THE SIMPLE COPY TASK: CLINICAL UTILITY, PSYCHOMETRIC PROPERTIES, AND NORMATIVE DATA

Submitted by

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A thesis submitted in partial fulfilment

of the requirements for the degree of

Doctor of Psychology in Clinical Neuropsychology

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March 2012

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Statement of Authorship

Except where reference is made in the text of this thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis submitted for the award of any other degree or diploma.

No other person's work has been used without due acknowledgement in the body of the thesis. This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

All research procedures reported in this thesis were approved by the La Trobe University Ethics Committee (approval numbers: UHEC 07-71; FHEC 09-R56; FHEC 08-R12) and Bendigo Health Research Ethics Committee (15/2007; 17/2008).

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This thesis is submitted in the alternative format approved by La Trobe University (see guidelines in Appendix A). As an alternative to the standard format of thesis, the candidate may submit their research as a series of two or more related manuscripts, which may or may not have been published.

Because of this format, there is often some repetition of descriptive information across the papers. It is hoped that the inconvenience this causes the reader is outweighed by the advantages provided by the format, including dissemination of research and the opportunity for peer review prior to thesis examination.

The supervision received for a thesis submitted in publication format is no greater than for a thesis submitted in the 'traditional' format. The thesis author is the first author on all publications, indicating the lead role in the research.

The author of this thesis was responsible for all aspects of the research. This included project design and management, data collection (except as indicated throughout), data scoring, entry, and analysis, preparation and submission of scientific articles, and all additional requirements including final thesis construction.

As recommended by the guidelines for the alternative format, this thesis presents a general introduction to past research, three journal papers (one in press, and two submitted to scholarly journals for review), and a general discussion collating and interpreting all the papers.

Candidate signature:______________________________ Date: ___________________

Acknowledgements

First and foremost I would like to thank my primary supervisor Ben Ong, for his patience and support throughout this project. I will be eternally grateful for the way he has been the antidote (and responded in good humour) to my several 'thesis related melt downs'. I would also like to extend thanks to Simon Crowe, Susan Lloyd, and Loretta Evans for their guidance and advice in supervising the project.

Completion of this thesis was facilitated by the love, support, and patience of my family. I am so fortunate to have been given the opportunities that I have by my wonderful parents, Matt and Michelle. I am sure I could not have been pleasant to live with during the more stressful periods of this candidature; and for their tolerance during these periods, I am extremely grateful. Thanks also to Susan and Christine Dridan for their hospitality and encouraging words throughout the degree.

The research process has been made bearable and at times even enjoyable by my fellow candidates. Special thanks to Jacinta Delprado and Jodi Samartgis who have been present throughout some of the most truly trying and at times delirious moments.

Finally, thanks to the large number of participants who contributed their time to completing my research. Without their assistance, there would be no project, and the Simple Copy Task would remain a mystery.

Thesis Abstract

The Simple Copy Task (SCT) is an unpublished Australian figure copying test used by neuropsychologists to gain qualitative information about visuo-spatial and constructional functioning. Prior to this thesis, there were no established scoring criteria or normative data available for the task. The objectives of the thesis were 1) to examine the clinical utility of the SCT, 2) to explore the psychometric properties of a proposed scoring system for the task, 3) to provide normative data for clinical use, and 4) to shorten the task for use as a brief screen.

The first chapter provides a review of the matters relating to development and refinement of figure copying tasks including scoring and normative issues. The second chapter examines the efficacy of the task in distinguishing between healthy control, schizophrenia, movement disorder, and dementia groups. Results indicated the SCT was as good as the Rey Complex Figure Task in distinguishing between groups, and various error patterns emerged for each clinical group.

The third chapter examines a proposed scoring system for the SCT. The system demonstrated brief application time and adequate psychometric properties. Healthy adult normative data was provided, including reference to the frequency of particular types of error commission. Results indicated that in the healthy control group, the most common errors were size distortions and omission of items.

In the fourth chapter, each of the six figures that comprised the SCT were examined for their predictive ability of a common neuropsychological condition— Alzheimer's disease. There were two figures that best predicted a positive diagnosis: the flower and bicycle. These two figures, combined, provided the same sensitivity to Alzheimer's disease as the full SCT, despite being one third the length of the original task.

In sum, the SCT is a reliable and valid measure of spatial/constructional functioning, which can be used in full to elicit error patterns in various clinical groups, or in part as a screen for dementia. This thesis provides preliminary evidence for the clinical utility of the SCT, as well as direction for its scoring and interpretation.

Chapter 1: Introduction

The Simple Copy Task (SCT) is an unpublished figure copying test which requires the patient to copy six target figures that progress in difficulty. The origins of the SCT are unclear, and there is as yet no published data regarding the task. As such, there is no consensus regarding the scoring and interpretation of the SCT, nor any evidence of its clinical utility.

Given the importance of figure copying tasks in neuropsychology, this review will address issues related to the development of an effective figure copying task, including appropriate scoring, psychometrics, and selection of suitable figures. Existing figure copying tasks will be evaluated, including well researched and less conventional measures (i.e., the SCT). Problems with the use of less conventional measures will be discussed. Finally, the potential utility of the SCT will be explored.

The Importance of Figure Copying Tasks in Neuropsychology

Figure copying tasks are used to measure the cognitive domains that can be collectively thought of as ‘higher order visual processing’ (HOVP); that is, the ability to process positioning in space, integrate visual components into a gestalt, and interact effectively with the visual environment (Sadock & Sadock, 2005). HOVP can be divided into separate constructs; specifically, perceptual (i.e., skills used for shape and object detection), spatial (i.e., skills used to understand relationships and positions of objects) and constructional skills (i.e., skills used to interact with the visual environment by building, drawing, or assembling) (Benton & Tranel, 1992; Hamsher, Capruso, & Benton, 1992; Lezak, Howieson, & Loring, 2004). Intact HOVP is required for a range of practical tasks, including: written mathematics, map reading, navigation in space, safe driving, and independent living (Diegelman, Gilbertson, Moore, Banou, & Meager, 2004; Edmans & Lincoln, 1990; Lezak et al., 2004).

Drawing and copying tasks are commonly used by neuropsychologists (Lezak et al., 2004) to measure various HOVP problems related to neurological disorders (e.g., Alzheimer's disease, stroke or traumatic brain injury). In particular, figure copying tasks, in which patients make freehand reproductions of simple line drawings, are thought to measure constructional and spatial functioning (Freeman et al., 2000; Griffiths, Cook, & Newcombe, 1988; Hécaen & Assal, 1970; Kaplan & Libon, 2000; Lezak et al., 2004; Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992). For example, the simple act of copying a line drawing of a bicycle (see Figure 1) can provide a wealth of information regarding HOVP. Firstly, perceptual skills are used to identify the shape and details of the bicycle (e.g., the wheels, handlebars, and pedals). Next, spatial skills are used to integrate the separate features into a meaningful whole (e.g., the seat goes above the wheels, the handlebars are to the left of the seat). Finally, constructional skills are required when making a series of accurate motor responses, using the pen to copy the target figure (Hamsher et al., 1992).

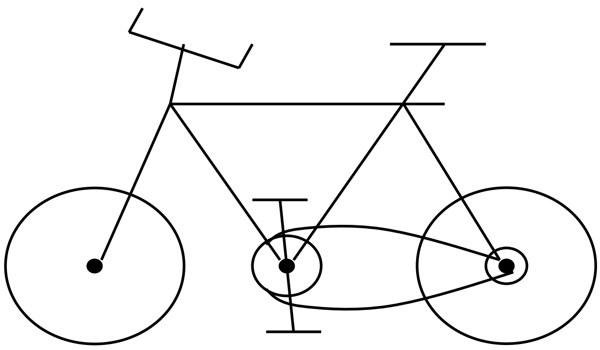

Figure 1. The bicycle figure.

Scoring Issues

Brief and simple scoring systems. Test length and time taken to apply a scoring system have been identified as critical factors in the successful uptake and popularity of a neuropsychological task (Wechsler, 2009). Arguably, the quickest means of assessing figure reproductions is via a qualitative approach, in which the clinician examines the drawings without reference to a scoring system (or by pre-determined idiosyncratic internal criteria), and makes a decision regarding the quality of the reproduction. It has been declared that “qualitative inspection of the patient’s designs is usually sufficient for clinical purposes” (Lezak et al., 2004, p.535). Despite this assertion, there are several problems with qualitative ‘scoring’; namely, 1) qualitative judgments are inherently subjective, 2) they are likely biased by past experience of the clinician, 3) the results are difficult to communicate, and 4) the approach undermines assessment of (and adjustments for) normal variation in a healthy population due to demographic/cultural influences.

Not surprisingly, quantitative scoring systems were developed to aid scoring consistency; however, there is much variability in the quality, detail, and complexity of these scoring systems. Some of the more simplistic quantitative systems are described in Table 1.

Whilst these basic quantitative scoring systems maintain ease of application due to their brevity, they have several limitations in utility. Specifically, they commonly feature a high degree of subjectivity in their wording (e.g., ‘minimal’ and ‘moderate’ distortions; ‘most unsatisfactory’). In other words, while numeric ratings provide quantitative information that relates to the overall quality of the figure coping, the ratings are often gross and subjective. Additionally, the results do not distinguish which aspect of performance is impaired (e.g., a score of zero may just as equally represent perseveration, fine motor control problems, or visuo-spatial neglect). Aside from these issues, the range of the scores (i.e., being no higher than zero to three across each of the systems outlined) is quite restricted, reducing the chance of detecting subtle deficits or change over time.

Table 1

Simple Quantitative Scoring Systems

Author (year)	Task	Score	Description
Elman et al. (2008)	Diamond, cross, cube, pipe, pyramid copy	3	Grossly distorted, loss of gestalt, figure difficult to recognise.
		2	Moderate distortion, rotation, size minimisation, lack of three-dimensionality
		1	Mild distortions and rotations
		0	Perfect or near perfect reproductions
Strub & Black (1993)	Diamond, cross, cube, & connected triangles copy	0	Non recognisable, grossly rotated (90° or more), any of following: perseveration, closing-in on target figure
		1	Loss of three dimensionality, moderate distortions, or moderate rotations.
		2	Minimal distortions/rotations (e.g. less than perfect three-dimensional designs; well integrated but slightly rotated two-dimensional designs).
		3	Reproductions closely resemble the target figure.
Griffiths, Cook, & Newcombe (1988)	Cube copy	3	Most unsatisfactory
		2	Unsatisfactory
		1	Satisfactory
		0	Most satisfactory
Folstein, Folstein, & McHugh (1975)	Copy of intersecting pentagons from MMSE	0	One or more sides are missing, the pentagons do not intersect, or the intersection does not produce a 4-sided figure.
		1	There are two 5-sided figures intersecting to produce one 4-sided figure.

Note. MMSE: Mini-Mental Status Exam.

Psychometric properties of scoring and ease of application: A balancing act. Aside from merely being brief and easy to apply, a scoring system must also demonstrate adequate inter-rater reliability, inter-item correlation, and construct validity (De Villis, 2003). Reliability analysis is a preliminary stage in the development of any test. If a score is not reliable (be that between raters, across testing sessions, or within the items of the scale itself), then it not possible to assess how well it measures the particular construct of interest (Wells & Wollack, 2003). Test length and internal consistency are inter-linked constructs, as increases in the length of a task generally result in higher reliability coefficients (Wechsler, 2009). This is because for any given item, there is a degree of measurement error; a chance that the patient's score is awarded a pass or fail for reasons other than their ability on the underlying construct (Wells & Wollack, 2003). In the context of figure copying tasks, this measurement error may be a slip of the hand when using the pen, a faulty pen running out of ink, or tremor in the patient's hand due to test anxiety. The danger of assessing the patient's skill using a simple quantitative system is that the risk of misclassification (i.e., falsely concluding the person has a HOVP deficit) is high. For example, using the simplistic scoring system for the pentagon copy task (Folstein et al., 1975), if a patient makes a single error, they are awarded a score of zero. Increasing the length of the system reduces the percentage of measurement error (Wells & Wollack, 2003). If, instead, the pentagon copy task was awarded one point for inclusion of each of the corners that comprise the task, this would effectively increase the range of possible scores from 0-12 rather than 0-1. Indeed, a clinician can be more confident in concluding that a person scoring 0 out of 12 has a true impairment in HOVP, as opposed to a score of 0 out of 1.

Inter-rater reliability and time taken to apply a scoring system are also linked. Less detailed scoring systems may be quick to apply but they can also lead to poor agreement between raters. For example, Duley et al. (1993) observed that vague guidelines result in clinicians developing their own personal rules of thumb for scoring, which differ between raters. Consequently, the authors argued for improving inter-rater reliability of a popular figure copying task by defining subjective terms (e.g., distortion, misplacement) with concrete, measurable descriptors (e.g., degrees of rotation, percentage of enlargement). However, these improvements come at a cost; more detailed systems take extra time to score and require the use of equipment (e.g., protractors, rulers), which may be an unattractive prospect to a time pressured clinician.

Consequently, impressive psychometric characteristics often compromise ease of application. As a result, balancing the needs for fast application time and acceptable psychometric properties tends to be a process of refinement over time. One particular example lies in an early scoring system for the Visual Reproduction Task featured in the Wechsler Memory Scale (3rd edition) (Wechsler, 1981). Appealing features of this scoring system include objectivity, high inter-rater reliability (no lower than .90 correlation between raters across several age groups), and a large range of possible scores reducing the chance of floor and ceiling effects (Tulsky, Zhu, & Ledbetter, 1997). The system itself is detailed and lengthy, based upon the inclusion and correct placement of all the key components of the figures. Scoring involves evaluation of each component of the figures, often including measurement, calculation of ratios and determination of angles. Not surprisingly, the system has been criticised for its complexity and protracted application time, taking up to 20 minutes to score (Wechsler, 2009). As a result, later versions of the scoring system have been simplified with the view of enhancing usability. The most recent version has reduced scoring time from 20 to 5 minutes, whilst maintaining impressive internal consistency (.93 across a range of age groups) and inter-rater reliability (97% agreement between raters) (Wechsler, 2009). Evidently, balancing psychometrics and usability is a delicate, yet important, process in neuropsychological assessment, which often requires ongoing revision and refinement.

Arguably the most objective scoring system is that which entirely removes the potential effects of clinician bias and human error; namely, digitised scoring. A specific example is the work of Guest and Fairhurst (2002), in which simple figure reproductions were scored electronically. Electronic scoring allows for an analysis of standard (e.g., errors in size or accuracy of the figure) as well as dynamic features of figure copying (e.g., time taken to complete the copy, pen pressure, number of pen lifts) (Guest & Fairhurst, 2002). Accordingly, this system yields impressive diagnostic specificity, correctly classifying a significantly higher number of cases with visuo-spatial impairment than when figures were scored using a standard system (Guest & Fairhurst, 2002). Clearly, there are attractive features to computerised scoring methods, owing to their ease of application and objectivity. Despite this, there are several practical limitations to their utility; including the cost of design, purchase, and extra time and training required to use the systems and interpret their outputs (Butcher, Perry & Atlis, 2000).

Quantitative totals versus error based analysis. In neuropsychology, often it is necessary to focus not only on overall task performance, but also on the particular areas that lead to poor total scores. One of the most common examples of this is the Wechsler Adult Intelligence Scale (Wechsler, 2008), which provides a full scale intelligence quotient, but also four index scores comprising the total: verbal comprehension, perceptual reasoning, processing speed, and working memory. The same is true of figure copying tasks; use of a solitary quantitative total may obscure the nature of underlying errors. Various types of errors have been documented to emerge on figure copying tasks, including: size distortions, omissions, confabulation, perseveration, spatial disorientation, rotation, and the 'closing-in'phenomenon (i.e., overlapping the target figure) (Brantjez & Bouma, 1991; Della Sala, Turnbull, Beschin, & Perini, 2002; Kwak, 2004). Despite the occurrence of these errors, some systems continue to focus upon a solitary total score.

One of the most common examples of this is that of the Rey Complex Figure Task (RCFT: Rey, 1941). The RCFT (see Figure 2) is one of the most commonly endorsed neuropsychological tests used in Australia (Sullivan & Bowden, 1997); however, it has produced some contentious results within clinical groups. In particular, some researchers have reported that those with conditions like Attention Deficit Hyperactivity Disorder (ADHD) perform the same as healthy controls on the RCFT (Pasini, Paloscia, Alessandrelli, Porfirio, & Curatolo, 2007). Others have reported clear impairment in these conditions in comparison to controls (Cahn et al., 1996; Schreiber, Javorsky, Robinson, & Stern, 1999). These differences appear attributable to the type of scoring system employed in the research: those with a single quantitative total or error based.

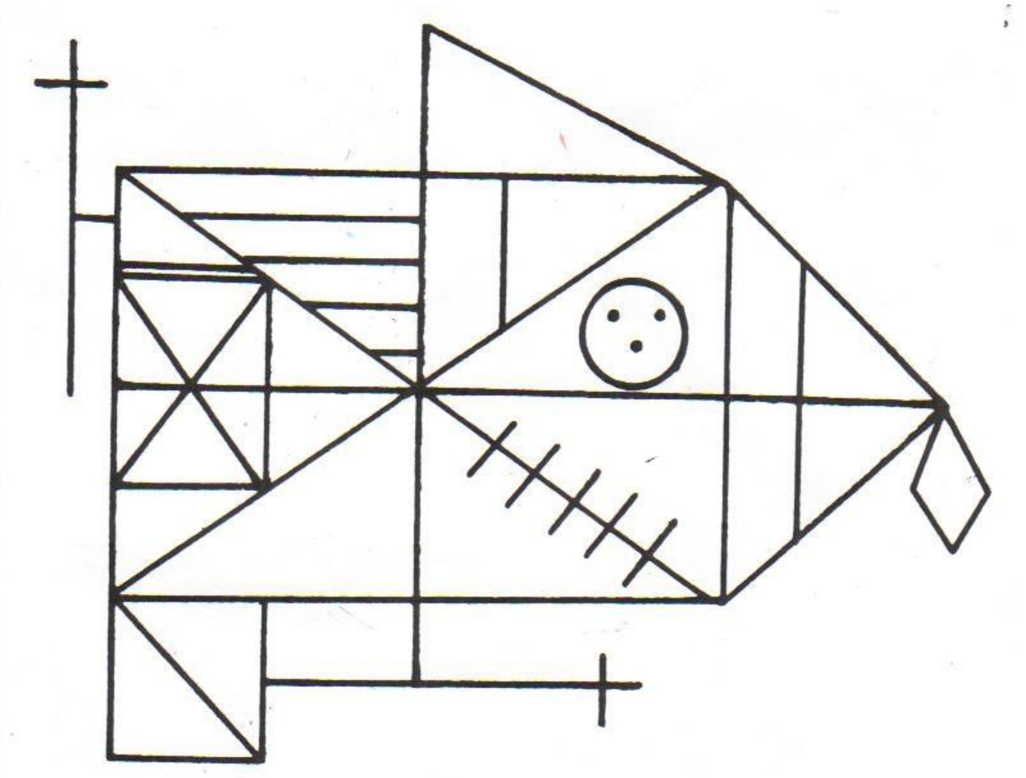

Figure 2. The copy stimuli comprising the Rey Complex Figure Task (Rey, 1941).

Since the early use of the task, the creator of the RCFT advised of the importance of attention to the qualitative aspects of error performance: “It goes without saying that the examiner must take into account...the severity and nature of the distortions" (Rey, 1941: translated by Corwin & Blysma, 1993, p. 6). Despite this, the scoring system for the RCFT devised by Rey (1941) and later condensed and simplified by Osterrieth (1944) provides a fairly uni-dimensional total quantitative score based upon 18 key features of the drawing. This system assesses only two aspects of the reproduction: element inclusion, and element placement. As a result, there is no recognition of the multitude of other problems that may occur to produce a low total score (e.g., poor planning, stimulus bound approaches, inclusion of extra items, major discrepancies in the size of the overall production or its component parts).

Not surprisingly, criticisms arose regarding the restricted potential of the traditional scoring system (Kaplan, 1990; Stern et al., 1994). As a result, several alternative systems were developed, focusing on task approach and identification of underlying errors (Bennett-Levy, 1984; Hamby, Wilkins, & Barry, 1993; Savage et al., 1999; Waber & Holmes, 1985). One of the most popular of these systems is the Boston Qualitative Scoring System (BQSS: Stern et al., 1994). The BQSS evaluates the RCFT for presence, accuracy, placement, organisational approach, size, rotation, perseveration, confabulation, and neatness (Stern et al., 1994). It has been commended for its wide-ranging reliable assessment of visuo-spatial functioning, and qualitative features that have the potential to impact upon the total score (Folbrecht, Charter, Walden, & Dobbs, 1999).

The superiority of the BQSS over the traditional method has been most clearly demonstrated in ADHD groups. In particular, the sensitivity and specificity of the RCFT to ADHD has been improved through use of the BQSS, with classification accuracy at 83% (Schreiber et al., 1999). This is an impressive result for an individual test being used in a complex clinical group. The BQSS has also been able to detect subtle, yet important differences where the traditional scoring method has failed. In ADHD patients, the system has been used to identify deficits in neatness, size accuracy, and inclusion of items (Cahn et al., 1996), while the traditional system has been unsuccessful in separating patients from controls (Pasini, et al., 2007).

In addition, the BQSS has made it possible to differentiate between cases that have equal impairment on the RCFT when the traditional scoring method is used. The authors of the system (Stern et al., 1994) demonstrate how two divergent cases— one with a history of closed head injury and the other a HIV positive male had virtually indistinguishable scores using the traditional method. When the BQSS was used, clear differences became apparent in the level of fragmentation, planning, perseveration, and size expansion (Stern et al., 1994).

Error analysis is by no means unique to the RCFT. Systems for a multitude of alternative figure copying tasks have been designed with a focus on the commission of error rates (Benton, 1974; Branjez & Bouma, 1991; Hécaen & Assal, 1970; Moore & Wyke, 1984; Rouleau, et al., 1992). Like the BQSS, these systems have demonstrated wide ranging efficacy by differentiating between clinical groups with similar quantitative scores (Rouleau et al., 1992), providing information regarding underlying cognitive deficits leading to poor quantitative scores (Moore & Wyke, 1984; Rouleau et al., 1992), identifying error types that distinguish performance from healthy controls (Brantjez & Bouma, 1991), and identifying error types that serve as markers for dementia severity (Robinson-Whelan, 1992).

In sum, scoring systems that focus on qualitative errors can provide additional information to those that focus on a quantitative total score. These findings are evident in several studies encompassing a wide range of clinical groups. The two main ways in which error analysis has demonstrated efficacy are: detection of subtle differences between groups, and explanation of the underlying causes for between-group differences.

Selecting the Best Figures to Assess Higher Order Visual Processing

Aside from the scoring method used, the figure/s comprising the task can have an impact on test utility. It has been asserted that "since any copying tasks can produce meaningful results, examiners should feel free to improvise tasks as they see fit" (Lezak et al., 2004, p. 549). While any figure may provide useful information, there are several issues to consider when selecting figures for clinical or research purposes. These issues include: suitability of the task for error analysis, the range/restriction of difficulty, the potential for floor and ceiling effects, and the resulting impact upon test sensitivity.

The RCFT has been studied fairly extensively in a range of clinical groups. Often, it is used as the sole stimuli for copying (e.g., Addington, Brooks, & Addington, 2003; Kim et al., 2003) or, of more concern, the only measure of HOVP (e.g., Ardila, Rosselli, & Strumwasser, 1991; Sacktor et al., 2002).

There are several problems with use of the RCFT in this manner. The task is complex and, as such, it makes demands on skills over and above HOVP, such as executive functioning, attention (Holtzer, SFtern, & Rakitin, 2005), working memory (Freeman et al., 2000), and planning (Akshoomoff, Feroleto, Doyle, & Stiles, 2002). Failure on the RCFT may therefore be due to a range of executive functioning difficulties rather than a true HOVP impairment. In addition, clinicians have reported that the task is simply not suitable for more cognitively impaired clients due to its complexity (Knight, Kaplan, & Ireland, 2003). This creates potential for floor effects. Not surprisingly, the task has demonstrated difficulty discriminating between conditions in which there is a high degree of cognitive impairment. Some of the clearest examples of these shortcomings are in dementia research, where RCFT has been unsuccessful in discriminating between different types of dementia (e.g., behavioural-variant fronto-temporal dementia and Alzheimer's Disease; Hodges et al., 1999; vascular dementia and Alzheimer's Disease; Chin et al., 2005; Golden et al., 2005). Finally, the use of any one figure in isolation leads to less chance of detecting a pattern of errors. The occurrence of any one error (e.g., omission, spatial misplacement, closing-in, rotation) can be given more weight when it occurs multiple times within a task (e.g., across several figures) rather than once using a single figure.

There are tasks available that overcome the problem of reliance on a single, complex figure by presenting multiple figures that ascend in difficulty. One such task is the Benton Visual Retention Test (BVRT: Sivan 1992). The BVRT, administration C (copy), is a test of visual perception and constructional skills, which involves the copy of 10 geometrical figures[1]. The task has a strong research background and is commended for being particularly sensitive to visuo-spatial neglect (Lezak et al., 2004). The copy administration is a complement to the other versions of the task which involve drawing the figures after a delay period and are used to assess visual memory (Benton, 1974). This is helpful, as it allows the clinician to separate spatial and motor deficits from memory impairment (Strauss, Sherman, & Spreen, 2006). However, as the name suggests (i.e., visual retention test), the task was primarily developed to identify visual memory problems. It has been pointed out that the figures comprising the BVRT are quite simple (Steck, 2005). This is not a problem when the BVRT is being used as a memory test, as placing a demand on memory raises the difficulty of the task. Not surprisingly, using the BVRT as a memory task has shown impressive utility even in fairly mild conditions such as multiple sclerosis (Ruggieri et al., 2003) and mild Alzheimer's disease (Kawas et al., 2003).

Unfortunately, this is not the case for the use of the task in the copy condition. The simplicity of the items creates the potential to produce ceiling effects as a

[1] Please note, depiction or discussion of the individual test items comprising the Benton Visual Retention Test is forbidden under copyright legislation.

consequence of poor differentiation amongst high performing groups (Steck, 2005). This restricted difficulty effect seems to become exacerbated in the copy trial, producing false negatives. These false negatives were present even in Benton's (1962) early clinical validation studies, in which the ability of the task to identify brain damaged patients from age and education matched controls using the total error score was alarming low (with only 20% correctly identified). Also, fairly early in its use, the copy version of the task was found to have questionable specificity, being poor to discriminate between left and right hemisphere lesions (Arena & Gainotti, 1978). This may explain the comparative unpopularity of the task in neuropsychology; 42% of psychologists endorse the BVRT, compared to 60% endorsing the RCFT (Butler, Retzlaff, & Vanderploeg, 1991).

An alternative task to the BVRT is the Bender Visual Motor Gestalt Test (Bender, 1946), a figure copying test featuring nine geometrical designs, in which the aim is for the examinee to copy each design accurately and to arrange them so they fit on a single A4 page. The task has generated significant research interest, ranking among the top three most researched instruments of its kind (Piotrowski, 1995).

Despite longstanding research interest in the Bender-Gestalt, the task has been used relatively infrequently by neuropsychologists; it was ranked 25th in a poll of test popularity, compared to the RCFT which was ranked 12th) (Camara, Nathan, & Puente, 2000). There are several possible reasons as to why the test may not be as popular as the RCFT. First and foremost, the task is relatively time consuming to apply, taking on average 40 minutes for trained neuropsychologists to administer, score, and interpret (Camara et al., 2000). Also, the score has long been associated with false negatives; historically, the Bender Gestalt has fallen short of sensitivity expectations, correctly identifying only 36% of dementia patients (Margolis, Williger, Greenlief, Dunn, & Gfeller, 1989). These sensitivity issues have been found most prominent in the early stages of dementia (Margolis et al., 1989; Storandt, 1990). Like the BVRT, sensitivity issues were most likely due to the simplicity of the figures: the first edition of the Bender Gestalt consisted of relatively simple geometric designs.

Later developments of the Bender-Gestalt recognised the need to extend the upper limits of the task to prevent ceiling effects (Brannigan & Decker, 2006). As such, the revised version (amongst other developments) featured an adult and children’s adaptation with additional figures extending the spectrum of difficulty to guard against both ceiling and floor effects (Brannigan & Decker, 2003). Curiously, despite the availability of the new edition, several more recent papers continue to use the early version (or variations thereof) in their research (Brosnan, Scott, Fox, & Pye, 2004; Ozen et al., 2006; Ozcebe, Kirazli, & Sevinc, 2009; Murayama et al., 2007; Sisto, Dos Santos, & Noronha, 2010). It is unclear why the new version has not been more widely embraced, however, some problems have been identified with the clinical utility of the task in subtle neuropsychological conditions (e.g., ADHD) (Allen & Decker, 2008).

Also of interest, despite developments of commercially available figure copying tasks, research and clinical interest has been mounting in individual figure copy tasks (i.e., using a single figure) and eclectic approaches (i.e., combinations of different figures). Some noteworthy examples include copy of a cube (Griffiths et al., 1988; Maeshima et al., 1997; Fountoulakis, Siamouli, & Magiria et al., 2011), a bicycle (Hubley & Hamilton, 2002), a clock (Rouleau et al., 1992), a cross (Guest & Fairhurst, 2002), intersecting pentagons (Folstein et al., 1975; Fountoulakis, Siamouli, & Panagiotidis et al., 2011), and multiple combinations of these individual figures (Ardila, Rosselli, & Rosas, 1989; Dansilo & Charamelo, 2005; Hécaen & Assal, 1970; Strub & Black, 1993). Reasons for the selection of these individual and eclectic approaches in favour of commercially available tests are not clearly documented, but may be due to the following: 1) faster administration time, 2) lack of copyright and associated cost of materials, 3) adaptability of eclectic approaches to the ability level of the patient, and 4) convenience due to lack of cumbersome stimuli (manuals etc.), especially in inpatient, bedside assessments.

Despite these attractive features, research on these individual figure copying tasks is patchy, with some having demonstrated clinical utility and others featuring sparsely in the literature. Recent research has indicated that three-dimensional figures can be useful in clinical groups where cognitive impairment is fairly subtle (e.g., cocaine dependent individuals), where simple, two-dimensional figures lack sensitivity (Elman et al., 2008). As such, cube copying is one area that has attracted much attention in the literature. Cube copying has been used over time to study increasingly complex clinical questions, ranging from identification of hemispheric differences (Hécaen & Assal, 1970), eliciting constructional apraxia after brain damage (Griffiths et al., 1988; Maeshima, et al., 2002), and identifying HOVP problems in clinical groups such as Parkinson’s Disease (Maeshima et al., 1997) and schizophrenia (Howanitz, Engelhart, Eisenstein, Harvey, & Lozonczy, 1998).

Although some of these individual and eclectic figure copying tasks may have demonstrated efficacy, there are several limitations to the use of idiosyncratic combinations of figures for copying. Of the multitude of individual figures that have been used in the past, there is no indication as to which combination of figures are the most sensitive to HOVP impairment. Of more concern is the failure of improvisational approaches to accurately take into account demographic variables that may have an impact on task performance. Without normative data, adjustment for social and cultural influences cannot be made. These issues may lead to misattribution of failure on the task to neuropsychological impairment, when it is indeed within the parameters of normal performance (i.e., a false positive).

Normative Data

As indicated earlier, neuropsychological impairment is not the only factor that can affect figure copying task performance. In fact, it has been documented that 50% of healthy controls cannot satisfactorily reproduce a cube (Griffiths et al., 1988). It appears there are a number of moderating variables (e.g., age and education) that can impact upon figure copying task performance (Groth-Marnat, 2009).

Age effects are one of the most consistently reported demographic factors that have been found to impact figure copying task performance. Performance on the RCFT (scored with the traditional quantitative system) has been frequently documented to decrease with age (Boone, Lesser, Hill-gutierrez, Berman, & D'elia, 1993; Gallagher & Burke, 2007; Rosselli & Ardila, 1991). Effects of age on alternate scoring systems for the RCFT, such as the BQSS, have revealed that declining performance is attributable to lower scores on the neatness scale in the context of preservation of all other scores (Hartman & Potter, 1998).

Effects of education on figure copying tasks have also been fairly widely studied. Positive effects of education on the RCFT have been identified (Rosselli & Ardila, 1991; Ardila, Rosselli, & Rosas, 1989), as well as other figure copying tasks such as a house and cube (Ardila, et al., 1989; Shimada et al., 2006). As a result, popular figure copying tasks such as the RCFT have detailed normative data that takes into account the effect of education (Mitrushina, Boone, Razani, & D'Elia, 2005; Wardill, Anderson, Graham, & Perre, 2009).

Gender is another important issue to take into consideration when analysing figure copying task performance, given that men have been found to outperform women on visually based tasks (Astur, Ortiz, & Sutherland, 1998). On figure copying tasks, such as the RCFT, it has been fairly consistently found that women have lower scores than men (Gallagher & Burke, 2007; Rosselli & Ardila, 1991). However, the effect of gender is not straightforward, as the findings appear to be confounded by education effects. In particular, the effect of gender is minimal in highly educated groups (Ardila et al., 1989), and once education is taken into account, gender differences tend to be negligible (Boone et al., 1993).

In sum, the relationship between demographic variables and figure copying task performance is fairly complex and may differ as a function of the figure used (e.g., cube, RCFT), scoring system (e.g., clinical error based as opposed to accuracy based, quantitative systems), or interactions amongst the demographic variables themselves. For this reason, it is particularly important to ensure that any figure and associated scoring system are appropriately examined for effects of demographic variables, and that these effects are taken into account in the generation of normative data.

Summary

In sum, an effective figure copying task should feature multiple figures, preferably with a mixture of basic and complex designs so as to guard against floor and ceiling effects. The task should have a well developed scoring system, which enables error analysis, is objective (i.e., features high inter-rater reliability), consistent (i.e., measures a unitary construct), and valid (i.e., correlates well with other tests within the relevant domain). The task itself and its accompanying scoring system should be time efficient, whilst maintaining sensitivity to a range of clinical disorders. Effects of any extraneous factors (i.e., demographic variables) that could influence task performance should be explored, and normative data should be current and take into account the effect of any such extraneous factors.

Popular measures in neuropsychology (i.e., the Bender-Gestalt, BVRT, and RCFT) have a wealth of research, normative data, and various scoring systems available for clinical use. Despite this, the well researched measures are not universally applied; some researchers prefer individual figure (e.g., cube or bicycle copy) or eclectic approaches. The literature does not clearly document why individual/eclectic approaches are preferred, however, there is evidence to indicate that well researched measures may not necessarily be suitable for all clinical groups. For instance, the RCFT is reported as too difficult for many clients to attempt (Knight, Kaplan, & Ireland, 2003) and the Bender Gestalt and BVRT have been documented to produce false negatives, especially in clinical populations where there is more subtle deviation from the norm (e.g., early stages of dementia, Attention Deficit Hyperactivity Disorder). These figure selection issues have resulted in clinicians supplementing well researched measures with their own preferences for individual or eclectic target figures.

The Simple Copy Task

One such eclectic task is the Simple Copy Task (SCT), a figure copying test featuring six target figures that vary in difficulty (see Figure 3). The origins of the task are unclear, however, it is attributable in part to Australian neuropsychologist Kevin Walsh who popularised the use of many of the figures (Walsh, 1985; Walsh 1987).

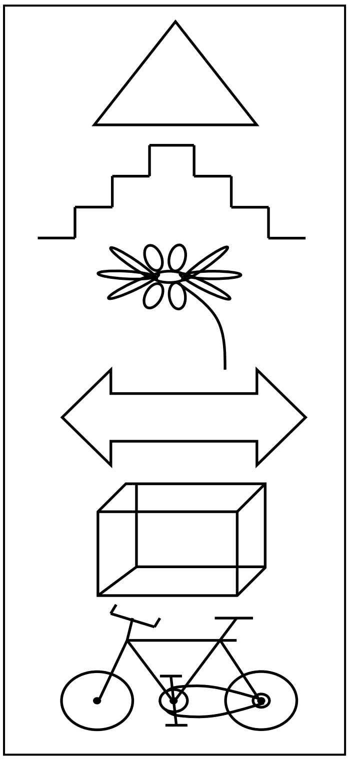

Figure 3. Figures comprising the Simple Copy Task.

There are several appealing features to the task, but perhaps the most attractive feature relates to figures included in the task. More specifically, the SCT ranges from fairly basic to quite complex figures, it features both two and three-dimensional pictures, and there are a mixture of symmetrical and non-symmetrical designs. Many of these individual figures have demonstrated clinical utility on their own—especially the cube (Griffiths et al., 1988; Hécaen & Assal, 1970; Howanitz et al., 1998; Maeshima et al., 1997) and the bicycle (Hubley & Hamilton, 2002), so it is not surprising they have been combined for clinical use. The symmetrical figures are thought to be particularly useful in assessing visuo-spatial neglect (Lezak et al., 2004), and the inclusion of simple figures (e.g., two-dimensional triangle) lessen the chance of floor effects occurring in clinical groups with high cognitive impairment. Aside from figure selection issues, the task may be appealing to time pressured clinicians as it features fewer figures than other commercially available tasks. Further, it is not restricted by copyright and therefore does not require the purchase of expensive test equipment. Although the task has not yet attracted attention in the research literature, it has a strong history of popularity in Australian Neuropsychology. It has been endorsed by neuropsychologists working in various disciplines including: acquired brain injury (Carol Burton, personal communication, Thursday November 17, 2011; Karen Bird, personal communication, Friday 18th November, 2011; Kim Roffel, personal communication, Wednesday 1st December, 2010), acute medical/surgical wards (Emilie Tijs, personal communication, Friday 11th November, 2011; Lina Forlano, personal communication, Thursday November 17th, 2011), sub-acute neurological wards (Gloria Smith-Tappe, personal communication, Tuesday December 6th, 2011), and outpatient geriatric assessment and dementia clinics (Lauren Dwyer, personal communication, Thursday November 10th, 2011; Dr Loretta Evans, personal communication, Sunday 22nd of April, 2007; Sophie

Kimonidies, personal communication, Thursday November 24th, 2011; Susan Lloyd, personal communication, Wednesday 7th of March, 2007).

Clinicians have explained that the task offers unique information to that provided by more formal measures. Doctor Karen Bird, Senior Clinical Neuropsychologist, explains that she frequently uses the SCT as a screening tool prior to administering the RCFT, which is often too complex for elderly persons with cognitive deficits. The SCT is often combined with other screening tests, such as the Clock Drawing Task, to gain qualitative information regarding the patients cognitive functioning, which can then be used as an adjunct to standardised cognitive measures (Emilie Tijs, personal communication, Friday 11th November, 2011; Karen Bird, personal communication, Friday 18th November, 2011).

Despite the inherent appeal of the SCT there is as yet no published research directing its scoring or clinical interpretation. As a result, the task is susceptible to all the dangers of qualitative judgment based 'scoring' (i.e., subjectivity based upon past experience), and there is no indication of the parameters that surround normal performance on the task. Essentially, this means that even if raters were to agree that a particular type of error had occurred on the task, there is no reference to the frequency of the error in the healthy adult population, and no means of knowing whether the error is diagnostically informative.

Consequently, the present author devised a proposed scoring manual for the SCT (see Appendix B) which was based upon systems used in other copying tasks, such as RCFT (Taylor, 1959), the Visual Reproduction Task (Wechsler, 1981), and the Benton Visual Retention Test (Benton, 1992).

The primary aim of this thesis was to assess the clinical utility the SCT, as scored by the proposed scoring system. A secondary aim was to investigate the scoring system itself in terms of psychometric properties. In conjunction, it was required that the performance of healthy adults was quantified by collating normative data. The final aim was to identify the figures in the SCT which provided the most information for screening purposes.

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Preface to Chapter 2

The first stage of investigation regarding the SCT was to examine whether the task had gross clinical utility; could it distinguish between clinical groups and healthy adults? If the test was unable to do so, there would be no sense in exploring the psychometric properties of the task in depth and providing normative data.

Consequently, the first paper focuses on the ability of the task to distinguish between four groups: healthy adults, those with a diagnosis of dementia, movement disorder, or schizophrenia.

Chapter 2: The Simple Copy Task: Detecting Higher Order Visual Processing Deficits in Schizophrenia, Dementia, and Movement Disorder Groups.

This chapter was accepted for publication by the Australian Psychologist 08/02/12,

doi:10.1111/j.1742-9544.2012.00067.x

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Abstract

The Simple Copy Task is a figure copying test that has inherent appeal due to its short administration time, graded task difficulty, varied stimuli, and potential to eliminate floor effects. Despite this, there is a lack of data regarding its construct validity and diagnostic sensitivity. The present study compared Simple Copy Task performance between schizophrenia (n = 29), dementia (n = 64), and movement disorder groups (n = 12) to that of unmatched healthy control participants (n = 49). Movement disorder patients committed a strikingly high degree of misplacement errors, whereas dementia patients tended to omit items, add extraneous detail, and perseverate. The schizophrenia group was most similar to the dementia group in their performance on the Simple Copy Task, committing primarily omission and perseveration errors. The Simple Copy Task was most closely related to the Rey Complex Figure Task (r = .68, p <.01) and the Block Design Task (r = .62, p <.01). The task was resistant to effects of demographic variables including gender and dominant hand use; however, age (r = -.14, p < .01) and education (r = .35, p < .01) effects were present. Taken together, these findings provide support for the utility of the task, and directions for clinical interpretation.

Introduction

Higher order visual processing – the collective of visuo-perceptual, spatial, and constructional skills is the cognitive domain that enables one to process spatial location, integrate visual components into a gestalt, and interact effectively with the visual environment (Benton & Tranel, 1992; Lezak, Howieson, & Loring, 2004; Sadock & Sadock, 2005). Neuropsychologists have long recognised the potential for figure copying tasks to provide a wealth of information regarding higher order visual processing (Lezak et al., 2004).

Schizophrenia and figure copying. Given this, it is not surprising that figure copying tasks have been used to elicit higher order visual processing difficulties in schizophrenia patients (Howanitz, Engelhardt, Eisenstein, Harvey, & Lozonczy, 1998; Jogems-Kosterman, Zitman, Van Hoof, & Hulstijn, 2001). Specifically, schizophrenia patients' performance on figure copying tasks tends to suffer when the designs to be copied increase in complexity (i.e., beyond symmetrical two dimensional shapes, to detailed or three dimensional shapes) (Howanitz, et al., 1998; Jogems-Kosterman, et al., 2000).

In schizophrenia, the underlying mechanisms leading to impaired figure copying performance are suggested to be secondary to impairments in executive functioning, including planning (Howanitz et al., 1998) and working memory (Lee & Park, 2005). Despite this, there is some evidence to suggest that even in relatively stable, outpatient, medicated schizophrenia patients there are demonstrable deficits in lower level visual processing tasks, such as shape discrimination and identification of spatial location (Tek et al., 2002). Therefore, whilst it is clear that patients with schizophrenia have more difficulty than controls on higher order visual processing tasks (including figure copying), and that the impairment becomes more profound with increases in design complexity, the etiology of the deficit is less clear.

This is likely owing to the manner in which figure copying tasks have been assessed in schizophrenia. Specifically, past research has generally focused on comparing an overall score on figure copying tasks between control and schizophrenia groups (Howanitz, et al., 1998; Jogems-Kosterman, et al., 2000). Such a comparison fails to address the qualitative nature of the errors in schizophrenia— if the groups were instead compared on error patterns (e.g. sizing, spatial placement, inattention type errors), the source of the deficit may be more clear.

Dementia and figure copying. Contrasting this, much research has focused on figure copying in the field of Alzheimer's Disease (AD), with comparisons being made both at quantitative and qualitative levels (Berry, Allen, & Schmitt, 1991; Bigler, Rosa, Schultz, Hal, & Harris, 1989; Brantjez & Bouma, 1991; Lezak et al., 2004). In particular, copying tasks in AD groups have been diagnostically informative (Berry et al., 1991), and (similar to schizophrenia groups) generally feature a strikingly high degree of overall impairment relative to controls (Brantjez & Bouma, 1991). Aside from these quantitative differences, AD patients' performance on figure copying tasks tends to be slow, with a high frequency of omission and confabulation type errors (Brantjez & Bouma, 1991).

Vascular dementia is similar to AD in the type of impairment in higher order visual processing skills (Looi & Sachdev, 1999). In particular, both groups are generally equally impaired on perceptual and constructional tasks, and both exhibit poor scores on simple and complex figure copying (Looi & Sachdev, 1999). A further similarity between the two groups is that of perseveration: a failure to terminate a specific behaviour when appropriate (Hotz & Helm-Estabrooks, 1995). Figure reproductions have been successful in eliciting perseverative behaviour in both AD (Ryan et al., 1995) and vascular dementia patients (Lamar et al., 1997). Overall, despite differences in the type of memory impairment seen in various forms of dementia, there are similarities between higher order visual processing performance in AD and vascular dementia groups (Graham, Emery, & Hodges, 2004), which are pronounced on figure copying tasks.

Movement disorders and figure copying. Although movement disorder patients, such as those with a diagnosis of Huntington's (HD) and Parkinson's disease (PD), demonstrate impaired higher order visual processing skills, they differ from dementia groups in the types of errors made on figure copying tasks (Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992). In particular, when copying a simple figure, HD patients make more errors of misplacement, imprecision, and size minimisation, whereas AD patients tend towards errors of perseveration and size enlargement (Rouleau et al., 1992).

Interestingly, the graphic errors seen in HD patients occur above and beyond that explained by physical aspects of the disability (e.g., chorea, motor disability) (Rouleau et al., 1992), suggesting that the impairment is in fact due to higher order visual processing difficulties rather than a difficulty in drawing per se. In fact, HD patients tend to show impairments early in the disease process on complex visual processing tasks and with disease progression, their scores generally decline on a range of spatial, perceptual, and constructional tasks (Gómez-Tortosa, del Barrio, Barroso, García Ruiz, 1996).

Although HD and PD patients represent distinct types of movement disorders, they both share similar patterns of impairment on tasks measuring perceptual functioning (Lawrence, Watkins, Sahakian, Hodges, & Robbins, 2000). Deficits in higher order visual processing have been reflected in unmedicated PD patients' poor copies of a three dimensional figure (Maeshima, Itakura, Nakagawa, Nakai, & Komai, 1997). Interestingly, the simple act of copying a cube has been effectively used in PD patients to predict functional impairment (Maeshima et al., 1997). A further frequently documented feature of PD is the presence of micrographia, which features in figure reproductions even when patients are well controlled with medication (Kim, Lee, Park, Lee, & Na, 2005). This again parallels HD patients, in that their figure reproductions tend to be notably smaller than the target figure (Rouleau et al., 1992).

In sum, it is clear that higher order visual processing difficulties are present in various clinical groups including dementia (AD and vascular dementia), movement disorder (HD and PD), and psychiatric groups (schizophrenia). These difficulties differ in nature between clinical groups, and tend to manifest as distinct error patterns on figure copying tasks. To date, there is little research directly comparing the error patterns of these specific clinical groups.

Problems with existing figure copy research. Existing research in neurological samples has generally focussed on the copying of a simple, individual figure, such as a clock (Rouleau et al., 1992), or a cross (Guest & Fairhurst, 2002); a single complex figure (Freeman et al., 2000; Looi & Sachdev, 1999; Maeshema et al., 1997); or a group of difficult figures (Hécaen & Assal, 1970). There are several problems in assessing figure reproductions in these ways. Firstly, administering figure/s with a limited range of difficulty (i.e., figures that are too simple or too complex) produces potential ceiling and floor effects. Consider the example of the Rey Complex Figure Task (RCFT; Rey, 1941; Osterrieth, 1944), a complicated copying task that has been documented to load on executive functioning, and in particular planning abilities (Smith & Zahka, 2006). Failure on the RCFT may not necessarily provide information regarding the patients higher order visual processing deficit, but may actually represent a decline in executive functioning (Smith & Zahka, 2006). Second, administration of an individual figure (e.g., the RCFT) does not allow for the clinician to observe a ‘pattern’ of errors. The occurrence of a particular error type (e.g., perseveration) is much less compelling when observed in isolation, rather than multiple times within a task. In the past, the tasks that have attempted to overcome these problems by including multiple figures that ascend in difficulty (e.g., Bender Gestalt Test: Pascal & Suttell, 1951) have fallen out of favour in clinical practice due to their cumbersome administration time (the Bender Gestalt Test is documented to take approximately half an hour to administer) (Dibner & Korn, 1969). In sum, an effective figure copying task should 1) feature more than one figure; 2) consist of items that are graded in difficulty; and, 3) be fast and easy to administer.

With these considerations in mind, the Simple Copy Task (SCT) may provide an attractive alternative to more commonly studied measures. The SCT is a figure copying test that requires the patient to reproduce a series of pictures presented in ascending levels of difficulty, beginning with simple geometric shapes and continuing on to three-dimensional and complex designs (see Figure 1). The origins of the task are unclear, however, it can be attributed in part to Australian neuropsychologist Kevin Walsh, who demonstrated the effectiveness of many of the figures in eliciting higher order visual processing deficits (Walsh, 1985; Walsh 1987). The task is potentially appealing to both clinicians and patients for several reasons. Firstly, it is inherently simpler than some of the more popular figure copying tests promoted in neuropsychology, such as the RCFT; and may lessen the load on executive functioning and eliminate floor effects. Further, it provides a mix of simple and more difficult figures, affording itself to examination of clinical error patterns occurring across figures. Finally, it is shorter than other commercially available tasks (e.g., the Bender Gestalt Test).

Surprisingly, despite the appeal of the SCT, there is no published data regarding the task. In particular, research is yet to be conducted on the SCT regarding construct validity, its ability to distinguish between various neurological groups, its robustness to potentially confounding demographic characteristics (e.g., gender, age), and normative data. Further, the SCT has yet to be explored as a tool for comparing higher order visual processing deficits in clinical groups (e.g., schizophrenia, dementia, and movement disorder patients). Given this, the aims of the current study pertaining to the SCT were 1) to examine construct validity, 2) to determine the impact of demographic variables (i.e., age, gender, education) on task performance, and 3) to examine differences in task performance across various neurological groups.

Method

Participants. There were two sources of data utilised in the current study: hospital file records, and a sample of healthy adults. Data for the clinical groups was gathered from Bendigo Hospital John Lindell Rehabilitation Unit neuropsychological filing storage. In total there were 1,137 files, dating from 1980 to 2010. Of these, there were 449 cases in which the SCT was used. For classification purposes, diagnoses were attained from the summary section of the neuropsychological report, which was formulated by the neuropsychologist based upon the following: neuropsychological test performance, imaging, medical records, patient history, and/or corroborative history. Note that in certain cases (e.g., AD), diagnostic classification is considered ‘probable’ until confirmed at autopsy. In order to increase confidence in diagnosis for inclusion in the current study, unclear and multi-factorial cases were excluded. Other exclusion criteria included the following: clinician queried insufficient effort/malingering, age under 18 years, or rare presentations (fewer than five cases of a particular diagnostic category). In total, 79 cases were excluded, leaving 370 cases remaining, with an age range of 18 to 89.

The resulting clinical group was comprised of 18 different diagnoses, including; alcohol related brain injury (n = 13), Alzheimer’s disease (n = 33), anxiety disorder (n = 15), depression (n = 19), depression plus anxiety disorder (n = 29), fronto-temporal dementia (n = 11), Huntington’s disease (n = 5), hypoxia (n = 12), intellectual disability (n = 18), multiple sclerosis (n = 17), mixed Alzheimer’s and vascular dementia (n = 23), schizophrenia (n = 30), Parkinson’s disease (n = 9), vascular cognitive impairment (n = 20), vascular dementia (n = 18), right hemisphere stroke (n = 37), left hemisphere stroke (n = 23), and traumatic brain injury (n = 38).

For clarity of analysis and in order to attain sufficient statistical power, specific groups of interest were combined into larger diagnostic categories of dementia (vascular dementia, Alzheimer's disease, and mixed vascular and Alzheimer's disease), movement disorders (Parkinson's and Huntington's disease), and schizophrenia. Note that there was not sufficient theoretical background to justify including fronto-temporal dementia patients into the dementia group. In particular some research has reported AD patients are more impaired on spatial tasks than FTD patients (Miller et al., 1997; Mendez et al., 1996; Razani, Boone, Miller, Lee & Sherman, 2001), whilst other studies have reported no difference between the groups (Grossi et al., 2002; Kramer et al., 2003). For this reason, the fronto-temporal dementia group was not included into the dementia group.

An additional unmatched control group (n = 49) was recruited via community groups in the Melbourne metropolitan area. Participants were selected on the basis that they did not have a positive history of neurological or psychological disorder, and had normal (or corrected) vision and hearing.

Demographic variables including age, gender, handedness, and years of education are summarised for the four groups in Table 1. The groups differed in terms of age, F (3, 163) = 67.10, $p < .01$, education, F (3,155) = 9.12, $p < .01$, and gender, x^2 (3, N = 167) = 11.31, $p = .01$, but not handedness, x^2 (3, N = 155) = 1.13, $p = .77$. Tukey's post hoc analyses indicated that the healthy control group had a higher level of education than the dementia ($p < .01$), schizophrenia ($p < .01$), and movement disorder group ($p < .01$). In addition, the healthy control group was older than the schizophrenia group ($p < .01$), and younger than the dementia group ($p < .01$), but not different with respect to age from the movement disorder group. Gender differences were not statistically significant, except for between the movement disorder and dementia group ($p = .02$). Given the presence of between group demographic differences, subsequent statistical analyses controlled for demographic variables where appropriate.

Table 1

Mean (M), Standard Deviation (SD), and Range of Demographic Characteristics of the Control and Clinical Sub-Groups.

	Age				Education				Gender		Hand	
Group	n	M	SD	Range	n	M	SD	Range	n	%F	n	%R
Control	49	60.59	11.07	35-83	49	12.04	2.81	6-20	49	46.90	49	91.80
Schizophrenia	30	39.63	14.69	18-79	29	10.07	1.67	7-15	30	40.00	26	92.30
Dementia	74	73.19	8.10	48-89	68	9.43	3.07	2-19	74	36.50	68	91.20
Movement disorder	11	62.93	14.57	32-83	13	9.31	3.23	4-18	14	21.40	12	100.00

Note. ** p <.001. The reflect transformation reverses the direction of the correlations with SCT. Figures presented in parenthesis represent untransformed descriptive statistics. Due to use of retrospective data, occasionally data was unavailable for one or more of the demographic variables.

Measures. The rationale for selection of neuropsychological tests was based upon two criteria, namely that 1) the test was part of the standard battery administered at Bendigo Health (as data was collected retrospectively), and 2) that the test measured non-verbal abilities or a construct that could have an impact upon neuropsychological test performance (e.g., depression or anxiety).

The measures included the SCT, the Austin Maze, the RCFT, the Clock Drawing Task, and visual subtests from the Wechsler Adult Intelligence Scale (3rd ed.) (Wechsler, 1997), including Block Design, Digit Symbol Coding, and the Picture Completion task. The Depression Anxiety Stress Scale, short version (DASS-21; Lovibond & Lovibond, 1995) was also included in the battery in order to screen control participants for psychiatric symptoms that may influence the results. These measures were collected from the files of the retrospective cases, and administered to the control participants in a 45 minute session taking place in their homes.

Simple Copy Task. Figures comprising the SCT are outlined in Figure 1. Patients are required to reproduce, as accurately as possible, the figures presented to them by drawing freehand. They were allowed to refer back to the target figures as much as they wished during the copying task, thus ruling out demands on memory. The current researchers designed a scoring system based upon systems used in other copying tasks, such as RCFT (Taylor, 1959), the Visual Reproduction Task (Wechsler, 1981), and the Benton Visual Retention Test (Benton, 1992). The total score is comprised of two subtotals; one that is figure specific and therefore requires inclusion of all the relevant parts that comprise each figure, and one that is general, and measures clinical errors that can occur on any figure regardless of the design. The clinical errors included absence of items, inclusion of extraneous items, perseveration (i.e., multiple retracing of a single line), misplacement of items, size distortions, rotation, and closing in (i.e., overlapping the target figure). Possible attainable scores range from 0-68, with higher scores indicating better performance. Scoring for the study was completed by the principal researcher, with a sub-set (n = 20) re-scored by a neuropsychology intern to ensure objectivity of the system. In the current sample, inter-rater reliability (r = .93) and internal consistency (Chronbach's α = .89) were both high.

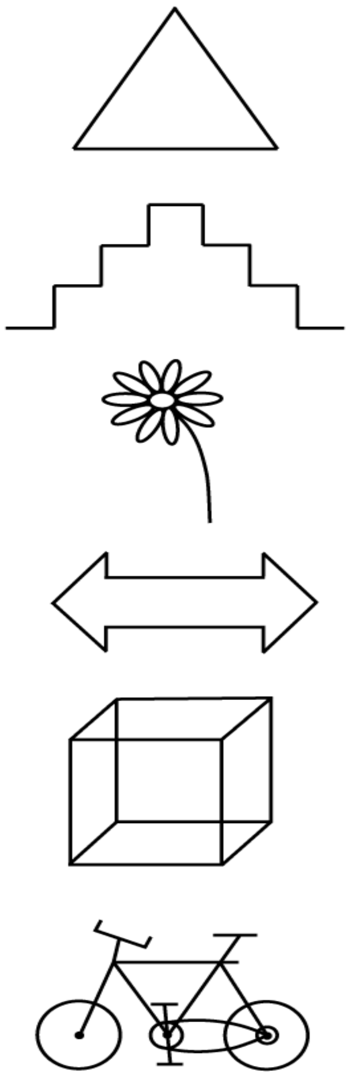

Figure 1. Target figures that comprise the Simple Copy Task.

Austin Maze. The Austin Maze, designed by Milner (1965), is a test of visuo-spatial abilities, including visuo-spatial memory and learning (Crowe et al., 1999). The task was administered via the standard guidelines as presented in Walsh (1985). The outcome measure used in the study was the total number of errors across trials, with a lower score indicating better performance.

Rey Complex Figure Task. The RCFT can be described as a test of visual perception, visuo-spatial organisation, and motor functioning (Strauss, Sherman, & Spreen, 2006). Both the immediate copy condition, and the 30 minute delay condition were administered in the current study. The original scoring system, featured in Taylor (1959) was used to score all RCFT figure reproductions. Total attainable scores ranged between 0-36. Inter-rater reliability of this system has been found at an acceptable .88, while intra-rater reliability has been demonstrated at an impressive .96 (Liberman, Stewart, Seines, & Gordon, 2006).

WAIS-III subtests. The WAIS-III subtests including the Block Design, Picture Completion, and Digit Symbol Coding tasks were administered via the standard procedure outlined in the administration and scoring manual (Wechsler, 1997). Age scaled scores were used in the analysis. The Block Design subtest is primarily considered a measure of constructional functioning, however, task completion can also be affected by processing speed and planning (Lezak et al., 2004). The Picture Completion subtest is a time dependent measure of visual attention (Kurachi et al., 1994). The Digit Symbol Coding Task requires a sequence of coordinated motor responses (Goldstein, Johnson, & Minshew, 2001) and loads upon processing speed and incidental memory (Strauss et al., 2006). The Matrix Reasoning subtest was not included in the study as the data was sparsely available in the retrospective records.

Clock Drawing Task. In the Clock Drawing Task (CDT; Borod, Goodglass, & Kaplan, 1980) the participant is required to draw a clock on a blank piece of A4 paper. The participant is instructed to "draw the face of the clock, with all the numbers in the right place, and set the time to ten minutes past eleven" (Lezak et al., 2004). The task provides a measure of spatial and constructional functioning, but also loads on executive functioning ability (Strauss et al., 2006). Clock drawings were scored using the Rouleau et al. (1992) system, which relates to the correct placement of hands, presence and sequencing of the numbers, and quality of the clock face. The CDT has a total attainable score ranging from 0-10, with low scores indicating poor performance. Scoring with the Rouleau et al. (1992) system has been shown to have a .70 correlation with driving ability (Freund, Gravenstein, Ferris, Burke, & Shaheen, 2005), and has been effectively used to differentiate between mild Alzheimer's and intact older adults (Esteban-Santillan, Praditsuwan, Euda & Geldmacher, 1998) thus demonstrating predictive and ecological validity.

Procedure. Ethical approval was obtained from Bendigo Health and the La Trobe University Ethics Committee. For the clinical group, data was transcribed and grouped as explained in the participants section. For the control group, informed consent was obtained and participants were tested in a 45 minute session in their homes on the battery of neuropsychological tests described in the measures section. Control participants were administered the tests in the following order: RCFT (copy condition), Austin Maze, DASS-21, Block Design Task, Digit Symbol Coding Task, RCFT (30 minute delay), CDT, and the SCT. Data from the Picture Completion subtest was not available in the healthy group, however, it was obtainable from the Bendigo Health filing storage and therefore is presented only for the clinical group.

Results

The effect of gender, age, handedness, and education on the SCT. The relationship between gender, age, handedness, education and SCT scores was examined using Pearson's Product Moment Correlation coefficients (see Table 2 for descriptive statistics and correlations between the variables). Preliminary analysis revealed the SCT score was negatively skewed, and thus it was treated with the reflect and square root transformation. As such, Table 2 presents correlations in the reverse direction of their true meaning (for clarity, the true direction of the correlations is reported hereafter in text). Education had a medium strength positive relationship with SCT scores, indicating that as education increases, so too do scores on the SCT. Age had a small negative correlation with the SCT. Gender and handedness had very weak correlations with the SCT, which were not statistically significant.

Table 2

Inter-Correlations and Descriptive Statistics of Simple Copy Task (SCT) Score and Demographic Variables

	Descriptives			Correlations			
	M	*SD*	Range	2	3	4	5
1 SCT †	3.95 (51.44)	0.99 (8.12)	24-67	.14**	-.35**	<.01	-.02
2 Age	56.03	17.52	18-89		-.10	.09	-.01
3 Education	10.20	2.83	0-21			-.04	.01
4 Gender (% male)	51.44						-.04
5 Handedness (% right)	93.04						

†Reflected and square-root transformed.

A standard multiple regression was conducted to further analyse the effect of age and education on the SCT. The analysis utilised all control cases, as well as all clinical cases with a complete SCT (N = 402), in order to gain sufficient statistical power. Preliminary analyses revealed the SCT total was negatively skewed, thus it was treated with the reflect and square root transformation. Age and education significantly predicted SCT total score, $R^2 = .14$, F (2, 384) = 29.768, $p < .001$ (see Table 3). Education ($sr^2 = .12$, $p < .001$) made a larger contribution than age ($sr^2 = .02$, $p = .02$).

Table 3

Standard Multiple Regression of Age and Education Predicting Simple Copy Task Total Score

Predictors	*B*	*β*	*p*	*sr*
Age	.01	.11	.02	.12
Education	-.12	-.34	<.001	-.35

Construct validity of the SCT. Correlations were investigated between SCT and other non-verbal measures of spatial ability (see Table 4). Again, to attain sufficient statistical power, all control participants and all clinical cases with a complete SCT were included in the analysis. Note that several of the measures violated the assumption of normality and thus were treated with transformations (see Table 4 for details). Results indicated that the SCT correlated strongly with the RCFT copy condition, as well as the Block Design task: signifying that patients with high scores on SCT would also have high scores on these tasks. The SCT was found to have moderate correlations with the Picture Completion task, RCFT delay, CDT, and Digit Symbol Coding. The correlation between the SCT and the Austin Maze task was small and, of note, was the only measure that failed to attain a statistically significant relationship with the SCT (p = .26)

Table 4

Inter-Correlations between the Simple Copy Task (SCT) and Additional Neuropsychological Measures of Non-Verbal Ability

Measures	*M*	*SD*	2	3	4	5	6	7	8
1 SCT †	3.95 (51.44)	.99 (8.12)	-.46**	.68**	-.41**	.40**	-.62**	.14	-.40**
2 Pic Comp‡	2.85 (7.40)	.53 (3.04)	-	-.47**	.39**	-.38*	.59**	.20	.57**
3 Rey1 ʛ	2.31 (27.24)	.55 (6.99)		-	-.51**	.44**	-.60**	-.01	-.39**
4 Rey2 ‡	2.87 (8.69)	1.22 (7.03)			-	-.33**	.41**	-.63	.37**
5 Clock ʛ	0.80 (8.22)	.66 (1.92)				-	-.38**	.02	-.24
6 Blocks	8.47	3.41					-	-.20	.64**
7 Austin	79.05	36.55						-	.10
8 Coding	7.11	3.12							-

† Reflected and square-root transformed
‡ Square-root transformed
ʛ Reflected and natural-log transformed

Note. * $p < .01$, ** $p < .001$; SCT = Simple Copy Task, Pic Comp = Picture Completion Task, Rey1 = Rey Complex Figure Task, copy condition, Rey 2 = Rey Complex Figure Task, 30 minute delay condition, Clock = Clock Drawing Task, Blocks = Block Design Task, Austin = total number of errors on the Austin Maze, Coding = Digit Symbol Coding Task. The following measures were negatively skewed and treated with the reflect transformation, thus reversing the true direction of the correlation: SCT, Rey1, Rey2, Clock. Picture Completion Task scores were positively skewed and corrected with a square-root transformation.

Group differences on SCT and RCFT performance. Given that a) healthy control, schizophrenia, dementia, and movement disorder groups differed in terms of age and education (see method section), and b) age and education both had significant effects on SCT performance, it was necessary to control for these variables when analysing between group differences on SCT score. For this reason, a one-way between-groups analysis of covariance (with age and education as the covariates) was conducted to compare SCT score between healthy control, schizophrenia, dementia, and movement disorder groups. After controlling for age and education, the groups were found to differ in their mean SCT scores, F (3, 148) = 24.77, p < .01, η^2= .33. Table 5 provides sample sizes and descriptive statistics for SCT scores for each of the groups. Post-hoc Tukey pairwise comparisons indicated that the healthy control group had a significantly higher mean score than the schizophrenia (p <.01), dementia (p <.01), and movement disorder (p <.01) groups. The schizophrenia group performed better than the movement disorder group (p = .03), but did not significantly differ from the dementia group (p = .52). Likewise, the movement disorder group and dementia group did not significantly differ in mean SCT scores (p = .39).

Table 5

Simple Copy Task (SCT) Performance by Group

Group	*n*	Range	*M*	*SD*	95% CI
Healthy Control	49	53-64	59.24	3.44	56.61-60.37
Schizophrenia	29	35-60	50.72	6.26	48.44-54.67
Dementia	64	31-60	48.14	7.61	46.40-50.11
Movement Disorders	12	30-61	44.17	9.04	41.02-48.30

It was of interest to investigate whether the RCFT was better able than the SCT to distinguish between groups (i.e., dementia versus movement disorder; dementia versus schizophrenia). Again, given the differences in age and education between the groups, and the potential for demographic variables to impact upon figure copy task scores, it was necessary to conduct a one- way between-groups analysis of covariance (with age and education as co-variates) to determine the difference in RCFT scores between groups (i.e., healthy control, schizophrenia, dementia, and movement disorders). Table 6 provides sample sizes and descriptive statistics for RCFT score for each of the groups. There was a statistically significant difference in RCFT scores between groups after controlling for age and education, F (3, 141) = 10.21, p <.01, η^2 = .18. Tukey pairwise comparisons revealed that the RCFT had similar characteristics to the SCT in some respects: the mean scores (as demonstrated in Table 6) differed between healthy control and dementia groups (p <.01); healthy control and movement disorder groups (p <.01); schizophrenia and movement disorder groups (p = .04), but not the dementia and movement disorder group (p = .71), or the schizophrenia and dementia group (p = .18). However, unlike the SCT, the mean RCFT scores did not differ between healthy control or schizophrenia groups (p = .73). The RCFT total score was therefore no better than the SCT in distinguishing between neurological conditions (i.e., dementia, movement disorder, and schizophrenia), and was in fact worse at distinguishing between the schizophrenia and healthy control groups.

Error patterns on the SCT. Analysis of error patterns on the SCT was conducted to examine whether there were underlying differences between the clinical groups obscured by the total score. Initially, frequencies were inspected for each of the error types (i.e., absence of items, inclusion of extra items, perseveration, misplacement of items, distortions in size, rotation, closing-in) between the different groups. Table 7 displays the percentage of people in each group who committed one or more of each of the errors on the SCT. Upon visual inspection, the neurological groups committed a higher frequency of all the error types than healthy controls.

Table 6

Rey Complex Figure Task (RCFT) Performance by Group

Group	*n*	Range	*M*	*SD*	95% CI
Healthy Control	49	25.00-35.00	31.19	2.68	28.62-32.29
Schizophrenia	27	19.00-35.00	27.83	4.15	25.08-31.20
Dementia	62	1.50-34.00	23.39	8.02	21.92-25.55
Movement Disorders	9	2.50-35.00	20.06	9.97	16.69-24.87

In order to discover the most important error types in predicting a diagnosis of various neurological disorders (i.e., movement disorder, dementia, and schizophrenia) whilst controlling for demographic differences between groups, three hierarchical logistic regressions were performed to compare healthy controls with each of the clinical groups. In each case, where there were demographic differences between groups (see method section), these variables were entered at the first step, and the seven error types entered at the second step.

Table 7

Percentage of People in the Healthy Control, Dementia, Schizophrenia and Movement Disorder Groups Committing One or More Clinical Errors on the Simple Copy Task

	n	Absent items	Extra items	Perseveration	Misplacement	Size distortion	Rotation	Closing-in
Healthy	49	49%	8%	2%	30%	71%	0%	0%
Dementia	64	93%	46%	23%	80%	94%	9%	13%
Schizophrenia	29	90%	30%	20%	67%	93%	10%	10%
Movement Disorders	12	92%	50%	42%	100%	100%	33%	42%

Movement disorders. Firstly, a hierarchical logistic regression analysis was conducted to predict membership to the healthy control (n = 49) or movement disorders group (n = 12). The final model, χ^2 (3) = 37.48, p <.001, had 90% prediction success. After controlling for education and gender, the misplaced items error type was the single significant prsedictor of group membership (Wald Statistic = 9.95, p <.01, e^B = 12.63, 95% CI [2.61, 61.10]. Figure 2 illustrates the characteristic misplacement errors in the movement disorder group.

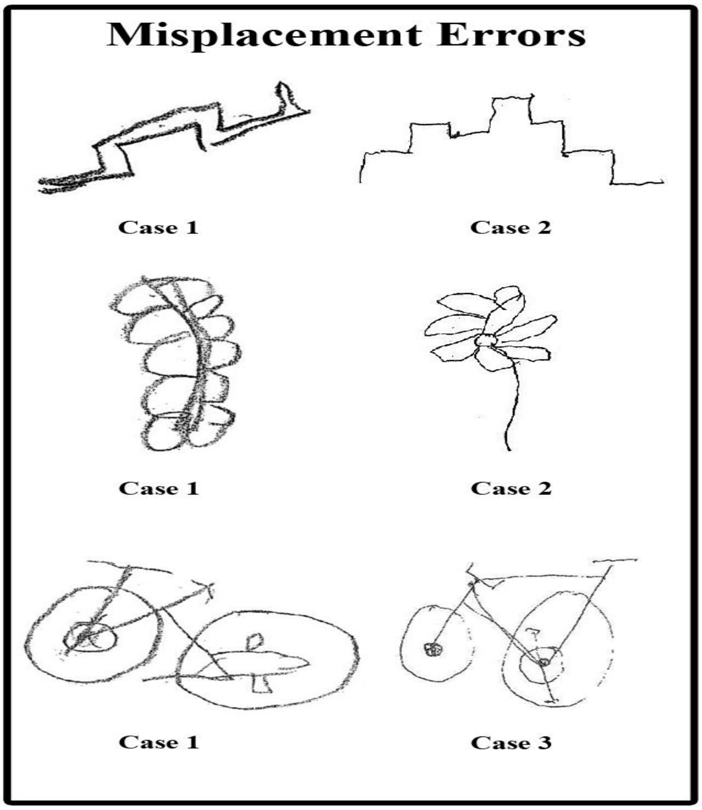

Figure 2. Misplacement errors on the Simple Copy Task in the movement disorder group. Case 1: 83 year old male, Parkinson's Disease; Case 2: 79 year old male, Parkinson's Disease; Case 3: 65 year old male, Parkinson's Disease.

Dementia. Next, a hierarchical stepwise logistic regression was conducted to predict membership to healthy control (n = 49) or dementia group (n = 69). The final model, χ^2 (6) = 76.66, p <.001, had 83% prediction success. After controlling for age and education, there were significant contributions from: absence of items (Wald Statistic (1) = 7.19, p <.01, e^B = 2.58, 95% CI [1.29, 5.17]), inclusion of extra items (Wald Statistic (2) = 6.11, p = .01, e^B = 4.09, 95% CI [1.34, 12.49]), and perseveration (Wald Statistic (3) = 3.78, p = .05, e^B = 5.29, 95% CI [0.99, 28.42]). Figure 3 demonstrates the error types that were common in the dementia group.

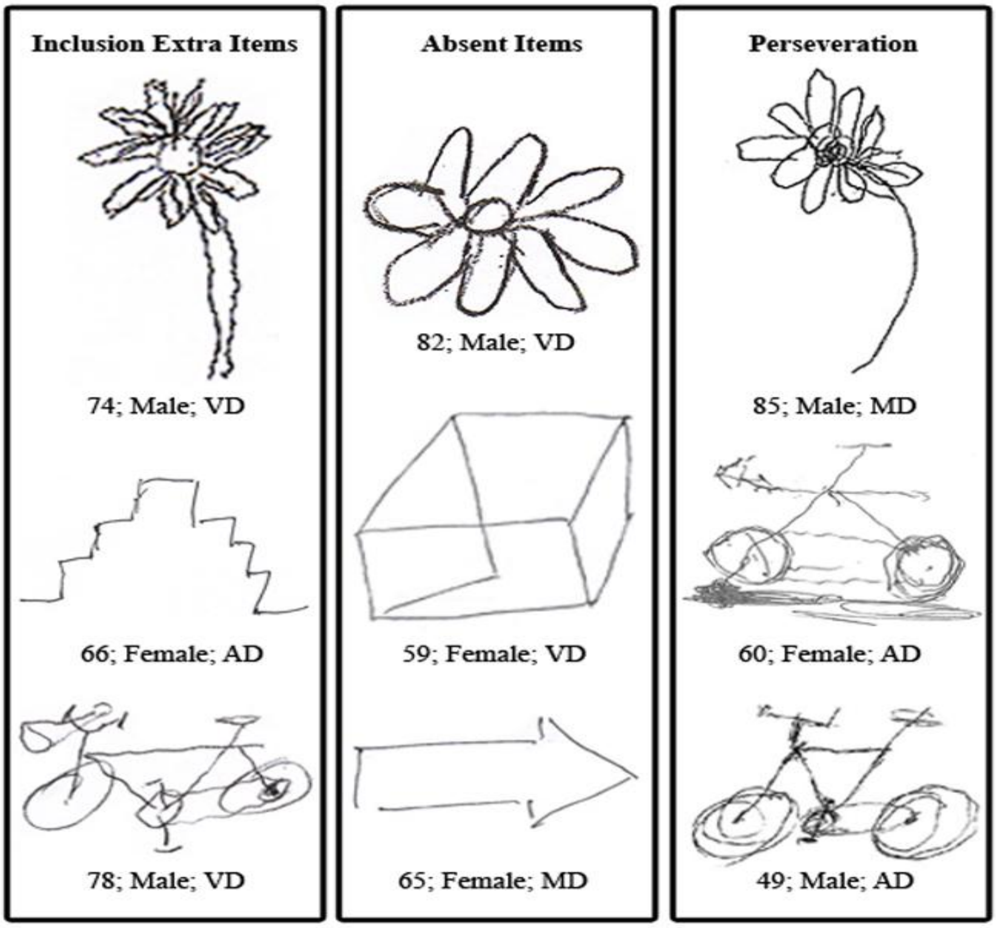

Figure 3. Simple Copy Task errors committed by the dementia group: inclusion of extra items, absent items, and perseveration. AD: Alzheimer's disease; MD: mixed Alzheimer's disease and vascular dementia; VD: vascular dementia.

Schizophrenia. Finally, a hierarchical logistic regression analysis was conducted to predict membership to healthy control (n = 49) or schizophrenia group (n = 30). The model, χ^2 (4) = 70.06, p <.001, had a prediction success of 92%. After controlling for age and education, there were two significant predictors of group membership: absence of items (Wald Statistic (1) = 6.79, p <.01, e^B = 4.95, 95% CI [1.49, 16.50]), and perseveration (Wald Statistic (2) = 7.42, p = <.01, e^B = 3.99, 95% CI [1.31, 5.91]. Figure 4 demonstrates the error types that were common in the schizophrenia group.

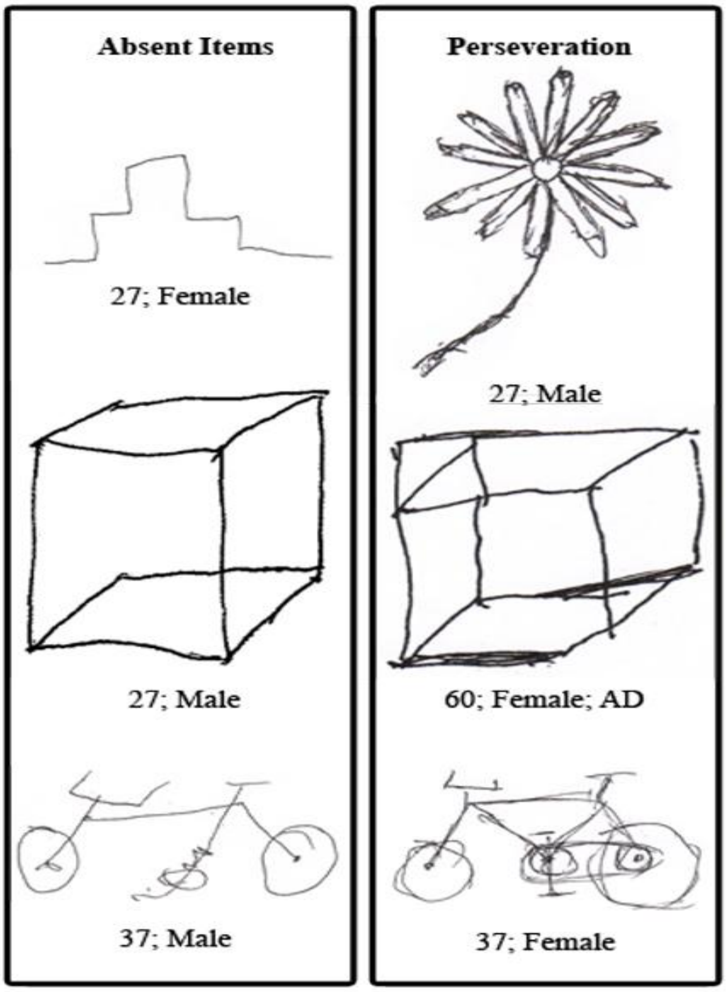

Figure 4. Simple Copy Task errors committed by the schizophrenia group: absent items and perseveration.

Discussion

The impact of demographic variables on the SCT. The results of the current study indicated that those who were younger and had higher levels of education tended to perform better on the SCT. However, these demographic variables explained only a relatively small amount of difference in the total score. Education was the strongest predictor, with age contributing only a very small portion of variance. The current study revealed that the SCT is unaffected by both gender and handedness.

In keeping with the findings of the current study, education effects have been found on a cube copying task, with research indicating that six years of formal education is required to complete an accurate reproduction of the three-dimensional figure (Shimada et al., 2006). Interestingly, Shimada et al. (2006) did not find that age had a significant effect on cube copying ability; however, their sample was restricted to older adults, and thus may not have encapsulated the tendency for younger adults to perform better on simple copying tasks. In a sample comprised of a broad age range, complex figure copying has been found to be effected by both age and education, but not gender (Caffarra, Vezzadina, Dieci, Zonato, & Venneri, 2002). Earlier research has indicated that age related decrements on figure copying tasks emerge only after the age of 70 years (Boone, Lesser, Hill-Gutierrez, Berman, D'elia, 1993). The apparent late decline in copying abilities that occurs with age helps to explain why this sample, with a broad age range, was sensitive to the effects of age on the SCT.

Overall, these results indicate that the SCT may be useful in a neurological population of both left and right handed males and females, with minimal effects of age. However, poor results on the task should be interpreted with caution when the patient's education is very low, particularly if they are of advanced age.

SCT as a measure of perceptual, spatial, and constructional abilities. Examination of the construct validity of the SCT indicated it was most similar to the copy administration of the RCFT. This is perhaps not surprising due to the similarities between the tasks – both involve direct reproduction of a target figure, attention to visual detail, and correct placement of items. The SCT may be attractive to clinicians in situations where the RCFT is too difficult for the client, or where it is unclear whether failure on the RCFT is due to poor planning rather than higher order visual processing difficulties.

The next most closely related task to the SCT was the Block Design subtest of the WAIS, a measure typically considered by neuropsychologists to tap into constructional abilities (Lezak et al., 2004). The SCT was related to a lesser extent to the Picture Completion subtest of the WAIS, a measure commonly thought to measure perceptual skills, visual attention and concentration (Groth-Marnat, 2003). These results were consistent with expectations, as past research utilising a quantitatively scored cube copying task has been found to have particularly high correlations with visual subtests of the WAIS, and in particular the Block Design Task (Maeshima et al., 2002).

Taken together, these results indicate the SCT may be a useful measure of higher order visual processing abilities in a neurological population, worth further development and research. Aside from merely correlating well with WAIS perceptual reasoning measures, it may add useful information when used in conjunction with these measures. Specifically, the SCT is not confounded by psychomotor speed, it provides both two and three-dimensional items (unlike the Block Design Task which consists solely of three-dimensional models), and it allows for delineation of error types rather than merely providing a solitary total score.

Group differences on the SCT. The total SCT score was useful in distinguishing between healthy and non-healthy participants, including the schizophrenia group. Despite this, there were some difficulties in using the total score to differentiate between the neurological groups themselves (i.e., dementia versus movement disorder; schizophrenia versus dementia). Difficulties using copying tasks to distinguish between neurological groups are not unique to the SCT. In fact, in the current study the RCFT had the same difficulty distinguishing between the neurological groups, and was actually worse than the SCT in distinguishing between healthy control and schizophrenia patients.

The utility of the SCT in distinguishing between control and psychiatric patients likely lies in the broad measurement of error types encapsulated by the SCT scoring system. The RCFT, using the commonly employed Taylor (1959) scoring method, rates figure reproductions based upon two criteria: inclusion and correct placement of items. Contrasting this, the quantitative scoring method used on the SCT measures a broader range of error types, including: missing items, inclusion of extra items, perseveration, misplacement of items, size distortions, rotations, and closing in on the target figure. Therefore, the diverse range of error types likely provides more opportunity for subtle deficits to be detected.

The current study indicated that the total score of the SCT can be used as a rough guide to distinguish between ‘impaired’ and ‘intact’ performances; however, this score does not appear to differ between movement disorder and dementia groups, nor dementia and schizophrenia groups. These results were expected, given that the task is intended for use as a brief screen. In order to yield richer clinical information, it is important to examine the frequency of individual error types.

Examination of error types. Overall, each of the clinical errors tended to occur more frequently in the neurological groups rather than in the healthy control group. These errors helped to provide more information regarding underlying differences obscured by the total score. For example, using the quantitative score alone, the movement disorder and dementia group did not differ in terms of SCT total score, however, some differences did emerge when comparisons were made using error analysis between the groups. In particular, there was a high degree of spatial misplacement occurring in the movement disorder group; each patient in this diagnostic category committed at least one misplacement error across the task.

The dementia and schizophrenia groups performed similarly, both in total score, and underlying error commission (i.e., absence of items and perseveration). The overlap in error commission between the schizophrenia and dementia groups were not surprising as the error types are thought to reflect underlying cognitive constructs (i.e. attention, higher order visual processing, executive functioning) that are not expected to be pathognomonic to any one clinical population. Indeed, executive functioning and higher order visual processing difficulties have been widely demonstrated in both schizophrenia (for review, see Stip, Lecardeur, & Sepehry, 2008) and dementia (Looi & Sachdev, 1999; Reed et al., 2007).

The one difference between the schizophrenia and dementia groups was that the inclusion of extra items (i.e., confabulation) error type was present in the model for dementia. Confabulation in figure reproductions has been proposed to relate to memory and executive compromise common in various forms of dementia (Pelati et al., 2011). Given that the SCT involves direct copy of the target figure (thus reducing demands placed on memory), the mechanism underlying the deficit in this case appears executive in nature. For example, inclusion of extra items on the SCT (e.g., addition of spokes or a horn on the bicycle) may represent poor attention to the target figure, or poor inhibition.

Directions for future work. The present study provides evidence for the potential utility of the SCT in distinguishing between patients with and without higher order visual processing deficits. Identifying individual predictors of a large range of more specific disorders (e.g., vascular dementia vs. Alzheimer’s disease) was unfortunately not possible due to the participant numbers required for analysis; however, it remains an interesting area to be explored in future work.

Additionally, the sample featured a moderately sized group of healthy volunteers as a basis for comparison to the clinical group; however, a full analysis of healthy control performance on the SCT was outside the scope of this study. The next logical step to aid clinicians in interpreting performance is to develop comprehensive normative data for the task, especially given the finding of education and age effects on SCT scores.

Summary. The SCT is a measure of visual attention, spatial cognition, and constructional skills. The task is relatively resistant to the effects of gender and handedness; however, low scores in patients of advanced age or particularly low education should be interpreted with caution. The total score of the SCT is actually more useful than the RCFT at distinguishing between healthy control and schizophrenia groups. Although the SCT total score itself cannot accurately distinguish between movement disorder and dementia patients, error analysis focusing on the frequency of errors made between the groups provides evidence that certain groups have a propensity towards particular error types. In particular, movement disorder patients tend to misplace items in their figure reproductions, whilst the dementia group leave out details, perseverate, and confabulate. Taken together, these results are impressive given the brief nature of the SCT. The findings provide evidence that the SCT is a useful screening tool for visual attention, spatial, and constructional difficulties – providing support that further research and development of the SCT is warranted.

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Preface to Chapter 3

In the second chapter, preliminary evidence was provided for the utility of the SCT. As a result of this study, there was now evidence that the SCT had the ability to distinguish between healthy and non-healthy adults, and that at a gross level, error patterns differed between clinical groups.

The previous chapter sampled a small number of healthy adults (n = 49) and provided some preliminary evidence for the reliability and validity of the task. At this stage, it remained unknown if both of the SCT sub-scales (i.e. figure-specific and clinical) were necessary. Therefore, prior to recommending the task for clinical use, it was important to quantify the perimeters of normal performance and further investigate the psychometric properties of the scoring system— including that of the sub-scales that comprise the total score.

As such, the third chapter examines construct validity, inter-rater reliability and internal consistency of the SCT sub-scales and provides Australian normative data for the task.

Chapter 3: The Simple Copy Task: Scoring Properties and Normative Data.

Running head: Normative data SCT

Manuscript submitted to: *Australian Psychologist*, 25/03/12.

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Abstract

The Simple Copy Task (SCT) — a figure copying test involving freehand reproduction of six target figures—has previously demonstrated clinical utility. Despite this, there is no established scoring system or normative data for this task. The current paper presents psychometric properties and normative data for the SCT, in terms of a figure-specific scale, a clinical scale, and a total score. Results based upon a neuropsychological group of mixed diagnosis (*n* = 370) demonstrated good internal consistency, inter-rater reliability, and construct validity for each SCT scale, including the total score. Administration and scoring time was brief; on average the task took approximately 3 min to administer and 3 min to score. Normative data (*n* = 147) based upon a broad age range (18-85) of moderately educated (*M* = 11.86, *SD* = 2.83) healthy adults was presented. The most common error types in the healthy population were size distortions and omissions, although these occurred at a relatively low frequency. Less common errors included rotation and closing-in (i.e., overlapping the target figure), the latter of which was entirely absent in the healthy control group. Occurrence of these relatively rare error types, particularly the closing-in phenomenon, should raise concerns regarding intact cognition.

Introduction

Drawing and copying tasks, although invaluable in neuropsychological assessment, differ from other neuropsychological tests where there are clear-cut definitions of correct and incorrect responses. Figures are inherently difficult to score as errors vary both in type and degree. Over the years, clinicians and researchers have attempted to quantify figure reproductions in numerous ways; from simplistic and qualitative to specific and quantitative.

Assessing figure reproductions using a qualitative approach requires the clinician to draw upon their experience with the task and make subjective decisions regarding the quality of the reproduction. Whilst some clinicians have suggested that “qualitative inspection of the patient’s designs is usually sufficient for clinical purposes” (Lezak, Howieson & Loring, 2004, p. 535), there are several problems with qualitative assessment, mostly related to issues of subjectivity. Specifically, clinical judgments are likely to be influenced by the idiosyncrasy of the clinician’s past experience; those frequently working with severe cases are more likely to miss subtle deficits. Aside from this, qualitative approaches do not allow for an accurate appraisal of extraneous factors (i.e., demographic, social, and cultural influences) that can impact upon test performance.

These issues have given rise to various scoring systems for figure copying tasks; however, there is marked variability in the quality, content, and complexity of available schemes. Historically, there are multiple examples of simple and brief scoring systems (Elman et al., 2008; Griffiths, Cook, & Newcombe, 1988; Strub & Black, 1993), however, their brevity often leads to compromises in quality. For example, simplistic systems (Elman et al., 2008; Griffiths at al., 1988; Strub & Black, 1993) frequently feature subjective, poorly operationalised terms (e.g., “minimal distortions”, “unsatisfactory reproductions”), a restricted range of possible scores, and poor delineation of error types. As a result, simplistic systems can have problems with inter-rater reliability, diagnostic utility, and detection of change over time.

A development on these rudimentary scoring systems are the so-called ‘figure-specific’ systems; that is, those that score figure reproductions based upon the presence and placement of elements that comprise a figure (e.g., wheels and handlebars to a bike). One of the more widely popularised figure-specific systems is that used for the Rey Complex Figure Task (RCFT) designed by Rey (1941) and later adapted by Osterrieth (1944) and Taylor (1959). This system awards points for the presence and accurate placement of the 18 key elements that comprise the complex figure. More recent developments on this traditional scoring system (Duley et al., 1993) provided specific detail of the scoring guidelines and have shown impressive inter-rater reliability; in approximately 90% of cases, raters were within two points of each other on a 0-36 point scale. However, reliability aside, this system does not evaluate the ‘clinical errors’ that have been documented to occur in neuropsychological populations. These clinical errors can occur regardless of the form of the figure, and may include rotation, perseveration, closing-in (i.e., overlapping the target figure), spatial misplacement, enlargement/shrinkage, lack of detail, or confabulation (Brantjez & Bouma, 1991; Della Sala, Turnbull, Beschin, & Perini, 2002; Moore & Wyke, 1984).

Consequently, several researchers later developed scoring systems for the RCFT that focused on clinical errors (Loring, Lee, & Meador, 1988; Stern et al., 1994) or the planning/approach to the task (Hamby, Wilkins, & Barry, 1993; Savage et al., 1999). These systems go beyond simply providing a quantitative total, and allow for analysis of the underlying types of errors (e.g., size distortions, rotation) that can be obscured by the summary score (Stern et al., 1994). Though widely utilised for research purposes, the error based systems have not commonly been embraced for clinical use (Lezak et al., 2004). The reasons behind this are unclear, but may relate to lengthy application time of the error based systems (some documented to take up to 20 minutes to apply) (Folbrecht, Charter, Walden, & Dobbs, 1999), and the appeal of the longstanding clinical and research history of traditional, quantitative systems (Everitt, 2008).

Similarly, in other figure copying tasks (e.g., copy of a cube, bicycle and house), many different error based systems have been developed over time (Branjez & Bouma, 1991; Fountoulakis et al., 2011; Hécaen & Assal, 1970; Moore & Wyke, 1984; Rouleau, Salmon, Butters, Kennedy, & Mc Guire, 1992; Seki et al., 2000). Despite this, some researchers continue to employ standard quantitative (i.e., figure-specific) methods (Maeshima, Itakura, Nakagawa, Nakai, & Komai, 1997; Seki, et al., 2000; Wardill, Anderson, Graham, & Perre, 2009). It may be that there is a place for both figure-specific and clinical systems in figure copying research. For instance, figure-specific systems have demonstrated utility in disorders where fine motor functioning is a primary concern (e.g., Parkinson's Disease) (Maeshima et al., 1997), and clinical error based systems have proven useful in conditions characterised by subtle, higher level cognitive difficulties (e.g., ADHD; Schreiber, Javorsky, Robinson, & Stern, 1999).

An equally important issue in quantifying figure reproductions is the robustness of the particular scoring system to potentially confounding demographic variables. Client's demographic characteristics, such as age (Boone et al., 1993; Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2002; Gallagher & Burke, 2007), gender (Gallagher & Burke, 2007), and education (Caffarra et al., 2002; Shimada et al., 2006) have been documented to impact upon test performance. Given this, there is strong rationale to refer to normative data that adjusts for demographic effects.

The Simple Copy Task (SCT) (see Figure 1) is an unpublished figure copying test which may be attractive to clinicians due to its brevity, graded task difficulty, and demonstrated efficacy in a range of clinical groups (Dridan, Ong, Evans, Lloyd, & Crowe, 2012). Despite this, little is known about the psychometric properties of the task, and there is no published normative data available. As such, the aims of the current study were to (1) examine the psychometric properties of figure-specific and clinical error based scoring methods for the SCT, (2) investigate the effects of potentially confounding demographic characteristics on figure-specific and clinical scoring indices; and (3) provide normative data for the task.

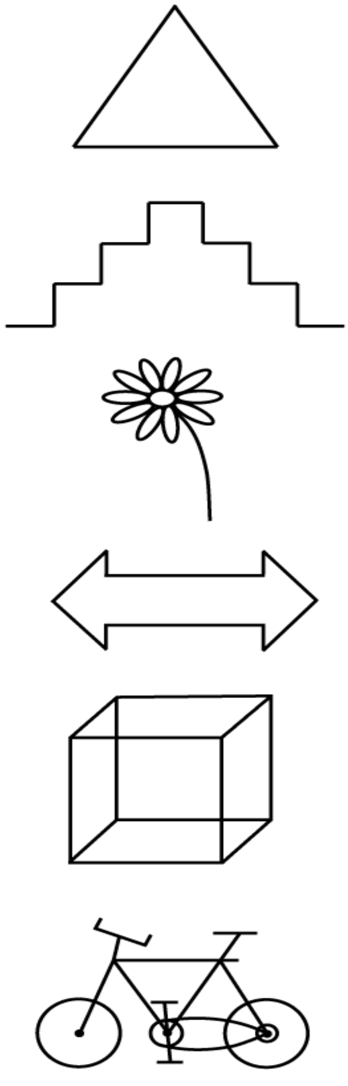

Figure 1. Target figures that comprise the Simple Copy Task.

Method

Participants.

Healthy group. In total, 156 control participants were recruited via community groups (i.e., sporting clubs, special interest groups) in the Melbourne metropolitan area. Participants were aged above 18 years, and had normal (or corrected) vision and hearing. Exclusion criteria included a positive history of psychiatric or neurological disorder as elicited via a telephone interview and in a demographics questionnaire that asked about participants' prior medical/substance use history. Five participants were excluded due to histories suggestive of a possible neurological condition (e.g., unexplained loss of consciousness, incidental vascular findings on neuro-imaging). Four participants with poor performance on the Clock Drawing Task were excluded, on the basis that the task has been identified as sensitive to early cognitive decline (Juby, Tench, & Baker, 2002). Descriptive statistics of age, gender, handedness, and years of education of the 147 healthy participants remaining after exclusion are provided in Table 1. Note that 49 of these 147 participants comprised the healthy control group in our earlier work (Dridan et al., 2012).

Clinical group. Secondary data for the clinical group was sourced from clinical records archived at Bendigo Hospital John Lindell Rehabilitation Unit. Clinical data was the same as that used in our earlier study (Dridan et al., 2012). In total there were 370 cases with a range of clinical diagnoses. Diagnostic sub-groups comprising the clinical group included: alcohol related brain injury (n = 13), Alzheimer's disease (n = 33), depression and/or anxiety disorder (n = 63), fronto-temporal dementia (n = 11), Huntington's disease (n = 5), hypoxic brain injury (n = 12), intellectual disability (n = 18), mixed Alzhiemer's Disease and vascular dementia (n = 23), multiple sclerosis (n = 17), schizophrenia (n = 30), Parkinson's disease (n = 9), vascular cognitive impairment (n = 20), vascular dementia (n = 18), right hemisphere stroke (n = 37), left hemisphere stroke (*n* = 23), and traumatic brain injury (*n* = 38). Demographic details of the clinical group are presented in Table 1.

Table 1

Demographic characteristics of the clinical and control sample

		Age			Education			Gender	Hand
	n	Range	*M*	*SD*	Range	*M*	*SD*	% F	% right
Control	147	18-83	53.83	18.57	4-20	11.86	2.83	61	91
Clinical	370	18-89	56.03	17.52	0-21	10.20	2.83	49	93

Measures.

Screening measures. A demographic screening questionnaire was used to determine participants' age, gender, education level, and medical/substance use history. Additionally, the Depression Anxiety Stress Scale, short version (DASS-21: Lovibond & Lovibond, 1995) was used to screen for symptoms of psychological distress that may have impacted upon neuropsychological performance. The Clock Drawing Task was administered as per the Rouleau et al. (1992) method, and scored using their 10 point scoring system. Healthy volunteers with a score of less than 8 on the Clock Drawing Task were excluded from the analysis, as this represented a score approximately 1.5 standard deviations below that of healthy adults reported in the validation study of the system (Rouleau et al., 1992).

***Simple Copy Task*.** Figures comprising the SCT are presented in Figure 1. The scoring system used in the current study was the same as that used in Dridan et al. (2012). The scoring system provides two subscales: figure-specific and clinical error based. The figure-specific component scores for motor accuracy (e.g., straightness of lines, joining of corners), component inclusion, and item placement. The clinical component evaluates the presence of seven types of errors (see Table 2) applied across all six figures. For simplicity, items comprising both components are worded so that higher scores indicate better performance. The total SCT score is derived by summing the total of the figure-specific and clinical scale scores. Table 2 presents an overview of the scoring system. Scoring for the current study was completed by the first author in accordance with the scoring manual[2].

Table 2

Summary of the scoring system for the Simple Copy Task

Scale	Criteria	Range
Figure-specific		0-25
Triangle	Three sides present	0-4
	Lines are straight	
	Corners are joined	
	Equal lengths	
Stairs	Correct number of stairs	0-5
	Equal at base (i.e., bottom stairs are level)	
	Height and width of stairs respected	
	Lines are straight	
	Corners are joined	
Flower	Correct number of petals	0-3
	Centre circle is present (not dot)	
	Stem is on right with bend in correct direction	

[2] Full scoring manual includes precise scoring direction and illustrations and is available from the first author upon email request.

Arrow	Both arrows are same size	0-4
	Centre lines parallel and in correct proportion	
	Lines are straight	
	Corners are joined	
Cube	Twelve lines are present	0-5
	The cube is facing the front and pointing left	
	Three-dimensionality is preserved	
	Lines are straight	
	Corners are joined	
Bike	Both wheels are present	0-5
	Handlebar is present	
	Centre triangle is present	
	Pedals are present	
	Chain present	
Clinical Error Based		0-42
(all figures)	No absence of items/hemi-neglect	0-7
	No inclusion of extra items	
	No perseveration	
	No misplacement of items	
	No major distortions in size/size relativity	
	No gross rotation	

	No closing-in on the target figure	
Simple Copy Task Total	Figure-specific total + clinical total	0-67

In order to determine inter-rater reliability, SCT data from 20 clinical and 20 healthy control participants were also scored by a neuropsychology intern. In order to determine time (in minutes) taken to score each case, the subset of 40 cases were also recorded for scoring time by an experienced rater (first author).

Neuropsychological measures. Neuropsychological measures were the same as that used in our earlier study (Dridan et al., 2012), where they are explained in some depth. Briefly, tasks were selected on the basis that they measured non-verbal functioning and were part of the standard neuropsychological battery of tests used at Bendigo Health. Neuropsychological measures included the Austin Maze (Milner, 1965), the Rey Complex Figure Task (RCFT: Rey, 1941; Osterrieth, 1944), the Block Design Task (Wechsler, 1997), and the Digit Symbol Coding Task (Wechsler, 1997).

Procedure.

Healthy Control. Ethical approval was obtained from La Trobe University Ethics Committee. Informed consent was obtained and participants were tested in their homes on the battery of neuropsychological tests described in the measures section. Participants were administered the tests in the following order: demographics questionnaire, RCFT (copy condition), Austin Maze, DASS-21, Block Design Task, Digit Symbol Coding task, RCFT (30 minute delay), Clock Drawing Task, and the SCT. The full battery took approximately 45 minutes to complete. In order to expedite testing, 100 participants were administered the full battery for the purpose of investigating construct validity in the healthy sample. The remaining 47 participants were administered a shortened version of the battery, which included only the tests that were pertinent to the generation of norms/inclusion of participants in the study. The shortened battery therefore consisted of the SCT plus the demographics questionnaire (to screen for exclusion criteria), the Clock Drawing Task (as a general cognitive screen), and the DASS-21 (to screen for psychiatric illness).

Clinical group. Data for the clinical group was transcribed as described in Dridan et al. (2012). Briefly, selected neuropsychological data archived at Bendigo Health John Lindell Rehabilitation Unit was extracted and de-identified (including diagnostic and demographic information and scores on tests listed in the measures section) for use in the present study.

Results

Psychometric characteristics of SCT scores. The psychometric properties of the SCT derived scores were assessed for internal consistency, inter-rater reliability, and ease of application. Psychometric characteristics reported herein pertain to the clinical group (psychometric characteristics using the control group are reported in Appendix C).

The internal consistency (Cronbach α), inter-rater reliability (Pearson Product moment correlation coefficient), and ease of application (mean minutes taken to apply the systems) of the SCT derived scores are presented in Table 3. The internal consistency of the figure-specific and clinical scales were both acceptable (i.e., > .70). Likewise, inter-rater reliability of both scores was high. The full scoring system took approximately 3 minutes for an experienced rater to apply.

Table 3

Psychometric characteristics of Simple Copy Task derived scores using the clinical sample

	Figure specific	Clinical	Simple Copy Total
Cronbach *a*	.74	.72	.88
Inter-rater reliability	.94	.87	.94
Time to score (mins)			
M	1.68	1.30	2.98
SD	0.22	0.39	0.50

Note. The inter-rater reliability (*r*) for SCT total was also presented in our earlier paper (Dridan et al., 2012).

Construct validity of the figure-specific and clinical scales. Construct validity of the figure-specific and clinical scales were assessed by correlations with other neuropsychological measures (see Table 4). Figure-specific and clinical scores themselves were highly correlated, indicating a degree of overlap between the two systems. The strength and direction of correlations between the two SCT subscale scores and other neuropsychological tasks were similar, with the strongest relationships for both scores being found between RCFT copy condition and the Block Design Task.

Table 4

Correlations between SCT subscale and total scores and neuropsychological measures of non-verbal intelligence and memory

	SCT figure-specific	SCT clinical	SCT total
SCT figure-specific			
SCT clinical	.77**		
SCT total	.95**	.93**	
Block Design	-.54**	-.55**	-.58**
Digit Symbol Coding	-.30**	-.35**	-.34**
Rey copy	.67**	.62**	.68**
Rey delay	-.39**	-.37**	-.41**
Clock Drawing task	.41**	.34**	.40**
Austin Maze total errors	.09	.02	.07
Austin Maze delay errors	.26	.04	.18

Note. All SCT scores were negatively skewed and were first reflected and then square-root transformed; Austin Maze scores were positively skewed and were square-root transformed; Clock Drawing Task score were negatively skewed and were first reflected and then square-root transformed. Note that reflected scores have the opposite meaning to the original score.

Healthy control normative data for the Simple Copy Task total scale. In the healthy control sample, the SCT took, on average, less than 3 minutes to administer (M = 2.66, SD = 1.10). In order to provide normative data, it was necessary to investigate the effect of demographic variables on each subscale (figure-specific and clinical), as well as the SCT total score. The only demographic variable to have a relationship with SCT total score[3] was age (r = .27, p = <.01).

Given the positive correlation of age effects on SCT total score, the control group was subdivided into four age groups with roughly equivalent participant numbers: 18-35 (n = 31), 36-55 (n = 38), 56-69 (n = 37), and 70-83 (n = 41). A one-way ANOVA was conducted to assess the pattern of variation of SCT total score between the age groups. There was a statistically significant difference between the age groups, $F(3, 143) = 3.85$, p =.01, $\eta^2 = .07$. Tukey's post-hoc comparison indicated that the mean score for the youngest two groups (i.e., 18-35 and 36-55) was different to the two older groups (i.e., 56-69 and 70-83). There were no other differences between the groups. For this reason, it was decided to stratify the norms for SCT total by two age levels (18-55 versus 56-83).

Healthy control normative data for the figure-specific scale of the SCT. The figure-specific scale had a medium strength correlation with age (r = .34, p = <.01), and a small correlation with education (r = -.22, p = .01). Of note, age and education themselves were also correlated (r = -.37, p = <.01). Gender was not significantly correlated with the figure-specific scale. As age and education themselves were correlated, a hierarchical regression was performed to determine the independent contribution of education to the figure-specific subscale, after adjusting for age. Age explained 10.7% of variance in the figure-specific scale $F(1, 147) = 18.46$, $p < .01$. The additional contribution of education (after adjusting for age) was less than 1%, R^2 change = .01, F change (1, 144) = 1.57, p = .21. Given the positive finding of an age effect on the figure-specific scale (and negligible effect of education), the control group was

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[3] Note that all Simple Copy Task derived scores (figure-specific total, clinical total, and Simple Copy Task total) were negatively skewed and treated with the reflect and square root transformation. Thus the true direction of correlations with scale totals are reversed.

broken down into four age groups with roughly equivalent participant numbers: 18-35 (n = 31), 36-55 (n = 38), 56-69 (n = 37), and 70-83 (n = 41). A one-way ANOVA was conducted to assess the pattern of variation of figure-specific scores between the age groups. There was a large and statistically significant difference between the age groups $F(3, 143) = 5.97$, $p < .01$, $\eta^2 = .11$. Tukey's post-hoc comparison indicated that the mean score for the youngest (18-35 year old) group was significantly different from the two older (56-69 and 70-83) groups. There were no other differences between the groups. As with SCT total, it was decided to split figure-specific total into two age groups: 18-55 and 56-83.

Healthy control normative data using the SCT clinical subscale.

Clinical scale total. The relationship between the clinical scale and demographic variables in the healthy control group was also investigated. The clinical scale featured small, non-statistically significant correlations with and age (r = .12), education (r = -.04), and gender (r = .12). Since the clinical score did not have a significant relationship with any of the demographic variables, normative data was presented for the group as a whole (i.e., not stratified).

Error frequency. Aside from the SCT clinical scale total score, it was also of interest to determine the frequency of the various individual error types (i.e., omission of items, inclusion of extra items, perseveration, misplacement of items, size distortions, rotations, closing-in) occurring across the task within the healthy sample. As the skewness and kurtosis values of some error types was very high (see Table 5), it was not appropriate to report means for normative data. As such, Table 5 presents the frequency of error commission in the healthy sample. Some types of errors were more common than others in the healthy control sample. For instance, more than half of the healthy control sample made either one or two omission or size/size relativity errors across the task, however, there were no instances of the closing-in phenomenon and rarely any rotational errors.

Table 5

Frequency of error commission in the healthy control sample

	Total Errors[a]	% Frequency[b]	z-skewness	z-kurtosis
Absent items			1.93	1.47
	0	38		
	1	42		
	2	20		
	3	1		
	4-6	0		
Inclusion extra items			9.01	2.35
	0	81		
	1	18		
	2	1		
	3-6	0		
Perseveration			18.31	9.57
	0	92		
	1	7		
	2	1		
	3-6	0		
Misplaced items			9.71	2.79
	0	79		
	1	18		
	2	4		
	3-6	0		
Size distortions			4.56	1.76

	0	33		
	1	31		
	2	23		
	3	11		
	4	1		
	5	1		
	6	0		
Rotation			33.09	10.43
	0	98		
	1	2		
	2-6	0		
Closing-in [c]				
	0	100		
	1-6	0		

[a]Total errors are the sum of all errors of a particular type occurring across the task, with a maximum possible score of 6. [b]The number of people in the healthy control sample committing the corresponding number of total errors, expressed as a percentage of the whole sample (n = 147) [c]The closing-in error type (i.e., overlapping the target figure) did not occur once in the healthy sample and as such, skewness and kurtosis values cannot be calculated for this variable.

Normative data summary. Normative data for the SCT scale totals are presented in Table 6. Stratification of normative data occurred only for the SCT total score and figure-specific scale (split by two levels of age), as these were the only two derived scores in which demographic variables had a statistically significant effect on the score.

Table 6

Normative Data for the Simple Copy Task Derived Scores

	n	*M*	*SD*	Min-Max	z-skewness	z-kurtosis
Simple Copy Total score						
Age group 18-55	69	60.12	3.66	51 - 66	-2.57	0.74
Age group 56-83	78	58.77	3.68	49 - 64	-3.10	0.15
Figure-specific scale						
Age group 18-55	69	20.74	2.15	15 - 24	-2.56	0.18
Age group 56-83	78	19.64	2.16	13 - 23	-2.52	0.29
Clinical scale						
Age group 18-83	147	39.44	1.71	34 - 42	-5.85	2.27

Discussion

Utility of the SCT total score. The SCT total score can be applied by an experienced rater in 3 minutes (on average) in a clinical sample. Internal consistency estimates (α = .88) were high for the total score, indicating possible redundancy or overlap between items comprising the total. Of note, internal consistency and inter-rater reliability were also acceptable for the SCT figure-specific and clinical scales, indicating the potential for these scales to be used in isolation.

SCT figure-specific scale. The figure-specific scale of the SCT awards points for motor accuracy, inclusion of items, and item placement. Not surprisingly, it is most strongly correlated with the RCFT as scored by the traditional (Osterrieth, 1944; Taylor, 1959) system, which awards points for item inclusion and placement. The current study revealed that inter-rater reliability estimates for the figure-specific scale (*r* = .94 in the clinical sample and .83 in the healthy control sample) were strong. These estimates were comparable to the traditional scoring method for the RCFT, which have previously been reported at $r = .88$ (Liberman, Stewart, Seines, & Gordon, 1994). According to guidelines for internal consistency (DeVellis, 2003; Nunnally & Bernstein, 1994), the figure-specific scale was homogenous and non-redundant ($\alpha = .74$). These results were impressive given the relative simplicity of the scale (taking on average approximately one and a half minutes for an experienced rater to score the task using the scale).

SCT clinical scale. The clinical scale of the SCT was quite highly correlated with the figure-specific scale. This is likely because the clinical scale shares some overlap with the figure-specific scale (i.e. both scales award points for inclusion of items and item placement). Correlations between the clinical scale and additional neuropsychological measures were similar in strength and direction as to that between the figure-specific scale and additional neuropsychological measures; both scales shared their highest correlations with the RCFT and Block Design Task. Despite this, the clinical scale had a marginally weaker correlation with the RCFT (as scored by the traditional system). Indeed, the clinical scale does provide some different information to the figure-specific scale. In particular, the clinical scale provides unique information about a broad range of error types (e.g., rotation, confabulation, perseveration, closing-in) not represented in the figure-specific scale. Given this, the clinical scale may be preferred by clinicians to the figure-specific scale when being used in patient groups where there is a requirement to quantify serious deviations from normal behaviour (e.g., rotation, closing-in phenomenon) as opposed to motor inaccuracies (e.g., straightness of lines, joining of corners) measured by the figure-specific system. In this sense, it can be considered similar in type to the newer systems for the RCFT, such as the Boston Qualitative Scoring System (BQSS: Stern et al., 1994). Interestingly, the clinical scale is comparable (or a little better) than the BQSS in terms of time taken to apply the system; BQSS takes experienced raters approximately 5 minutes to apply (Stern et al., 1994) whereas the clinical scale for the SCT takes, on average, approximately one and a half minutes to apply. Whilst maintaining brevity, the clinical scale upholds sound inter-rater reliability (r = .88) and internal consistency (α = .74).

Type of error commission. A further feature of the clinical scale is that (like the BQSS) it provides supplemental analysis by domain of error. The frequency of individual error commission in the healthy control sample (as featured in Table 5) provides a useful benchmark for comparing clinical performance. Of particular interest, there were error types that occurred at a very low frequency in the healthy control sample (e.g., rotation), or those that did not occur at all (e.g., closing-in error type). As a result, the occurrence of these relatively rare error types (particularly the closing-in phenomenon), should signal as markers to raise concerns regarding the individuals cognition, especially if they occur in high frequency. These findings are supported by earlier work which indicated that overlapping of the target figure was entirely absent in healthy controls, however, most prevalent in Alzheimer's Disease (Kwak, 2004).

Of equal importance, some error types were more common in the healthy adult population (namely the size/size relativity distortion and the absent items error types). As a result, these errors occurring in isolation or at a relatively low frequency (i.e., one to two times across the task) are not uncommon and should not be attributed to neurological compromise.

Limitations. The norms devised in this study were designed to represent the 'average' Australian population. Whilst every attempt was made to recruit persons with a range of education, the majority of the sample had approximately 12 years schooling. Test interpretation in extreme educational groups (i.e., persons with no formal education) is likely to be difficult as past research has indicated a tendency for illiterate persons to perform poorly on figure copying tasks (Dansilio & Charamelo, 2005). This should be taken into consideration when using the SCT in patients with very low/no formal education. Further, the sample was comprised of English fluent, Australian individuals, in order to ensure adequate comprehension of task instructions. Therefore, the applicability of these norms across cultures cannot be guaranteed.

Summary. The psychometric characteristics for both the figure-specific and clinical scales were adequate, whilst maintaining brief application time. The figure-specific scale may be useful in detecting fine motor problems, however, the clinical scale provides additional unique information about a broad range of error types. In particular, our earlier work has shown notable differences between clinical groups in the commission of error types covered in the clinical scale (e.g., misplacement errors in movement disorders; absent items, inclusion of extra items, and perseveration errors in the dementia group) (Dridan et al., 2012). Given that figure-specific and clinical scales demonstrate sound psychometric properties and brief application time, it appears that both scales have the potential for future clinical utility.

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Preface to Chapter 4

Thus far, the SCT has been examined for clinical utility and direction has been provided regarding its scoring and interpretation. However, the rationale for selection of the individual figures remains unclear, as there is no documentation regarding the creation of the task. It is therefore not known whether there are redundant figures included in the task or whether each figure provides unique information.

For the task to be of maximum impact, it was necessary to identify the figures in the test that provide the most information about neuropsychological impairment. As a result, the task can be used in two ways: in full as a neuropsychological test (with the assistance of the normative data outline herein), and in its abbreviated version for screening purposes.

As such, Chapter 4 focuses on identifying the figures that best predict a common neuropsychological condition (Alzheimer's disease). These analyses serve as an adjunct to Paper 1, Chapter 2. With extra time, additional Alzheimer's Disease patients were recruited and the larger pool of healthy control data (as featured in Paper 2, Chapter 3) provided the opportunity for matching to demographic characteristics which was not possible during earlier stages of the research due to the small number of healthy adults used in Paper 1.

Chapter 4: A Brief Screening Measure of Visuo-Constructional Abilities in Alzheimer's Disease

Running head: Simple Copy Task in Alzheimer's disease

Manuscript submitted to: *Dementia and Geriatric Cognitive Disorders*, 25/03/12.

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Abstract

Figure copying is thought to be a useful means of measuring constructional impairment in Alzheimer's disease, however, it is unclear whether there are particular types of figures that provide more information than others. Six different figures: the triangle, stairs, flower, double-headed arrow, cube, and bicycle (as featured in the Simple Copy Task) were used to differentiate Alzheimer's patients from age and education matched controls. It was found that two of the six figures, the flower and the bicycle, were best able to differentiate between Alzheimer's patients and healthy controls. The sensitivity of the new, two figure version of the Simple Copy Task (consisting of the flower and bicycle only) was no different to the full version of the task, despite being one third the length. Administration of the brief version of the Simple Copy Task may be particularly useful in primary health care settings when screening for dementia.

Introduction

Dementia is a major global cause of morbidity and mortality, with recent world-wide prevalence estimates at approximately 36 million (Wimo & Prince, 2010). The most common type of dementia is Alzheimer's Disease (AD), which accounts for 60 to 80% of people diagnosed with dementia (Alzheimer's Association, 2009) Early diagnosis in dementia is crucial to provide access to services, assist in planning for future care, and to direct appropriate pharmacological and cognitive interventions (Prince, Bryce, & Ferri, 2011). Cognitive screening tools are helpful in detecting patients who require further assessment to establish diagnosis. Tasks that are brief to administer and score are particularly useful as they can be used in primary health care settings, which is often the first point of contact for referral to specialist assessment centres.

The mini-mental-status examination (MMSE; Folstein, Folstein, & McHugh, 1975) features items thought to measure primarily orientation, language, attention and calculation (Lopez, Charter, Mostafavi, Nibut, & Smith, 2005), and is one of the most widely used screening tools in dementia (Pang, Pearson, Lynch, & Fong, 2009). Despite its popularity, one major criticism of the task is that it is biased towards the measurement of verbal abilities, with unequal representation of items related to right-hemisphere functioning, such as visuo-constructional abilities (Tombaugh & McIntire, 1992). This is problematic when screening for common types of dementia, such as AD, for which visuo-constructional impairment is an important component of the clinical picture (Graham, Emery, and Hodges, 2004).

There is only a single figure copying task in the MMSE (i.e., the intersecting pentagon copy), that is scored crudely using a dichotomous pass/fail criteria. Concerns have been raised regarding the sensitivity and specificity of this task. For instance, it has been found that over one third of healthy non-demented adults have impairments in copying the figure (Bennett et al., 2003), and over a third of AD patients perform normally (Bourke, Castledon, Stephen, & Dennis, 1995).

As a result of these criticisms, clinicians have used alternative figures in screening for constructional problems in dementia, such as the circle, geometric cross, diamond, and cube from the Alzheimer's Disease Assessment Scale (Mohs, Rosen, & Davis, 1983). The cube in particular has been widely studied in dementia (Buchhave et al., 2008; Gaestel, Letenneur, Dartigues, & Fabrigoule, 2006; Maeshima, et al., 2004; Palmqvist, Hansson, Minthon, & Londos, 2008). This figure may be more useful than basic, two-dimensional figures as complex figures have been found to correlate better with dementia severity (Ericsson, Forssell, Holmon, Viitanen, & Winblad, 1996). Indeed, it has been suggested that a cube copying task could be included in dementia screening to supplement the MMSE pentagon copy in order to improve the assessment of non-verbal abilities (Palmqvist et al., 2008).

The Simple Copy Task (SCT; an unpublished six figure copy test including line drawings of a triangle, stairs, flower, double sided arrow, cube and bicycle) offers several promising figures in screening for visuo-constructional impairment in dementia. For example, the bicycle figure in the SCT is comprised of several components with complex spatial relationships. Copying the bicycle may be particularly difficult for AD patients, who have been reported to demonstrate poor visual attention and spatial difficulties (Cherrier, Mendez, Dave, & Perryman, 1999; Liu, McDowd, & Lin, 2004; Possin, Laluz, Alcantar, Miller, & Kramer, 2011).

Although the SCT has been found to be useful in distinguishing dementia patients from controls (Dridan, Ong, Lloyd, Evans, & Crowe, 2012), it is unclear whether each figure in the task contributes unique information in the identification of dementia, or whether some figures are more useful than others. For screening purposes, it is of benefit to understand which subset of stimuli can produce the greatest results in the shortest time. As such, the aims of the current study were 1) to identify a subset of the most useful figures from the SCT in predicting diagnosis of AD, and 2) to compare the specificity and sensitivity of the shortened version of the task (which is comprised of a subset of figures as identified in the first aim) to the existing 6 figure version.

It was anticipated that the figures most dependent on visual attention and spatial relationships (e.g., the bicycle, the flower) as well as complex figures (e.g., the cube) would predict a diagnosis of AD. Conversely, it was expected that the very basic figures (i.e., the triangle) would not be useful in the prediction of AD diagnosis.

Method

Participants. There were two groups of participants in the current study: a group of 35 with a diagnosis of AD and a group of 35 matched healthy controls. The AD patients (40% male) were aged 48-89 (*M* = 71.66, *SD* = 8.96), and had an education range of 2 – 19 years (*M* = 10.49, *SD* = 3.40). The majority (*n* = 31) were selected from a clinical database described in our earlier paper (Dridan, Ong, et al., 2012), with the exception of four patients who were recruited after the existing data was collected. Diagnostic classification of AD was made by the treating neuropsychologist at Bendigo Health John Lindell Rehabilitation Unit, and was consistent with the most recent Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2000).

The group of 35 healthy control participants (37% male) were aged 49 – 83 (*M* = 71.60, *SD* = 7.86), and had an education range of 6 – 20 years (*M* = 10.51, *SD* = 2.78). They were selected from a larger healthy control sample described in our earlier paper (Dridan, Lloyd, Evans, Ong, & Crowe, 2012) to match age (± 5 years), education (± 4 years), and gender (where possible) of the dementia patients. As expected, there was no difference between the dementia and healthy control groups in gender, χ^2 (1, *n* = 70) =

.06, p = .81; age, F (1, 68) <.01, p = .98; or education F (1, 68) <.01, p = .97, due to sample matching.

Measures. In the healthy control group, the SCT was administered to all participants by the primary researcher. In the clinical group, the task was administered by the treating neuropsychologist at Bendigo Health as part of a battery of standard neuropsychologist tests. The task was scored using criteria outlined in our earlier study (Dridan, Lloyd et al., 2012). For each of the six figures, there was a figure-specific score (which awards points for motor accuracy and inclusion and correct placement of parts) and a clinical error-based score (which is negatively worded to award points when performance is free from clinical errors). The two sub-totals are summed across each figure to provide a total score. The maximum possible scores for triangle, stairs, flower, arrow, cube, and bike, were 11, 12, 10, 11, 12 and 12, respectively. Inter-rater reliability for this system (using the total score) has previously been found to be high (r = .88 in mixed neuropsychological sample, and .93 in a healthy control sample), and concurrent validity has been demonstrated by moderately high correlations with the Block Design Task (r = .62) and the Rey Complex Figure Task (copy administration) (r = .68) (Dridan, Lloyd et al., 2012).

Procedure. Selected data (SCT figure total scores and demographic information) were taken from a pool of tests administered in our earlier studies (Dridan, Ong et al., 2012; Dridan, Lloyd et al., 2012), with the exception of the four dementia patients who were recruited prospectively. In this case, participants were sent study information and consent forms with their appointment letter for a neuropsychological assessment. If patients consented to participate, demographic details and SCT hard files were de-identified and transcribed for use in the study. Scoring of all SCT files used in the current study was completed by the principal author.

Results

Identifying the best individual figures to predict AD. A forward stepwise logistic regression was conducted to determine the utility of the six SCT figures in predicting a diagnosis of AD (*n* = 35) versus matched healthy controls (*n* = 35). The predictors were the total scores of the six figures that comprised the SCT (i.e., the triangle, stairs, flower, arrow, cube, and bicycle). Two figures were selected in the final model that significantly predicted AD diagnosis, χ^2 (2) = 30.24, p <.01, with 79% accuracy of classification. The two significant predictors were the flower, Wald Statistic = 7.67, p = .01, e^B = 0.48, 95% CI [0.29, 0.81], and the bicycle, Wald Statistic = 8.48, p <.01, e^B = 0.44, 95% CI [0.25, 0.77].

The Simple Copy Task (Brief Version). Given that the flower and bicycle figure were the only two figures that significantly predicted AD, a shortened version of the task called Simple Copy Task brief version (SCT brief) was created featuring the sum of the flower and bicycle score.

A ROC analysis was conducted to assess the sensitivity of the shortened version of the SCT (SCT brief) in comparison to the full version. The ROC analysis (see Table 1) indicated that the SCT brief had high classification accuracy in AD.

Table 1

Summary of the ROC analyses for Alzheimer's disease (n = 35) and healthy control (n = 35) groups

	AUC	*SE*	95% CI	Cut-off	Sensitivity	Specificity
SCT	.85	.04	[.77, .94]	<57	77%	78%
SCT brief	.85	.05	[.76, .94]	<19	80%	77%

Note. AUC = area under the curve; SCT = Simple Copy Task, full version; SCT brief = Simple Copy Task, short version.

Moreover, the SCT brief was as good as the full version of the SCT ($z_{difference}$ = 0.07) in predicting AD. Note that the $z_{difference}$ score was calculated using formula provided by Hanley & McNeil (1983) for comparing areas under the curve in ROC analysis derived from the same sample; a cut off score of z ≥1.96 is employed for statistical significance based upon Guassian distribution. The ROC curves are presented in Figure 1.

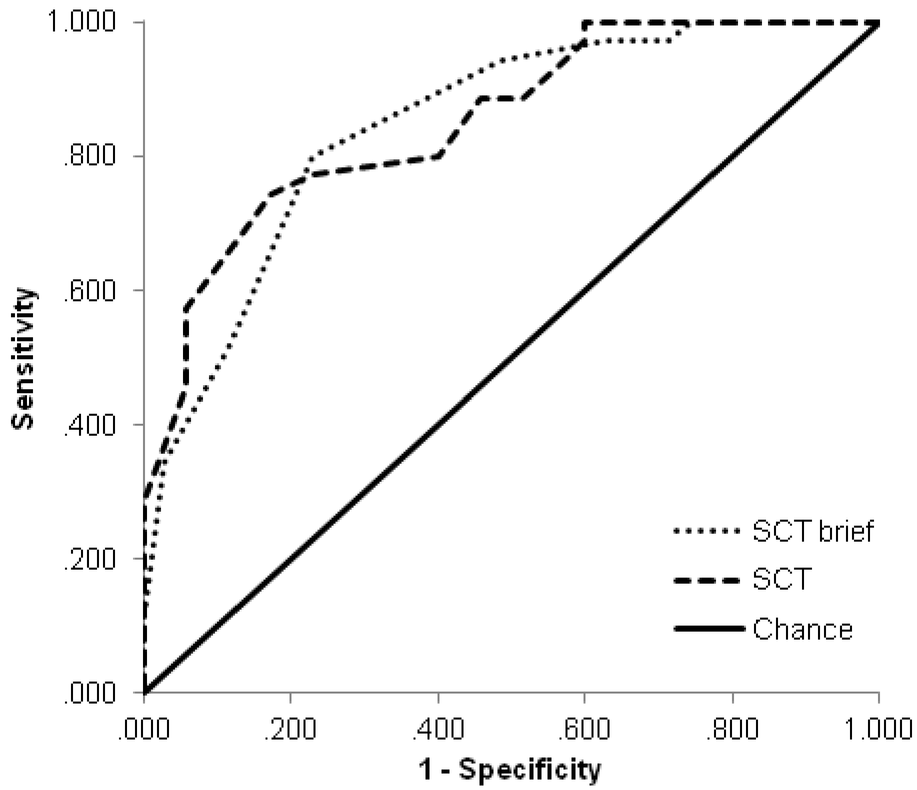

Figure 1. ROC curve analysis assessing classification accuracy of the Simple Copy Task (SCT) and the Simple Copy Task, brief version (SCT brief).

Discussion

Theoretical implications. The results of the current study identified the SCT flower and bicycle figures as useful in screening for AD. The bicycle, being comprised of several components with multiple spatial relationships, was expected to be impaired in AD. This was due to previous findings that AD patients show poor visual search, judgment of spatial relations, and visual inattention difficulties (Cherrier et al., 1999; Liu, et al., 2004; Guérin, Belleville, & Ska, 2002). Bicycle copy has been studied elsewhere, such as in healthy control participants (Hubley & Hamilton, 2002), however, in dementia (Schmitt, Livingston, Galusha, & Davis, 2009), as well as other clinical conditions (Johnson, O'Toole, Burns, & Wagner, 1992; Reuven, 1998) it has generally only been studied in a free drawing, rather than copying condition, which is confounded by skills other than constructional functioning (e.g. memory).

Successful completion of the flower figure requires one to pay attention to finer details of the figure (i.e., count the petals, note the orientation of the stem) and place the respective items correctly (i.e., arrange the petals so that they all fit, place the stem on the correct side with a bend in the correct direction). For these reasons, like the bicycle, the flower affords itself well to measurement of AD due to the presence of several inter-relating details.

The flower figure (in a slightly different form) has previously been used in isolation (Seki & Ishiai, 1996) or in combination with other figures (e.g., in the Behavioural Inattention Test) (Halligan, Cockburn, & Wilson, 1991) primarily in the assessment of unilateral spatial neglect (Seki & Ishiai, 1996; Shindo et al., 2006). To our knowledge, this is the first study that has examined flower copying ability in dementia.

Another interesting finding of the current study was that cube copying, once taking into account information provided by the bicycle and flower, was not predictive of AD diagnosis. This was unexpected, as the cube is one of the most frequently cited figures in dementia (Buchhave et al., 2008; Gaestel et al., 2006; Maeshima, et al., 2004; Palmqvist et al., 2008). A possible explanation for this discrepant result is that our study controlled for the effects of education by matching our sample for demographic variables, while some other similar studies investigating cube copying have not: some studies have utilised non-matched control groups with higher education (Gaestel et al., 2006), whilst others have failed to report the education level of their control (Maeshima et al., 2004) or clinical comparison groups (Buchhave et al., 2008). This is problematic, as education has a significant impact upon figure copying ability, especially complex figures such as the cube (Ardila, Rosselli, & Rosas, 1989; Ericsson et al., 1996; Rosselli & Ardila, 1991; Shimada et al., 2006).

The mechanism for this education effect may be explained as a result of previous exposure to cube drawing throughout education. The cube is a familiar object, and once an individual knows 'shortcuts' to effectively draw the figure, they need not analyse the spatial components of the target. As stated by Erricson et al. (1996) "Perhaps the familiar cube is recognised as a whole unit (according to the Gestalt hypothesis) and there is no need to analyse its components" (p. 117). Therefore, for those with previous exposure to cube drawing, the task is likely less reliant on attention to visual detail and spatial processing, and more reliant on procedural memory: a skill preserved until fairly late in dementia (Sabe, Jason, Juejati, Leiguarda, & Starkstein, 1995).

Alternatively, it may be that cube copy is not a poor test in and of itself, but simply that it does not provide additional unique information to the other useful figures (i.e., the bicycle and flower). Our results support this explanation in that the addition of the cube (along with the arrow, stairs, and triangle) did not significantly improve the area under the curve in the prediction of AD. Indeed, of the studies that found the cube useful, other figures were not compared to the cube in predictive utility (Buchhave et al., 2008; Maeshima et al., 2004; Palmqvist et al., 2008). In the one study that did assess the cube in comparison to other figures (Ericsson et al., 1996), the bicycle and flower were not examined. While the cube may have some utility, the current research indicates that it does not seem to provide unique information over and above the flower and bicycle in AD prediction.

The SCT brief: Sensitivity and specificity. The SCT brief, using the cut off score of less than 19, demonstrated a good balance of sensitivity and specificity in the current study. In the closest related study to ours (i.e., dementia patients of a similar age range), the MMSE, using the recommended cut-off score of 23 (Tombaugh, 1992), yielded a pattern of low sensitivity and higher specificity: 69% and 89%, respectively (Wind et al., 1997). In screening for dementia, adequate sensitivity is of pivotal importance; it is undesirable for dementia patients to falsely ‘pass’ a screening test and fail to receive adequate support and treatment in the community.

This is not to say the SCT brief should replace the MMSE, as it is clearly intended only to measure visuo-constructional functioning. It may, however, be a useful adjunct to the MMSE, particularly when the referring clinician suspects dementia in spite of an MMSE score above the cut-off value. Use of the SCT brief as an adjunct to the MMSE may also resolve criticisms of the MMSE having a biased weighting towards verbal items (Tombaugh & McIntire, 1992). Indeed, other authors have suggested that adding an additional figure to the MMSE can serve to improve its measurement on visuo-constructional abilities, however, they only studied one figure (the cube) rather than comparing several to find the most useful (Palmqvist et al., 2008).

Despite the utility of the SCT brief, the full 6-figure version of the SCT is still of vital importance. When the purpose is for more thorough assessment, as in the setting of a neuropsychological assessment, the full version of the SCT may be a more attractive option for several reasons. Normative data, taking into account the effect of demographic variables (e.g., age and education) are available for the full version (Dridan, Lloyd et al., 2012). Also, the use of the full task allows for analysis of the frequency of error commission, which may provide additional clinical information to the total quantitative score alone (as shown in Dridan, Ong et al., 2012). Further, basic figures not featured in the SCT brief (e.g., the triangle) may be useful in the full version of the SCT to eliminate floor effects. As pointed out by Ericsson et al. (1996), inclusion of basic geometric figures in copying tasks allows for an evaluation of visuo-constructional skills to take place even in patients with severely impaired cognition.

Limitations and future directions. We have focussed on one major type of dementia (AD), but not other causes such as vascular or fronto-temporal dementia. The sensitivity of the SCT brief to other less common forms of dementia is therefore not clear. Further, our AD participants were not confirmed with biopsy at autopsy, and instead we were provided a diagnosis by the treating neuropsychologist. Due to use of primarily retrospective data, we were limited to classifying the participant based upon information presented in the neuropsychological report, and although this is consistent with the Diagnostic and Statistical Manual of Mental Disorders (American Psychological Association, 2000), the diagnosis must be considered 'probable' until confirmed at autopsy.

Although MMSE data was not available for this study, inclusion of the bicycle and flower figure in addition to, or in place of the pentagon copy remains an interesting area to be explored. If the sensitivity of the MMSE can be improved through use of these additional figures, it may assist in addressing longstanding concerns regarding the tests inability to identify visuo-constructional impairment (Tombaugh, 1992).

Finally, the nature of this study was exploratory and whilst it has highlighted some important findings, it is important to confirm these findings in a larger sample. This could increase confidence in the results and eliminate concerns regarding possible over fitting of data in the logistic regression model.

Summary. The SCT brief is a measure comprised of two figures: a flower and a bicycle, which was demonstrated to have good sensitivity and specificity in an outpatient dementia group. This study represents unique findings in that the figure previously thought to be useful in assessing constructional figures in dementia (i.e., the cube), has been superseded by two other figures – the flower and bicycle— not typically used in past dementia research.

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Chapter 5: General Discussion

Summary of Findings

Prior to the present investigation, little was known about the Simple Copy Task (SCT). There was no published scoring system, indication of clinical utility, evidence of construct validity, or normative data. As a result, clinicians were left to use subjective judgment to rate and interpret performance on the task. The present studies have demonstrated that the SCT holds potential for use in clinical groups. In particular, they have provided evidence that a brief scoring system can be applied to the task, which differentiates clinical neuropsychological patients from healthy adults. Moreover, differences in qualitative performance on the task have now been identified; movement disorder patients exhibit a high degree of misplacement errors, whereas dementia patients tend to leave out details, confabulate, and perseverate.

Aside from clinical utility, the scoring system itself is internally consistent and objective (i.e., demonstrates high inter-rater reliability). It can be scored in approximately three minutes by an experienced rater, and the total score provides a measure of visuo-constructive ability (i.e., correlates best with the Block Design Task and Rey Complex Figure Task). Data has now been provided for comparison with 'normal' performance for future clinical use, with reference to the types of errors most frequently committed by healthy adults. For instance, healthy control participants rarely ever made rotated copies of the figures, and never exhibited the closing-in phenomenon (i.e., made drawings that overlapped the target figure). These findings were expected, given that rotation and closing-in errors are generally associated with severe neuropsychological conditions (Ambron, Allaria, McIntosh, & Della Sala, 2009; Lee et al., 2004; Solms, Turnbull, Kaplan-Solms, & Miller, 1998). Of greater potential utility are the norms for the more common error types (e.g., size distortion errors, absent item errors). While, in the past, clinicians could perhaps reasonably intuit that omission of a small detail from a complicated figure (e.g., a pedal from a bicycle) may be a benign oversight by an otherwise healthy patient, they can now quantify deviations from the norm that would previously have been in a 'grey area' of judgement. For instance, if a patient commits an omission error on two of the figures, their performance would be no worse than 20% of the healthy sample. However, increases in the frequency of this error type should raise clinical suspicion; only 1% of the healthy sample committed three omissions across the task, and not one person committed four or more.

Given that the process of creation of the SCT was not well documented, the justification for inclusion of each of the figures that comprise the task was unclear. For this reason, the present studies have provided indication as to which figures may be most sensitive to a common type of dementia: Alzheimer's disease. Results indicated that the flower and bicycle figures appear to provide the most information in the prediction of this disease. Administering these two combined figures (i.e., the SCT brief)- although one third the length on the original test - is as useful as giving the full task in predicting dementia diagnosis. For screening purposes (e.g., by general practitioners referring patients to neuropsychology), this is ideal as it provides maximum information in the minimum amount of time.

Practical Implications

The findings suggest that the SCT may be useful to neuropsychologists working with clients fitting within the demographics of the norms: that is, Australians aged 18-83 with approximately 12 years education. The full version of the task may be attractive to clinicians as it consists of a mix of easy (e.g., triangle) and complicated figures (e.g., bicycle), guarding against floor and ceiling effects. There may be an increase in the appeal of the task due to evidence of its utility in distinguishing between healthy adults and various clinical groups (e.g., dementia, movement disorder and schizophrenia), and availability of current normative data, including reference to the frequency of particular errors.

The short version of the task (SCT brief) is particularly well suited for use in primary care settings (e.g., by general practitioners and nursing staff) and in situations where dementia is suspected to support a referral to neuropsychology. It is quick and simple to administer, and may be used as an adjunct to traditional screening measures (e.g., the MMSE) that lack sensitivity or do not adequately measure non-verbal skills (Tombaugh & McIntire, 1992).

With regard to existing neuropsychological measures, the SCT may be a viable alternative to traditional figure copying tasks. The SCT features figures of mixed complexity, including relatively basic figures, which allows for assessment of constructional abilities even in the most impaired clients. This is an advantage over other tasks, such as the Rey Complex Figure Task, which load on planning and working memory. Failure on complex, multi-factorial tasks makes it difficult to identify the underlying cognitive deficit (i.e., poor scores on the Rey Complex Figure Task may be due to planning, working memory, or constructional difficulties). The SCT may also be an attractive alternative to the Benton Visual Retention Test and Bender-Gestalt Visual Motor Task due to its brief administration and scoring time, and suitability to inpatient bedside assessments as a function of its portability (i.e., the task requires only a single A4 page rather than stimulus manuals or figure cards).

In other situations, alternative tasks may be more suitable than the SCT. For example, when the clinician wishes to study visual memory in addition to constructional abilities, the Rey Complex Figure Task or the Benton Visual Retention Test may be more attractive as normative data is available for delayed recall versions. In addition, for a patient with very high pre-morbid functioning, tasks consisting of more difficult figures than those used in the SCT may be more appropriate. The role of intellectual functioning on the SCT has not been measured, although IQ effects have been found on other figure copying tasks (Gallagher & Burke, 2007; Gurvits et al., 2002) and may impact upon results in cases of very high intellectual functioning.

Theoretical Implications

The role of age and education in figure copying. The current studies indicated both age and education impacted upon SCT scores, with older and less educated people tending to perform worse. Interestingly, the impact of demographic variables was different between the (mixed diagnosis) clinical and control groups; in the clinical group, education was a stronger predictor than age, and in the healthy control group the reverse was true. This may have been a result of differences between the clinical and control samples; the clinical group had a broader education range (0-21 years versus 4-20 years) and thus may have encapsulated the tendency for those with a lack of formal education to perform poorly on figure copying tasks (Ardila, Rosselli, & Rosas, 1989). Alternatively, it may be that neuropsychological impairment has an interactive effect with education, exacerbating difficulties seen in lower educational groups. The latter explanation supports past research indicating that education is a protective factor of spatial and constructional decline in various clinical groups (Sánchez,, Rodríguez,, & Carro, 2002a; Sánchez,, Rodríguez,, & Carro, 2002b).

Age was also found to have an effect on SCT performance. Different theories have been proposed for the underlying cognitive deficits resulting in age related decline on visuo-spatial tasks. Some propose that age related decrements on visuo-spatial tasks are mediated by a decline in executive functioning skills with age (Libon et al., 1994), which can cause low scores on figure copying tasks (particularly more difficult items) due to poor planning (Janowsky & Thomas-Thrapp, 1993). Others propose age related deficits on figure copying tasks are due to minor motor inaccuracies in drawing (Hartman & Potter, 1998).

The results of the current work support the fine motor inaccuracies hypothesis. There was a differential impairment on the two sub-scales of the SCT; the figure-specific subscale was affected by age, however, the clinical subscale was not. The main difference between the two subscales is that the figure-specific subscale features an emphasis on motor accuracy (i.e., straightness of lines, joining of corners). If age related deficits on the SCT were attributable to visuo-spatial or executive compromise, one would expect impairment to also be present on the clinical subscale of the SCT given that it includes items typically thought to reflect executive (e.g., perseveration), spatial (e.g., item placement), and visual attention skills (e.g., inclusion of items). These findings were consistent with earlier work, which indicated age related declines in neatness scores on the Rey Complex Figure Task (e.g., innacurately joined corners, wobbly lines) (Hartman & Potter, 1998), in the context of preserved planning (Janowsky & Thomas-Thrapp, 1993) and item placement (Hartman & Potter, 1998).

Utility of the SCT in dementia. The current research supports the use of the SCT in dementia research. In particular our findings indicate that dementia patients' performance (Alzheimer's disease and vascular dementia) on the SCT is both quantitatively and qualitatively different to healthy controls; they score lower overall, and they tend to omit items, add in extraneous detail, and perseverate. Moreover, our research indicated that in Alzheimer's disease patients, a subset of figures (the bicycle and the flower) were most useful in providing diagnostic information regarding the disease.

The deficits observable on the SCT in dementia patients are consistent with the underlying cognitive impairments typically associated with dementia. In particular, dementia patients are thought to display visual attention problems (Liu, McDowd, & Lin, 2004), confabulate (Pelati et al., 2011), and perseverate (Lamar et al., 1997; Ryan et al., 1995). Poor attention, confabulation, and perseveration are typically thought of as ‘executive functioning deficits’—skills required for higher level thinking (Lezak, Howieson, & Loring, 2004). Indeed these skills have been found to be equally impaired in both Alzheimer’s disease and vascular dementia groups relative to controls (McGuinness, Barrett, Craig, Lawson, & Passmore, 2010). The presence of these underlying ‘higher level thinking’ difficulties may explain why the more difficult figures with higher demands on attention and spatial planning (i.e., the bicycle and flower) were the most useful in prediction of positive diagnosis of Alzheimer’s disease. With lesser demand (i.e., on the two-dimensional triangle figure), these skills are not likely engaged, and thus were not involved in the prediction of dementia status.

Limitations and Future Directions

The bulk of data sourced in the study was from retrospectively collected patient files. As a result, control over test selection and classification criteria for diagnostic groups was limited. In a prospective study, it would have been possible to select a broader range of tests including those that measured lower level perceptual and spatial skills (e.g., the Visual Object Space Perception Battery: Warrington & James, 1991) for a more thorough assessment of construct validity, or existing figure copying tasks (e.g., Benton Visual Retention Test, Bender Gestalt Visual Motor Test) to directly compare these tasks with the SCT for diagnostic utility.

The other limitation imposed as a result of using retrospective data is that diagnostic classification criteria were provided by the treating neuropsychologists. This was a problem in conditions where diagnostic taxonomies are controversial and constantly evolving, such as in vascular dementia. For example, though the diagnosis of vascular dementia at Bendigo Health is consistent with the DSM-IV (American Psychiatric Association, 2000), this criteria does not distinguish between subcortical ischaemic vascular dementia and multi-infarct dementia, which are seen as diagnostically and neuropsychologically distinct by some authors (O’Brien et al., 2003). The transcribed data utilised in this study often did not provide enough information to discern the different types of vascular dementia (e.g., full MRI reports were rarely available). Further, the DSM-IV requires memory impairment as one of the core features of diagnosis of vascular dementia, although more recently, it has been proposed that vascular dementia is characterised by executive dysfunction and often memory is spared (Román, 2004). This may mean that our sample is comprised of vascular patients at the more severe end of the spectrum, which may not be directly comparable to patients classified by different criteria.

The aim of the first paper was to provide preliminary evidence for the clinical utility of the SCT. However, in terms of practical application, distinguishing error profiles between clinical ‘super-groups’ (i.e. movement disorders versus dementia) is less helpful than distinguishing between the sub-groups themselves (i.e., vascular dementia versus Alzheimer’s disease). Unfortunately, a restricted sample size within the sub-groups prevented these analyses from being conducted. It may be of use in future research to characterise the error patterns of dementia syndromes, particularly those which comprise primary differential diagnoses (e.g., Alzheimer’s disease, vascular dementia, and fronto-temporal dementia).

A further issue pertaining to the use of retrospective data was that the sample size was fixed. This was more of a problem in some groups than others (i.e. the sample size was considerably smaller in the movement disorders group than the dementia group). For the purposes of the logistic regression, this places the groups with smaller sample sizes at risk of over fitting of the data. As a result, findings from the clinical groups in which there were smaller sample sizes should be treated as preliminary and exploratory in nature. Specifically, this involves the movement disorder group and perhaps to a lesser extent the schizophrenia group (Chapter 2), and Alzheimer’s disease group (Chapter 4). Replication of the findings in a larger sample could provide more confidence in the generalisability of the results. Notwithstanding this, this group of studies provides the function for specific areas of interest for follow up.

Another issue with logistic regression is that it is designed to compare ‘disease’ to ‘non-disease’ conditions. For this reason, statistical comparisons using logistic regressions were between healthy adults and specific clinical conditions, rather than direct comparisons between the clinical groups themselves (i.e. movement disorder versus dementia). Although the same healthy adults were used as a comparison with the various clinical groups—therefore the only thing changing within the separate analyses was the clinical condition itself—it is important to keep in mind that the clinical conditions have not been statistically compared to each other, per se. This means that any comparisons drawn between the clinical groups themselves should be tentative.

Finally, this thesis was primarily driven by clinical practice; there was an existing Australian task being used without any research to guide its scoring and interpretation. Rather than creating a new figure copying task, the aim of this thesis was to investigate the utility of an existing, poorly understood task. As such, there is scope to further develop the SCT by assessing whether addition or substitution of certain figures may help to improve the sensitivity of the task. For example, the cube, which (as shown by our results) failed to contribute to the prediction of a diagnosis of dementia may be better replaced by a less familiar three-dimensional figure of similar complexity (e.g., a three-dimensional pyramid). This may reduce the loading on procedural memory and increase the demands on spatial and constructional functioning. Indeed, this figure has potential to improve sensitivity of the task as it has been useful in conditions that feature relatively subtle constructional impairment, such as cocaine dependence (Elman et al., 2008) and post-traumatic stress disorder (Gurvits et al., 2002). Alternatively, there are a range of other figures that are not included in the SCT that have been found useful elsewhere, such as the intersecting pentagons (Fountoulakis et al., 2011), a Greek cross, a house, or a star (Halligan, Cockburn, & Wilson, 1991), which may be added to the task to increase its utility.

Summary

In sum, this thesis presents a scoring system for the SCT, which can be used as a reliable and valid measure of spatial/constructional functioning in neuropsychological groups. The task can be used in full, with reference to the normative data outlined herein to detect quantitative and qualitative deviations from normal performance. Alternatively, the brief version of the task holds promise as a rapid screen of visuo-constructional abilities in suspected AD patients. Several avenues for future work exist including further refinement of the task by substitution of figures, a more in depth exploration of differences between specific clinical groups (e.g., Alzheimer's disease versus vascular dementia), and exploration of the SCT brief as an adjunct to other well known screening tools (e.g., the MMSE).

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APPENDIX A

Guidelines for Submission of Thesis by the Alternate Format

Thesis by Published and Unpublished Papers

Candidates also have the option of submitting their thesis via the ‘alternative publication format’ method. A decision to submit by this method should first be discussed with your supervisor(s). Submission of a thesis by this method must conform to the Higher Degrees Committee’s (Research) following points:

1. As an alternative to the traditional format for a higher degree thesis, it is permissible for candidates to submit a thesis in the form of a series of articles arising from the candidate’s higher degree research. These must be along a central theme and may or may not be already published. The presentation of the articles should take into account current regulations for PhDs (see R21.2.9), for Professional Doctorates (see R21.3.9) and for Masters by Research (see R21.5.9). Where the thesis includes work of joint authorship the candidate shall include in the thesis a signed declaration for each article, stating the extent and nature of his or her contribution and justifying the inclusion of the material. A signed declaration from at least one of the co-authors should also be included, verifying the extent and nature of the candidate’s contribution.

2. It may be that all articles are in press, but it is required that at least one must be in press. The remaining articles may be submitted for publication or in a form that is ready to be submitted for publication.

3. The presentation of a thesis as a collection of articles must include at least one substantial integrating article or preferably a separate introduction, and general discussion and conclusion that in combination provide an integration of the material presented.

4. The number of articles to be included will depend on the content and length of each and should take full account of the University’s requirements for the degree as well as the amount of research expected for the degree in that discipline. However, as a broad guideline, it can be suggested that a masters by research and doctoral (coursework) thesis include at least two papers, and a doctoral (research) and PhD research thesis include at least 3 papers. The aim should be to achieve papers of potential high impact rather than multiple papers with potential low impact. The student and supervisor will collaboratively take responsibility in deciding on the number and form of papers that will be necessary to achieve a level of research output sufficient for award of the degree.

5. With respect to the regulation governing the completion of work undertaken during candidature, (see point 1), it is expected that unless written approval is given to include work undertaken prior to candidature at La Trobe University, e.g., a small proportion of data collected during the Honours degree to be re-analysed, all work will have been completed during the period of candidature. Work published prior to commencement of candidature must **not** be included in the thesis, although reference to such material is permitted.

6. With respect to the regulation governing joint authorship (see point 1) the candidate would have been expected to have made a significant and leading contribution to the work reported, equivalent to that expected for a traditional thesis.

7. A published book can also be submitted as a thesis for a Masters, PhD or professional doctorate, provided that it fulfils the requirements set out in the above six clauses of these guidelines.

8. The thesis will be examined in the normal way and according to the normal requirements set out for the degree. (see Appendix A and Appendix D of the Handbook for Candidates and Supervisors for Masters Degrees by Research and Doctoral Degrees issued by RSO at enrolment.) Examiners of a thesis by published and unpublished papers will be given a copy of these guidelines.

9. The decision to submit a thesis in the form of a series of published or unpublished articles should be given careful consideration. In particular candidates should note that submitting a series of articles is not a universally accepted practice. Moreover, it is likely, especially with published articles along one theme, that there may be considerable repetition across the articles which may detract from the presentation of the thesis. Occasionally, due to the word length constraints of published articles, students may choose to include an additional section on methodology which provides more information about the specifics of how the research was conducted. For these reasons, it may be more appropriate to prepare the thesis in the traditional format, including reprints of any published articles arising from the thesis in an appendix. A clear statement must be included in the thesis indicating which chapters are based on published articles, full publication details of these articles, and details of the relative contributions of all authors if the publications are multi-authored, as follows:

   Where the thesis includes work of joint authorship the candidate shall sign a declaration for each article, stating the extent and nature of his or her contribution and justifying the inclusion of the material. A signed declaration from at least one of the co-authors should also be included, verifying the extent and nature of the candidate's contribution.

APPENDIX B

Scoring System for the Simple Copy Task

Simple Copy Task (SCT) Scoring Manual

Table of Contents

Introduction

The Simple Copy Task (SCT) scoring system features two sub-scales: figure-specific and clinical error based. These can be summed to make the SCT total score. Normative data is provided for each of the sub-scales scores, and the total, thus the clinician can select the appropriate scale for interpretation.

The manual is arranged so that there is a short description of each item, followed by three pictures. The first picture depicts a correct response for the item, the second and third depict examples of errors for each item.

Figure Specific Scoring Scale

The figure specific scoring section refers to the inclusion of key parts of the figure. Scores of '0' represent a fail for an individual item, and scores of '1' represent a pass. This approach to scoring can be considered a 'there or not' system, as each criterion asks whether an item is present or a condition is satisfied (i.e. whether the lines are straight or not). The system requires you to judge whether a criterion has been met, <u>not whether it is within the range of what you would deem as normal</u> (e.g. some over-lapping, wobbly lines are likely to be present within a normal population, however, you are required to award a score of '0' for items pertaining to straightness of lines and joining of corners. You will not need to use protractors or rulers, instead, the vast majority of the criteria are visibly obvious (i.e. handlebars on a bike are either present or not present), and for those that are more ambiguous (i.e. symmetry of a figure) you should use the diagrammatic examples as laid out in this manual to guide your decision as to what constitutes a correct response.

Clinical Scoring Scale

The clinical scoring system is based upon common error types observed in clinical practice. The items are the same for each picture. They are negatively worded (e.g. "no inclusion of extra items") so that a score of 1 represents a pass and a score of 0 represents a fail for the item. As there is some ambiguity (e.g. "no gross rotation", "no major distortions in size") in the terms used, it is particularly important that you refer to the example figures as laid out in this manual. In cases that are borderline, precise specifications for permissible errors (e.g. degrees of rotation, variance in size) are provided in the following section entitled **'definition of terms'**.

Definition of terms

Absence of items: A case in which any of the details that comprise the figure are missing.

*Inclusion of extra items***:** Inclusion of any superfluous detail into the reproduction (e.g. extra petals on the flower, additional steps on the stairs figure). Inclusion of a single extra line stroke (see figure 1 below) is classified as an inclusion of extra items error. Where there is more than one extra line included, or any shading and multiple re-tracing of lines, see *perseveration*.

Figure 1. Inclusion of extra item on the triangle figure.

Perseveration: Shading or multiple retracing where there is more than one extra line stroke (see figure 2 and 3 below).

Figure 2. Perseveration on the triangle figure.

Figure 3. Perseveration on the triangle figure.

Misplacement of items: Any spatial misplacement of an item comprising a figure.

Distortions in size relativity: Cases in which an element of a figure is visibly out of proportion to the rest of the figure.

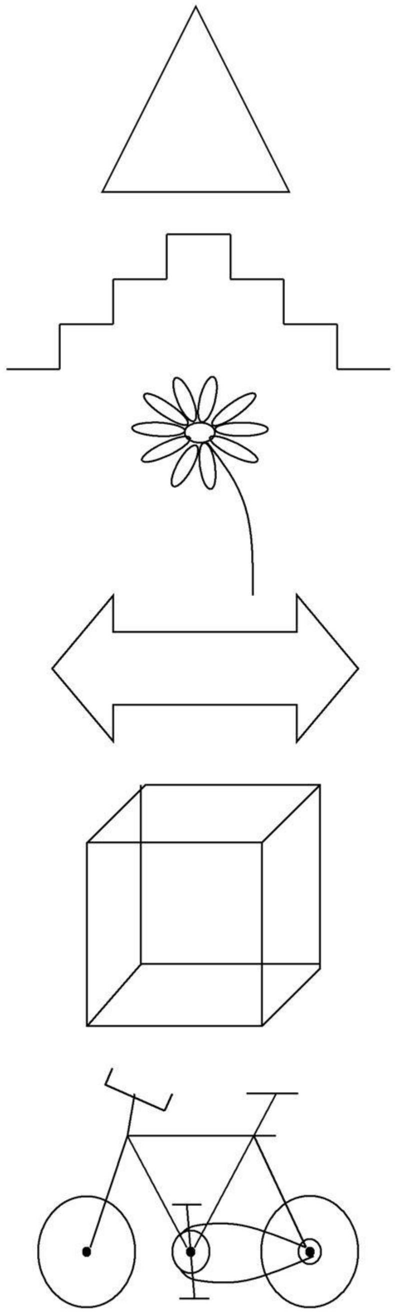
Distortions in size: Cases in which the overall figure is 25% larger or smaller than the target. NB: The diagrammatic examples provided in this manual show figures at + or – 25% of the target thus a visual inspection of the figure is usually sufficient for scoring purposes (i.e. if your figure falls between the two examples as depicted in the manual, it should be scored as correct).

Closing in: A case in which any part of the reproduction touches or overlaps with the target figure

Rotation: misalignment of the figure by 10° or more. NB: The diagrammatic examples in the manual depict the point at which the rotation should be scored as an error, thus a visual inspection of the figure is usually sufficient for scoring purposes[1] .

[1] In ambiguous cases, or as a reference, atypical figures (i.e. the bike, flower, pipe, and triangle within triangle) are scored as a rotation at 20° rotation or more, whereas for typical, geometrical figures (i.e. all remaining figures), the degrees of rotation = 10.

Simple Copy Task Stimuli



Scoring Template

				Name/ID number: ____________	
TRIANGLE		STAIRS		FLOWER	
Figure specific	Clinical	Figure specific	Clinical	Figure specific	Clinical
1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.
3.	3.	3.	3.	3.	3.
4.	4.	4.	4.		4.
	5.	5.	5.		5.
	6.		6.		6.
	7.		7.		7.
ARROW		CUBE		BIKE	
Figure Specific	Clinical	Figure specific	Clinical	Figure specific	Clinical
1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.
3.	3.	3.	3.	3.	3.
4.	4.	4.	4.	4.	4.
	5.	5.	5.	5.	5.
	6.		6.		6.
	7.		7.		7.
				Figure-specific total[a]	
				Clinical total[b]	
				SCT total[c]	
		Error frequency:			
				Absent items[d]	
				Inclusion of extra items[e]	
				Perseveration[f]	
				Misplaced items[g]	
				Size/size relativity distortions[h]	
				Rotation[i]	
				Closing-in[j]	

[a] the sum of triangle, stairs, flower, arrow, cube and bike figure specific items (with a maximum possible score of 26).

[b] the sum of triangle, stairs, flower, arrow, cube, bike (with a maximum possible score of 42).

[c] the sum of figure-specific total and clinical total (with a maximum possible score of 68).

[d] the sum of clinical scale item 1 across all 6 figures (with a maximum possible score of 6).

[e] the sum of clinical scale item 2 across all 6 figures (with a maximum possible score of 6).

[f] the sum of clinical scale item 3 across all 6 figures (with a maximum possible score of 6).

[g] the sum of clinical scale item 4 across all 6 figures (with a maximum possible score of 6).

[h] the sum of clinical scale item 5 across all 6 figures (with a maximum possible score of 6).

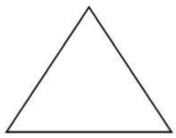
[i] the sum of clinical scale item 6 across all 6 figures (with a maximum possible score of 6).

[j] the sum of clinical scale item 7 across all 6 figures (with a maximum possible score of 6).

SCT Scoring System

TRIANGLE – figure-specific

TARGET FIGURE



1. Three sides are present

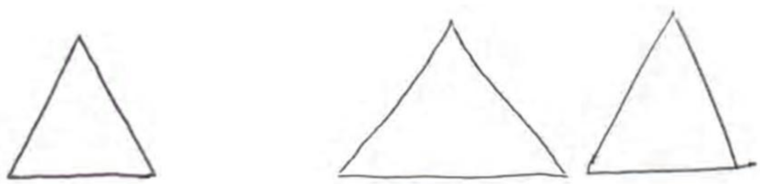
CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**

2. Lines are straight

All the lines comprising the triangle must be straight

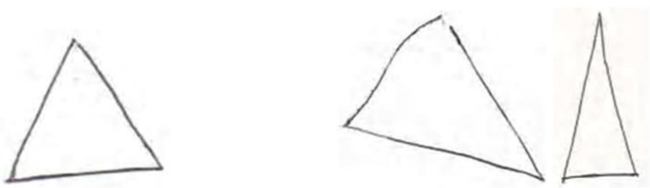
3. Corners are joined

There are no overlapping edges or gaps at the corners



4. Equal lengths

The triangle must not be lop-sided/too narrow. ***NB: This is also scored as a size relativity error (item 5) in the clinical scale***

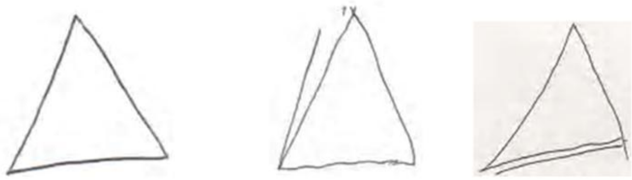


TRIANGLE – clinical

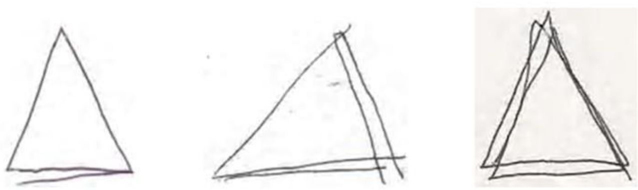
1. No absence of items/hemi-neglect

CORRECT	**EXAMPLE ERROR 1**	**EXAMPLE ERROR 2**

2. No inclusion of extra items



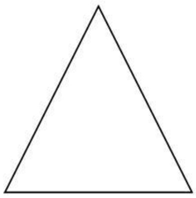
3. No perseveration



4. No misplacement of items

5. No major distortions in size/ size relativity

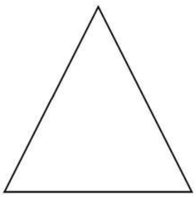
TARGET FIGURE (actual size)



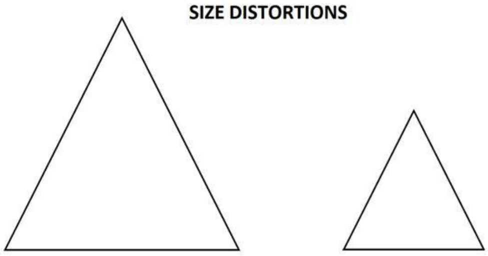
SIZE RELATIVITY DISORTIONS

OR

TARGET FIGURE (actual size)



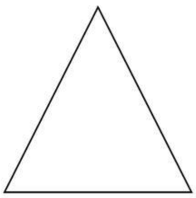
SIZE DISTORTIONS



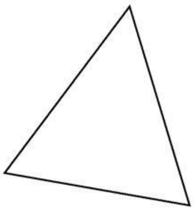
Too large **Too small**

6. No gross rotation

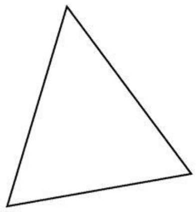
TARGET FIGURE



EXAMPLE ERROR 1

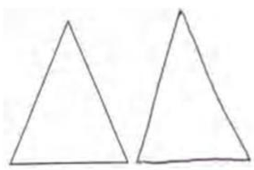


EXAMPLE ERROR 2

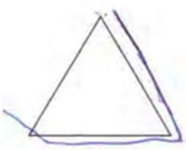


7. No closing in on the target figure

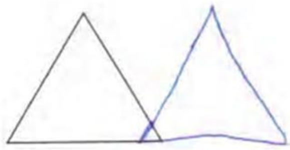
CORRECT



EXAMPLE ERROR 1

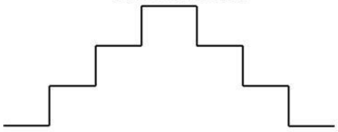


EXAMPLE ERROR 2



STAIRS – figure-specific

TARGET FIGURE



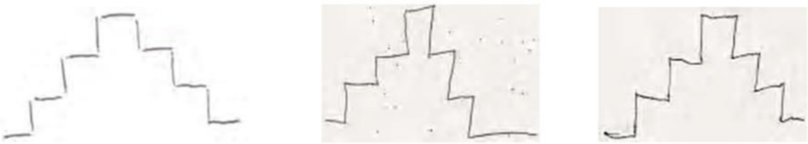
1. The correct number of stairs are present

   There are no more and no fewer than three steps on each side.

CORRECT | **EXAMPLE ERROR 1** | **EXAMPLE ERROR 2**

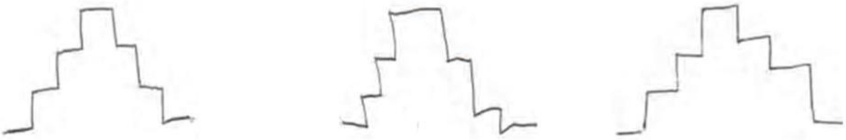
2. The stairs are equal at the base

   Both of the bottom stairs are visibly level, one side is not visibly higher than the other.



3. Height and width of stairs are respected

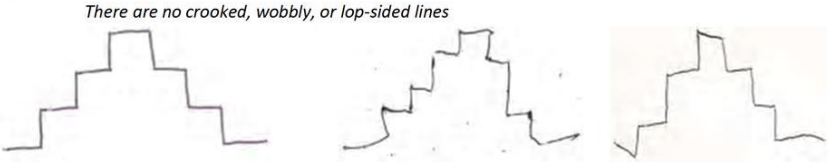
   The stairs are all roughly the same size, there should not be big stairs or squashed little stairs



NB: Stairs with obvious size inequality should also be scored as a size relativity error under the clinical system (item 5).

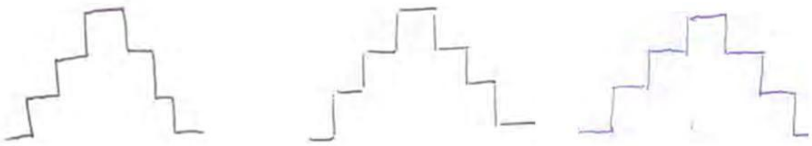
4. The lines are straight

   There are no crooked, wobbly, or lop-sided lines



5. The corners are joined

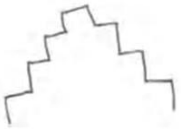
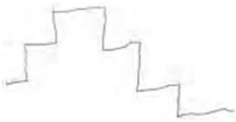
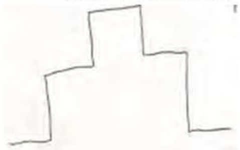
   There are no overlapping lines or gappy, unjoined corners



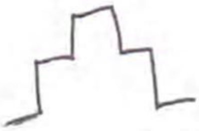
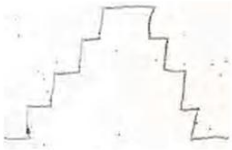
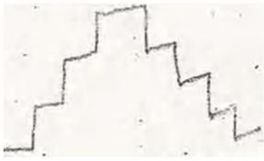
STAIRS – clinical

1. No absence of items/hemi-neglect

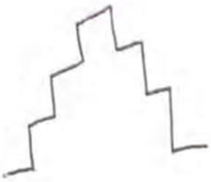
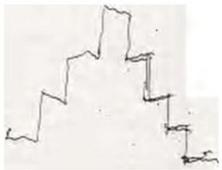
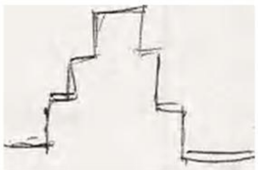
CORRECT | **EXAMPLE ERROR 1** | **EXAMPLE ERROR 2**

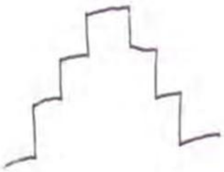
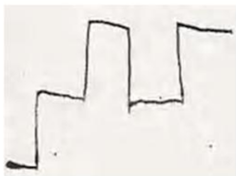
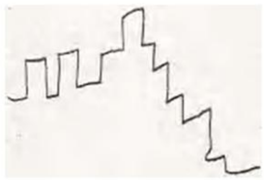
2. No inclusion of extra items

3. No perseveration

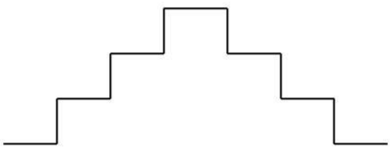




4. No misplacement of items

5. No major distortions in size/ size relativity

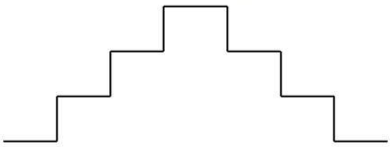
TARGET FIGURE
(actual size)



SIZE RELATIVITY DISTORTIONS

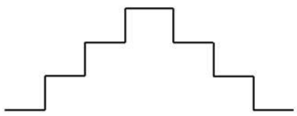
OR

TARGET FIGURE
(actual size)

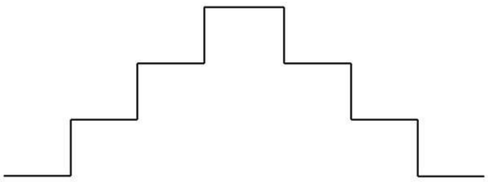


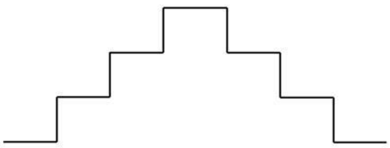
SIZE DISTORTIONS

Too small



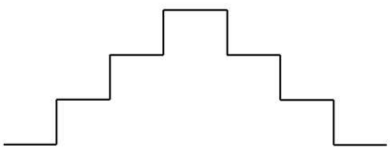
Too large



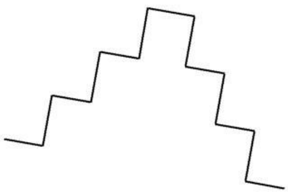


6. No gross rotation

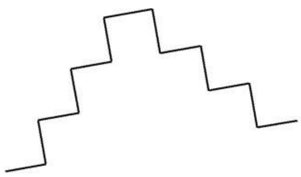
CORRECT



EXAMPLE ERROR 1

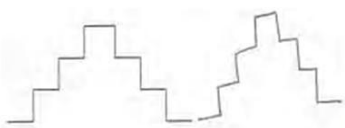


EXAMPLE ERROR 2

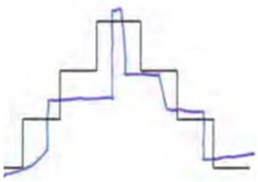


7. No closing in on the target figure

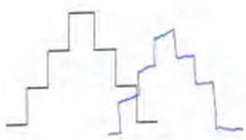
CORRECT



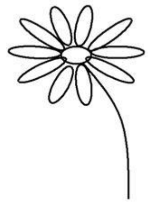
EXAMPLE ERROR 1



EXAMPLE ERROR 2



FLOWER – figure-specific



TARGET FIGURE

1. The correct number of petals are present

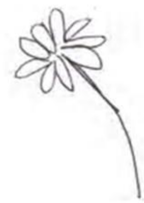
   There are no more and no fewer than 10 petals present

CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**



2. The centre circle is present

   Centre circle must be unshaded, not a dot

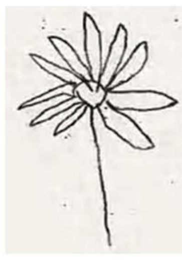




NB: If the centre circle is missing, this must also be scored as an absent item (item 1) in clinical system

3. The stem is placed on the right with a bend to the left

   The stem must be placed on the correct side, there must be a bend, and the bend must be pointing in the correct direction



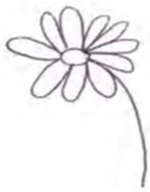


NB: This is also scored as a 'misplacement error' under the clinical scoring system

FLOWER – clinical

1. No absence of items/hemi-neglect

CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**



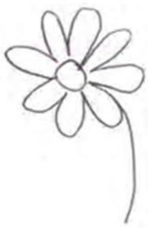
NB: If there are fewer than 10 petals, this criterion must be scored as zero.

2. No inclusion of extra items

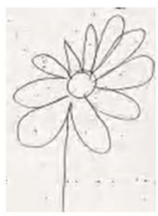
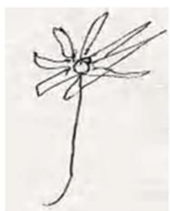


NB: If there are more than 10 petals, this criterion must be scored as zero.

3. No perseveration

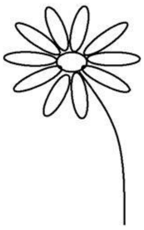


4. No misplacement of items

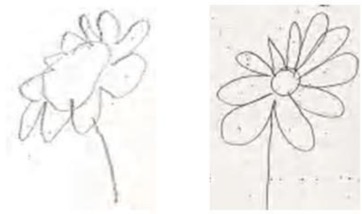




5. No major distortions in size/ size relativity

TARGET FIGURE

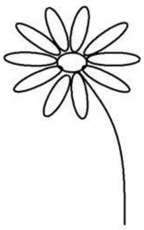


SIZE RELATIVITY DISTORTIONS

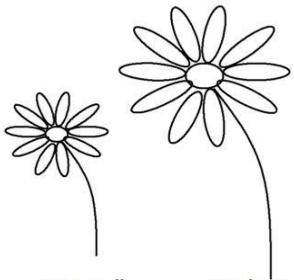


OR

TARGET FIGURE
(actual size)



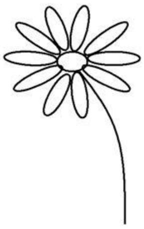
SIZE DISTORTIONS



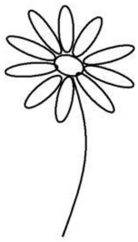
Too small **Too large**

6. No gross rotation

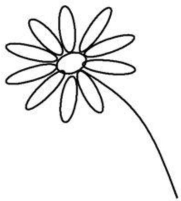
CORRECT



EXAMPLE ERROR 1

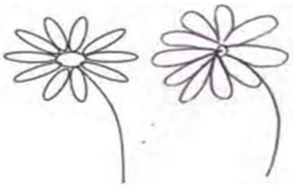


EXAMPLE ERROR 2



7. No closing in on the target figure

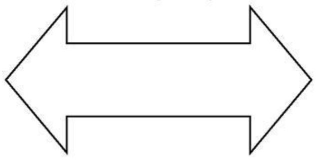
CORRECT



EXAMPLE ERROR 1

EXAMPLE ERROR 2

ARROW – figure-specific



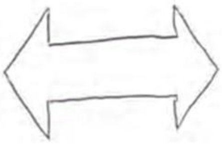
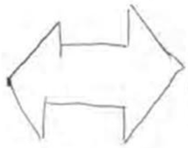
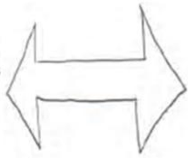
TARGET FIGURE

1. Both arrows are the same size

Arrows should be roughly the same size &shape: there should not be one arrow visibly bigger than the other.

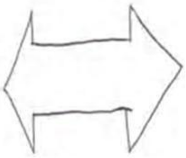
NB: Obvious size inequality between arrow heads is also scored as a size relativity error under the clinical system (item 5).

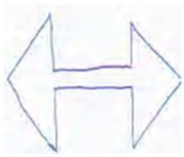
CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**

2. Centre lines are parallel and in correct proportion

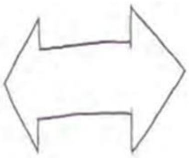
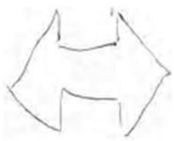
The centre lines should be roughly parallel and not be too narrow or wide in relation to the arrow heads





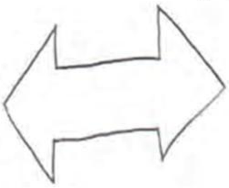
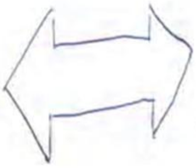
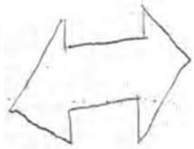
3. Lines are straight

The lines that make up the arrow should not be wobbly


4. Corners are joined

There are no overlapping or gappy unjoined corners

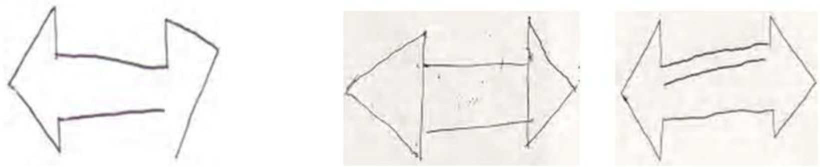




ARROW – clinical

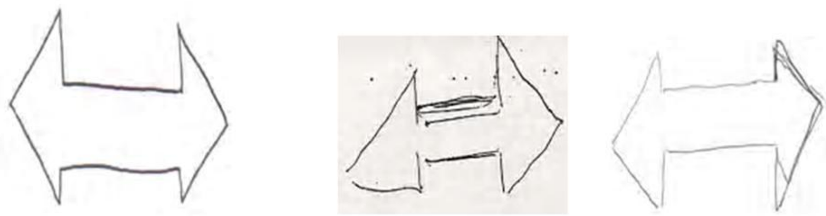
1. No absence of items/hemi-neglect

CORRECT	**EXAMPLE ERROR 1**	**EXAMPLE ERROR 2**

2. No inclusion of extra items



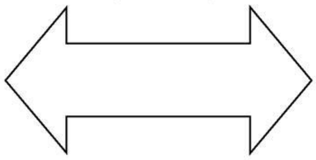
3. No perseveration



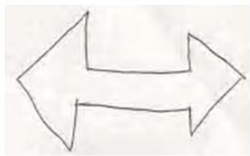
4. No misplacement of items

5. No major distortions in size/ size relativity

TARGET FIGURE
(actual size)

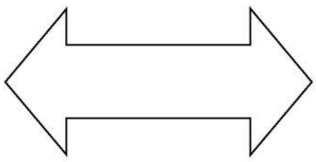


SIZE RELATIVITY DISTORTIONS

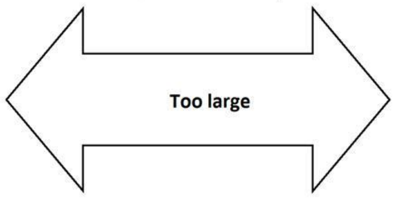


OR

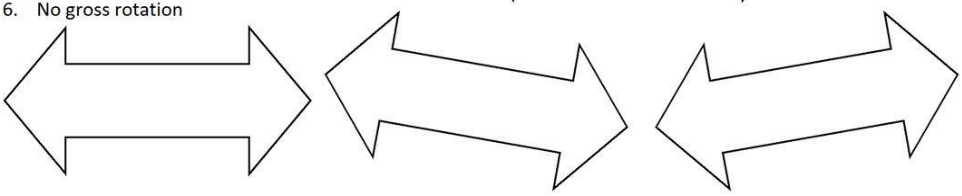
TARGET FIGURE
(actual size)



SIZE DISTORTIONS

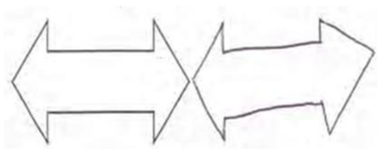


6. No gross rotation

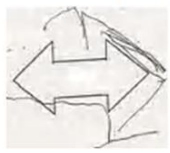


7. No closing in on the target figure

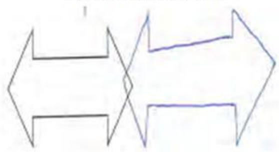
CORRECT



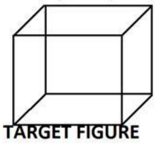
EXAMPLE ERROR 1



EXAMPLE ERROR 2



CUBE – figure-specific

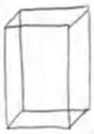


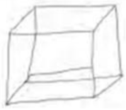
TARGET FIGURE

1. There are 12 lines present

   There should be four lines comprising a front square, four lines comprising a back square, and four connecting lines.

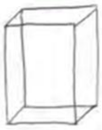
CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**

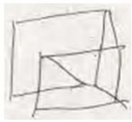




2. The cube is facing the front and pointing left

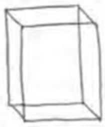
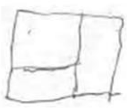
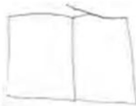
   The orientation of the cube is the same as the target figure





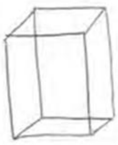
NB: Orientation errors are also scored as 'misplacement errors' in the clinical system (item 4)

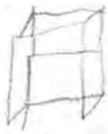
3. Three-dimensionality is preserved

4. The lines are straight

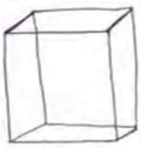
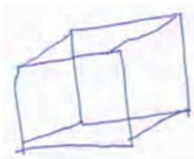
   The lines that make up the cube should not be wobbly





5. The corners are joined

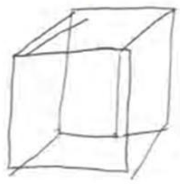
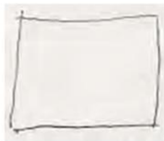
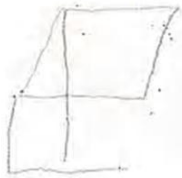
   There are no overlapping or gappy unjoined corners

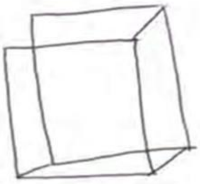
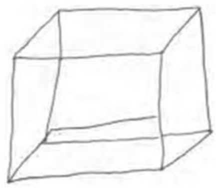
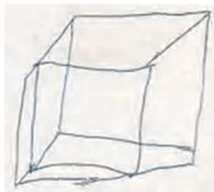

CUBE – clinical

1. No absence of items/hemi-neglect

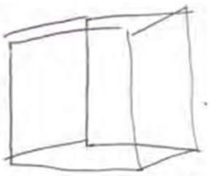
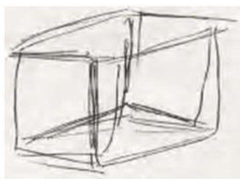
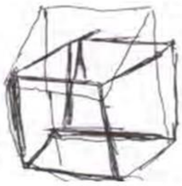
CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**

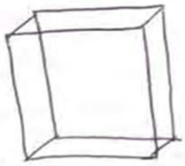
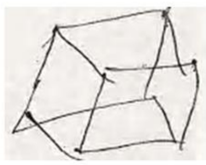
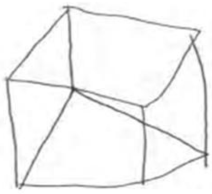
2. No inclusion of extra items

3. No perseveration

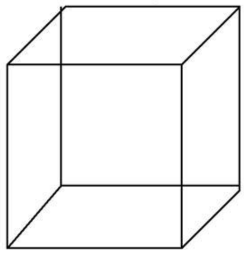
4. No misplacement of items

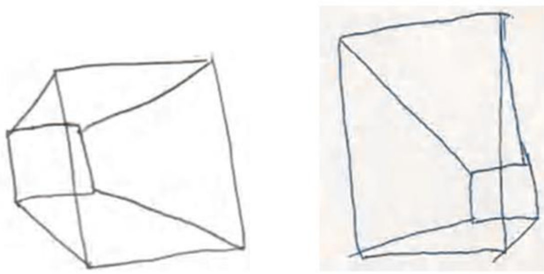
NB: If item 2 in the figure specific system is scored as zero, this item must also be zero.

5. No major distortions in size/ size relativity

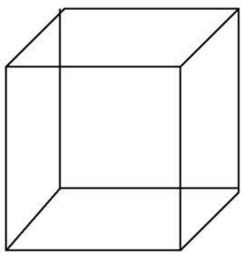
TARGET FIGURE (actual size)



SIZE RELATIVITY DISTORTIONS

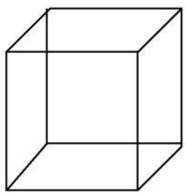


TARGET FIGURE (actual size)

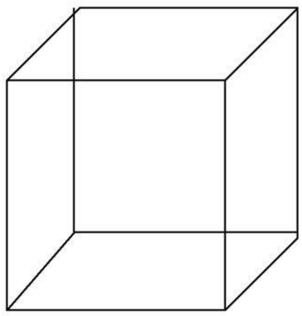


SIZE DISTORTIONS

Too small

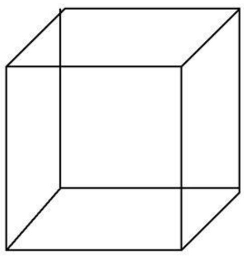


Too large

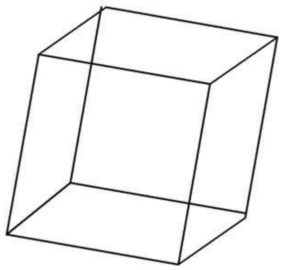


6. No gross rotation

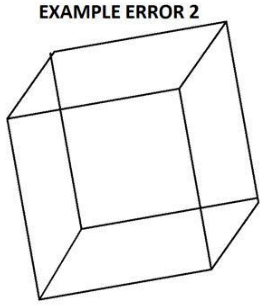
TARGET FIGURE



EXAMPLE ERROR 1

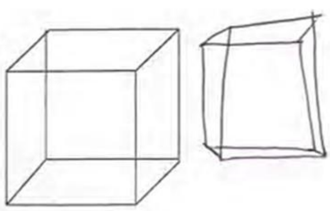


EXAMPLE ERROR 2

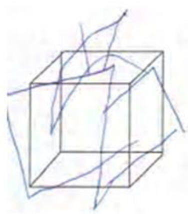


7. No closing in on the target figure

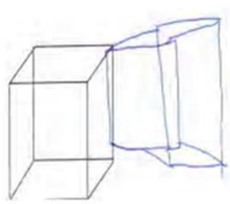
CORRECT



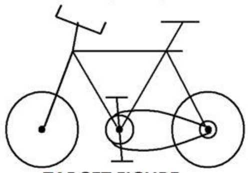
EXAMPLE ERROR 1



EXAMPLE ERROR 2



BICYCLE – figure-specific



TARGET FIGURE

1. Both wheels are present

CORRECT	EXAMPLE ERROR 1	EXAMPLE ERROR 2
		

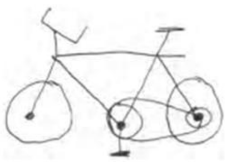
2. Handlebars and seat are present

3. Centre triangle is present

4. Pedals are present

5. Chain is present

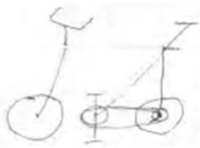
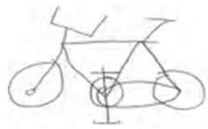
NB: If any of items 1-5 are scored as zero, criteria 1 in the clinical system (i.e. missing items) must also be scored as zero).

BICYCLE – clinical

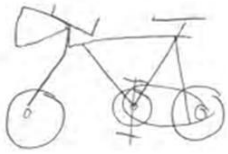
1. No absence of items/hemi-neglect

NB: Don't forget to check for less obvious items such as the cog on the back wheel & the flick on the tail of the bike.

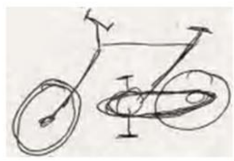
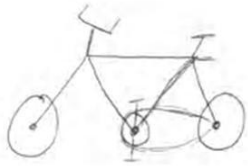
CORRECT **EXAMPLE ERROR 1** **EXAMPLE ERROR 2**

2. No inclusion of extra items


3. No perseveration

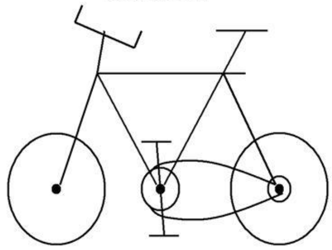




4. No misplacement of items



5. No major distortions in size/ size relativity

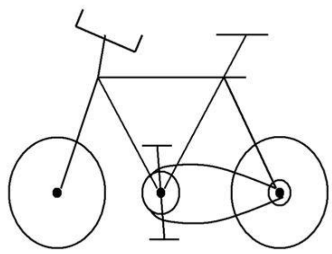
TARGET FIGURE
(actual size)



SIZE RELATIVITY DISTORTIONS

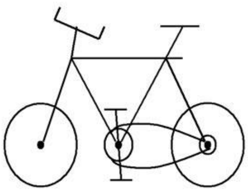
OR

TARGET FIGURE
(actual size)

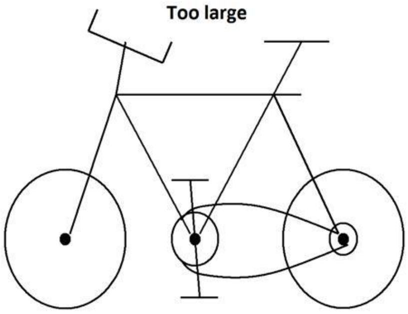


SIZE DISTORTIONS

Too small

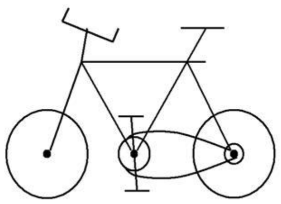


Too large



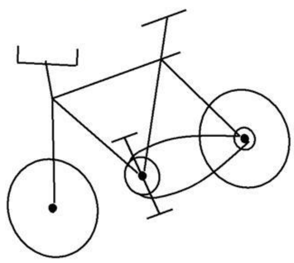
6. No gross rotation

TARGET FIGURE



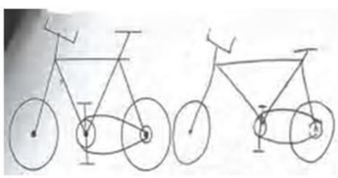
EXAMPLE ERROR 1

EXAMPLE ERROR 2



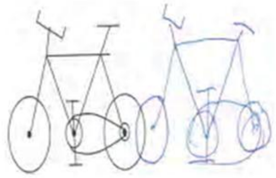
7. No closing in on the target figure

CORRECT



EXAMPLE ERROR 1

EXAMPLE ERROR 2



APPENDIX C

Additional Results from Chapter 3: The Simple Copy Task: Scoring Properties and Normative Data

For the healthy control group, the internal consistency (Cronbach α), inter-rater reliability (Pearson product moment *r*), and ease of application (mean minutes taken to score the task using each of the scales) of the Simple Copy Task (SCT) scales are presented in Table 1. The internal consistency of the SCT total was very high, however, the individual scales were comparatively low. Inter-rater reliability of both of the subscales and the total score were high. Applying both scales of the SCT took, on average, approximately three and a half minutes for an experienced rater.

Table 1

Psychometric Characteristics of the Healthy Control Sample for SCT Subscale and Total Scores

	SCT figure-specific	SCT clinical	SCT total
Cronbach *a*	.36	.52	.93
Inter-rater reliability (*r*)	.83	.88	.88
Time to score (mins)			
M	2.03	1.54	3.58
SD	0.40	0.54	0.76

Construct validity for the SCT scores are presented in Table 2. Both the figure-specific and clinical scales had moderate correlations with the Rey Complex Figure Task, copy administration. In addition, the clinical system had a medium strength relationship with the Block Design task.

Table 2

Correlations between SCT Subscale and Total Scores and Neuropsychological Measures of Non-Verbal Intelligence and Memory in the Healthy Control Sample

	SCT figure-specific	SCT clinical	SCT total
SCT figure-specific			
SCT clinical	.55**		
SCT total	.90**	.87**	
Block Design	-.20	-.39**	-.33**
Digit Symbol Coding	-.06	-.08	-.08
Rey copy	-.37**	-.32**	-.39**
Rey delay	-.10	-.16	-.15
Clock Drawing Task	.12	.16	.16
Austin Maze total errors	.12	.16	.16
Austin Maze delay errors	.20	.19	.22*

Note. * p <.05, ** p < .01; All SCT scores were negatively skewed and were first reflected and then square-root transformed; Austin Maze scores were positively skewed and were square-root transformed; Clock Drawing Task score were negatively skewed and were first reflected and then square-root transformed. Note that reflected scores have the opposite meaning to the original score.