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# The influence of different error estimates in the detection of post-operative cognitive dysfunction using reliable change indices with correction for practice effects

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## Abstract

The reliable change index (RCI) expresses change relative to its associated error, and is useful in the identification of post-operative cognitive dysfunction (POCD). This paper examines four common RCIs that each account for error in different ways. Three rules incorporate a constant correction for practice effects and are contrasted with the standard RCI that had no correction for practice. These rules are applied to 160 patients undergoing coronary artery bypass graft (CABG) surgery who completed neuropsychological assessments preoperatively and 1 week post-operatively using error and reliability data from a comparable healthy non-surgical control group. The rules all identify POCD in a similar proportion of patients, but the use of the within subject standard deviation, expressing the effects of random error, as an error estimate is a theoretically appropriate denominator when a constant error correction, removing the effects of systematic error, is deducted from the numerator in a RCI.



*Keywords:* Coronary artery bypass graft surgery; Neuropsychological assessment; Post-operative cognitive dysfunction; Reliable change index; Statistics

## 1. Introduction

In neuropsychology there is increasing interest in the methodological and statistical processes by which change in cognitive function can be identified in individual patients. This issue has been raised in the context of the assessment of cognitive dysfunction after surgery for epilepsy, and we have begun to investigate the use of different individual change calculations when using cognitive tests to decide whether athletes should return to play after head injury resulting in concussion, or determining the response to stimulant medication in individual children with attention deficit disorder. However, this issue has been extremely important in the identification of post-operative cognitive impairment after surgery, in particular coronary artery bypass graft (CABG) surgery, and there is currently a high level of investigation and debate regarding the best methods to reliably identify cognitive change in individual patients.

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It is accepted that some patients will show a decline in cognitive function after (CABG) that was not present prior to surgery and is believed to have arisen peri-operatively. This decline is identified by comparing the pre to post-operative performance on objective tests of cognition in individual patients, has no objective clinical presentation or external markers, and is termed post-operative cognitive dysfunction (POCD). Thus, the identification of POCD depends entirely on the application of statistical rules to neuropsychological performance data of individual patients. To date, the statistical POCD rules used most commonly to classify abnormal change in performance require the individual to have declined by one standard deviation (computed from the group baseline performance) on a nominated number of tests, or by 20% of their baseline score on 20% of the tests in the battery. The application of these methods in different studies has indicated that POCD may be present in up to 80% of patients at 1 week following CABG and that some performance detriment may be observed in 40% of patients 5 years after surgery. These statistical rules for classifying POCD have been criticized however because they do not address the impact of practice effects, do not properly account for the impact of error in the statistical determination of change, and do not include a control group to gauge the expected false positive change associated with each rule. Furthermore, the application of these rules to healthy non-surgical control groups has shown that they are also associated with large false positive classification rates.

Critical reviews of the methods used to determine change in the cognitive function in individuals now suggest that the application of reliable change indices (RCI) to neuropsychological data may provide a better basis for decisions about cognitive change generally and POCD specifically. This is because RCIs can control the sources of error that are associated with repeated neuropsychological assessment. However, the term "reliable change index" has been applied to numerous formulae that express change in terms of the error associated with its assessment. All of these differ slightly in their computation and therefore their application to the same data set will be likely to yield different results. There has been some discussion in the literature regarding the best computation of the RCI, but no consensus has been reached. Researchers may not be aware that different calculations of the RCI exist, and that they may classify different rates of change among the same population. Therefore, in the current study, estimates of the incidence of POCD after CABG, based on commonly used neuropsychological tests, is determined using four calculations of the RCI.

In its most basic form, the RCI ($RCI_{J\&T}$) expresses the difference in performance between two assessments (e.g. post-operative performance minus preoperative performance) as a function of the standard error of the difference ($S.E._{difference}$) score for the test (see Table 1). Expressing the change in terms of its error allows the change in the individual to be viewed in context of the spread of the distribution. This provides an indication of the magnitude of the change. Variations to this RCI have been developed that may also be relevant to the classification of POCD. Each modification to the RCI estimates the error associated with repeated neuropsychological assessment differently. Some groups have employed a correction for systematic error in order to control the practice effects that occur commonly when standard neuropsychological tests are given repeatedly over relatively short re-test intervals (e.g. $RCI_{Chelune}$; $RCI_{ISPOCD}$: ISPOCD—International Study of Post-Operative Cognitive Dysfunction; see Table 1). In the context of POCD, Kneebone and colleagues first demonstrated that this rule was useful in cardiac research as it more adequately

Table 1
Formula for the $RCI_{J\&T}$, the $RCI_{ISPOCD}$, the RCI $_{Chelune}$, and the $RCI_{WSD}$, the systematic change observed in the control group, and the error estimates used in the RCI calculations for each neuropsychological test

| RCI | Formula | Error and group change estimates used in the RCI equations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | WLT | TMTA | TMTB | COWAT | DSST | GPD | GPND |
| ΔXc | | 0.8 (3.8) | −0.1 (15.6) | 8.5 (24.7) | 4.5 (10.5) | −1.5 (8.3) | −7.6 (14.5) | −0.1 (15.6) |
| $RCI_{J\&T}$ | $\Delta X/S.E._{difference}$ | 3.54 | 8.90 | 12.85 | 26.49 | 11.02 | 12.64 | 12.10 |
| $RCI_{ISPOCD}$ | $(\Delta X - \Delta Xc)/S.D._{(\Delta Xc)}$ | 3.80 | 8.28 | 15.59 | 24.70 | 10.47 | 14.48 | 15.58 |
| $RCI_{Chelune}$ | $(\Delta X - \Delta Xc)/S.E._{difference}$ | 3.54 | 8.90 | 12.85 | 26.49 | 11.02 | 12.64 | 12.10 |
| $RCI_{WSD}$ | $(\Delta X - \Delta Xc)/WSD_{(\Delta Xc)}$ | 2.73 | 5.92 | 10.96 | 18.37 | 8.02 | 11.53 | 10.96 |

*Note.* $\Delta X$ = individual time 2 performance − time 1 performance; ΔXc = mean control group time 2 performance − time 1 performance; $S.E._{difference} = \sqrt{2}(S.D._{baseline\ control}\sqrt{(1 - r_{xx})})^2$ where $r_{xx}$: test–retest reliability of the measure; $S.D._{(\Delta Xc)}$: standard deviation of the control group change; and $WSD_{(\Delta Xc)}$: within subject standard deviation of the control group.

*Tasks.* WLT, CERAD word learning task; TMTA, Trail Making Task Part A; TMTB, Trail Making Task Part B; COWAT, Controlled Oral Word Association Task; DSST, Digit Symbol Substitution Task; GPD, Grooved Pegboard Dominant; and GPND, Grooved Pegboard Non Dominant.