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Visuoconstructional Impairment: What Are We Assessing, and How Are We Assessing It?

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VISUOCONSTRUCTIONAL IMPAIRMENT:

WHAT ARE WE ASSESSING, AND HOW ARE WE ASSESSING IT?

BY

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OF

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ABSTRACT

Visuoconstruction (VC) is a commonly-assessed neuropsychological domain that involves the ability to organize and manually manipulate spatial information to make a design. Tests used to measure VC are considered multifactorial in nature given their multiple demands (e.g., visuospatial, executive, motor), and therefore, interpretation of VC impairment can be difficult. Additionally, a wide variety of tests and methods are used to measure VC, further complicating interpretation of results. Although clinicians and researchers spend a great deal of time studying "VC," there has been much confusion about what it is, what is being measured, and how to best measure it. The following study compared a variety of commonly-used, commercially available VC tests for similarities and differences, and also examined the underlying neuropsychological domains of each test. Rather than conceptualizing VC as a unified construct, it was proposed that categorizing VC tests into the following subtypes may improve interpretation: assembly vs. graphomotor, copy vs. draw-to-command, and complex vs. simple tasks. Using 114 mixed neurologic and neuropsychiatric patients, VC test results were assessed with the use of impairment indices, correlational analyses, standard multiple regression, and multivariate analysis of covariance. Study results revealed that the most useful distinction between VC tests appears to based on complexity level. Complex VC tasks tended to be more heterogeneous in their underlying neuropsychological domains, had greater rates of impairment, and were more demanding of executive skills. In contrast, simple VC tests tended to have lower rates of impairment and were more homogenous in function, mostly assessing visuospatial and perceptual skills. Study limitations, future directions, and clinical implications are discussed.

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Statement of the Problem

Neuropsychological assessment involves the administration of tests to gain an understanding of patients' cognitive functioning in various functional domains (e.g., attention, mental control, language, memory). One commonly assessed neuropsychological domain is that of visuoconstruction (VC). Generally, VC may be considered the ability to organize and manually manipulate spatial information to make a design. Common VC tasks include assembling blocks and copying or drawing pictures. Due to the multiple demands of these tasks, VC may be considered multifactorial in nature. That is, many different cognitive functions, such as visuospatial skills, motor programming, and executive functioning, are required.

Given the heterogeneous nature of VC, interpretation of impairment can be difficult. In addition, VC is often assessed using a wide variety of tasks and methods, further complicating the picture. VC tasks have been incorporated into most neuropsychological test batteries and cognitive screening instruments. Yet, although clinicians and researchers spend a great deal of time studying "VC," there is still much confusion about what it is, what is being measured, and how to best measure it. Therefore, because VC is such a critical part of neuropsychological assessment, it deserves to be better operationalized and better understood theoretically. This study was designed to better define the construct of VC. This was accomplished by comparing and contrasting a selection of commonly-used VC measures and by studying the neuropsychological functions underlying VC. The results of this study hope to translate into improved knowledge of VC, selection of VC measures, interpretation of results, and communication among researchers.

PART I: Visuoconstruction (VC)—What is It?

VC: Many Definitions

What is "VC?" Given that VC can be conceptualized and defined in different ways, finding an answer to this question can be somewhat difficult. In fact, it has been suggested that differing terminology and definitions used by authors has lead to confusion of this construct (Benton & Barton, 1970; Piercy, Hecaen, & De Ajuriaguerra, 1960). Some definitions of this construct are as broad and loosely defined as "all the disturbances that can be observed during the execution of a constructive task" (Gainotti, 1985, as cited in Trojano & Grossi, 1998, p.623) to as precise as Benton and Trandel's (1993) definition:

> . . . any type of performance in which parts are put together or articulated to form a single entity or object, for example, assembling blocks to form a design or drawing four lines to form a square or diamond. Thus it implies organizing activity in which the spatial relations among the component parts must be accurately perceived if these parts are to by synthesized into the desired unity. (p.195).

To define constructional disorder in her popular book on neuropsychological assessment, Lezak (1995) uses Benton's (1969) earlier definition of "disturbances in formulative activities such as assembling, building, drawing, in which the spatial form of the product proves to be unsuccessful without there being an apraxia of single movements" (p. 36). Other definitions include Feinberg and Farah's definition of "constructional apraxia" (i.e., VCal impairment) as "the inability to assemble the elements of a bidimensional or tridemensional whole, respecting their orientations and spatial relationships" (1997, p.298) and Lanca, Jerskey, and O'Connor's (2003) definition of visuoconstructive disturbances, "a failure in organizing the spatial relations among parts of a visually perceived or imagined object" (p. 400).

Old Terminology—"Constructional Apraxia"

In addition to being defined in different ways, VC has also been known by different names. It was first introduced by Kliest (1934) as "constructional apraxia." Apraxia is the inability to perform voluntary movements, typically resulting from damage to the left hemisphere (Kolb & Whishaw, 1990; York & Cermak, 1995). Therefore, Kliest hypothesized that the inability to construct objects was related to a left hemisphere difficulty with apraxia and purposeful movements. Since then, numerous studies have contradicted this earlier claim that VC deficits arise from left hemisphere damage. In fact, it is typically believed that damage to the right hemisphere is highly related to deficits in VC (e.g., Mack & Levine, 1981; Piercy, Hecaen, & De Ajuriaguerra, 1960; Villa, Gainotti, & De Bonis, 1986). Therefore, although the terminology of constructional *apraxia* is still used by some (e.g., Carlesimo, Fadda, & Caltagirone, 1993; Forstl, Burns, Levy, & Cairns, 1993; Guerin, Belleville, & Ska, 2002; Guerin, Ska, & Belleville, 1999; Sunderland, Tinson, & Bradley, 1994), it has been abandoned by many.

Reconsidering Constructional "Apraxia" as a Visuospatial Disorder

Instead of considering constructional deficits as impairments in praxis, many now conceive of VC as involving the "execution of visuospatial tasks," (Goodglass &

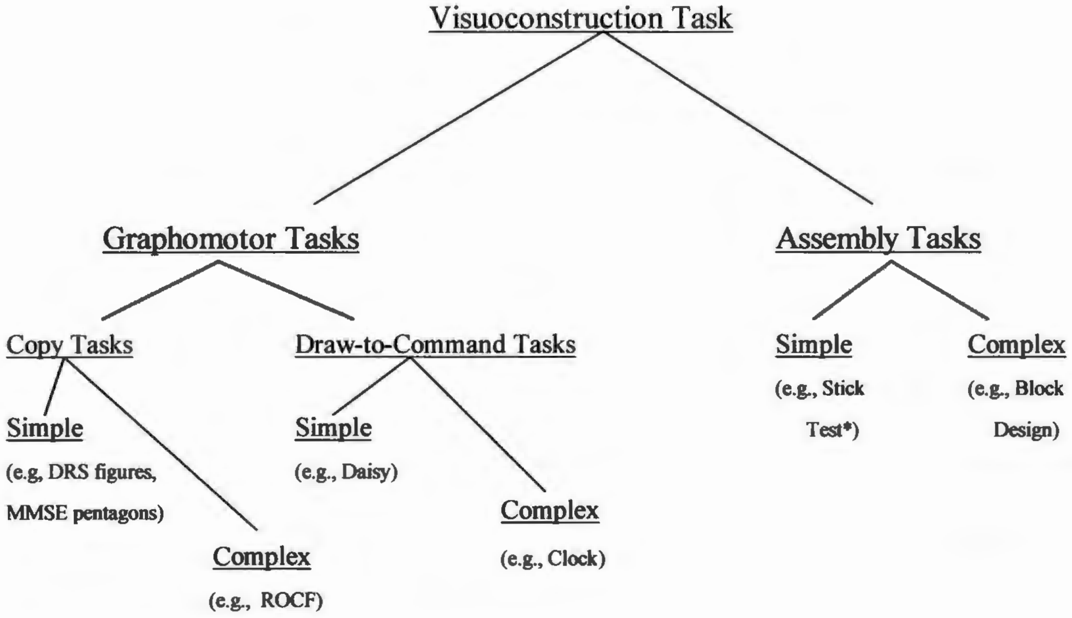
Kaplan, 1983), and some authors may interchangeably refer to VC tasks as "visuospatial tasks" (Benowitz, Moyas, & Levine, 1990; Delis et al., 1992; Fujii, Lloyd, & Miyamoto, 2000; Gainotti, Parlato, Monteleone, & Carlomagno, 1992; Groth-Marnat & Teal, 2000; Levin et al., 1991; Massman et al., 1993; Sunderland et al., 1989; Tuokko, Hadjistravropoulous, Miller, & Beattie, 1992; Wolf-Klien, Silverstone, Levy, & Brod, 1989). Typically, assessing one's visuospatial skills may involve judging the direction of lines, localizing points in space, or judging various distances or depths (Benton & Trandel, 1993). Therefore, the appropriateness of substituting the term "visuospatial" for "VC" is arguable, given that many VC tasks involve more than visuospatial skills. In fact, numerous studies have demonstrated that VC impairment may result from factors other than visuospatial deficit or from other damage than right, parietal lesions (e.g., Arena & Gainotti, 1978; Benton, 1973; Ebert, Vinz, Goertler, Wallesch, & Herrmann, 1999; Forstl et al., 1993; Gainotti, D'Erme, & Diodato, 1985; Kirk & Kertesz, 1989; Leger et al., 1991; Lezak, 1995).

PART II: Visuoconstruction—How are we Measuring It?

VC: Many Tasks with Differing Demands

VC can be assessed with many different types of tasks, and each task may have different requirements and/or demands. As described in Figure 1, some VC tasks include assembling blocks, some require copying designs, and others involve drawing pictures "from memory"/to command (e.g., "draw me the face of a clock"). In addition, these tasks can vary in complexity from very simple (e.g., copy a square) to more difficult (e.g., copying a complex geometric figure like the Rey-Osterrieth Complex Figure [ROCF]).

Figure 1. *Proposed Categories of VC Tasks and Examples of Each Category Subtype.*



*Stick Test (Benson & Barton, 1970; Butters and Barton, 1970) not used in the current study.

As will be described below, patients may perform differently based on the VC task used, suggesting that all VC tasks are not alike. For example, "some patients will experience difficulty in performing all VC tasks; others who make good block constructions may consistently produce poor drawings; still others may copy drawings well but be unable to do free drawing, etc." (Lezak, 1995, p. 36).

Many Tasks to Measure One Construct?

Even with much variability between tests, most VC tasks are conceptualized as measuring a similar function or construct. And often, different types of VC tasks are used together in studies to measure "constructional ability" (e.g., Benson & Barton, 1970; Black & Strub, 1976; Cahn-Weiner et al., 1999; Huff et al., 1987; Libon, Swenson, Barnoski, & Sands, 1993). With many different tasks being used to measure this construct, it raises the question as to "what is really being measured?" Is VC truly one global construct or really the combination of various different constructs? According to Benton and Trandel (1993):

> the fact that such a wide diversity of [visuoconstruction] tasks has been utilized and the observation that different tasks appear to interact in different ways with other factors to determine performance level had led some researchers to conclude that the visuoconstructive disability concept is too broad to be optimally useful in clinical or investigative work (cf. Benton, 1967; Benson and Barton, 1970). Instead, a classification in terms of types of constructional tasks differing in their demands on visuoperceptive, motor, and linguistic capacities offers greater promise of relating performance to cerebral function. (p. 198).

Attempts at Better Defining the Global Construct

Many different types of VC tasks, such as assembly (e.g., block construction; stick construction) and graphomotor tasks (i.e., copying or drawing tasks) still commonly reside under the umbrella term of "VC," and they have largely been assumed to measure the same construct. Whether or not this is appropriate has yet to be determined. Currently, "visuoconstruction impairment" can denote impairments on any type of VC task. However, possibly in an effort to clarify the global term of "VC impairment," some authors use more specific terminology to indicate impairment on a specific type of task. For example, some authors define impairments on graphomotor tasks as "drawing disability" (Forstl at al., 1993; Gainotti, & Tiacci, 1970; Warrington, James & Kinsboure, 1966), "acopia," or "graphomotor dysfunction" (Kolb &

Whishaw, 1990). However, only Benton (1967, 1985, 1993) clearly differentiates between both graphomotor and assembly tasks.

Subgrouping VC: Assembly vs. Graphomotor Tasks

Lezak (1995) agrees that graphomotor and assembling tasks "need to be evaluated separately" (p.587). It has been suggested that differences in drawing versus assembly tasks may be due to different cognitive functions required for each (Angelini, Frasca, & Grossi, 1992). Intuitively, this seems to make sense given the different demands placed on examinees when putting together blocks, sticks, or puzzles versus drawing or copying a design. However, whether graphomotor or assembly tasks actually result in different performances within patients has never been directly studied.

Research Support that Assembly and Graphomotor Tasks may be Different

A few research studies have used assembly tasks along with graphomotor tasks and found different performances on each type of task. For example, in a study of 60 missile wound patients by Black and Strub (1976), comparing the effects of lesions in each of four brain quadrants (i.e., left anterior, right anterior, left posterior, right posterior), they found differing percentages of impairment in the four groups based on whether the tasks was an assembly task (i.e., WAIS Block Design and Object Assembly) or drawing task (i.e., Bender Gestalt), suggesting differential performances based on the type of task used. In a similar study of 52 missile wound patients by Black and Bernard (1984), it was found that right hemisphere lesioned patients performed worse than left lesioned patients, but only on the drawing task given (i.e., Bender Gestalt) and not the assembly task (i.e., Block Design).

In a study by Dee (1970) of 40 unilaterally brain lesioned patients, 15% of their sample performed poorly on *either* a drawing or assembly task, but not on both. An assembly task and a graphomotor task were also used in a study by Cahn-Weiner and colleagues (1999) investigating the relationship of clock drawing performance to various brain volumes and brain functions in 29 Alzheimer's patients. As part of this study, it was also found that WAIS Block Design did *not* account for a significant amount variance in clock drawing performance, even though these two types of tasks are thought to measure the same function (i.e., "VC").

In 1970, Benson and Barton conducted one of the more comprehensive studies on various VC tasks (though these tasks were not commercially published or commonly used today) using 24 patients with lesions to one of four brain quadrants. One interesting finding of this study was that all four brain lesion groups produced impairment on drawing tasks, though assembly tasks were sensitive only to specific brain lesions (e.g., left posterior). This provides further evidence to suggest that assembly and drawing tasks may not be as comparable as they may have been considered to be.

Subgrouping Graphomotor Tasks: Copying vs. Drawing-to-Command

In addition to the primary dichotomy of assembly versus graphomotor tasks, there are also two different types of graphomotor tasks: copying tasks and "drawing-to-command" tasks (e.g., "draw me a clock"). Although both are purported to measure "VC," the demands are quite different in each. With a copying task, a stimulus (e.g., a complex figure, a cube, square) is placed in front of an examinee, who is then asked to copy the design as accurately as possible. However, in a "draw-to-command" condition, no stimulus is provided, and patients are simply asked to "draw a" common item, such as a clock, daisy, bicycle, house, or human figure.

Copying tasks appear to depend heavily upon visuospatial and perceptual abilities (Feinberg & Farah, 1997; Lezak, 1995). In fact, patients with hemispatial neglect (a type of attentional impairment in which patients neglect to attend to one side of space, typically the left) will usually omit one side of the figure or cramp the figure onto one side of the page (Freedman et al., 1994; Joseph, 1988; Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992). Depending on the complexity of the figure, intact executive functioning, (e.g., planning, organizational skills) may also be required (Brantjes & Bouma, 1991; Freeman et al., 2000; Libon et al., 1996; Ogden, Growdon, & Corkin, 1990).

Drawing-to-command tasks require a patient to draw a figure from "memory" (i.e., from a mental representation). Unlike a copying task that requires patients to analyze the spatial components of a presented stimulus, patients must rely on their own internal representation of space, as well as memory of what the object looks like, when drawing the figure to command. Because copying and draw-to-command tasks place different demands on visuospatial and attentional functioning, patients with left hemi-inattention (i.e., neglect) may demonstrate more spatial disorganization in copy than command conditions (Freeman et al., 1994). In addition, there are other separate cognitive demands required in a draw-to-command condition. First, examinees must understand the examiner's request (e.g., "draw me the face of a clock, put in all the numbers and set the hands for 10 after 11"), placing added demands on language, semantic knowledge, memory, and conceptual skills (Freedman et al., 1994; Libon, Malamut, Swenson, Sands, & Cloud, 1996; Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992). Executive dysfunction may also become more apparent during a draw-to-command task (Freedman et al., 1994; Royall, Cordes, & Polk, 1998). For example, it is possible that without a stimulus to guide the drawing, a person may have more difficulty planning and organizing the figure, as well as understanding the complex relationships of the request/instructions. Perseveration may also present itself more readily without an external representation to refer to, and "stimulus bound" errors may be more frequent in command conditions (Freedman et al., 1994; Shallice, 1982). With stimulus bound errors, participants tend to "latch on" to what is perceptually salient in a drawing. For example, instead of setting the time of a clock to "10 after 11", it is not uncommon for participants to be drawn directly to these numbers and place the hands of the clock directly on the 10 *and* the 11.

Evidence Supporting Copy and Draw-to-Command Differences

Research studies which have included both copy and draw-to-command conditions have demonstrated different findings between and within subject groups. For example, patients with right parietal damage may produce poor *copies* due to neglect, but adequate spontaneous drawings (Freedman et al., 1994). Conversely, patients with right temporal lesions may copy a figure adequately, though poorly space numbers and omit the contour of a clock when drawing-to-command (Freedman et al., 1994). Some patient populations, like those with Alzheimer's disease, appear to benefit from the added structure of a copy condition. In a study by Ober, Jagust, Koss, Delis, and Friedland (1991), none of their 20 Alzheimer's patients were able to correctly set the time on a clock face in the draw-to-command condition. However, five of them were then able to correctly set the time in the copy condition. In addition, when the patients' copies of a house, daisy, and clock were averaged and compared to the draw-to-command conditions, the patients performed better in the copy condition on overall recognizability, attention to detail, accuracy of detail, and attention to configuration (Ober et al., 1991). Similarly, in a study of 31 Alzheimer's patients and 27 ischemic vascular patients (IVD) by Libon, Malamut, Swenson, Sands, and Cloud (1996), the Alzheimer's patients significantly improved their performance on clock drawing in the copy condition (over the command condition). In contrast, the IVD patients did not show an improvement in the copy condition, possibly related to poorer executive control/frontal systems dysfunction in this group (Libon et al., 1996). There have also been case reports of patients with dementia who were selectively able to draw to copy but not to command, possibly related to an imagery deficit (Denes & Semenza, 1982; Farah, 1984 and Ehrilichman & Barrett, 1983 as cited in Grossman, 1988). Grossi, Orsini, and Modafferi (1986) also cited a case of a patient with a left occipital lesion who was able to copy pictures but was not able to draw-to-command, and they termed this disturbance "visuoimaginal constructional apraxia" (Grossi et al., p. 255). Interestingly, the patient in this case study was also tested for visuoperceptual identification problems, recognition deficits, and output difficulties, and none were found.

Further Subgrouping VC Tasks: Complex vs. Simple

Finally, visuoconstruction tasks could be further differentiated by whether they are simple (e.g., copying a square) or more complicated tasks (e.g., copying the ROCF). Although subdividing VC tasks by degree of complexity has never been formally discussed in the literature, it may still be an important differentiation between various tasks (Mesulam, 2000). As suggested by Benton and Trandel (1993), some clinicians disregard the difficulty level of VC tasks, even though it may vary widely, and interpret all VC tasks together as a whole to arrive at a patient's "constructional ability." As suggested by Lanca and colleagues (2003), "the difficulty of each task must be considered when assessing visucoconstructional ability" (p. 400).

Do Authors Distinguish Between Simple and Complex Tasks?

Currently, tasks from the very simple to the very complex are all included in various neuropsychological batteries as measures of VC. Perhaps one reason why these tasks are used interchangeably may be that a clear order of difficulty among VC measures has yet to be established. For example, Lezak (1995) refers to the clock drawing task as a "simpler task" and the MMSE pentagons design as a "more difficult copy task" (p. 213), similar to the Rey-Osterrieth Complex Figure (Lezak, 1995). On the other hand, other authors have commended the clock test on its multidimensional and "complex" nature (Freedman et al., 1994), which appears to make it a good screening measure for dementia (Shulman, 2000). As seen above, the fact that some authors may categorize a given task as a simple task while others may consider a task more complex may lead to problems with interpretation of data. Because there is currently a lack of empirical support for how to distinguish tasks as simple or complex, it appears that more formal comparisons between tasks is needed.

Are Simple Tasks Given more Credit than they Deserve?

To some researchers and clinicians, drawings of *a single geometric shape* may be meaningful enough to base a conclusion regarding a person's overall VC abilities.

For example, in a study by Royall, Cordes and Polk (1998), subjects were split into high or low VC ability *based on* their performance on the VC task of the Mini-Mental Status Examination (i.e., interlocking pentagons). Additionally, Gfeller (1995) divided the sample in his study into "constructionally intact" or "constructionally impaired" based on patients' performance of a single Greek cross. Describing a patient's VC abilities based on the performance of a specific task may be inappropriate (Benson & Barton, 1970; Hadano, 1984). Lezak (1995) termed this approach as "ridiculous" (p. 531), and Walsh (1987) commented:

> " in view of the fact that many brain damaged patients fail on some of these [VC tasks] and pass on others, it is obviously unsatisfactory to use failure on any one as an operational definition of constructional apraxia as some writers have done" (p. 223).

Simple vs. Complex Tasks: Could They Serve Different Purposes?

Depending on the purpose of the assessment, increased complexity may be considered an added benefit <u>or</u> a complication. Some argue that complexity tends to bring out deficit (Warrington, James, & Kinsbourne, 1966), and, therefore, the ROCF or Block Design may be preferable choices. In addition, it has been suggested by some authors (Freedman et al., 1994; Shulman, 2000) that clock drawing provides an advantage over drawing a daisy or house because the clock places more demands on linguistic and executive factors, thereby making it a more sensitive screening instrument for dementia. However, this added complexity may also decrease specificity and interfere with other clinicians' desire to use VC tasks more as tasks assessing visuospatial skills (Kim, Morrow, Passafiume, & Boller, 1984; Mack &

Levine, 1981). In fact, Arena and Gainotti (1978) have stated that the use of complex VC tasks may be "inappropriate" given that impairment may result from many possible deficits or diffuse impairment, thereby making it difficult "to study specific visuoconstructive or visuoperceptive disabilities" (p.464). According to Angelini, Frasca, and Grossi (1992), the construct of VC may be better understood if terms like VC were better clarified, including specifying whether it means a deficit in drawing a simple geometric figure (e.g., square) or a complex figure (e.g., ROCF).

PART III: Visuoconstruction—What Are We Measuring?

Methodological Concerns in Visuoconstruction Research

As with many areas of neuropsychological research predating current neuroimaging techniques, the primary goal of early visuoconstruction research was to understand the relationship between local brain lesion site and neuropsychological test performance. Although many studies were conducted comparing the degree of visuoconstruction impairment resulting from different brain lesions (e.g., right vs. left hemisphere injury), no clear answers were concluded. Poor agreement within these studies may be due to different methodologies used by different researchers. Among many methodological concerns (e.g., the use of different patient populations, different exclusionary criteria) is the fact that very different VC tasks were employed across studies (Benton & Trandel, 1993; Kim, Morrow, Passafiume, & Boller, 1984; Lezak, 1995; Mack & Levine, 1981; Mesulam, 2000).

Problems in VC Research: Many Tasks Purporting to Measure One Construct

The tasks used in research on VC typically differ in administration technique, as well as in complexity level and cognitive demands. For example, studies may base their findings on subjects' ability to draw simple lines (e.g., Riddoch & Humphreys, 1988) or simple geometric shapes (e.g., square, star, Greek Cross) (e.g., Gainotti, Parlato, Monteleone, & Carlomagno, 1992; Gfeller, 1995; Piercy, Hecaen, & De Ajuriaguerra, 1960) or more demanding tasks such as WAIS Block Design or the ROCF (e.g., Black & Bernard, 1984; Ogdegn, Growden & Corkin, 1990; Sunderland, Tinson, & Bradley, 1994. This variability between these tasks can make it difficult to compare findings across studies.

Studying VC as a Multifactorial Domain

It has also been suggested that inconsistencies in VC research may be attributed to the fact that VC is a multifactorial domain, and impairment may result from deficits in many different abilities (Carlesimo, Fadda, & Caltagirone, 1993; Fall, 1987; Marshall et al., 1994; Sunderland, Tinson, & Bradley, 1994). Among other current trends in VC research (e.g., assessing qualitative differences in various patient groups), recent research has turned its interest to understanding the underlying mechanisms behind visuoconstruction impairment. VC appears to require multiple cognitive processes, such as perception, visuospatial analysis, motor skills, and "executive functioning." Executive functioning pertains to how higher-order functions, such as planning, organization, cognitive response set maintenance, mental flexibility, and impulse control. It is quite possible that these higher order executive functions may impact visuoconstruction performance. In addition, it is also assumed that attention is required in VC performance, and in some tasks (i.e., draw-to-command), basic language and memory skills are also required.

should be noted, however, that other simpler VC tasks have not been examined. These studies were conducted on select patient groups and/or with only one or two VC and executive measures. Whether or not executive functioning plays a significant role in simpler tasks has yet to be determined, though it has been argued that simpler copying tasks "depend less on executive functioning" (Royall, Cordes, & Polk, 1998, p. 590).

Considering Other Factors in the Multifactorial Domain of VC

In addition to executive deficits, other cognitive impairments, such as perceptual and motor dysfunction, have also been found to impact VC. For example, in a study of 79 Alzheimer's disease patients by Huff and colleagues (1987), there was a strong relationship between visual discrimination (i.e., perceptual ability) and VC, and it was stated that the two domains "are clearly interdependent" (p. 1123). Additionally, Dee (1970) examined 40 unilaterally brain damaged patients and found that visuoconstruction impairment was closely associated with perceptual dysfunction (using a discrimination task). However, in some patients, like those with Huntington's disease, poor motor performance can also impair VC performance (Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992). Furthermore, in a study of 30 Parkinson's patients (Grossman et al., 1993), perceptual skills, motor skills, and executive functioning were all related to ROCF performance. To partial out the motoric requirement of visuoconstruction tasks, Boller and colleagues (1984) studied visuospatial and visuoconstruction measures along with the Hooper Visual Organization Test (HVOT), which "challenges complex visuospatial abilities without requiring overt manual responses" (p. 487), in a sample of 24 nondemented Parkinson's patients. Because their sample was impaired on both types of tasks, they concluded that impairments on visuoconstruction measures likely involve deficits in visuoperception and/or visual organization. However, it should be noted that Parkinson's patients have been shown to have impairments in motor functioning, executive functioning, and spatial skills, as well (e.g., Adams, Victor, & Ropper, 1997; Cronin-Golomb & Braun, 1997, Levin et al., 1991, Tamaru, 1997). In a study of patients with vascular dementia by Paul and colleagues (2001), performance on the block design test, a visuoconstruction assembly task, accounted for 60% of the variance on the HVOT, suggesting a strong relationship between visual organizational skills and visuoconstruction ability.

The underlying cognitive components of visuoconstruction were explored by Guerin and colleagues (2002) in a sample of eight probable Alzheimer's patients using simple and complex copying tasks. In this study, VC performance was related to deficiencies in visual exploration and judgment of spatial relations. Contrary to expectation, however, graphical planning was not significantly related to VC performance (these results were cautiously interpreted given the small sample size). A study by Angelini and Grossi (1992) found a significant relationship between visuospatial skills (e.g., JLO) and VC abilities (i.e., Benton Visual Retention Test-copy); however, they suggested that visuospatial skills are insufficiently related to the cognitive demands of a VC task. The authors stated that inspection of scattergrams showed that, in some cases, severe VC impairment was evident without comparable visuospatial deficit (and vise versa: visuospatial deficit without VC impairment), suggesting that "many factors are involved in generating the constructional disorders" (Angelini & Grossi, 1992, p. 601). Similarly, an early study by De Renzi and

Faglioni (1967) of right versus left hemisphere lesioned patients, VC impairment was not consistently related to visuospatial deficit (especially for the left hemisphere lesioned patients). The authors suggested that VC impairment may often be attributed to other factors than visuospatial impairment, such as executive dysfunction or ideomotor apraxia (it should be noted that executive dysfunction and apraxia were not formally assessed in this study, though one patient with significant VC impairment was noted to have severe ideomotor apraxia).

Is VC One Entity or a Mixture of Multiple Cognitive Components?

Because VC appears to be the product of multiple cognitive domains, and because it can be measured with various tasks with differing demands, understanding and conceptualizing this construct appears to be difficult. VC has been loosely used as a "unitarian clinical entity" (Villa, Gainotti, & De Bonis, 1986, p. 497) and it has been deemed as "overly inclusive in nature" (Walsh, 1987, p. 227). Because of the variability observed between tasks, the question has been asked by some: "is constructional apraxia a single entity or are there separate, distinct types of disorder under this heading?" (Walsh, 1987, p.221). Perhaps there would be less confusion and frustration in understanding this construct if more detailed discriminations were made between tests and their underlying components.

Summing It All Up

In conclusion, various VC tasks have been used in clinical practice to assess "VC ability," and they have been used in numerous research studies over the past four decades. However, these studies have rarely focused directly on the construct of VC or comparing and contrasting popular VC measures. Furthermore, it has never been systematically determined whether different results should be predicted from assembly versus graphomotor (i.e., drawing and copying tasks), from a drawing-to-command versus copying tasks, or from tasks of varying levels of complexity. Thus far, decisions about the appropriateness of a selected task for a particular purpose has either been based on clinical judgment or appears to have been given little thought at all.

Purposes of the Current Study

The present research study has two interrelated purposes. Both are related to redefining the construct of VC to gain clarity and improve interpretation. The first goal is to understand how "VC performance" may vary, depending on the type of task used. Accordingly, this study will attempt to determine the usefulness of discriminating among different VC tasks, based on their differing requirements and cognitive demands, by breaking them into "types." This will be performed by comparing and contrasting a select group of commonly used VC tasks and determining the relationship between (1) graphomotor and assembling tasks; (2) draw-to-command versus copying conditions; and (3) simple versus complex VC tasks.

The second purpose of the current study is to determine the role of fundamental underlying neuropsychological mechanisms of VC. Although some authors may argue that deficits in VC are largely attributable to visuospatial impairment, others disagree and have found that executive functioning and visuoperceptual skills may play a large role in VC ability. In addition, VC (or "constructional apraxia") has also been conceptualized as a disorder of apraxia or movement, and therefore the ability to perform purposeful and/or coordinated movements will be investigated.

Table 1. *Predicted Impact of Neuropsychological Function on Type of VC Task*

VC TASK

NPSYCH FUNCTION	Assembly[1]	Draw-Copy-Complex[2]	Draw-Copy-Simple[3]	Draw-Command-Complex[4]	Draw-Command-Simple[5]
Visuospatial/ Perceptual	++	++	+	++	+
Visual-Organizational	++	++	+	++	+
Executive	++	++	–	++	+
Apraxia/ Motor	++	+	–	+	–

Note: *VC = Visuoconstruction; Npsych = Neuropsychological*

++ = *Strong effect/relationship*
\+ = *Some effect/relationship*
– = *Little/no effect/relationship*

1 = e.g., Block Design; 2 = e.g., ROCF, VR Copy, copy clock; 3 = e.g., DRS Constructional Figures, MMSE pentagons, copy daisy; 4 = e.g., Draw-to-command clock; 5 = e.g., Draw-to-command daisy

The major study predictions of this study are stated below (please also refer to Table 1 above for more detailed predictions between groups).

Study Predictions:

1. Assembly tasks will be comparable only to very complex graphomotor tasks. These tasks will require high demands on perception, visuospatial skills, executive functioning, visuospatial integration/organization, and motor skills.
2. Simple graphomotor tasks are predicted to be mostly dependent upon perceptual, visuospatial, and motor ability. Unlike complex tasks, it is predicted that executive and visuospatial integration/organization should not play as large a role in simpler tasks.
3. Within graphomotor tasks, copying tasks will be more impacted by perceptual and/or visuospatial impairment than the draw-to-command tasks. Additionally, the draw-to-command tasks should require more demands on executive functioning (e.g., planning, organization, stimulus pull, perseveration).

METHODS

Participants

Participants included 140 outpatient neurologic and neuropsychiatric patients referred for neuropsychological evaluation at the neuropsychology service of a large urban university-based medical center. Those participants who were unable to complete the neuropsychological measures examined in the present study (typically due to fatigue, severity of illness/confusion, or poor cooperation) were not included in the study analyses. Therefore data from those 114 participants who were able to complete all neuropsychological tests are presented. Demographics for this sample are reported below in Table 2.

Table 2. *Participants' Demographic Variables*

Demographic	Means (SD)
Age	58.0 (17.0)
Education	13.7 (3.0)
Estimated IQ*	105.5 (10.6)
MMSE / 3MS	28 (2.5) / 90.1 (8.8)

	Frequencies (N)	Percent of Sample
Gender	Male=49	43.0%
	Female=65	57.0%
Handedness	Right=101	88.6%
	Left=11	9.6%
	Ambidextrous=2	1.8%
Race	Caucasian=106	93.0%
	African American=4	3.5%
	Hispanic=2	1.8%
	Asian=1	0.9%
	Other=1	0.9%
Marital Status	Single=16	14.1%
	Married=65	57.0%
	Divorced=18	15.8%
	Widowed=15	13.2%
Work Status	Working=41	36.0%
	Unemployed=4	3.6%
	Retired=42	36.8%
	Disabled=22	19.3%
	Other=5	4.4%

**** Estimated IQ was based on the average between the Barona score and WRAT-R/III Reading subtest Score***

Within the patient sample, 22% received a primary diagnosis of Cognitive Disorder NOS/Mild Cognitive Impairment, 16% dementia, 16% stroke/cerebral vascular disease, 9% epilepsy, 8% Multiple Sclerosis, 6% traumatic brain injury, 5% Attention Deficit Hyperactivity Disorder, 2% psychiatric disorder, 2% brain neoplasm, and 14% other neurologic/medical disorder (e.g., Chronic Lyme disease, Hydrocephalus, anoxic brain damage). The duration of primary illness was greater than one year in 80% of the sample, 6 months-1 year in 14%, 1-6 months in 4%, and less than one month in 2%. In addition to their primary diagnosis, 50% of the sample also carried an additional secondary medical diagnosis considered to possibly affect cognitive functioning, such as thyroid disease, sleep apnea, lupus, chronic fatigue syndrome, or chronic alcohol abuse. Review of participants' medical history also revealed that 46% of the sample had additional medical diagnoses (e.g., hypertension, diabetes, hypercholesterolemia, coronary obstructive pulmonary disease), beyond their primary or secondary diagnoses, which may or may not indirectly contribute to cognitive dysfunction. Finally, 42% of the sample were diagnosed with either a current or lifetime psychiatric disorder (e.g., depression, anxiety) that was not accounted for in their primary or secondary diagnoses.

Materials

All patients received a variety of neuropsychological measures as part of routine neuropsychological evaluation at the Memory and Cognitive Assessment Program (MCAP) at Rhode Island Hospital (RIH). Among these measures were several commonly-used VC tests, as well as other measures hypothesized to be related to VC (e.g., tests of visuospatial skills, executive functioning, motor ability). The measures (and scoring systems) used in this study were chosen for various reasons. First, an attempt was made to use commonly-used, commercially available tasks. Second, tasks were chosen to tap each proposed VC subtype (i.e., assembly, copying, and drawing-to-command, as well as simple and more complex measures), and other neuropsychological tasks were chosen to represent each proposed underlying neuropsychological mechanism (e.g., visuospatial skills, perceptual skills, motor skills, executive functioning). Third, tests were chosen that were as time efficient and as feasible as possible, so as to get patients' best possible performance during their neuropsychological evaluation. However, it is important to note that all tests used in this study are those routinely used by the MCAP as part of their standard neuropsychological test battery.

Visuoconstruction Measures

Simple Copy Tasks

The VC task included in the commonly used *Mini-Mental Status Examination* (MMSE; Folstein, Folstein, & McHugh, 1975) was administered. This task involves having the participants copy a design of interlocking pentagons. Within the MMSE, the pentagons are typically scored as either 1 (correct) or 0 (incorrect). However, the scoring system used in the *Modified Mini-Mental Status Examination* (3MS; Teng & Chui, 1987; Teng & Chui, 1990) was used to increase the variability in scoring (range = 0-10).

The Constructional subtest of the *Dementia Rating Scale* (DRS; Mattis, 1988), a commonly used screen for dementia, was also used in the current study. It contains a set of 5 simple geometric designs which participants must copy from a stimulus booklet. Each copy was then scored according to the manual as correct or incorrect, providing a total range of scores from 0-5.

Complex Copy Tasks

The Copy Condition of the *Visual Reproduction* subtest of the *Wechsler Memory Scale-III* (WMS-III; Wechsler, 1997) contains the same five geometric figures used in the memory portions of this test. These figures increase in difficulty, and each are scored according to specific criteria in the WMS-III manual. All five figures combined provide a range of 0-104.

The Copy Condition of the *Rey-Osterrieth Complex Figure* (ROCF; Rey, 1941; Osterrieth, 1944) was used. The ROCF was scored with the *Boston Qualitative Scoring System* (BQSS; Stern et al., 1999) which is the most comprehensive qualitative scoring system available for the ROCF (Knight & Kaplan, 2004). Many studies have demonstrated excellent reliability (e.g., Folbrecht, Charter, Walden, & Dobbs, 1999; Stern et al., 1994; Stern et al., 1999) and validity (e.g., Cahn et al., 1996; Dawson & Grant, 2000; Freeman et al, 2000; Folbrecht et al., 1999; Javorsky, Rosenbaum, & Stern, 1999; Schreiber, Javorsky, Robinson, & Stern, 2000). Although the BQSS provides 17 qualitative scores and two quantitative summary scores for the copy condition, only one variable was chosen for the main analyses of the current study, in an effort to control for type 1 error. The Copy Presence and Accuracy (CPA) summary score (range = 0-20) was used as an overall estimate of the amount of information accurately copied. This score has excellent convergent validity with the traditional 36-point ROCF score (Stern et al., 1999).

Draw-to-Command Tasks

From the *Spatial Quantitative Battery* (SQB) of the *Boston Diagnostic Aphasia Examination* (BDAE), both the *daisy* (simpler task) and the *Clock Drawing Test* (more complex task) were used. With the daisy, participants are first asked to "draw a daisy" (command condition) and then (without seeing their original production) they are asked to copy a line drawing of a daisy (copy condition). Administration of the clock

1997) was used. Participants were required to correctly match one of six figures to a stimulus figure. There were seven trials, making the range of scores = 0-7.

The short-form for the *Judgment of Line Orientation* (JLO; Benton Hamsher, Varney & Spreen, 1983) consists of 15 pairs of angled target lines placed in different spatial positions. Subjects must identify the correct angular relationship between line segments by comparing them to an array of 11 reference lines positioned in a semicircle below. In the current study, the short-form JLO was chosen over the longer 30-item JLO because it is quicker to administer, and does not sacrifice reliability or validity (Woodward et al., 1996; Woodward et al., 1998). The range of scores is from 0-15.

The *Hooper Visual Organization Test* (HVOT; Hooper, 1983) is an instrument used to measure visuoperception, visuospatial-organization, and visual synthesis/integration. It consists of 30 line drawings of common objects that have been disassembled into puzzle-like pieces. Subjects must mentally reassemble and integrate these pieces and then name the object. Immediately following the standard administration of the HVOT, all subjects also received multiple-choice answer options to those items answered incorrectly. This procedure has been found to be useful for those patients with naming difficulties (i.e., anomia) which can interfere with accurate responses (Schultheis, Caplan, Ricker, & Woessner, 2000). Two scores were obtained (the range of scores for both is 0-30): (1) score with standard administration, and (2) score obtained with the aid of multiple-choice responses.

Executive Functioning Measures

The *Controlled Oral Word Association* (COWA; Benton, 1968) is a common measure of executive functioning, examining verbal fluency and generativity. This task requires participants to generate as many words as possible that begin with a designated letter (i.e., F, A, S) within 60 seconds. The selected variable chosen for data analyses in the current study was FAS Total Words (there is no upper limit in range of scores).

The *Similarities Subtest* from the *Wechsler Adult Intelligence Scale-III* (WAIS-III; Wechsler, 1997) assesses abstract verbal reasoning, an aspect of executive functioning. In this measure, participants are given two related words, and they must say how those two words are alike. The Similarities Raw Score variable was used for data analyses, and the range of scores = 0-33.

Part B of the *Trail Making Test*[*] (TMT; Reitan & Wolfson, 1985) is a commonly used test in neuropsychological assessment which measures important aspects of neuropsychological functioning, such as cognitive response set and multi-tasking skills. Participants must maintain the cognitive set of alternating between numbers and letters, connecting a line in order, as quickly as possible. The Total Time

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[*] **Because the TMT and WCST (as described below) are difficult tests that are very sensitive to executive dysfunction, patients are commonly unable to complete the entire test. When these tests are discontinued due to significantly impaired executive functioning, some researchers may miss out on these valuable data by not including them in their analyses. However, in a study on missing values by Smeding and de Koning (2000), the researchers did not disregard discontinued WCSTs or TMTs. By substituting the lowest obtained score within their sample for each discontinued test, they obtained a better understanding of patients' performance and concluded that their data was more realistic, valid, and useful. Therefore, in the current study, this technique was used in cases where missing values exist for WCST and TMT because of discontinuation due to behavioral disturbance (i.e., executive dysfunction) as determined by the clinical examiner.**

is measured in seconds from start to finish, and this was the variable used in the present study (there is no upper limit in range of scores).

The short form of the *Wisconsin Card Sorting Test* (WCST-64; Kongs, Thompson, Iverson, & Heaton, 2000) is a measure of executive functioning which assesses conceptualization, complex problem-solving skills, and cognitive response set. The standard WCST is one of the most commonly studied executive measures in neuropsychology. To be sensitive to the time issues in this study, the 64 card version was used instead of the longer 128 card version. In numerous research studies (Axelrod, Henry, & Woodward, 1992; Heaton & Thompson, 1992; Robinson, Kester, Saykin, Kaplan, & Gur, 1991; Sillanpaa et al., 1993), it has been demonstrated that very few differences exist between scores obtained from the WCST-64 and the standard WCST. In this test, patients are required to match cards to one of four key cards with stimuli varying in shape, color, and number, and they must figure out the specified matching strategy based on feedback from the examiner. To control for type one error, only the Perseverative Responses raw score variable was used (there is no upper limit in range of scores). The Perseverative Responses score is commonly used as a measure of executive functioning in research literature (e.g., Arnett et al., 1994; Beatty & Monson, 1996; Everett, Lavoie, Gagnon, & Gosselin, 2001; Minassian, Perry, Carlson, Pelham, & DeFilippis, 2003; Reeve & Schandler, 2001; Sherer, Nick, Millis, & Noavack, 2003).

Motor Functioning Measures

The *Grooved Pegboard* (Kløve, 1963; Matthews & Kløve, 1964) is a commonly used measure of coordination/manual dexterity in which participants must quickly place pegs into holes of different rotated orientations. The Total Time for completion for the dominant hand was used as the variable for analyses in the present study (there is no upper limit in range of scores).

An *Apraxia Screening* measure was used in order to assess the potential role of ideomotor apraxia in VC impairment (i.e., "constructional apraxia"). Participants were required to demonstrate (i.e., pantomime) the action sequence of common activities. These requests include: "show me how to: (1) brush your teeth; (2) blow out a match; (3) hammer a nail; and (4) cut a slice of bread." Each hand was tested to obtain a range of scores from 0 (unable to perform any sequences) to 8 (all 4 sequences correct for both hands).

Intellectual Estimate/Global Functioning Measures

Two measures were used to obtain an estimate of intellectual ability. First, the *Reading* subtest of the *Wide Range Achievement Test-R* (WRAT-R; Jastak & Wildinson, 1984), a commonly used estimate of premorbid intellectual ability (Johnstone & Wilhelm, 1996; Williams, 1997), was used (note: 34% of the sample received the updated WRAT-III Reading subtest due to changes in the MCAP's standard battery during data collection. Reliability between these two reading subtest versions (i.e., WRAT-R and WRAT-III) is excellent (*r*=.90; Wilkinson, 1993). Secondly, the *Barona* index (Barona, Reynolds, & Chastain, 1984), a formula based on such variables as gender, education, occupation, and geographic location, will also be calculated for each subject.

The full *Mini-Mental Status Examination* (MMSE; Folstein, Folstein, & McHugh, 1975) (range = 0-30) was administered as an estimate of global cognitive impairment.

Procedures

Evaluations were conducted by all clinicians at the MCAP (i.e., graduate practicum students, interns, post-doctoral fellows in clinical neuropsychology, and staff neuropsychologists). As part of the routine clinical exam, information was gathered on each patient regarding recent events leading to the current injury or illness, previous medical and psychiatric history, as well as educational, work and social history. This information was gathered from the medical record, family members, and when appropriate, from the patients themselves. As routinely performed, all clinicians administered the neuropsychological measures according to standard procedures and instructions as outlined in each test manual.

All tests (except for the clock test as described below) were scored by the clinicians administering each neuropsychological test battery. To assure accuracy of scoring for this study, approximately half (54%) of the participants' tests were rescored by a highly trained, Brown University undergraduate research assistant. She had extensive scoring experience with the BQSS, WCST, Trail Making Test, COWA, and Grooved Pegboard. In addition, she also received thorough training in the scoring procedures of the other instruments used in this study. To best assess inter-rater reliability, two test scores, the BQSS CPA score and Visual Reproduction (VR) Copy score, were selected because their scoring is the most difficult (i.e., the most criteria per figure and the most "clinical judgment" involved). Inter-rater reliability was excellent for both the CPA (r=.94) and the VR Copy (r=.96) scores. Because the MCAP practice uses a different clock scoring system than the one chosen for the present study, clocks were scored by either the above mentioned research assistant (54% of clocks) or the author (48% of clocks). A subset of 30 clocks were twice scored by each of the two raters to assess inter-rater reliability. Again, reliability was excellent (r=.92).

RESULTS

Descriptives

The means and standard deviations for each of the neuropsychological test variables are included in Table 3 below. To make descriptive comparisons across neuropsychological measures, impairment indices were created and are also reported in Table 2. Rates of impairment for each VC task (based on the average scores across participants) were assessed to compare the current sample to age matched, healthy controls (i.e., normative data). These impairment indices lend insight as to the difficulty of each VC task as compared to another. Comparisons between impairment indices of VC tasks to other non-VC cognitive tasks (e.g., visuospatial, executive) were also made to investigate patterns of performance across domains. For all tests with available normative information, impairment indices were based on the percentage of patients scoring in the impaired range (defined by -1.5 S.D.s below the mean). For the tests in which normative data were not available (e.g., drawing a daisy), cut-off scores were derived to determine the percentage of patients who scored in the impaired range. These were based on the range and frequency analyses of the scores for each of these measures.

Table 3. *Means, Standard Deviations, and Impairment Indices for Neuropsychological Tests Administered to 114 Mixed Neurologic and Neuropsychiatric Patients.*

Neuropsychological Test	Means (SD)	% Pts. Impaired
Visuoconstruction		
WAIS-III Block Design	29.8 (12.7)	11.4
Rey-Osterrieth Complex Figure	16.0 (2.8)	21.9
WMS-III Visual Reproduction Copy	95.6 (5.7)	8.8
3MS Pentagons	9.2 (1.1)	7.9*
DRS Construction	5.7 (0.7)	5.3*
Clock		
Copy	9.0 (1.0)	0.0
Draw-to-Command	8.1 (2.1)	13.2
Daisy		
Copy	1.9 (0.3)	0.0*
Draw-to-Command	1.7 (0.6)	8.8*
Visuospatial/Perceptual		
Judgment of Line Orientation	10.9 (3.2)	14.0
WMS Discrimination	6.5 (0.7)	9.6
Visual/Organizational		
HVOT	23.8 (4.4)	14.9
Executive		
WCST-64 Perseverative Responses	19.8 (18.1)	28.9
TMT-Part B	175.8 (156.2)	34.2
WAIS-III Similarities	19.7 (7.2)	8.8
COWA Total Score	33.1 (14.7)	30.7
Motor		
Grooved Pegboard	101.0 (40.3)	47.4
Apraxia Score	7.7 (0.7)	7.9*

* *Impairment indices based on cut-off scores (others based on normative data). Impaired pentagons score ≤ 7/10; impaired DRS construction score ≤ 4/6; impaired apraxia score ≤ 6/8; impaired daisy score = 0/2.*

Comparisons of impairment indices were made cautiously given different normative data used across each measure, and these impairment indices are reported in

Table 3 above. It can be inferred from these indices that this sample appeared to have the most difficulty with the ROCF (21.9% impaired). Following this, the draw-to-command clock (13.2% impaired) and block design (11.4% impaired) were the second most difficult VC measures. The simplest measures appeared to be the daisy command condition (8.8% impaired; cut-off score: $\leq$1 out of 2), pentagons (7.9% impaired; cut-off score: $\leq$7out of 10), DRS construction figures (5.3% impaired) and the copy conditions of the clock and daisy (0% impaired; cut-off score: $\leq$1 out of 2). It should also be noted that for both the clock and the daisy, the copy conditions appeared to be much easier than the draw-to-command conditions (8.8-13.2% impaired). One surprising finding was that the Visual Reproduction copy (8.8% impaired), hypothesized to be a more difficult task, was equivalent to the draw-to-command daisy, estimated to be a more simple task.

When examining other non-VC cognitive measures, almost half of the participants had difficulty with the Grooved Pegboard (47.4% impaired). Otherwise, the executive measures were generally the most difficult non-VC measures (approximately 30% of the sample were impaired on the WCST, TMT-B, and COWA), though the Similarities measure was comparatively easier (only 8.8% impaired). The sample performed equivalently on the JLO visuospatial measure and the HVOT visual-organizational measure (14.0-14.9% impaired). The perceptual/discrimination task was comparatively easier (9.6% impaired). Finally, although many participants had difficulty with the Grooved Pegboard (fine motor coordination), few had impairments in apraxia (7.9%; cut-off score: $\leq$6 out of 8).

Correlational Analyses

To help illuminate the shared variance between tasks, Pearson correlations were performed (please refer to Table 1 for apriori relationships among tasks). The correlations between and amongst VC measures are reported in Table 4.

Table 4. *Correlations Between VC Measures.*

	BD	ROCF	VRC	Pntgns	DRSC	ClkC	ClkDC	DsyC	DsyDC
BD	--								
ROCF	.56***	--							
VRC	.45***	.60***	--						
Pntgns	.35***	.38***	.37***	--					
DRSC	.37***	.47***	.53***	.38***	--				
ClkC	.40***	.43***	.44***	.35***	.35***	--			
ClkDC	.54***	.47***	.39***	.46***	.36***	.56***	--		
DsyC	.23*	.37***	.32***	.08	.34***	.23*	.14	--	
DsyDC	.20*	.08	.21*	.09	.31***	.28**	.31***	.27**	--

Note: *BD= WAIS-III Block Design; ROCF= Rey-Osterrieth Complex Figure; VR-C=WMS-III Visual Reproduction Copy; Pentagons= 3MS Pentagons; DRS-C=DRS Construction; Clock-C= Clock Copy; Clock-DC=Clock Draw-to-Command; Daisy-C= Daisy Copy; Daisy-DC= Daisy Draw-to-Command.*
* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

Specifically, the following correlations were of interest based on apriori hypotheses: (1) between the assembly and the drawing tasks; (2) between simple tasks and complex tasks; and (3) between the copy and command tasks drawing task. As depicted in Table 4, almost all correlations between tasks were highly statistically significant, thereby making it difficult to compare the strength of relationships based on their significance level. Therefore, the patterns of relationships between tests were inferred descriptively by the magnitude of the correlations (with $r > .50$ representing moderate to high relationship and $r < .50$ representing low to moderate relationship; Bordens & Abbott, 1988; Gravetter & Wallnau, 1988).

First, when the assembly (block design) task was compared to other drawing tasks, the correlations were the highest with more complex copying tasks (i.e., ROCF and VRC) and the command condition of the clock. Medium correlations were found between the assembly task and simpler copy tasks (i.e., pentagons and DRS Construction), as well as the clock copy (proposed to be simpler than the clock command). The Block Design assembly task used in this study, which is quite complex/multimodal, was only mildly correlated with the simpler daisy task (both copy and command). In summary, the assembly task was significantly related to each drawing task, though the strongest correlations were with complex copy tasks.

Secondly, correlations were examined to see whether VC tasks could be differentiated based on their complexity. It was estimated that similar tasks would have the strongest relationships, that is, complex tasks with other complex tasks and simpler tasks with other simpler tasks. As revealed in Table 4, the complex tasks were the most correlated with other complex tasks, and these represented some of the strongest relationships of all the VC tasks. However, except for the simple daisy task, other simpler tasks (i.e., pentagons, DRS construction) were moderately correlated with both simple and complex tasks. The daisy was the only VC task that was not significantly correlated with every other VC task. Some correlations were moderate, while others were mild or nonsignficant).

Thirdly, for both the clock and daisy, relationships were examined between copy and draw-to-command conditions. For the clock (more complex than the daisy), these two conditions were highly correlated with each other, though for the daisy, they were only mildly-to-moderately correlated. When examining how both conditions for the clock related to other complex VC measures, the strength of the relationship between the clock command and complex VC tasks (particularly the assembly task) was slightly higher than for the clock copy condition. However, the clock command condition was also slightly more correlated to the simpler pentagons and DRS construction tasks. On the other hand, VR Copy and the daisy copy were slightly more correlated with the clock copy. In general, most of these comparative differences were very small and, therefore, may not represent meaningful trends.

Correlations between VC measures and other non-VC neuropsychological measures are presented in Table 5 below. These correlations show how each VC test is related to tests of other cognitive domains. First, we can consider the block design assembly task. This task was highly correlated with visuospatial skills (i.e., JLO), visual-organizational skills (i.e., HVOT), executive functioning, and one motor measure (i.e., fine motor coordination; Grooved Pegboard). Although significantly correlated, it was less related with perceptual discrimination and apraxia. A similar pattern resulted with the complex ROCF which was most related to visuospatial skills and secondly with visual-organization. Additionally, executive measures were moderately to highly correlated with the ROCF. Discrimination and fine motor coordination were also moderately correlated with ROCF, while apraxia was not significantly correlated. The Visual Reproduction (VR) Copy figures were moderately correlated with almost all the cognitive domains (i.e., visuospatial, visuo-organizational, executive, discrimination, fine motor coordination). Only one executive measure (COWA) and the apraxia score were mildly correlated with VR Copy.

Table 5. *Correlations between VC measures and other neuropsychological measures.*

	JLO	Discrm	HVOT	WCST	TMTB	Similr	COWA	GrvPeg	Apraxia
BD	.62***	.30***	.58***	-.52***	-.52***	.64***	.42***	-.55***	.25**
ROCF	.65***	.41***	.52***	-.37***	-.47***	.50***	.35***	-.40***	.10
VRC	.49***	.45***	.47***	-.37***	-.42***	.49***	.24**	-.34***	.22*
Pntgns	.59***	.24**	.37**	-.29***	-.41***	.49***	.29**	-.31***	.32***
DRSC	.51***	.42***	.42***	-.36***	-.42**	.44***	.35***	-.22*	.26**
ClkC	.42***	.29**	.53***	-.30***	-.34***	.43***	.22*	-.30***	.18
ClkDC	.52***	.36***	.67***	-.42***	-.48***	.58***	.31***	-.42***	.28**
DsyC	.27**	.34***	.20*	-.18	-.19	.17	.19*	-.16	.07
DsyDC	.07	.16	.34***	-.13	-.23*	.18	.12	-.15	.20*

Note: *BD = WAIS-III Block Design; ROCF= Rey-Osterrieth Complex Figure; VR-C=WMS-III Visual Reproduction Copy; Pentagons= 3MS Pentagons; DRS-C=DRS Construction; Clock-C= Clock Copy; Clock-DC=Clock Draw-to-Command; Daisy-C= Daisy Copy; Daisy-DC= Daisy Draw-to-Command; JLO= Judgment of Line Orientation; Discrm = WMS-III Discrimination; HVOT = Hooper Visual Organization Test; WCST = WCST-64 Perseverative Responses; TMTB = Trail Making Test, Part B; Similr = WAIS-III Similarities; COWA = Controlled Oral Word Association Test; GrvPeg = Grooved Pegboard Test.*

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

Both of the simpler copy tasks, pentagons and DRS construction, were highly correlated with the visuospatial measure (JLO). They were also mildly to moderately related to the other domains assessed in this study (e.g., executive functioning, motor functioning). When examining the clock drawing test, the copy and command conditions had similar patterns of correlation with other cognitive domains. However, the strength of correlations was higher for the command condition. In contrast, the two conditions of the daisy had different patterns of correlations. The copy condition was moderately correlated with discrimination, secondly with visuospatial skills, and mildly with one executive measure. The command condition was moderately correlated with visual-organization and mildly with one executive measure and apraxia.

Finally, correlations among all the remaining non-VC measures were performed to determine similarities among cognitive domains (e.g., WCST and COWA), as well as between different cognitive domains (e.g., WCST and JLO). These correlations are reported in Table 6. Although the relationships between these variables were not the focus of the current study, it is still worth examining the validity between these measures (i.e., the degree to which a test measures a construct it is supposed to measure). Unfortunately, these non-VC measures were more interrelated than would be expected. For example, the visuospatial measure (JLO) was highly to moderately correlated with the executive measures and a motor measure. As predicted, it was also moderately correlated with perceptual and visual-organizational measures. Perhaps because of the complex, heterogeneous nature of these tasks, the executive and visual-organizational measures were also moderately to highly correlated with most measures (though to a lesser degree with the apraxia measure). Discriminability was most correlated with visual organization and moderately correlated with other measures. The two motor-type measures were only mildly (though significantly) correlated with each other, and they had different patterns of relationship with other non-VC measures. The grooved pegboard was moderately correlated with all other non-VC tests, while the apraxia measure was only mildly to moderately correlated with other non-VC measures.

Table 6. *Correlations between non-VC measures.*

	JLO	Discrm	HVOT	WCST	TMTB	Similr	COWA	GrvPeg	Apraxia
JLO	--								
Disrim	.39***	--							
HVOT	.53***	.51***	--						
WCST	-.43***	-.27**	-.51***	--					
TMTB	-.57***	-.40**	-.62***	.55***	--				
Similr	.67***	.36***	.58***	-.58***	-.63***	--			
COWA	.46***	.29**	.39***	-.44***	-.50***	.58***	--		
Grvpeg	-.50***	-.42***	-.57***	.50***	.56***	-.51***	-.38***	--	
Apraxia	.29**	.39***	.35***	-.17	-.40***	.33***	.19*	-.24**	--

Note: *BD = WAIS-III Block Design; ROCF= Rey-Osterrieth Complex Figure; VR-C=WMS-III Visual Reproduction Copy; Pentagons= 3MS Pentagons; DRS-C=DRS Construction; Clock-C= Clock Copy; Clock-DC=Clock Draw-to-Command; Daisy-C= Daisy Copy; Daisy-DC= Daisy Draw-to-Command; JLO= Judgment of Line Orientation; Discrm = WMS-III Discrimination; HVOT = Hooper Visual Organization Test; WCST = WCST-64 Perseverative Responses; TMTB = Trail Making Test, Part B; Similr = WAIS-III Similarities; COWA = Controlled Oral Word Association Test; GrvPeg = Grooved Pegboard Test.*

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

Multiple Regression

Standard multiple regression (MR) evaluates how each independent variable (IV) adds to the prediction of the DV that is different from that predicted by the other IVs (Tabachnick & Fidell, 1996). Therefore, standard MR was used to predict VC performance (for each different VC task) based on underlying neuropsychological domains (e.g., visuospatial, executive, motor). The nine non-VC measures were used as the independent variables in each of the MRs: JLO (visuospatial skills), WMS-III Discrimination (perceptual discrimination), HVOT (visual organization skills; *note*: HVOT-MC was not used in the place of standard HVOT given that using this format did not significantly alter MR results), TMT-B (executive functioning), WCST perseverative responses (executive functioning), COWA (executive functioning), WAIS-III Similarities (executive functioning), Grooved Pegboard (motor functioning), apraxia (motor functioning). The dependant variable for each MR was a VC measure, resulting in nine separate test-specific MRs (i.e., Block Design, ROCF, clock drawing test-copy, clock drawing test-command, daisy-copy, daisy-command, MMSE pentagons, DRS construction, WMS-III Visual Reproduction Copy). In addition, an MR was also performed on an overall score for VC impairment. Because multiple tasks were used to assess VC impairment, this variable was created by converting the scores for each VC test to z-scores and then creating an average VC score.

Examination of residuals scatterplots for each MR indicated that the assumptions of normality, linearity, and homoscedasticity were met (Tabachnick & Fidell, 1996). The sample size used in this study (N=114) was adequate for testing individual predictors as based on the formula for sample size prediction in standard MR: $N \geq 104 + m$ (m = #IVs; 9) (Green, 1991, as cited in: Tabachnick & Fidell, 1996, p.132).

The first MR was conducted on the block design assembly task. The amount of variability accounted for by the IVs (i.e., R^2) was .55, and the regression was significant; $F(9, 113)=14.1$, $p <.001$. Four of the IVs contributed significantly to the regression: JLO ($t = 2.9$, $p =.005$), Similarities ($t = 2.1$, $p = .036$), HVOT ($t = 2.1$, $p = .039$), and Grooved Pegboard ($t = -2.0$, $p = .049$).

The MR for the complex copy task, the ROCF, was also significant, $F(9, 113)= 12.1$, $p <.001$, with $R^2 = .51$. Three IVs contributed significantly to the regression: JLO ($t = 4.9$, $p <.001$), apraxia ($t = -2.8$, $p =.006$), and VR Discrimination ($t = 2.2$, $p =.031$), with the HVOT approaching significance ($t = 1.9$, $p =.055$).

The copy condition for the WMS-III Visual Reproduction (VR) task contains a series of shapes to copy of increasing complexity. The MR for VR copy was significant; F (9, 113)= 12.1, p <.001 with R^2 = .38, though surprisingly, only one IV, VR Discrimination, contributed significantly to the regression (t = 2.9, p =.005). Although the VR Discrimination task (a perceptual discrimination task) and the VR copy task are different in their demands, they do use the same VC figures, possibly confounding the results. Therefore, to explore how the regression would be different if the VR Discrimination task was removed, another standard MR was performed without this variable. This MR was also significant F (9, 113)= 6.4, p <.001 (R^2 = .33). Again, only one IV, the JLO (a visuospatial task) contributed significantly to the regression (t = 2.1, p =.042).

Both of the MRs for the two simple copy tasks were significant; 3MS Pentagons, F (9, 113)= 7.4, p =.000, R^2 = .39 and DRS construction, F (9, 113)= 7.1, p =.000, R^2 = .38). For the pentagons task, only one IV, JLO, contributed significantly (t = 4.4, p =.000). The JLO also contributed significantly to the DRS construction task (t = 3.0, p =.004), however, the VR discrimination task (t = 2.6, p =.012) and grooved pegboard task (t = 2.5, p =.012) did also.

The MRs for the clock drawing test, which has both copy and draw-to-command conditions, were significant (copy: F (9, 113)= 5.4, p <.001, R^2 = .32; command: F (9, 113)= 11.2, p <.001, R^2 = .49). Although it was proposed that the command and copy conditions are different in their demands, surprisingly, the conditions did not differ in the number or type of IVs contributing to their regression equations. For both conditions, only the HVOT score contributed significantly to the

MR (copy condition: $t = 3.6$, $p = .012$; command condition: $t = 4.6$, $p = .012$). The daisy also has copy and command conditions, and these MRs were also significant, though the amount of variance accounted for by the IVs (R^2) was much less than for other construction tasks (copy condition: $F(9, 113) = 2.0$, $p = .047$, $R^2 = .15$; command condition: $F(9, 113) = 3.0$, $p = .030$, $R^2 = .16$). Similar to the clock drawing test, the only IV to contribute significantly to the daisy command task was the HVOT ($t = 2.8$, $p = .006$). In contrast, only the discrimination score contributed significantly to the daisy copy condition ($t = 3.0$, $p = .004$).

Finally, a VC index score, which served as an overall estimate of VC performance was created in order to test which IVs would best predict *overall* VC performance. This index score is not an impairment score, rather it represents the *average performance* for all VC measures which contained normative data (i.e., based on z-scores for block design, ROCF, VR Copy, clock copy, clock command). It should be noted that this score did not include performance on more simple VC tasks. Additionally, because the score was based on z-scores in order to compare across tests on a common metric, the index score also represents the effects of age covaried out of the variable.[1] The MR for the overall VC score was significant; $F(9, 113) = 18.9$, $p < .001$, and a large amount of variance from the IVs was accounted for by the regression ($R^2 = .62$). Examination of each IV revealed that only three contributed significantly to the regression; JLO ($t = 5.1$, $p < .001$), HVOT ($t = 3.3$, $p = .001$), and Similarities ($t = 2.3$, $p = .021$).

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[1] **When age was entered as an additional IV in each of the separate MRs, it only contributed significantly to two tasks (clock command and block design).**

As a follow-up exploratory analysis, the MMSE score was also added to each multiple regression. The MMSE is considered to serve as an estimate of global cognitive decline, and therefore, could possibly account for a significant amount of performance variance. For 8/9 follow-up MRs, MMSE scores did not significantly contribute to the overall analysis. MMSE was only a significant predictor for the ROCF; $F\,(10, 113) = 12.33$, $p = .000$ ($R^2 = .55$). As mentioned above, only the JLO, apraxia, and discrimination scores were significant predictors in the original ROCF regression (with HVOT approaching significance). In this follow-up analysis, JLO ($t = 5.3$, $p < .001$), MMSE ($t = 2.8$, $p = .007$), and HVOT ($t = 2.0$, $p = .05$) were the significant predictors (with discrimination and apraxia approaching significance).

Only in the case of the block design MR and the overall VC MR (based on the average of all complex tasks) was an executive measure found to significantly contribute to the regression. This may be due to the complex nature of executive functioning. That is, because executive functioning may underlie many cognitive domains, it may not contribute a significant amount of unique variance. The degree to which executive functioning may be employed in each task is an interesting question, so exploratory MRs were performed to help answer it. These MRs contained the four executive measures as the IVs, and the DVs remained the same (i.e., VC tasks). A hierarchy emerged which was largely consistent with apriori hypotheses about the complexity of each task. Based on the total amount of variance predicted by the executive variables (i.e., $R2$), the hierarchy was as follows (from greater to lesser degree of executive functioning required): (1) block design, a complex assembly task; $F\,(4, 113) = 22.33$, $p < .001$ ($R^2 = .450$; significant predictors were Similarities, $t = 4.2$,

$p <.001$ and WCST, $t = -2.1, p =.041$), (2) clock command, a complex free-drawing task; $F(4, 113)= 14.18, p<.001$ ($R^2 = .342$; significant predictors were Similarities, $t = 3.5, p =.001$ and TMT-B, $t = -2.0, p =.047$), (3) ROCF, a complex copy task; $F(4, 113)= 11.28, p <.001$($R^2 = .293$; significant predictors were Similarities, $t = 2.5, p =.014$ and TMT-B, $t = -2.22, p =.028$), (4) VR Copy, an intermediate copy task (contains a range from simple to complex copy items); $F(4, 113)= 10.06, p <.001$ ($R^2 = .270$; significant predictor was Similarities, $t = 3.2, p =.002$), (5) pentagons, simple copy task; $F(4, 113)= 9.39, p <.001$ ($R^2 = .256$; significant predictor was Similarities, $t = 3.4, p =.001$), (6) DRS construction, simple copy task; $F(4, 113)= 8.69, p <.001$ ($R^2 = .242$; Similarities was a predictor, approaching significance, $t = 1.8, p =.074$), (7) clock copy (proposed to be less difficult than clock command); $F(4, 113)= 6.61, p <.001$ ($R^2 = .197$; significant predictor was Similarities, $t = 2.9, p =.005$), (8) daisy command (proposed to be more difficult than daisy copy); $F(4, 113)= 1.56, p =.192$ ($R^2 = .054$), and (9) daisy copy; $F(4, 113)= 1.42, p =.233$ ($R^2 = .050$).

Group Differences

Group differences were performed to help understand the impact of underlying neuropsychological domains on the performance of various VC measures (please refer to Table 1 for proposed relationships among tasks), as well as to assess for similarities and differences between different VC measures/administration styles. To control for type I error, three separate, Multivariate Analyses of Covariance (MANCOVAs) were conducted with the nine VC measures (i.e., Block Design, ROCF, Visual Reproduction Copy, DRS Construction, MMSE Pentagons, Clock Copy, Clock Command, Daisy Copy, Daisy Command) serving as the dependant variables. The IV for the first analysis included executively intact (n=94) versus executively impaired (n=18) groups (based on the average of all executive measures falling above or below the cut-off = -1.5 SD). For the second analysis, the IV included visuospatially intact (n=96) versus visuospatially impaired (n=16) groups (based on -1.5 SD above or below the mean on the JLO—the most standard visuospatial measure in the battery), and the third analysis included motorically intact (n=58) versus motorically impaired (n=54) groups (based on -1.5 SD above or below the mean on Grooved Pegboard). The MMSE score was used as a covariate in an attempt to control for overall cognitive impairment.

All three MANCOVAs were significant; (1) $F(9, 101)=27.44$, $p <.001$ for the executively impaired versus intact groups analysis, (2) $F(9, 101)=30.24$, $p < .001$ for the visuospatially impaired versus intact groups analysis, (3) $F(9, 101)=28.70$, $p < .001$ for the motorically impaired vs. intact groups analysis. Follow-up ANCOVAs (MMSE still serving as the covariate) revealed that the executively impaired group performed significantly worse than the executively intact group for all VC measures except for the two daisy conditions (the clock copy condition was significant at $p = .027$ and the other VC measures were significant at the $p < .001$ level). Follow-up analyses also revealed that the visuospatially impaired group performed significantly worse than the visuospatially intact group for all VC measures ($p = .034$ for the daisy command condition, $p=.001$ for the daisy copy condition, and $p <.001$ for all other VC measures). Finally, the motorically impaired group performed significantly worse than the motorically intact group for all VC measures except for the two daisy conditions (the clock copy condition was significant at $p = .014$ and the other VC measures were significant at the $p < .001$ level).

DISCUSSION

VC tasks are multi-modal, requiring the manual manipulation and organization of spatial elements, and subsequently, interpretation of VC test results is often complicated. Additionally, a wide variety of different instruments are used to assess VC ability, and comparisons across measures can, therefore, be difficult. Although VC is incorporated into most research and clinical neuropsychological batteries, it remains poorly understood and understudied. The purpose of the present study was to improve our understanding of this important part of neuropsychological assessment by examining commonly-used VC measures for similarities and differences. To simplify comparisons and aid in interpretation of results, VC tasks were categorized into assembly versus graphomotor/drawing tasks, as well as simple versus complex tasks. Additionally, drawing tasks were also categorized into copy versus draw-to-command conditions. This study also investigated the underlying neuropsychological functions of various VC tasks to better understand *what* is being measured by each (e.g., visuospatial functioning, executive functioning, motor functioning) and whether this is similar or different across tasks (i.e., is VC a unified construct?).

Major Findings

It was hypothesized that both assembly tasks and complex drawing tasks would inherently be the most difficult given that they have the greatest likelihood for employing multiple underlying cognitive domains. Therefore, it was predicted that assembly tasks would be comparable only to complex drawing tasks, with both placing high demands on multiple cognitive domains, including perception, visuospatial skills, executive functioning, visuospatial integration/organization, and motor skills. Similarly, it was predicted that simpler copy tasks would be less demanding and mostly tap into visuospatial, perceptual, and motor skills (see Table 1). Results of multiple regression analyses supported these predictions and revealed that the block design assembly task required multiple neuropsychological domains (i.e., executive, visuospatial, visual-organization, and motor), similar to the complex ROCF copy task (i.e., visuospatial, visual-organization, perception, motor). Examination of correlations among VC tasks also revealed that the assembly task was more strongly correlated with complex drawing tasks than other simpler drawing tasks. Additionally, the intracorrelations among complex VC tasks (e.g., ROCF, Block Design) were higher than the intercorrelations of complex tasks with simpler tasks (e.g., daisy, DRS construction, pentagons).

The degree of executive functioning employed across measures was also examined to assess whether more complex tasks would require a greater degree of executive functioning. The Block design task, Clock Copy, and ROCF task were the most executively demanding VC tasks, also suggesting that these tasks may be more difficult than other simpler copy tasks. Finally, in an additional effort to examine difficulty level across tasks, impairment indices were also created. Of all the VC measures used in this study, block design, ROCF, and clock drawing test (command condition) had the highest degree of impairment (i.e., percentage of patients scoring <1.5 standard deviations below the mean), supporting the fact that these tasks may be more demanding than other simpler copy tasks. Perhaps not coincidentally, the three most executively demanding/difficult/complex tasks in the present study are also the three tasks most consistently found to be related to executive functioning in other research studies; that is, the clock drawing test (Juby et al., 2002; Libon et al., 1993; Libon et al., 1996; Royall et al., 1998; Royall et al., 1999), the ROCF (Freeman et al., 2000; Grossman et al., 1993; Odgen et al., 1990; Somerville et al., 2000), and Block Design (Bondi et al.,1993; Williams et al., 1998).

When examining simpler copy tasks, such as the MMSE pentagons, DRS construction, and daisy, it was hypothesized that these tasks would be mostly dependent upon perceptual, visuospatial, and/or motor ability, and less demanding on executive and visual-organizational skills, as suggested by some authors (Royall et al., 1998). Results of multiple regression analyses supported this prediction by revealing that higher-order executive and visual-organizational skills were not significantly predictive of performance for these simpler VC tasks. As predicted, simple VC tasks were largely impacted by visuospatial and perceptual skills, and in some cases (DRS construction figures), motor skills, as well. The exception to this was the command condition of the draw-a-daisy task which was dependant on visual-organizational skills, perhaps due to the added demands of drawing an imagined object.

Draw-to-command tasks (e.g., "draw me a clock") were hypothesized to be more difficult than equivalent copy tasks (e.g., "copy this clock"), requiring organizational abilities that copy tasks may not (Freedman et al, 1994, Royall, Cordes, & Polk, 1998). In fact, this was the case for the simple daisy task, in which the copy condition was predicted by perceptual skills, whereas the command condition was predicted by visual-organizational skills. The clock drawing test was another VC task with both copy and draw-to-command conditions; however, perhaps because of the complexity of the clock drawing test, results were contrary to expectation. For the relatively more complex clock drawing task, both conditions (copy and command) were dependent primarily upon visual-organizational skills. This was somewhat surprising given that a larger percentage of patients had difficulty performing the command condition (13.2% were impaired) than the copy condition (0% impaired), implying that the two tasks were not equivalent in difficulty level. It is also interesting to note that although other studies have found clock drawing performance to be significantly related to executive functioning (e.g., Juby, Tench, & Baker, 2002; Libon et al., 1993; Libon et al., 1996; Royall et al., 1998; Royall et al., 1999), the present study only found visual-organizational skills to be significantly predictive. Although it is possible that executive functioning does predict clock drawing performance, the present study assessed the amount of *unique* variance contributed by each executive task (e.g., TMT-B, WCST, COWA, Similarities). When examined in this manner, it appears that only the HVOT, which assesses a component of executive functioning (i.e.,"organizational" skills) specific to visuospatial information, provided the most unique variance above and beyond other executive tasks.

As predicted, more complex VC tasks (e.g., block design, ROCF) appear to be more heterogeneous in cognitive demands, whereas more simple VC tasks (e.g., pentagons, DRS construction figures) appear to be a less complicated assessment of visuospatial skills. Between simple and complex VC tasks, there also appear to be tasks of intermediate difficulty, such as the clock drawing task, which do not utilize as many underlying constructs as Block Design and ROCF, but more than simple VC tasks which mostly assess one construct, visuospatial skills. Because of added demands of setting hands and planning the spacing of numbers, the clock required both visuospatial and organizational skills (i.e., visual-organizational skills).

The WMS-III Visual Reproduction-Copy condition (VR Copy) task was assessed in this study because the complexity level of this task is unclear. This task has a set of five drawings ranging from very simple to more difficult, and it was estimated, overall, to be intermediate in complexity. Given this, performance on this task could have been primarily due to basic visuospatial skills or a more complicated combination of other neuropsychological domains (e.g., executive, visuospatial, motor). However, results of multiple regression analyses revealed that VR copy was only predicted by visuospatial/perceptual skills. Although it was predicted that this task may be more intermediate in complexity, these results suggest that it may actually be less demanding of other neuropsychological abilities, such as executive functioning and motor skills. On the other hand, inspection of impairment indices supports the prediction that VR Copy is moderate in difficulty. The more difficult tasks (e.g., ROCF, Block Design) were impaired at a higher rate (21.9%, 11.4%) than VR Copy (8.8%), whereas the simpler tasks (e.g., DRS construction figures) were impaired at a slightly lower rate (5.3%).

Comparisons across different VC measures highlight differences among tests, particularly between simple and complex tasks. In addition, small differences also appear to exist between draw-to-command and copy conditions, such that copy conditions are somewhat easier (i.e., lower impairment rates), as well as less dependant on organizational skills (particularly for the simpler tasks). However, the results of group differences analyses also reveal *similarities* among these various VC measures. It was found that for almost all the VC tests examined in this study (draw-a-daisy was the one exception), significant impairment in executive, visuospatial, or motor skills could significantly differentiate VC performance. In other words, if a patient was notably impaired in executive, visuospatial, or motor functioning, it was highly likely that the patient would have difficulty performing a variety VC tasks. It is worth noting that this finding was significant even with the effects of global cognitive impairment covaried out of the equation (i.e., MMSE score). Therefore, it is possible that actual *differences* between VC tasks may be more relevant for patients with mild cognitive impairment. For example, patients with significant executive dysfunction (greater than 1.5 S.D. below the mean) may have difficulty with even simple VC tasks, whereas patients with only mild executive impairment may only struggle with more complex VC tasks. This prediction is supported by the finding that various VC tasks varied in the degree of executive functioning required, with the more complex tasks having higher executive demands, as well as greater impairment indices.

Some authors (Lezak, 1995, Angelini et al., 1992) have argued that assembly tasks and graphomotor tasks should be evaluated separately given that these two types of tasks appear to require different cognitive demands. Contrary to expectation, these results suggest that assembly tasks and graphomotor tasks are quite similar in their cognitive demands, *but only* when matched on complexity level. Research studies which have found differences in patient performance on assembly versus graphomotor tasks (e.g., Dee, 1970; Benson & Barton, 1970, Black & Strub, 1976) appear to support differences between assembly and graphomotor copying tasks. However, these studies used graphomotor measures not assessed in this present study (e.g., Bender Gestalt Test) or measures not commercially available. It is quite possible that when differences have been found between graphomotor and assembly tasks, that the tests were not matched on complexity level.

For many years, VC tasks were assumed to be largely dependant on visuospatial functions (Goodglass & Kaplan, 1983), and not until recently, was the role of executive functioning in VC performance also questioned (e.g., Bondi et al., 1993; Freeman et al., 2000; Libon et al., 1996; Royall et al., 1999). One purpose of the present study was, therefore, to try and partial out the role to which executive dysfunction may play in VC performance. Certainly, executive functioning was related to performance, as demonstrated in the strength of correlations among executive and VC tasks. Additionally, group differences analyses (executively impaired versus not impaired groups) revealed that executive dysfunction greatly impacts VC performance. However, results of multiple regression analyses revealed that executive dysfunction only contributed unique variance to VC performance in the more complex VC tasks. Together, these findings suggests that there are two conditions in which executive dysfunction appears to impact VC performance; (1) when the task is very complex, and (2) when executive dysfunction is notably impaired, regardless of task difficulty level.

It was predicted that executive dysfunction would impact complex tasks greater than simple tasks. However, to date, it had not yet been determined which VC tasks were truly "complex" and which were more "simple." Based on the present study findings, complex tasks can be seen as those that are more heterogeneous (i.e., dependant on multiple neuropsycholgical functions), specifically more dependant on executive functioning, and more “difficult” (greater rates of impairment compared to other VC tasks). Simple VC tasks appear to be more homogeneous (i.e., largely predicted by one neuropsychological domain, visuospatial skills) and “easier” (lower impairment rates). However, it should be emphasized that even simple VC tasks were impacted by severe executive or motor impairment. In general, however, interpretation of VC impairment appears to be more complicated for complex VC tasks, given their heterogeneity of cognitive function.

Implications for VC Assessment

Assessment of VC with simple tasks is preferable to some authors, given that it may increase specificity (Arena & Gainotti, 1978; Kim et al., 1984; Mack & Levine, 1981). That is, it is safer to assume that VC impairment is actually due to difficulties with visuospatial skills, and less due to dysfunction in other cognitive domains. Other authors have argued that using more complex VC tasks is preferable because these tasks are more sensitive to neuropsychological impairment, thereby making them more ecologically useful or better for screening purposes (Freedman et Al., 1994; Shulman, 2000; Warrington et al., 1966). Results of the present study confirm that depending on the purpose of the evaluation, VC tasks should be chosen based on complexity level. Simple VC tasks should be used when the goal is primarily to assess a patient’s visuospatial skills. Given the multiple cognitive domains assessed with more complex VC tasks, these measures should be used when the goal is to detect impairment, particularly in patients with more mild cognitive impairment (i.e., sensitivity is increased). One could argue that the best strategy would be to incorporate *both* simple and complex VC tasks into neuropsychological assessment in order to accomplish both goals (i.e., good sensitivity and specificity). Given that interpretation of impairment for complex VC tasks can be difficult, it is likely best understood in relation to patterns of performance in other domains of functioning (e.g., executive, motor, visuospatial).

When administering draw-to-command graphomotor tasks (e.g., clock, daisy), results would appear to suggest that it may not *always* be necessary to also give the copy condition of the task. Given that the command condition is more difficult (greater impairment rate), it is highly likely that if a patient can adequately perform the command condition, that the copy condition would also be adequate. This is consistent with the finding that some patient populations, such as those with Alzheimer's disease, have greater difficulty with the command than the copy condition of the clock drawing test (Ober et al., 1991). In the present study, results of multiple regression analyses revealed little differences between command and copy conditions, except that for simple tasks (e.g., draw-a-daisy) where less organizational skills are required. Based on the literature, patients with hemispatial neglect would be the most likely have difficulty with the copy condition of a graphomotor task (Freedman et al., 1994). None of the patients in this study had this type of spatial/attentional deficit, and so it could not be assessed whether, in this instance, the copy condition would be more impaired than the command condition. Regardless, based on the current patient sample, it appears that *in general*, administering a draw-to-command task is preferable in instances when both conditions exist (i.e., command and copy), though it would be useful to also administer the copy condition whenever a patient either: (1) was impaired on the command condition (whether or not the patient can perform a similar copy task can provide useful information); (2) was at risk for demonstrating hemi-spatial neglect (e.g., stroke patient); (3) had demonstrated unilateral spatial neglect on other VC or visuospatial tasks; (4) has demonstrated neglect on neurologic examination or in other aspects of functioning (e.g., dressing); or (5) has been shown to have specific visuoperceptual/discrimination deficits.

Table 7. *Study Results: Impact of Neuropsychological Function on Type of VC Task.*

VC TASK

NPSYCH FUNCTION	Assembly[1]	Draw-Copy-Complex[2]	Draw-Copy-Simple[3]	Draw-Command-Complex[4]	Draw-Command-Simple[5]
Visuospatial/ Perceptual	++	++	++	–	–
Visual-Organizational	+	+	–	++	++
Executive	+	–	–	–	–
Apraxia/ Motor	+	++	+	–	–

Note: *VC = Visuoconstruction; Npsych = Neuropsychological*

++ = *Strong effect/relationship*
+ = *Some effect/relationship*
– = *Little/no effect/relationship*

1 = e.g., Block Design; 2 = e.g., ROCF, VR Copy, copy clock; 3 = e.g., DRS Constructional Figures, MMSE pentagons, copy daisy; 4 = e.g., Draw-to-command clock; 5 = e.g., Draw-to-command daisy

The different types of VC tests and their most predictive underlying neurocognitive domains are depicted in a Table 7 above. This table can be directly compared to Table 1 which summarized the apriori predictions of the current study. It is interesting to note that visuospatial skills are an important factor in most VC tasks, even complex tasks. Therefore, even though complex tasks may be heterogeneous in their cognitive demands, performance appears to be *predominantly* impacted by visuospatial skills. In the case of draw-to-command tasks, visuospatial skills also play a significant role; however, organizational skills appear to be equally important. Surprisingly, this was the case for both complex and simple draw-to-command tasks. It was also interesting to note that motor functioning played a somewhat larger role in copying tasks than was predicted, particularly for complex tasks (i.e., motor coordination for Block Design, apraxia for ROCF). This implies that when interpreting impaired performance on a complex task, the impact of purposeful, coordinated motor movements should not be overlooked.

Improving Conceptualization of VC with Subcategories:

Simple vs. Complex Tasks

The results of this study lend insight about different VC tasks and how to aid in interpretation of task-specific results. However, it is more commonly the case in clinical practice that "VC ability" is interpreted as the *overall* performance of multiple VC tasks taken together as a whole. Multiple different VC tasks are also used in research studies (e.g., Huff et al., 1997; Libon et al., 1993) to measure "constructional ability." Given suspected differences among VC measures, the question has been raised as to whether it is useful to lump all VC tasks together to assess VC as a solitary construct (Benton & Trandel, 1993; Walsh, 1987). Results from this study suggest that VC tasks are perhaps more alike than different, and that when differences exist, it is primarily due to complexity level. VC tasks can all be seen as similar in that they primarily assess visuospatial skills and are all equally impacted by severe executive, visuospatial, or motor impairment. However, they are different in that only the complex VC tasks appear to also assess organizational abilities and are impacted by mild-to-moderate neuropsychological dysfunction. Therefore, although the present results lend support to maintaining the general construct of "VC," they also suggest that differentiating between two subcategories of VC tasks (i.e., simple versus complex) may improve interpretation of test results and clarify important distinctions.

Utilizing the subcategories of "simple" and "complex" appears more useful than discriminating VC tasks according to whether they are assembly or graphomotor tasks, as was suggested by Benton (1967, 1985, 1993). Some authors (e.g., Angelini and colleagues, 1992) have suggested that the construct of VC would be better understood if the complexity of VC tasks was clarified, and certainly, based on the current results, the most useful distinction between tasks does appear to be based on complexity level. Given that valuable information can be gained from *both* simple *and* complex VC tasks, neuropsychological test batteries should probably include both types of tests. Using more than one type of VC task has been advocated by some authors as preferable to only using one test (Benson & Barton, 1970; Lezak, 1995; Walsh, 1987). However, it had not been specified as to what types of tests would provide the best balance between sensitivity and specificity. To provide this balance, including both simple and complex tasks is likely the best method to assess a patient's overall "VC abilities."

VC tasks of moderate to complex difficulty (e.g., ROCF, block design, VR Copy, clock command, clock copy) are fairly similar in their neuropsychological demands, and together, they generate a construct that can be explained by a large amount of explainable variance. In a multiple regression of overall VC performance, 62% of the variance was explained by visuospatial, organizational, and executive skills. Unfortunately, very simple VC tasks were not considered in this overall VC score given limitations in their scoring systems and/or lack of normative data. It is possible that if more simple measures were also included in the overall VC performance score, that the regression equation may have been altered. However, at the very least, it appears that for VC tasks of moderate to complex difficulty level (regardless of type of task, i.e., assembly, copy, command), performance can be explained with good certainty. That is, overall VC performance appears to be largely a product of visuospatial ability, and for VC tests of at least moderate complexity, organizational/executive skills are also utilized.

Limitations and Future Directions

It is important to consider limitations to this study, as well as directions for future research to expand upon the current findings. One potential limitation involves the number of underlying constructs that were assessed. Based on literature review, the constructs of visuospatial/perceptual skills, visuo-organizational skills, motor skills, and executive functioning were explored, and only a select number of tests were used to represent each of these constructs. Ideally, it would have been interesting to explore the role of other constructs, as well, such as language (e.g., semantic memory, auditory comprehension) and attention, to examine their role in VC performance. Additionally, each construct could have been explored in more detail (e.g., examining working memory as a part of attention/executive functioning, examining visual exploration as a part of visuospatial skills). However, when designing this study, the number of variables used was purposefully restricted for two major reasons. First, the number of tests examined was kept to a minimum to reduce type one error and also maintain power in the regression analyses. Secondly, data for this study was collected from a wide variety of patients as part of their standard neuropsychological examination, and it would have been burdensome to the patients if the examination was not kept to a reasonable length (i.e., limiting the number of tests administered). To overcome this, future studies could possibly include multiple examinations (i.e., testing over two days) to answer these questions; however, steps would still have to be taken to reduce type one error. Similarly, future studies could also investigate other VC measures not used in this study, such as the Bender-Gestalt Test, WAIS-III Object Assembly, Visual Motor Integration test, and Neuropsychological Assessment Battery (NAB) construction subtest. Specifically, the complexity level of each commonly-used VC test should be understood given that this appears to greatly impact interpretation of results. Without formal investigation, tests can be wrongly categorized into "simple" versus "complex" based on assumptions, as has been done in the past. For example, the MMSE pentagons were referred by Lezak (1995) as a "difficult" copy task, similar to the ROCF, when to the contrary, the present study found the MMSE pentagons to be less difficult/heterogeneous compared to the ROCF.

Another potential limitation to this study could include the multiple examiners used to collect the data. It could be argued that this may have threatened the internal validity of the findings. However, this is unlikely given that results were adequately powered and highly significant. Furthermore, multiple examiners likely increased the external validity, or generalizability, of the findings. Finally, the limited range of impairment within the patient sample could also be seen as a potential limitation. The overall sample used in this study was only mildly impaired overall (average MMSE=28, S.D.=2.5), possibly reducing the variability of the test results and limiting the findings. The range of impairment may have been limited because patients with incomplete data were excluded from analyses, and these patients, in particular, were the most likely to be moderately to severely impaired patients (e.g., poorer perseverance with testing, poor comprehension of test directions). Although future studies should include a wider range of impairment across subjects, the statistical validity of the present study was still sufficient enough to produce highly significant results. The only regression equations that were not highly significant were those for the draw-a-daisy test, which leads to another potential limitation: the poor scoring system for the draw-a-daisy test. Given that the range for the daisy test scoring system is only 0-2, and that this system has never been normed or validated, results for this measure are questionable. Unfortunately, there is not another simple, draw-to-command test with a better scoring system that could have been used in its place. In the future, a new scoring system for the daisy could be created and validated for use in a replication study.

To better understand the underlying mechanisms of VC, future research could also use factor analysis, including confirmatory factor analysis. Although this could not be performed on the current sample given its sample size, a replication study with a larger sample could use factor analysis to elucidate the underlying factors of different VC measures. Finally, it may be interesting to investigate differences between VC measures with the use of different patient populations. Based on research suggesting that VC test performance may vary based on diagnosis (Ala, Hughes, Kyrouac, Ghobrial, & Elble, 2001; Cherrier, Mendez, Dave, & Perryman, 1999; Diehl & Kurz, 2002; Freeman et al., 2000; Libon et al., 1996; Heinik, Solomexh, Raikher, & Lin, 2002), a comprehensive study of multiple VC measures could shed light as to whether certain patient populations (e.g., Alzheimer's disease, Parkinson's disease) may produce different patterns of performance across various VC tests. As suggested by Guerin and colleagues (2002), longitudinal case studies could also be used to study the development of VC impairment in various disorders.

Summary and Conclusions

In summary, how should we answer the ultimate question of: "what is VC and how are we measuring it?" First, when considering "what" it is, VC is simply a construct to help explain and interpret performance on spatial manipulation tasks. There are a variety of very different measures used for this purpose, and therefore, this construct has been vague and misunderstood. Therefore, to truly answer "what" is VC, we must turn directly to the tasks being used. Secondly, when answering "how" we are measuring VC, many assessment methods exist to examine it, including assembly tasks, copy tasks, and draw-to-command tasks. The differences between these tasks are reduced when they are matched on complexity level. Given this, the "what" and the "how" of assessing VC are inseparable. Ultimately, the "what" we are measuring *depends* on "how" we are measuring it. For tasks of at least moderate complexity, the construct is more multifactorial, and in this case, what we are measuring appears to be visuospatial skills, organizational/executive skills, and motor skills. For simpler tasks, however, what we are generally measuring appears to be visuospatial and perceptual skills, and to some degree, motor skills, as well. In conclusion, an examiner should consider the goal of the assessment when choosing VC measures to use. For greater sensitivity, one should consider using complex VC tasks, and interpret performance on these tasks within the context of performance in other cognitive domains (i.e., executive, visuospatial, motor). However, if one's ultimate goal is to assess visuospatial skills, simpler VC tasks can be more easily interpreted for this purpose, or rather, non-motor visuospatial tasks (e.g., JLO) should be used. Although it has been common until now to interchange "VC" for "visuospatial skills," it is not always appropriate to do so. Understanding this should lead to improved interpretation of test results and communication among clinicians and researchers.

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