



PII S0887-6177(99)00005-0

# Biological Versus Psychometric Intelligence: Halstead's (1947) Distinction Revisited

Gerry Pallier, Richard D. Roberts, and Lazar Stankov

University of Sydney

*This article reports an investigation into the empirical status of a little understood cognitive factor—tactile-kinesthetic ability. To this end, a variety of haptic tasks, including three subtests of the Halstead-Reitan Neuropsychological Test Battery (HRB), were administered to 108 participants, along with established markers commonly employed in contemporary psychometric investigations. The results suggest that these subtests of the HRB measure cognitive abilities conceptually equivalent to fluid intelligence. Since these tests reflect efforts to operationalize Halstead's (1947) concept of "biological intelligence," the results reported herein allow evaluation of this concept in relation to current models of human intelligence. Previous studies investigating the nature of abilities assessed by the HRB have reached contradictory conclusions. Present findings clarify the source of these anomalies. © 2000 National Academy of Neuropsychology. Published by Elsevier Science Ltd*

*Keywords: theory of fluid and crystallized intelligence (Gf/Gc), Wechsler Adult Intelligence Scales (WAIS), Halstead-Reitan Neuropsychological Test Battery (HRB)*

## THEORETICAL BACKGROUND

It is now over 50 years since the publication of Ward Halstead's (1947) landmark monograph *Brain and Intelligence*, a work having significant influence on both theoretical and practical considerations of clinical and neuropsychologists. This dissertation is, after all, the primary source of a prominent test instrument employed in assessment of impairment in brain function—the Halstead-Reitan Neuropsychological Test Battery (HRB;

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This article was supported (in part) by a University of Sydney Research Grant to the second author, and a large ARC grant to the third author.

We would like to thank the following people for their efforts in test construction, data collection, and/or scoring of protocols: Anne Antonios, Robyn Bartlett, Elle Bednall, Evelyn Kim Boon, Fleur Buffier, Michaela Davies, Bradley Dolph, Emad Hanna, Charissa Mak, Greg Petterson, Eugene Phang, Isa Stankov, and Rhonda Ting. In addition, we would like to thank Vanessa Danthiir for her help in editing. Finally, we are particularly grateful to Associate Professor Robyn Tate, Professor Cecil Reynolds, and two anonymous reviewers for their insightful comments on earlier versions of this manuscript.

Address correspondence to: Gerry Pallier, Department of Psychology, The University of Sydney, Sydney, NSW, Australia; E-mail: gerrypp@psych.usyd.edu.au

Halstead, 1947; Reitan & Wolfson, 1985). Halstead (1947) chose the term *biological intelligence* to differentiate his concept of human cognitive functioning from that assessed by the dominant psychometric paradigm at the middle of this century, which he referred to as “psychometric intelligence.”<sup>1</sup> Halstead (1947) makes clear, however, that “this distinction is a methodological one . . . (that) need not commit the reader to any such dichotomy” (p. 5).

Within the neuropsychological literature, this distinction has remained intact in studies examining the validity of the HRB (e.g., Goldstein & Shelly, 1984; Moehle, Rasmussen, & Fitzhugh-Bell, 1990). The situation appears to have been maintained by the consistent use of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981) as an adjunct to the HRB (e.g., Yeudall, Reddon, Gill, & Stefanyk, 1987). The need to use the WAIS-R as a supplementary measure of cognitive functioning is, apparently, considered a necessity if a comprehensive neuropsychological profile is to be derived from the HRB (Hallett, 1994)<sup>2</sup>. In fact, Raven’s Progressive Matrices (RPM; Raven, 1938) aside (e.g., Yeudall, Fromm, Reddon, & Stefanyk, 1986), Wechsler’s scales appear uniquely in the literature as *the* measure of “psychometric intelligence,” supplementing information on various neuropsychological functions assessed by the HRB.

Among psychologists currently using psychometric approaches to study individual differences, however, diverse measures of multiple cognitive abilities are commonly employed (Horn & Noll, 1994). The diversity of test instruments reflects the necessity of using varied and distinctive elementary cognitive tasks to capture the range of relatively independent primary (and second-order) mental abilities identified by nearly a century of psychometric research. Prominent among attempts to provide a conceptual framework for understanding and classifying these abilities is the theory of fluid (Gf) and crystallized intelligence (Gc) (Carroll, 1993, 1995; Cattell & Horn, 1978; Horn, 1988, 1998; Horn & Cattell, 1966; Stankov & Horn, 1980).

### *Gf/Gc Theory*

The theory of fluid and crystallized intelligence derives its name from the two broad intellectual functions most extensively studied. The main distinguishing feature between fluid and crystallized intelligence is the amount of formal education and acculturation present in the content of, or operations required during, tests measuring these abilities. It is well-established that Gf depends to a much smaller extent on formal education experiences than does Gc (see e.g., Horn & Hofer, 1992; Stankov, Boyle, & Cattell, 1995). Gf/Gc theory incorporates a number of factors in addition to the ones from that it derives its name. Some constructs, such as broad auditory function (Ga) and broad visualization (Gv), are related to perceptual processes. Further factors, including short-term acquisition and retrieval (SAR) and tertiary storage and retrieval (TSR), are related

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<sup>1</sup>The nature of the prevailing psychometric paradigm is discussed more fully later. Nevertheless, for the present, accept that during Halstead’s time there existed a preference for a single entity (psychometric *g*). Clearly, this concept does not encompass what is now envisaged as the full range of human cognitive capabilities (see e.g., Stankov, Boyle, & Cattell, 1995).

<sup>2</sup>Interestingly, the conjuncture of the Wechsler Scales and the HRB was initiated by Reitan (rather than by Halstead). Nevertheless, it appears an association maintained by the majority of subsequent users of the test battery.

to memory processes, while others, such as clerical-perceptual speed (Gs), reflect speed in performing tasks of relatively trivial difficulty. Each of these factors is conjectured to share differential relations with external measures (such as age or education) and each is postulated to arise from the workings of different cognitive and neurophysiological functions.

Indeed, Gf/Gc theory has emerged as the dominant paradigm of the individual differences subdiscipline of psychology (Horn, 1998; Roberts, Pallier, & Goff, 1999; Stankov et al., 1995). As such, it encapsulates a convention that appears to represent the most promising approach to the assessment and conceptualization of human cognitive abilities (see e.g., Carroll, 1995; Messick, 1992; Roberts & Goff, 1998; Sternberg, 1985). Implicit within Gf/Gc theory is the possibility of isolating distinct cognitive abilities currently unidentified by empirical findings (Carroll, 1993; Roberts, Stankov, Pallier, & Dolph, 1997; Stankov et al., 1995).

Consistent with the forgoing propositions, Sternberg (1996) and his associates (e.g., Sternberg & J. Kaufman, 1998) have recently argued that many psychometric concepts of intelligence are too narrow to encompass the diverse range of intellectual abilities expressed by humankind. Similarly, Reitan and Wolfson (1996) have presented a detailed and expanded evaluation of the HRB, which emphasizes the “efficacy of (intellective) functioning in a practical everyday sense” (p. 12). These convergent lines of reasoning are suggestive of a need to integrate theories of intelligence from disparate origins, in order to expand the concepts upon which neuropsychological theory might be grounded. The current study represents a movement toward such broader interpretations of human cognitive abilities, which are necessary to accommodate notions such as Sternberg’s (1996) “successful intelligence.”

### *Neuropsychology and Gf/Gc Theory: Toward a Rapprochement*

On a conceptual level, many similarities exist between Halstead’s biological intelligence and constructs composing the structural model generated by Gf/Gc theory. For example, both can be expressed as viewing intelligent behavior along a continuum of abilities. Inclusion of a subset of tests used by Halstead (and others) to operationalize biological intelligence, along with established markers of factors underlying Gf/Gc theory, may shed light on the contemporary relevance of Halstead’s (1947) dichotomy. Using evidence outlined below, we hypothesized that part of HRB (in particular, Tactual Performance [Recall, Localization, and Time] and Fingertip Writing) may be tapping cognitive factors currently identified within Gf/Gc theory, rather than a unique construct (i.e., biological intelligence).

Because of its seemingly noncognitive nature, the Fingertip Writing Perception Test, which derives from the Reitan-Kløve Sensory Perceptual Examination (rather than Halstead’s [1947] original battery) is of particular interest in the current research. Mistakes on this test may indicate possible “contra-lateral parietal lobe damage or dysfunction” (Reitan & Wolfson, 1985, p. 35). Although Reitan & Wolfson (1985) propose that this task is largely perceptual in nature, they also point out that it “requires more concentrated attention (than the Tactile Finger Recognition Test)” (p. 35). Indeed, L. Fitzhugh, K. Fitzhugh, and Reitan (1962) note that the Fingertip Writing Test has some correlation with measured intelligence. This line of neuropsychological research resonates with recent proposals among differential psychologists concerning the status of relatively complex perceptual tasks (see e.g., Deary, 1994; Li, Jordanova, & Lindenberger, 1998; Roberts et al., 1999).

## THE AIMS OF THE STUDY

The study employed a multivariate design in order to ensure the integration of both psychometric and neuropsychological approaches. In the passages that follow, we outline its two main aims.

### *Clarifying Constructs Measured by Tests of the HRB*

A major issue that may be clarified by the current study concerns anomalies in the conclusions of several research reports on the nature of abilities captured by the HRB and their relationship to the WAIS-R.<sup>3</sup> Factor analytic investigations of the HRB, in conjunction with the WAIS-R, suggest that the Performance Scale, tactile performance, and the perceptual processes underlying vision are difficult to disentangle. Fowler, Zillmer, and Newman (1988), for example, identify a “*Perceptual Organization* (factor), principally defined by loadings for the Tactual Performance Test (of the HRB and) the WAIS’s Performance Scale” (p. 901). Similarly, Leonberger, Nicks, Goldfader, and Munz (1991) report that “loadings on (their) Factor 1 occurred from Visual Reproduction-immediate and delayed, TPT (i.e., Tactual Performance) total time, TPT memory, TPT location, and PIQ (i.e., Performance IQ)” (p. 84). Further, they argue that this “could be described as tapping a spatial reasoning factor” (p. 84). These findings suggest that there is a relation between parts of the HRB and “psychometric intelligence,” as measured by the WAIS-R. Importantly, the WAIS-R Performance Scale has previously been interpreted in factor analytic studies as capturing abilities related to fluid intelligence (see McArdle & Horn, 1983).

Other investigators, however, present conflicting evidence. Yeudall et al. (1987), for example, claim that “the HRB (with certain exceptions) is comprised of motor and tactual tests” and that “in order to assess cognitive functions, the WAIS-R . . . often is used to augment this battery” (p. 366). Furthermore, Yeudall et al.’s (1987) investigation of the HRB reported that “few substantial correlations were found . . . with the WAIS-R Verbal or Performance IQ scores” (p. 366) (for a different perspective see in particular, Reitan [1956a, 1956b]).<sup>4</sup>

This apparent contradiction may stem from overreliance on a measure of psychometric intelligence (i.e., WAIS-R) that does not comprehensively evaluate the broad spectrum of cognitive abilities (cf. Yeudall, Fromm, et al., 1986; Yeudall et al., 1987). In fact, such an outcome is predicted by the results of Yeudall, Fedora, and Fromm’s (1986) study of the WAIS-R. These findings led Yeudall et al. (1987) to recommend that the WAIS-R be supplemented by other cognitive measures to avoid deficiencies in “neuropsychological information about cognitive functioning” (p. 366). Factor analysis of the Wechsler scales suggests a four-factor model that excludes measurement of several abilities recognized within Gf/Gc theory (McArdle & Horn, 1983; see also Horn, 1968; Mat-

<sup>3</sup>The WAIS-R has recently been superseded by the WAIS-III. However, there has yet to appear a substantive body of literature assessing the relationship between the new test and the HRB. Therefore, the current study restricts itself to commenting only on the WAIS-R. Implications concerning the revised WAIS-III are discussed later in this article.

<sup>4</sup>It is important to note that Yeudall et al. (1987) appear to have set a definition of “substantial” as capturing 10% of the variance (i.e.,  $r = .32$ ). Using the .05 level, a number of correlations in their study reached statistical significance.

arazzo, 1972).<sup>5</sup> One ability underrepresented by the WAIS is the general visualization factor (Gv), which is indicated by some research findings to contain an important component captured by tactile measures (e.g., Duncan, Weidl, Prichett, Vernon, & Hollingsworth-Hodges, 1989; Ungar, Blades, Spencer, & Morsley, 1994). Obviously, it is not possible to find correlations between measures that are not sufficiently represented in the same test battery. Clearly, if an empirical relationship between tactile and visual abilities exists, this would account for the anomalous empirical findings of Yeudall and his associates.

### *Examining Tactile-Kinesthetic Performance in Relation to Other Cognitive Abilities*

The empirical investigation reported in this article, examines a hitherto poorly understood individual difference factor—tactile-kinesthetic ability. Research evaluating neuropsychological assessment, and especially the HRB (e.g., Fowler et al., 1988; Leonberger et al., 1991; Moehle et al., 1990; Thompson & Heaton, 1991; Yeudall et al., 1987; Zarantonello, Munley, & Milanovich, 1993), provided a major impetus for the present study. The investigation also prompted reconsideration of Halstead's (1947) concept of biological intelligence. Notwithstanding, tacit support for tactile-kinesthetic ability also comes from other areas of the psychological discipline. For example, cognitive studies involving tactile processes (Broscole & Mollozzi, 1993; Gibson, 1962; Heller, 1989) and work among the visually impaired (Duncan et al., 1989; Ungar et al., 1994) have highlighted the independence (and relative importance) of this domain. Furthermore, within differential psychology, Gardner (1993) has proposed the existence of "bodily-kinesthetic" intelligence, although there is no direct empirical evidence for this construct. The current research was aided by adopting methods employed by many of the aforementioned investigators, in an attempt to simulate (in tactile form) tests that have become recognized markers of abilities circumscribed by Gf/Gc theory.

The present investigation included a broad assessment of abilities defined within the framework provided by Gf/Gc theory, alongside three subtests of the HRB. In so doing, the present study may provide evidence that more perceptual parts of the HRB are mobilizing cognitive abilities and thus parallel tasks such as the Category Test, which appears to measure an ability analogous to fluid intelligence. It is also intended that this design "extend(s) the tradition of research on the Halstead-Reitan procedures" (Fowler et al., 1988, p. 899), by providing correlational data between parts of the HRB and psychometric tests from within Gf/Gc theory.

## METHOD

### *Participants*

In total, 108 participants (52 females) were recruited by advertisement and paid \$30 for their participation in the experiment. The mean age of the sample was 26.04 years ( $SD = 7.39$ ) with an average of 14.81 years of education ( $SD = 2.42$ ) from which data the reader may correctly deduce that most had obtained undergraduate degrees. The

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<sup>5</sup>According to McArdle and Horn (1983), a single-factor solution, (i.e., "g") as equated to the WAIS Full Scale IQ, produced a chi-square of 2982—nearly 20 times as great as the 153 degrees of freedom generated by the model. This result is clearly unacceptable.

majority of participants (i.e., 100) had English as their first language and 101 reported being right-handed.

From a clinical viewpoint, the current study might be criticized for examining a highly educated group of (presumably) neurologically intact people, and for employing a range of tests that are not usually included in neuropsychological assessment. However, the choice of both participants and instruments in this instance follows “traditional” multivariate designs examining hypothesized correspondence between a broad array of cognitive abilities (see Carroll, 1993).

### *Psychometric, Mental Speed, and Tactile Tasks*

*Measures of level.* The tests measuring these constructs are used routinely in studies of intelligence undertaken within the Gf/Gc framework (see Anstey, Stankov, & Lord, 1993; Horn, 1988; Roberts, Pallier, & Stankov, 1996). These cited studies have demonstrated that each test brings added clarity to the underlying structural modeling generated by psychometric concepts. These tasks are outlined briefly in the passages that follow. (Note also that Table 1 provides a reference summary of the tests and their numbers). For the frequently used tests, the standard procedures were implemented and the original sources can be consulted for fuller descriptions.

#### Fluid Intelligence (Gf):

1. Raven’s (Standard) Progressive Matrices Test (Raven, 1938; Raven, Court, & Raven, 1979)
2. Letter Series Test (after Thurstone, 1938)
3. Letter Counting Test (Stankov, 1983)

#### Crystallized Intelligence (Gc):

4. Synonyms Vocabulary Test (French, Ekstrom, & Price, 1963)
5. General Knowledge Test (Stankov, 1997). This test is similar in design to Wechsler’s (1981) General Information Test, but more appropriate for use within “elite” Australian populations.
6. Esoteric Analogies Test (Stankov, 1997)

#### Short-Term Acquisition and Retrieval Function (SAR):

7. Digit Span Forward (Wechsler, 1981)
8. Digit Span Backward (Wechsler, 1981)
9. Visual Bead Memory (from the Stanford-Binet IV Scale; Thorndike, Hagen, & Sattler, 1985)

#### Broad Visualization (Gv):

10. Card Rotations Test (Ekstrom, French, & Harman, 1976)
11. Hidden Figures Test (Ekstrom et al., 1976)
12. Hidden Words Test (Stankov, 1997)

*Mental speed measures.* The majority of these tasks are commonly employed in studies that examine individual differences in speed of mental processing. Throughout these tasks (except Test 13, which measured response time), the dependent variable was output per unit time (usually 60 seconds). Output measures avoid problems of interpretation (particularly of correlational and factor pattern matrices) encountered when com-

paring “pure” speed and level indices. In order to allow ready comparisons across these data, correlations for Test 13, reported later in this article, have been reflected.

#### Clerical Perceptual Speed (Gs):

To demarcate this factor, two tests that have been used extensively in studies of mental speed were employed:

13. Number Comparison Time (Ekstrom et al., 1976)
14. Digit Symbol (Wechsler, 1981)

#### Choice Reaction Time (CRT):

To demarcate a CRT (or Broad Processing Speed) factor, three tests were employed:

15. Math Classification Test. Participants were required to give the arithmetic operator that would solve a simple numeric problem (e.g.,  $2 ? 4 = 6$  [Answer: +]) (Roberts, 1997a).
16. Stimulus-Response Compatibility (SRC) Test. This test actually involved a series of three conditions in which participants were required to match letters or numbers to the direction of arrows. Compatibility was manipulated in the following manner. (a) High SRC—participants responded to obvious directions (e.g., “U” for the upward arrow). (b) Mid-level SRC—participants responded to numeric indicators in clockwise fashion representing direction (e.g., 1, 2, 3, 4). (c) Low SRC—participants responded to meaningless letters representing the alignment of the arrows (e.g., “Z” for up, “T” for down) (Roberts, 1997a).
17. Card Sorting Test. This task, derived from Crossman’s (1953) procedures, utilized the informational properties of a deck of playing cards, which may be conceptualized according to the principles of information theory. Participants were required to sort the cards into piles of varying complexity (e.g., by color, by suit, and so forth), which allowed manipulation of task difficulty.

#### Movement Time (MT):

To have some indication of the possible intrusion of psychomotor movement (i.e., MT) into both processing speed and tactile measures (see Shaffer, 1991), a psychomotor paradigm was also included in the multivariate design:

18. Fitts’ Movement Task. Participants tapped a small stylus between two targets as quickly and accurately as possible. Difficulty was increased across five trials by reducing the target area with each presentation (Fitts, 1954).

*Tactile tasks.* In each of these tests, the dependent variable was number correct score, except for Test 23, where solution times were obtained. Participants used their preferred hand where appropriate. When performing the tests participants were either blindfolded or had their hands inside a box that obscured objects from direct visual inspection. These tests were:

19. Finger Counting Test. This task was designed to be the tactile equivalent of Test 3 (i.e., Letter Counting) (after Kainthola & Singh, 1992).
20. Tactile Bead Memory Test. This task was a tactile version of Test 9 (i.e., the Visual Bead Memory Test from the Stanford-Binet Scale).
21. Halstead-Reitan Tactual Performance (Level) Test. This measure was a composite of the score obtained from both the Recall and Localization Tests described by Halstead (1947).
22. Halstead-Reitan Tactual Performance (Time) Test. The scoring protocol for this task was the total time (in seconds) to complete the three subtrials of Tactual Per-

formance (Time). In terms of the overall objectives of the study, it is important to point out that Tasks 21 and 22 come directly from the HRB and were administered according to the instruction manual (Reitan & Wolfson, 1985). A composite was formed from these two measures in order to avoid the critical issue of experimental dependency (which might otherwise have “contaminated” subsequent analyses).

23. Tactile Shapes Test. Participants were allowed to inspect twice, by touch, an incised design, after which they were asked to choose visually which of five alternatives matched the inspected pattern (Kazen-Saad, 1986).
24. Fingertip Writing Test. Reitan and Wolfson (1985; see also L. Fitzhugh et al., 1962) claim that this test, which is part of the HRB, shares a relationship with intelligence, especially if participants have a low IQ score. We found that in the prescribed form a notable ceiling effect resulted from administration to an undergraduate sample. However, by using letters instead of numbers, the stimulus uncertainty could be raised, according to the principles of information theory, from 2 bits in the normal presentation to 5 bits for Test 25.<sup>6</sup> Unbeknownst to the participants, only capital letters that could be written in a continuous stroke (e.g., “Z”) were employed. Apart from this necessary modification, which allows meaningful variance, Test 25 was administered in a manner similar to the conventional HRB task. Note that the score adopted for this test was number-correct, rather than the prescribed HRB score (i.e., number of errors).
25. Gibson’s Active/Passive Touch Test. Participants were required to identify the shape of a cookie cutter that was pressed into the palm of their preferred hand. In the passive condition, the cutter was static, while in the active state it was gently rotated once contact had been made with the hand (see Gibson, 1962). The score we report represents a composite of these two conditions.

### *Procedure*

Total testing time for the whole study was about 4 hours, although, since some tests were self-paced and others continued until participants failed, the time taken varied between individuals. Testing was generally broken up into two, 2-hour sessions with a rest period of 10 minutes after each hour’s work. In one session, each participant was allocated to a trained researcher for the “face-to-face” tests (e.g., the tactile and card sorting tasks). The second session was conducted in small groups that contained the paper and pencil, and computerized tests, again administered by an experienced researcher.

## **RESULTS**

### *Descriptive Statistics*

The mean and standard deviation for each test is presented in Table 1. These results indicate that the “novel” experimental tasks were neither too difficult nor too easy. Comparison of performance on the Tactile Performance Test of the present study with that provided by Fromm-Auch and Yeudall (1983) on their standardization sample ( $N = 193$ ) exhibit close correspondence (Mean [Localization + Recall] = 14.0; Mean [Total

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<sup>6</sup>Lehrl and Fischer (1990) offer an underlying rationale for this procedure within a similar context of letter series tests. See, however, Roberts et al. (1996) for a critique of these testing methods.



Time] = 630 seconds). Note also that means of the marker tests of psychometric abilities were also close to those reported in the literature for comparable samples (see e.g., Davies, Stankov, & Roberts, 1998; Horn, 1988; Roberts, 1997b). Therefore, the current sample of participants may be regarded as representative of a normal university population.

### Correlations Between Variables

Pearson product-moment correlations between each of the variables given in Table 1 are presented in Table 2. Inspection of Table 2 indicates substantial correlation amongst the tactile measures. Furthermore, an appreciable relationship between the widely accepted marker of Gf—Raven's Progressive Matrices (Test 1)—and the tactile measures appears in the matrix, the averaged correlation being  $r = 0.42$ . This outcome suggests that tactile abilities are not only related across the experimental tasks, but also exhibit shared variance with established cognitive measures (see Roberts et al., 1997). Fore-shadowing the exploratory factor analysis reported later, it is worth noting that the HRB tests show moderate to high correlation with Gf, Gv, and other tactile-kinesthetic measures, but near zero correlation with Gc, mental speed, and SAR marker tests.

### Exploratory Factor Analysis

The result of an exploratory factor analysis employing an oblimin rotated principal component solution is presented in Table 3. Note that the first latent root accounted for

**TABLE 1**  
Means and Standard Deviations of the Cognitive Ability, Mental Speed, and Tactual Performance Variables with the Test Number Allocated to Each Measure

Measure	<i>M</i>	<i>SD</i>	Number of Items
Cognitive ability: Level			
1. Raven's Progressive Matrices (RM)	50.57	5.32	60
2. Letter Series (LS)	11.13	2.22	15
3. Letter Counting (LC)	5.46	3.48	12
4. Synonyms Vocabulary (SV)	11.28	3.29	18
5. General Knowledge (GK)	12.98	3.01	20
6. Esoteric Analogies (EA)	17.43	3.47	24
7. Digit Span Forward (DF)	6.71	1.38	
8. Digit Span Backward (DB)	6.36	1.46	
9. Visual Bead Memory (VB)	12.67	4.91	
10. Card Rotations (CR)	51.97	13.20	80
11. Hidden Figures (HF)	7.78	4.25	16
12. Hidden Words (HW)	12.37	3.15	20
Mental speed measures			
13. Number Comparison (NC)	200.79	55.30	
14. Digit Symbol (DS)	65.26	12.85	
15. Math Classification (MC)	28.71	8.72	
16. Stimulus-Response Compatibility (SR)	158.86	26.12	
17. Card Sorting (CS)	50.92	12.76	
18. Fitt's Movement (FM)	177.81	22.75	
Tactual tasks			
19. Finger Counting (FC)	11.92	5.56	24
20. Tactile Bead Memory (TB)	5.90	3.02	
21. HRB Tactual Performance-Level (HL)	13.01	3.36	
22. HRB Tactual Performance-Time (HT)	489.46	182.28	
23. Tactile Shapes (TS)	11.65	3.88	24
24. HRB Finger-Tip Writing (FW)	13.59	3.29	24
25. Gibson's Active/Passive Touch (GT)	18.16	4.33	24

**TABLE 2**  
**Correlations Between Psychometric, Mental Speed, and Tactile Variables**

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1. Raven's Matrices (RM)	-																								
2. Letter Series (LS)	.58	-																							
3. Letter Counting (LC)	.48	.43	-																						
4. Vocabulary (SV)	.16	.30	-.05	-																					
5. General Knowledge (GK)	.18	.28	.01	.61	-																				
6. Esoteric Analogies (EA)	.45	.45	.31	.54	.54	-																			
7. Span Forward (DF)	-.01	.02	.20	.20	.21	.25	.32	-																	
8. Span Backward (DB)	.44	.31	.35	.08	.08	.13	.06	.12	-																
9. Visual Memory (VB)	.40	.36	.31	.04	.04	.19	.07	.18	.27	-															
10. Card Rotations (CR)	.53	.45	.36	.23	.29	.40	.13	.19	.37	.32	-														
11. Hidden Figures (HF)	.32	.29	.25	.15	.18	.28	.11	.13	.25	.31	.33	-													
12. Hidden Words (HW)	.25	.03	.29	-.03	.07	.07	.03	.02	.18	.28	.19	.19	-												
13. Comparison (NC)	.28	.18	.20	-.11	-.02	.13	.09	.08	.20	.24	.36	.11	.29	-											
14. Digit Symbol (DS)	.44	.45	.39	.09	.20	.37	.17	.12	.30	.35	.35	.06	.20	.34	-										
15. Classification (MC)	.43	.42	.42	.12	.14	.26	.09	.07	.33	.24	.30	.14	.19	.48	.49	-									
16. Compatibility (SR)	.18	.21	.12	-.13	.04	.04	-.12	-.15	.16	.18	.14	.07	.18	.30	.31	.37	-								
17. Card Sorting (CS)	.18	.06	.05	.21	.02	.14	.13	.00	.09	.06	.01	.00	.31	.23	.12	.21	-.02	-							
18. Fitts' (FM)	.45	.41	.44	.10	.10	.32	.18	.32	.30	.27	.37	.14	.25	.21	.34	.39	.12	.02	-						
19. Finger Counting (FC)	.43	.29	.40	-.02	.12	.21	.13	.37	.36	.38	.19	.20	.28	.16	.34	.38	.32	.07	.31	-					
20. Tactile Memory (TB)	.34	.34	.24	.16	.14	.14	-.01	.14	.23	.12	.22	.08	.14	.08	.06	.18	.09	-.05	.30	.14	-				
21. HRB TP-Level (HL)	.47	.34	.28	.10	.07	-.06	.15	-.03	-.21	-.27	-.35	-.23	.16	-.21	-.07	-.16	-.27	.01	-.32	-.31	-.49	-			
22. HRB TP-Time (HT)	.42	.43	.48	.08	.00	.23	.10	.36	.27	.16	.34	.21	.18	.18	.27	.25	.11	.00	.49	.36	.31	-.35	-		
23. Tactile Shapes (TS)	.39	.19	.03	-.02	-.08	.16	-.05	.14	.12	.17	.14	.08	.01	.22	.05	.20	.10	.13	.18	.29	.08	-.24	.18	-	
24. HRB FT Writing (FW)	.40	.19	.14	-.01	-.02	.11	-.09	.10	.17	.16	.36	.01	.36	.23	.20	.09	.12	-.02	.30	.22	.26	-.32	.27	.24	-
25. Gibson's Touch (GT)																									

Note. The time measures obtained from Test 13 have been reflected for ease of interpretation.

25.9% of total variance, indicating that a general ability factor (i.e., psychometric *g*) is not strongly supported by the present data. Although root-one criterion allowed for eight factors, the most parsimonious solution suggested the extraction of six factors. This solution was in line with the scree-plot (Cattell, 1966), which leveled out after six factors and avoided singlet factors present in both seven and eight factor solutions. Interpretation of this factor analysis is as follows:

*Factor 1: Decision Time (DTg).* This factor appears to encompass a broad range of abilities, perhaps reflecting the view of Gustafsson (1988) that a superordinate cognitive factor (psychometric *g*) may be indistinguishable from fluid intelligence. Horn and Hofer (1992), who suggest a division of cognitive factors into “vulnerable” and “maintained” abilities, offer a more compelling interpretation. The cognitive functions subsumed by conventional tests loading on Factor 1 are Gf (Tests 1, 2, and 3), Gv (Tests 9 and 10), SAR (Test 3), and mental speed (Tests 14, 15, 16, and 17). All these abilities have been demonstrated elsewhere to be subject to decline over the adult life-span and thus “vulnerable” to the effects of aging (Anstey et al., 1993; Stankov, 1988; Stankov, Roberts, & Spilbury, 1994). The most salient loadings on this factor, however, come from mental speed tasks that require some kind of decision-making. Therefore, we, in accordance with Roberts and Stankov (in press), classify it as a General Decision Time factor

**TABLE 3**  
**Exploratory Factor Analytic Solution (Principal Component with Oblimin Rotation) of the Psychometric, Mental Speed, and Tactile Tasks**

Measures	F1: DTg	F2: Gc	F3: TK/Gf	F4: WM	F5: Gv	F6: MTg/Gs	h <sup>2</sup>
<b>Cognitive ability: Level</b>							
1. Raven’s Matrices (RM)	.31	.24	-.51				.70
2. Letter Series (LS)	.43	.41	.31			-.22	.65
3. Letter Counting (LC)	.34			.45	.37		.62
4. Vocabulary (SV)		.89					.78
5. General Knowledge (GK)		.82					.68
6. Esoteric Analogies (EA)		.74					.68
7. Span Forward (DF)				.66			.58
8. Span Backward (DB)				.80			.66
9. Visual Memory (VB)	.30				.24		.34
10. Card Rotations (CR)	.26				.30		.37
11. Hidden Figures (HF)		.33	.36		.22		.51
12. Hidden Words (HW)					.53		.42
<b>Mental Speed Measures</b>							
13. Comparison (NC)					.42	.71	.72
14. Digit Symbol (DS)	.50					.42	.52
15. Classification (MC)	.72						.62
16. Compatibility (SR)	.77						.66
17. Card Sorting (CS)	.74			-.33			.58
18. Fitts’ (FM)						.75	.62
<b>Tactile tasks</b>							
19. Finger Counting (FC)			.29	.49			.51
20. Tactile Memory (TB)	.36			.44			.47
21. HRB TP-Level (HL)			.64				.45
22. HRB TP-Time (HT)			-.79				.66
23. Tactile Shapes (TS)			.38	.56			.57
24. HRB FT Writing (FW)			.40		-.63		.63
25. Gibson’s Touch (GT)			.64			.30	.50

*Note.* Table 3 includes only salient loadings (i.e., those above .20).  
 DTg = general decision time factor; Gc = crystallized intelligence; TK/Gf = tactile/fluid intelligence; WM = working memory; Gv = broad visualization; MTg/Gs = movement time/perpetual speed.

(DTg). Interestingly, the fact that mental speed is a pivotal component of vulnerable abilities is predicted in recently published aging research (see e.g., Kail, 1994, 1996; Salt-house, 1994).

*Factor 2: Crystallized Intelligence (Gc).* This factor is defined by marker tests for Gc (Tests 4, 5, and 6) although, as often occurs, some low loadings from Gf (Tests 1 and 2), and Gv (Test 11) markers are present. This interpretation is supported by the acculturated nature of the tests having the highest factor loadings. Furthermore, the low loadings from three other tests may reflect either the presence of a (small) learned component in each of these tests design or the tapping of a common resource. In any case, this type of result is indicative of Gc since it stems from a “common genetic determiner” (Horn & Noll, 1994, p. 192). It should also be noted that there is no loading on this factor from any of the tasks included in the experimental design as measures of either mental speed or tactile-kinesthetic ability.

*Factor 3: Tactile/Fluid Intelligence (TK/Gf).* This factor has salient loadings from all the tactile tasks except Test 20 (Tactile Bead Memory) as well as two Gf markers (Tests 1 and 2) and one Gv test (Test 11). We interpret this as a Tactile/Gf factor, henceforth denoted as TK/Gf. This outcome, in turn, suggests the need for a re-examination of the effect of the modality of stimulus presentation in “intelligence” testing (see Jäger, 1984; Kyllonen, 1994; Roberts et al., 1999). The presence of this component in the factor structure clearly suggests the cognitive nature of the tactile-kinesthetic abilities examined in the current test battery. While the present combination of measures are unable to differentiate these abilities from fluid intelligence, there is at least one study that does provide some separation when a different “blend” of test items is used (see Stankov, Seizova-Cajic, & Roberts, in press).

*Factor 4: Working Memory (WM).* This factor appears to represent tasks that place demands on short-term memory (Tests 7 and 8) and manipulations of stored information (Tests 3, 19, 20, and 23) and may therefore be classified as “Working Memory” (WM; see Kyllonen & Christal, 1990).<sup>7</sup> Two tasks that do *not* share salient loadings (but might have been expected to for this interpretation to have merit) are Tests 9 (Visual Bead Memory) and 21 (Halstead-Reitan Tactual Performance [Level]). Nevertheless, Test 21 represents an example of memory in an incidental learning context, which may explain its low loading on this factor.

*Factor 5: Broad Visualization (Gv).* This factor is easily identified as broad visualization ability, since salient loadings come from either established Gv markers (Tests 10, 11, and 12) or from tests that clearly contain a strong visualization component (Tests 3, 9, 13, and 24). In fact the highest loading here comes from Test 24—Fingertip Writing—which involves an internal visual matching process of information presented in the tactile modality (see Roberts et al., 1997). Similarly, participants often report placing the letters presented as stimuli in Test 3—Letter Counting—in “mental storage bins,” which are later visualized to provide the response.

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<sup>7</sup>It appears probable that working memory will be more clearly defined within the revised WAIS-III test battery than was the case with the previous (WAIS-R) instrument (Psychological Corporation, 1997). Even so, we qualify this and the present findings by noting that Carroll (1993) was unable to find evidence for an independent Working Memory factor throughout his extensive reanalysis of the psychometric domain.

*Factor 6: Movement Time/Perceptual Speed (MTg/Gs).* The highest loading on this factor comes from Fitts' Movement Task (Variable 18). In addition, psychomotor speed, in terms of writing (Tests 2, 13, and 14) and recognizing tactually presented stimuli (Test 25), is a part of all other tests loading here. Further still, Roberts (1997b) notes that all perceptual speed (i.e., Gs) markers (e.g., Number Comparison [Test 13], Digit Symbol [Test 14]) contain an important sub-component of psychomotor movement (see also Roberts & Stankov, in press). Failure to differentiate between these two dimensions is a function of practical limitations imposed upon our design (we did not sufficiently sample psychomotor and perceptual speed constructs). Taking each of the preceding into consideration, we label this construct a combined broad Movement Time/Clerical Perceptual Speed factor (MTg/Gs).

### *Factor Intercorrelations*

Table 4 shows the correlations between factors. A noteworthy observation from this table is the relative independence (i.e., low correlation) of all factors. Indeed, only one correlation coefficient exceeds 0.30. These correlations are, however, of theoretical import and readily interpretable since linkages between working memory, decision speed, and Gf are predicted both from experimental cognitive psychology (e.g., Kyllonen & Christal, 1990) and aging research (e.g., Kail, 1994, 1996; Salthouse, 1994). Note especially, the low correlation that Gc shares with all other constructs. Elsewhere, this has been shown to be a critical component of many psychometric intelligence tests (e.g., WAIS) used in both clinical (Matarazzo, 1972) and selection (Stauffer, Ree, & Carretta, 1996) contexts. It also remains the only broad ability of the present battery known to return to normal function after brain trauma (Horn & Noll, 1994). These issues are taken up in detail shortly. Finally, findings within the cognitive ability domain generally show higher correlation than evidenced in Table 4. Thus, from this sample, there would appear only minimal evidence for a factor of "general intelligence" (see Roberts et al., 1999).

## DISCUSSION

The results of the present study provide evidence for the existence of a tactile-kineshetic ability factor, TK, that captures some fluid intelligence processes as well—therefore, the TK/Gf label. This relation suggests that TK is likely a component of intellective

**TABLE 4**  
**Factor Intercorrelation Matrix of the Solution Given in Table 3**

Factor	F1: DTg	F2: Gc	F3: TK/Gf	F4: WM	F5: Gv	F6: MTg/Gs
F1: DTg	1.00					
F2: Gc	.11	1.00				
F3: TK/Gf	.31	.08	1.00			
F4: WM	.24	.23	.21	1.00		
F5: Gv	.15	.10	.12	.14	1.00	
F6: MTg/Gs	.19	.03	.08	.13	.01	1.00

DTg = general decision time factor; Gc = crystallized intelligence; TK/Gf = tactile/fluid intelligence; WM = working memory; Gv = broad visualization; MTg/Gs = movement time/perpetual speed.

functioning. In fact, tactile cognitive ability is related to all the other factors except Gc—that is, tactile tests have loadings on five out of six factors. This provides further support for the claim that tactile and kinesthetic processes captured by the present battery should be seen as a part of the broader spectrum of cognitive ability. Three of the tactile tasks employed here originate in the HRB. It seems reasonable to speculate that Halstead (1947), and his collaborators, were correct in including at least these subtests to tap cognitive abilities of a kind not commonly assessed by the dominant psychometric procedures in vogue during World War II. This follows from the fact that composite measures of “general intelligence” were highly biased toward acculturated learning during this period of the mental testing movement.

### *Integrating Biological and Psychometric Intelligence within Gf/Gc Theory*

*Halstead Re-Re-visited.* Halstead (1947) chose L. L. Thurstone’s factor analysis as the principal means to explore the distinction between “biological” and “psychometric” intelligence. The psychometric tests employed by Halstead (1947) were the Henmon-Nelson Tests of Mental Ability and the Carl Hollow-Square Performance Test for Intelligence. The former would today be regarded as a “mixture theory” measure (Horn & Noll, 1994)—tapping as it does a number of abilities recognized within the Gf/Gc framework, but with a considerable bias toward acculturated abilities (i.e., Gc).<sup>8</sup> The latter, however, has been described as “nonverbal” (Halstead, 1947, p. 56). As such, it appears to capture both visual (Gv) and reasoning abilities (Gf) to varying degrees. Similar abilities are conceivably measured by Halstead’s Category Test, an interpretation supported by the original factor analysis in that both have their highest loading on a factor described by Halstead (1947) as a “factor of abstraction” (p. 147). Also having significant loading on this factor are TPT Localization and Recall. These measures were combined in the current study (i.e., Variable 21). The two factors extracted by Thurstone (1938) may with some justification, be considered as paralleling the Gc and TK/Gf factors identified in this report. Hence, low loadings from Gv and Gf (abstraction?) markers are replicated on the first factor, while a similar low loading from a Gv marker is present on the second factor. If our interpretation of the similarity of Thurstone’s (1938) analysis to that of the present study is correct, then Halstead’s (1947) account of intelligence and that provided by proponents of Gf/Gc theory would appear compatible.

The Category Test, an integral component of the HRB and one of seven tests forming the original Halstead Impairment Scale, is of particular relevance to the present discussion. Halstead is cited as relating biological intelligence to the adaptive ability of a healthy brain (Reitan, 1994). According to “the Reitan-Wolfson theory of neuropsychological functioning, the highest level of central processing is represented by abstraction, concept formation, and logical analysis skills” (Reitan & Wolfson, 1996, p. 13). Presumably, these two concepts are closely aligned, such that the Category Test is “probably the best measure in the HRB of abstraction, reasoning, and logical analysis abilities” (Reitan & Wolfson, 1996, p. 14). The Category Test is nonverbal and requires the participant to distinguish similarities and differences between groups of figures according to a rule that they must deduce themselves. A similar description of “the test taker look(ing) across the rows and look(ing) down the columns to determine the rules and then to use the rules to determine the correct solution” (Carpenter, Just, & Shell, 1990, p. 405) has been

<sup>8</sup>This line of reasoning is supported by Halstead (1947), noting that the authors of the Henmon-Nelson claim that their tests “correlate in the neighborhood of 0.80 with the revised Stanford-Binet scale” (p. 46).

applied to the RPM. The RPM is regarded as a “classic” measure of Gf, so described as “analytic intelligence, the ability to reason and solve problems, deal with novelty and adapt one’s thinking to a new cognitive problem” (Carpenter et al., 1990, p. 404). Given this conceptual correspondence, it hardly seems necessary to point out that the psychological constructs underlying both the RPM and the Category Test are very similar.

Furthermore, there exist other conceptual similarities between the two aforementioned positions. Firstly, Halstead (1947) regards intelligence as “a basic function of the brain” (p. 148) that encompasses a much wider range of cognitive functioning than was commonly espoused by psychometricians during the middle of this century. Although subject to continuing development, the theory of fluid and crystallized intelligence represents, according to Carroll (1993), “a true hierarchical model covering all major domains of intellectual functioning” (p. 62). This model is thus, we contend, very much in line with Halstead’s principles. Secondly, this interpretation is strengthened by Halstead’s (1947) citation of the work of Hebb (1942), who proposed a division of intelligence into Types A and B. Elsewhere, Carroll (1993) has noted that Hebb’s model parallels Cattell’s (1943) original theoretical conceptualization of fluid and crystallized intelligence.

*Vulnerable versus maintained cognitive abilities.* Hebb’s (1942) conclusions on the nature of adult intelligence were derived from observations of the differential effect of brain damage during (and after) a developmental period (peaking at 16 years) of “direct intellectual power” (p. 289). The parallel with Horn and Hofer’s (1992) “maintained” and “vulnerable” abilities is readily apparent. By coincidence, Hebb first presented his theory at the 1941 American Psychological Association Annual Meeting, the same forum at which Cattell introduced the theory of fluid and crystallized intelligence. Indeed, Cattell (1943) remarks that “Hebb has independently stated very clearly what constitutes two thirds of the present theory (i.e., Gf/Gc theory)” (p. 179). Given that researchers starting from a neurological (Hebb) and a psychometric (Cattell) basis reached a similar conclusion on the nature of cognitive abilities, it seems strange that this apparent relation escaped further detailed investigation. The import of this omission is emphasized by Horn and Noll’s (1994) conclusion in differentiating between “vulnerable” and “maintained” abilities:

Gf and SAR are said to be vulnerable abilities. Not only are these the abilities that decline first and most with age in adulthood, they are most irreversibly affected by—are most vulnerable to—injuries to the central nervous system. In contrast to the vulnerable abilities, Gc and TSR are maintained abilities: they do not decline with age over most of adulthood. Also, although these abilities are depressed immediately following brain damage (such as that produced by stroke) they spring back to nearly pre-injury level in the weeks of the recovery period. (p. 196)

Horn and Noll’s (1994) conclusion is by no means unique. A. Kaufman and Horn (1996), for example, present findings that reflect the well replicated decline in fluid abilities from early adulthood onward. Crystallized abilities in their study showed the typical “maintained” effect “until after age 65 years” (Kaufman & Horn, 1996, p. 118). They note, however, that using their battery (i.e., the Kaufman Adolescent and Adult Test–KAIT) smaller decline in fluid abilities was observed than would be expected from the WAIS-R Performance Scale. This, they claim, is due to the influence of more speeded clerical tasks (Gs) in the WAIS-R than in the KAIT. The differential amount of cognitive decline indicated by the two test batteries signifies the need for caution when examining test results as a function of chronological aging. A. Kaufman and Horn (1996) also draw attention to the need to take into account the so-called “Flynn effect” (Flynn, 1984,

1987), which describes an increase in intelligence test scores across generations. While the cause of the Flynn effect remains contentious, its confounding effect on interpreting neuropsychological assessment across different age groups is readily apparent. It is surely no coincidence that one of Halstead's major interests was human aging and its effects on the evaluation of neuropsychological change (Reitan, 1994).

*The Role of Psychometric g.* It is of no little import that Halstead (1947) does not consider the so-called psychometric "g" as paramount to clinical assessment. This is also the view of proponents of Gf/Gc theory, especially with respect to the assessment of normal cognitive functions. For example, Horn (1998) points out that the well-known phenomena of "positive manifold" need *not* mathematically imply "g" and that a number of clearly noncognitive variables also exhibit positive manifold (see also Roberts et al., 1999). Horn (1998) further contends that a third-order "g" factor often fails to "meet the standards of even the weakest form of factorial invariance" (p. 14). It is therefore interesting to note that the present study offers only minimal evidence of a "general intelligence" factor.

*On the Biology of Neuropsychological Assessment.* Halstead was by no means an "arm-chair psychologist." He spent considerable amounts of time observing his patients in the real-life settings of their home, workplace, and recreational venues (Reitan, 1994). These observations allowed Halstead to appreciate that mid-century psychometric measures were inappropriate for assessing many of the behavioral abnormalities expressed by his clients. This was particularly true of persons who had undergone frontal lobe excisions as treatment for epilepsy. Hebb (1939, 1941) reported on the results of IQ tests administered to such patients and declared that their scores remained within normative limits. Halstead's observations, and the results of his test procedures (especially the Category Test), indicated otherwise (Reitan, 1994). Indeed, it seems Halstead appreciated a need to distance his concept of intelligent behavior from the academically orientated mental testing movement dominating differential psychology throughout the period of his research.

Modern neuroimaging techniques are confirming that Halstead, Hebb, and Cattell were all on the right path. Reitan and Wolfson (1996) point to the high correlation between neurological imaging examinations and assessment using the HRB, qualifying this point by arguing that such evaluations are complementary. Similarly, E. Smith and Jonides (1997) have used positron emission tomography (PET) to study brain activation when a participant performs tasks that place demands on working memory. Their results indicate that, as hypothesized by proponents of Gf/Gc theory, different areas of the brain (localized in the prefrontal cortex) are activated by spatial and verbal tasks and for passive and active memory. Furthermore, a functional magnetic resonance imaging (fMRI) study by Prabhakaran, J. Smith, Desmond, Glover, and Gabrieli (1997) suggests that, while participants perform RPM tasks, the same prefrontal cortex areas are active. However, again as predicted by Gf/Gc theory, fluid intelligence tasks cause the more general activation of several neural systems.

In sum, while Halstead (1947) appears correct in differentiating mid-century "psychometric intelligence" from "biological intelligence," this dichotomy appears artificial in light of contemporary Gf/Gc theory. Indeed, refinements to this theory (such as those resulting from the investigation of the role of mental speed in cognitive ability [e.g., Roberts & Stankov, in press]) suggest that Halstead's (1947) position, and the HRB, might benefit from revision. Furthermore, recent publications in the individual differences domain have emphasized the important role of mental speed (e.g., Jensen, 1994;



see also Stankov & Roberts, 1997 for a cautionary note). Because this field of research offers improved understanding of neurological components, rigorous measurement procedures, and established links with other cognitive abilities, measurement of mental speed constructs would appear a useful adjunct to neuropsychological assessment.

### *Comprehensive Neuropsychological Assessment: A Gf/Gc Theory Prospective*

Another issue raised in the introduction of this article, that of contradictory conclusions in some of the research findings previously cited, may also be clarified by recourse to Gf/Gc theory. As was noted earlier, the WAIS-R remains as an almost universal instrument for assessing cognitive ability in studies evaluating the nature of the HRB. However, this psychometric instrument either minimizes or excludes factors currently believed to form integral parts of overall intellectual functioning.<sup>9</sup> Horn and Noll (1994) conclude that, as is the case when considering the WAIS-R, such mixture measure tests are effective only for assessing designated technical criteria. However, “no mixture measure test is known to be representative of the entire repertoire of acquired skills, knowledge, learning sets, and generalization tendencies considered intellectual in nature” (Horn & Noll, 1994, p. 165). Indeed, the ineffectiveness of psychometric approaches in identifying neurological dysfunction led Halstead (1947) to propose the notion of “biological intelligence” and to supplement psychometric instruments with a range of measures designed to achieve a more comprehensive neuropsychological assessment. The findings of this study support Halstead’s position and indicate that the inability of the WAIS-R to capture the full range of human cognitive ability has led to misinterpretation of the nature of processes evaluated by the HRB.

Bearing in mind Carroll’s (1993) assertion that an extensive range of tests are required to obtain meaningful results when exploring the cognitive domain, it is hardly surprising that contradictory conclusions have been evidenced amongst empirical findings cited previously. Clearly, it will be pertinent for future researchers investigating the HRB to include instruments that adequately cover all the factors that are now recognized as part of the continuum of human cognitive abilities. Recognition of these shortcomings has undoubtedly been a motivating factor in the recent construction of revised versions of both the Wechsler scales and the Stanford-Binet Tests. In fact, the authors of the WAIS-III explicitly indicate that “Current research suggests that cognitive functioning encompasses more than what is measured by VIQ and PIQ scores (of the WAIS-R)” (Psychological Corporation, 1997). A specific Gf measure (the Matrix Reasoning Test), a working memory measure (the Letter-Numbering Sequencing Test), and a new measure of processing speed (the Symbol Search Test) are included in the WAIS-III in an attempt to remedy this deficit. Unfortunately, it will probably take some time before the revised scale is universally employed, especially outside the United States. Although the Verbal versus Performance distinction remains in place, a finer tuning of assessment of cerebral malfunctioning will hopefully prevail with increased use of the revised scale.

Recently, Woodcock (1998) has proposed the use of Gf/Gc theory as a basis for neuropsychological assessment. Woodcock (1998) states that “Gf/Gc theory and Carroll’s (1993) (closely related) three-stratum theory are the major empirical theories of multiple intelligences available today” (p. 12). This, and the fact that neither model relies on

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<sup>9</sup>We are aware that, in recent times, several alternative scoring protocols for the WAIS-R have been developed, including at least one that recognizes the utility of the Gf/Gc framework (Senior, 1996). The efficacy of such procedures within an instrument that does not include or under-represents factors is however diminished.

any particular test battery for its efficacy, has led Woodcock (1998) to advocate their use as the basis for a cognitive neuropsychological model. Stemming from the model, Woodcock (1998), further proposes a “Diagnostic Worksheet . . . that may be used as a tool by a clinician evaluating the implications of functional deficits on a patient’s performance” (p. 12). From the previous discussion, such use of an instrument based on Gf/Gc theory appears appropriate. However, it is also important to emphasize that the HRB/WAIS combination contains measures that may not be equivalently included in Woodcock’s (1998) instrument and considerable cross-validation would be judicious before accepting a radical departure from established procedures.

## CONCLUSION

The results of the present study point to the existence of an area of cognitive ability that, while previously receiving little formal treatment, appears to have been anticipated by Halstead (1947). His review of the inadequacy of the psychometric paradigm prevalent at that time to explain “intelligence” was clearly justified. However, arguing from both empirical and theoretical perspectives it would no longer appear necessary to promote a distinction between intellectual functioning as proposed by clinical neuropsychologists and psychometricians espousing the theory of fluid and crystallized intelligence. This attempt at reconciliation is, however, by no means complete. There will have to be further research efforts to clarify the position of other subtests of the HRB within the factorial structure of human abilities (the auditory tests, for example, appear prime candidates).

At the same time, it would seem worthwhile to subject other neuropsychological test batteries to similar scrutiny. One outcome of such a project might be a greater understanding of the role of localized brain functioning (if any) in cognitive abilities and thus the processes involved in intelligent behavior. Such outcomes might well emerge from investigations of cognitive deficits in neurologically impaired persons using tests from within the Gf/Gc framework. Indeed, such research, with participants who have brain lesions diagnosed by established criteria, represents an important and challenging task for potential exploration.

The theory of fluid and crystallized intelligence, we contend, provides a sound basis for improving understanding of the relationship between the abilities considered pertinent to neuropsychological assessment using the HRB. It also offers a conceptual framework within which those abilities may be placed. We hope that there exists a symbiosis in this relationship, which may provide further means of examining possible brain impairment by the inclusion of instruments developed within the Gf/Gc framework. Already evident from the current study is the possibility of substituting the Tactual Performance Tests with a yet to be determined combination of visualization and fluid intelligence measures for persons having impaired motor control.

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