factor A [$F_{(1, 80)} = 16.933$; $p = 0.001$] with 17.2% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.172$), and Factor B [$F_{(1, 80)} = 17.154$; $p = 0.001$] with 0.7% of the variability in cognitive performance explained by the factor of time ($\eta^2 = 0.007$) respectively. On inspection of group means, it is noticed that the control group (M = 26.381), performed significantly better than the CABG group (M = 22.788) when time is disregarded. Baseline means (M = 24.231) were also significantly lower than follow up means (M = 24.938), illustrating improvement of both groups at the one-month time frame.

The Beck Depression Inventory (BDI-II) score measured the self-reported level of depression among participants and was found to have significant main effects on Factor A [$F_{(1, 80)} = 11.455$; $p = 0.001$] with 11.3% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.113$). When comparing the means between the two groups, it can be seen that the CABG group ($M = 5.275$) is significantly more depressed than the control group ($M = 2.450$) when the factor of time is disregarded.

The Spielberger State-Trait Anxiety Inventory (STAI) score was utilized to measure self-reported levels of anxiety among participants. Significant main effects on Factor A [$F_{(1, 80)} = 8.353$; $p = 0.005$] was observed, with 7.5% of the variability in cognitive performance explained by the factor of cardiac procedure ($\eta^2 = 0.075$). On examining the group means, it is noticed that the CABG group ($M = 27.788$) is significantly more anxious than the control group ($M = 23.850$) regardless of time.

The other repeated measures ANOVA analysis done on the Stroop Test (Error score) which is a measure of executive functioning, was found to have no significant main effects on Factors A or B. Additionally, no interaction effects were detected (see Tables 4 and 5 for non-significant ANOVA results).

Table 2

Repeated ANOVA (mixed designs) results for significant domains

Domain	Source	*df*	*F*	*p*-value
Visioconstruction Rey Complex Figure (Copy)	Factor A (Procedure)	1	3.11	0.082
	Factor B (Time)	1	5.98*	0.017
	Interaction (A*B)	1	0.80	0.373
Visual Memory Rey Complex Figure (Immediate recall)	Factor A (Procedure)	1	1.608	0.209
	Factor B (Time)	1	82.033**	0.001
	Interaction (A*B)	1	0.153	0.697
Rey Complex Figure (Delayed recall)	Factor A (Procedure)	1	1.739	0.191
	Factor B (Time)	1	76.108**	0.001
	Interaction (A*B)	1	0.070	0.793
Verbal Memory RAVLT (Total recall score)	Factor A (Procedure)	1	5.414*	0.023
	Factor B (Time)	1	5.174*	0.026
	Interaction (A*B)	1	1.247	0.268

Domain	Source	*df*	*F*	*p*-value
Attention RAVLT (Trial 1)	Factor A (Procedure)	1	8.674**	0.004
	Factor B (Time)	1	3.611	0.061
	Interaction (A*B)	1	1.657	0.202
Digit Span	Factor A (Procedure)	1	10.537**	0.002
	Factor B (Time)	1	2.344	0.130
	Interaction (A*B)	1	0.012	0.913
Psychomotor Speed Digit Symbol	Factor A (Procedure)	1	16.208**	0.001
	Factor B (Time)	1	51.936**	0.001
	Interaction (A*B)	1	1.909	0.171
Executive functioning Stroop Test (Time score)	Factor A (Procedure)	1	13.534**	0.001
	Factor B (Time)	1	6.648*	0.012
	Interaction (A*B)	1	0.938	0.336

Domain	Source	*df*	*F*	*p*-value
Executive functioning Similarities	Factor A (Procedure)	1	11.048**	0.001
	Factor B (Time)	1	11.245**	0.001
	Interaction (A*B)	1	0.938	0.336
Language Boston Naming Test	Factor A (Procedure)	1	16.933**	0.001
	Factor B (Time)	1	17.154**	0.001
	Interaction (A*B)	1	1.463	0.230
Depression BDI-II score	Factor A (Procedure)	1	11.455**	0.001
	Factor B (Time)	1	0.052	0.821
	Interaction (A*B)	1	0.144	0.706
Anxiety STAI score	Factor A (Procedure)	1	8.353**	0.005
	Factor B (Time)	1	0.198	0.658
	Interaction (A*B)	1	0.198	0.658

$^{*}p < .05$. $^{**}p < .01$.

Table 3

Descriptive statistics for significant repeated measures ANOVAs

Domain			Baseline	Follow up	Marginal Means
Visioconstruction					
Rey Complex Figure (Copy)	CABG Group (*n* = 40)	*M*	32.425	33.637	33.031
		SD	4.287	2.230	
	Control Group (*n* =40)	*M*	33.788	34.350	34.069
		SD	3.364	1.889	
	Marginal Means		33.106	33.994	
Visual Memory					
Rey Complex Figure (Immediate recall)	CABG Group (*n* = 40)	*M*	15.425	21.250	18.337
		SD	7.362	6.920	
	Control Group (*n* =40)	*M*	17.050	23.400	20.225
		SD	7.522	7.397	
	Marginal Means		16.237	22.325	

Domain			Baseline	Follow up	Marginal Means
Visual Memory					
Rey Complex Figure (Delayed recall)	CABG Group (*n* = 40)	*M*	15.450	20.262	17.856
		SD	6.654	6.541	
	Control Group (*n* =40)	*M*	17.212	22.325	19.769
		SD	7.452	7.177	
	Marginal Means		16.331	21.294	
Verbal Memory					
RAVLT (Total recall score)	CABG Group (*n* = 40)	*M*	7.325	6.975	7.150
		SD	3.437	3.238	
	Control Group (*n* =40)	*M*	9.400	8.375	8.887
		SD	3.657	4.030	
	Marginal Means		8.363	7.675	
Attention					
RAVLT (Trial 1)	CABG Group (*n* = 40)	*M*	4.975	4.325	4.650
		SD	1.527	1.716	
	Control Group (*n* =40)	*M*	5.775	5.650	5.713
		SD	1.874	2.225	
	Marginal Means		5.375	4.988	

Domain			Baseline	Follow up	Marginal Means
Attention					
Digit Span	CABG Group (*n* = 40)	*M*	13.700	14.025	13.863
		SD	3.625	3.676	
	Control Group (*n* =40)	*M*	16.475	16.850	16.663
		SD	4.397	4.210	
	Marginal Means		15.087	15.438	
Psychomotor Speed					
Digit Symbol	CABG Group (*n* = 40)	*M*	43.775	49.525	46.650
		SD	12.741	13.956	
	Control Group (*n* =40)	*M*	57.300	61.200	59.250
		SD	15.457	14.948	
	Marginal Means		50.538	55.362	
Executive functioning					
Stroop Test (Time score)	CABG Group (*n* = 40)	*M*	103.330	95.175	99.250
		SD	38.505	35.195	
	Control Group (*n* =40)	*M*	77.300	73.600	75.450
		SD	22.769	23.040	
	Marginal Means		90.31	84.388	

Domain			Baseline	Follow up	Marginal Means
Executive functioning					
Similarities	CABG Group (*n* = 40)	*M*	16.725	18.175	17.450
		SD	6.004	5.892	
	Control Group (*n* =40)	*M*	21.425	22.225	21.825
		SD	6.076	6.318	
	Marginal Means		19.075	20.200	
Language					
Boston Naming Test	CABG Group (*n* = 40)	*M*	22.538	23.037	22.788
		SD	4.478	4.556	
	Control Group (*n* =40)	*M*	25.925	26.838	26.381
		SD	3.538	3.163	
	Marginal Means		24.231	24.938	
Depression					
BDI-II score	CABG Group (*n* = 40)	*M*	5.175	5.375	5.275
		SD	4.489	5.377	
	Control Group (*n* =40)	*M*	2.475	2.425	2.450
		SD	2.572	2.960	
	Marginal Means		3.825	3.900	

Domain			Baseline	Follow up	Marginal Means
Anxiety					
STAI score	CABG Group (*n* = 40)	*M*	28.125	27.450	27.788
		SD	7.552	8.443	
	Control Group (*n* = 40)	*M*	23.850	23.850	23.850
		SD	5.798	5.709	
	Marginal Means		25.988	25.650	

Note: *SD* = Standard deviation; *M* = Mean

Table 4

Repeated ANOVA (mixed designs) results for non-significant domains

Domain	Source	*df*	*F*	*p*-value
Executive functioning Stroop Test (error score)	Factor A (Procedure)	1	1.919	0.170
	Factor B (Time)	1	1.553	0.216
	Interaction (A*B)	1	0.667	0.417

Table 5

Descriptive statistics for non-significant ANOVAs

Domain			Baseline	Follow up	Marginal Means
Executive functioning					
Stroop Test (error score)	CABG Group (n = 40)	*M*	4.400	4.275	4.338
		SD	4.211	4.696	
	Control Group (n =40)	*M*	3.525	2.925	3.225
		SD	3.234	2.850	
	Marginal Means		3.963	3.600	

Note: *SD* = Standard deviation; *M* = Mean

Multiple regression analyses

On completing the primary statistical analysis, it was found that there was an increase in cognitive performance on six cognitive domains in both CABG and control groups at the one-month level. Improvement occurred on the domains of visioconstruction ($p = 0.017$) visual memory ($p = 0.001$), verbal memory ($p = 0.026$), psychomotor speed ($p = 0.001$), executive functioning ($p = 0.001$) and language ($p = 0.001$).

In an effort to explain why no cognitive decline was found, multiple regression analyses were run to investigate whether emotional states (depression and anxiety) predicted and therefore, influenced cognitive performance, as depression ($p = 0.001$) and anxiety scores ($p = 0.005$) of the CABG surgical group were significantly higher than those of the control group.

Multiple regression analyses were performed for each of the neuropsychological test change score measures for each cognitive domain using depression and anxiety change scores as predictors that were entered into the regression analyses.

Regression diagnostics showed that assumptions of multivariate normality were upheld. Histograms of raw residuals showed that the data were normally distributed and approximately symmetrical. Scatterplots also showed randomness of residuals, with no obvious patterns detected in the scatter.

Tolerance scores

Relatively high tolerance scores in the regression model for depression and anxiety (range = 0.8 – 1) reflect overall low multicollinearity, hence low correlations with other independent variables.

Cook's Distance (D)

The Cook's D score indicates that there were no extreme outliers. The mean standard residual scores are low for this regression model (range = 0.0000047 – 0.210), therefore indicating no multivariate outliers in the data set.

The results of the multiple regression analyses found that a change in the anxiety and depression scores could not significantly predict a change in any cognitive domain. Although the Boston naming change score (for the domain of language) was included in the standard regression model, the results yielded were non-significant [$F(2,77)$ =

0.281; $p = 0.755$]. This shows that anxiety and depression change scores were unable to predict changes in the domain of language (see Appendix B, Table 6 and 7 for non-significant multiple regression results).

In sum, the change in depression and anxiety from baseline to the one-month level had no significant effects on neuropsychological functioning among the participant sample.

Discussion

In this prospective study investigating cognitive change after CABG surgery, 40 patients undergoing CABG were compared to 40 nonsurgical, age and education matched controls. Results from the repeated measures ANOVA with mixed designs procedure, showed that cognitive functioning in both CABG and control groups significantly improved at the one-month level, on a number of the main cognitive domains assessed; these being visioconstruction, visual memory, psychomotor speed, executive functioning and language. These results are contrary to previous findings which have reported either short-term cognitive decline after CABG surgery, or that no change could be determined (Selnes *et al.*, 1999; Van Dijk *et al.*, 2000; Ahlgren *et al.*, 2002). However, the results are in concordance with other research findings which found improvement on domains of verbal memory, attention and word fluency (using the same tests as the present study) shortly after CABG surgical interventions (Selnes *et al.*, 2003; Du Puis *et al.*, 2006).

Following the results, it is noticed that the CABG and control participants in this prospective study are relatively younger (with mean ages of 58.5 and 59.05 years respectively) than those in previous samples investigated (mean age = 66.3 years in Silbert *et al.*, 2004; mean age = 65.07 years in Tsushima *et al.*, 2005). This age difference possibly explains why cognitive decline after CABG was not found on almost all cognitive domains tested in this study, as pre-operative baseline scores showing cognitive deterioration in older CABG patients could be confounded with cognitive decline associated with ageing (Tsushima *et al.*, 2005). Younger patients undergoing CABG surgery are likely to have fewer associated health problems when compared to their older counterparts (Selnes & McKhann, 2001).

Improvement in performance with repeated exposure to a battery of neuropsychological tests is known to occur (Slade *et al.*, 2001). Practice effects occur with specific processes as well as content of tests, and could possibly contribute to an increase in cognitive performance from baseline to follow up in the cognitive domains assessed in this study. The inclusion of an age and education matched nonsurgical control group enables us to distinguish between practice effects and improvements possibly due to successful surgical intervention.

It has been recommended that alternative forms of tests be utilised in situations where repeated testing is required (Van Dijk *et al.*, 2000). Alternative forms for the Rey Complex Figure (which assesses visioconstruction and visual memory), namely the Taylor Complex Figure, was used for follow up testing. Both CABG and control participants improved significantly over the one-month interval indicating that cognitive progress on this test, at least, must be explained by factors other than practice effects. All the other specific neurocognitive tests that were utilised in this study are known to be resistant to practice effects (Lezak, Howieson & Loring, 2004). This again suggests that the cognitive improvement in both CABG and control groups must be attributed to factors which have not been identified. Further in-depth investigations in this field are required to explain this pertinent issue.

While improvement on the domains of visioconstruction, visual memory, psychomotor speed, executive functioning and language were found in both CABG and control groups, cognitive functioning in the area of attention did not yield statistical significance from baseline to follow up, thereby showing no change in either CABG or control group at the one-month level. This finding is in accord with that of mainstream literature as mentioned above.

The only domain that yielded significant cognitive decline on the repeated measures analyses done was verbal memory at the one-month level in both CABG and control groups. However, when the conventional method for cognitive decline was applied, namely the downward change in 1 SD (one standard deviation) of a domain of cognition (in this case, verbal memory) (Blumenthal *et al.*, 1995), the result showed no cognitive deterioration in either CABG or control group. This example shows how varying ways of defining cognitive decline yields differing results.

On examining the scores measuring depression and anxiety of CABG patients and controls, it was found that overall the surgical group was significantly more depressed and anxious than the nonsurgical controls. Following this result, multiple regression analyses were performed to ascertain whether a change in mood and anxiety could predict any changes in participants' cognitive test scores.

Results yielded were insignificant, thus indicating that changes in anxiety and depression do not influence participants' changes in neuropsychological test performance. These results are in concordance with those of McKhann *et al.* (1997) and Andrew *et al.* (2000) who found no correlation between depressed mood and cognitive decline in their studies. Furthermore, the results of this study show that neurocognitive improvement in both CABG and control groups cannot be explained by emotional status, further illustrating that other factors are involved.

A possible explanation of cognitive improvement post-surgery could be attributed to the advancement of CABG surgical techniques. It has been observed that continuous improvement in anaesthetic and surgical techniques offer good clinical effects post-surgery, thereby decreasing cognitive morbidity (Andrew *et al.*, 2001; Selnes & McKhann, 2001; Stroobant *et al.*, 2002; Rymaszewska *et al.*, 2003). This explanation however, does not explain why cognitive improvement is seen in both control and CABG surgical groups, further stressing that unidentified factors are influencing these results.

Limitations

Several limitations of this prospective study are noteworthy. The findings are based on a limited sample of 40 CABG and 40 nonsurgical control participants, while in other larger, multicentre studies; samples are significantly greater in size (Mahanna *et al.*, 1996; Wolman *et al.*, 1999; Pierson *et al.*, 2003). Owing to this restriction, the results generated may not be representative of the broader CABG patient population. A more extensive sample population could have been gathered to give the study more statistical power. Tredoux and Durrheim (2002) explain that this allows hypotheses to be proven beyond a reasonable doubt. A larger sample population also allows the researcher to make more generalisable interpretations regarding whether actual cognitive dysfunction exists in the CABG group post-surgery.

The present study included only English and Afrikaans speaking population groups, and excluded other language populations (such as the Xhosa group), hence further limiting the degree of generalisability of results found with the larger, multilingual South African population. The tests in the neurocognitive battery which was utilised did not have Xhosa norms. Owing to this, as well as the researcher not having proficiency in the Xhosa language, it was decided that Xhosa patients who were not proficient in English be excluded from the sample.

Attrition of the patient sample is a drawback which cannot be controlled in any research study. Some patients that initially completed the baseline assessment, but refused or were not available for post-operative testing were excluded from the final patient sample. Another limitation which is closely tied to sampling difficulties is the possibility of selection bias. All participants, CABG and controls were enrolled into the study of their volition, hence volunteering to partake at their own will. Consequently, results may possibly be biased because it excludes those CABG patients who may be more cognitively impaired and refused to participate in this study.

A further limitation which hindered this study was collection of data pertaining to patients' full medical histories and demographic data. Continuous data regarding patients' smoking behaviour, alcohol usage, and other general medical conditions (whether patients had diabetes mellitus, hypercholesterolaemia, hypertension etc.) were not completely available hence further statistical analyses and predictions could not be performed.

Suggestions for future research

A number of suggestions for further work in the area of measuring cognitive change after CABG surgery have been proposed. As the sample population in this present study is fairly small, thus limiting the researcher in answering some pertinent questions on the subject of CABG surgery and cognition, it has been advised that power calculations be determined before data collection commences as it is a central aspect in a good study design (Tredoux & Durrheim, 2002). Having adequate statistical power allows the researcher to determine the sample size which in turn allows for greater generalisability and comparability of results to other studies and population groups.

Parallel forms of tests measuring all core cognitive domains, namely visioconstruction, visual memory, verbal memory, language, psychomotor speed, attention and executive functioning need to be utilised to further control for learning and practice effects at the one-month assessment interval. It has been mentioned that cognitive dysfunction post-CABG intervention may be a multifactorial problem (Selnes *et al.*, 1999; Van Dijk *et al.*, 2000; Taggart & Westaby, 2001), hence all patients' medical histories and demographic data should be collected in a systematic and comprehensive way so that all extraneous factors are accounted for when interpretations are considered regarding the aetiologies of cognitive dysfunction after CABG surgery.

Conclusion

Neurocognitive deficit after CABG surgery affects an increasing number of people who have the procedure done today. Impairments in cognitive abilities reduce working capacity and lower quality of life (Zimpfer *et al.*, 2004). Despite limitations that have already been discussed, this study assumes meaning and is significant because it attempted to overcome previous methodological limitations in the field of research studying short-term post-CABG cognitive performance, and contributes knowledge to this stream of literature.

Overall, the results yielded in this study are mixed. They accord with previous research which finds short-term neurocognitive improvement after CABG surgery; but contradict the literature finding short-term cognitive decline post-CABG surgery (Newman *et al.*, 1995; Mahanna *et al.*, 1999; Selnes *et al.*, 1999). These findings are important in the field of post-operative CABG and cognition research as they confirm the multifactorial nature of cognitive functioning after CABG surgery.

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Appendix A

CONSENT FORM

TITLE OF PROJECT:

Study into the Short-term and Long-term Effects of Three Cardiac Procedures on Cognitive Performance.

	Please cross out as necessary
Have you read the Subject Information Sheet?	YES/NO
Have you had an opportunity to ask questions and discuss the study?	YES/NO
Have you received satisfactory answers to all your questions?	YES/NO
Have you received enough information about the study?	YES/NO
Who have you spoken to? Dr/Mr/Mrs/Ms/Prof.	YES/NO
Do you understand that you are free to withdraw from the study:	
• at any time	YES/NO
• without having to give a reason for withdrawing	YES/NO
• and without affecting your future treatment?	YES/NO
Do you understand that some of your answers in the study may be audio-taped?	YES/NO
Do you consent to the unattributed and confidential use of these recordings for scientific purposes?	YES/NO

Name (in BLOCK LETTERS:

Signature: **Date:**

PARTICIPANT INFORMATION SHEET

TITLE OF PROJECT:

Study into the Short-term and Long-term Effects of Three Cardiac Procedures on Cognitive Performance

- You are invited to participate in a neuropsychological study conducted in the cardiac clinic and cardiothoracic surgery at Groote Schuur Hospital and Gatesville Medical Centre. Please read this information sheet carefully and do not hesitate to ask the researcher for any additional information.
- The overall purpose of the study is to investigate and compare cognitive performance following three different cardiac procedures.
- You are asked to take part in this study by participating in three, maybe four interviews, designed to assess your cognitive functioning. The interviews may be audio-taped and sessions will last approximately 1-hour, and some of your relatives may also be asked to participate in the study on separate occasions.
- There are no anticipated risks involved in this research, but if you should experience mental and/or physical fatigue, or any form of psychological distress please be aware that you can inform the researcher immediately.
- It is up to you to decide whether or not you take part. If you decide to take part you will be given this information sheet to keep and asked to sign a consent form. If you decide to take part you are still free to withdraw from the study at any time, without having to give a reason and without this affecting future treatment.
- The confidentiality of your answers and your identity will be protected. All data recordings made will be suitably anonymous, securely stored, made accessible only to the researchers.
- This study is an educational project, forming part of a Ph.D. thesis at the University of Cape Town (UCT). The research will be carried out by researchers from UCT and will be funded by the same university.
- The study has been reviewed by the UCT Psychology Department's ethics committee and the Faculty of Health Sciences Research Ethics Committee.
- If you have any questions regarding this study, or concerns regarding the manner in which the study was conducted, or would like to be informed of the results when the study is completed, please feel free to contact the principal researcher.
- Address for communications:

Professor Mark Solms Ph. (021) 650-3435
Department of Psychology
University of Cape Town, Rondebosch 7701

Appendix B

Table 6

Multiple regression summary for depression and anxiety on language

	Beta	Std. Error of Beta	B	Std. Error of B	t(77)	*p*-level
Depression	0.072	0.127	0.037	0.066	0.563	0.575
Anxiety	-0.088	0.127	-0.020	0.029	-0.696	0.489

N = 80

Table 7

Summary statistics for depression and anxiety on language

	Multiple R	Multiple R^2	Adjusted R^2	F(2,77)	*p*	Std. Error of estimate
Value	0.085	0.007	-0.019	0.281	0.756	1.544