Wechsler Adult Intelligence Scale non-dominant hand corrections.

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Correcting for the Effects of Non-Dominant Hand Administration on Select Subtests of the Wechsler Adult Intelligence Scale- Fourth Edition (WAIS-IV)

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A Clinical Research Project presented to the faculty of the Argosy University Atlanta in partial fulfillment of the requirements for the degree of Doctor of Psychology in Clinical Psychology.

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The purpose of this study was to correct for the effects of non-dominant hand administration on the WAIS-IV Block Design, Symbol Search, Coding, and Cancelation subtests. Twenty nine participants were administered the subtests according to standard administration procedures (SA group) and 29 were instructed to use their non-dominant hand (NDA group). Mean scores were compared between groups. NDA resulted in lower performance across all four subtests, with SA-NDA discrepancies achieving statistical significance for the Symbol Search and Coding subtests. For those subtests, mean NDA scaled scores were reduced by 3.24 and 3.03 points respectively as compared to SA. A method was proposed to calculate expected SA scores from actual NDA scores.

Correcting for the Effects of Non-Dominant Hand Administration
on Select Subtests of the Wechsler Adult Intelligence Scale- Fourth Edition (WAIS-IV)

This Clinical Research Project by Jonathan D. Gross, directed and approved by the candidate's Clinical Research Project Committee, was approved by the faculty of Argosy University Atlanta in partial fulfillment of the requirement of the degree of Doctor of Psychology in Clinical Psychology

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January 14, 2011

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Dedication

To Chai Ilana, my Tree of Life.

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Correcting for the Effects of Non-Dominant Hand Administration on Select Subtests of the Wechsler Adult Intelligence Scale- Fourth Edition (WAIS-IV)

Stroke, or cerebrovascular accident (CVA) is a non-traumatic acquired brain injury (ABI) caused by a disruption in the brain's vasculature causing sudden neurologic dysfunction (Loring, 1999). The majority of strokes are ischemic (67%-80% of new strokes), i.e. the consequence of a blockage within the cerebral blood flow significant enough to cause alterations in neural metabolism and function leading to cell death (Grant & Adams, 2009). Advanced age is a significant risk factor associated with ischemic CVA; while the worldwide incidence of these strokes is less than 2 cases in 1000 per year in individuals 45 through 54 years, the incidence increases to 20 cases in 1000 per year for those 85 years and older (Grant & Adams, 2009). Beyond being widespread, the neuropsychological implications of stroke are significant. Up to 65% of stroke survivors experience initial onset or worsening of cognitive deficits post-stroke, with older adults most vulnerable to stroke-related cognitive sequelae (Grant & Adams, 2009).

Various cognitive domains have been correlated with post-stroke decline. A meta-analysis of five studies investigating memory dysfunction following stroke found reduced verbal memory among stroke survivors as compared to healthy controls or normative data (Snaphaan & de Leeuw, 2007). Other cognitive domains negatively affected by cerebrovascular accident include visuoperceptual function (Hildenbrandt, Giesselmann, & Sachsenheimer, 1999), language/communication abilities (Salter, Jutai, Foley, Hellings, & Teasell, 2006), general mental status, global cognition, attention, abstract thinking, and executive function (Grant & Adams, 2009).

Because the ways in which stroke can impair cognition is varied, assessment must cover a broad range of neuropsychological domains. A recent consensus panel comprised of the National Institute of Neurological Disorders and Stroke and the Canadian Stroke Network recommended that post-stroke neuropsychological evaluations assess executive functioning, attention, visuospatial performance, language, learning and memory, emotional functioning, and premorbid status (Grant & Adams, 2009).

As opposed to CVA, traumatic brain injury (TBI) is an ABI that is caused by an external mechanic force (most often associated with motor-vehicle accidents, falls, or violence) that impacts the brain (Loring, 1999). TBIs affect approximately 1.4 million individuals in the United States each year and leave an estimated 80,000-90,000 people with long-term disability (Grant & Adams, 2009). Many of these individuals experience significant difficulty returning to their prior roles and responsibilities following their brain injury (Grant & Adams, 2009).

The consequences of TBI vary greatly, with striking variance observed in the nature and extent of the impairment regardless of the severity of injury (Grant & Adams, 2009). A study examining the performance of 436 individuals with TBI on a battery of neuropsychological tests 1 year post-injury found that the TBI group performed significantly below a group of 121 general trauma controls across domains of functioning including general intellectual abilities (verbal and non-verbal), attention, memory, speed of information processing, novel problem solving, and motor skills (Dikmen, Machamer, Winn, & Temkin, 1995). Research pertaining to individuals with residual cognitive sequelae following mild traumatic brain injury has revealed deficits in the areas of complex attention (Bohnen, Jolles, & Twijnstra, 1992), memory across verbal and visuospatial modalities (Dikmen, McLean, & Temkin, 1986), and executive functions (Stuss & Gow, 1992).

Regardless of the etiology of the event, the neuropsychological examination comprises a key aspect of an individual's care following brain injury. Neuropsychological instruments are sensitive to alterations in brain functioning and can therefore provide evidence of damage that may not be otherwise apparent from neurophysiological or neuroradiological imaging (Devinsky & D'Esposito, 2004). Neuropsychological conclusions are based largely on performance patterns across multiple measures (Axelrod, Fichtenberg, Liethen, Czarnota, & Stucky, 2001). The neuropsychological examination may also be used to determine lateralization and localization of brain lesions, or to reveal patterns of an individual's strengths and weaknesses following neurological insult (Devinsky & D'Esposito, 2004). The clinical utility of neuropsychological testing includes the ability to predict real-world functioning which may inform recommendations pertaining to treatment, educational or vocational reentry, or capacity to live independently (Devinsky & D'Esposito, 2004). Additionally, by establishing a base-line measurement of neurocognitive functioning, testing can help detect patterns of improvement or deterioration over time in order to clarify diagnosis and guide further treatment planning and recommendations (Devinsky & D'Esposito, 2004).

A typical neuropsychological evaluation will assess arousal and alertness, orientation, attention and concentration, memory and new learning, language and communication, praxic functions (the ability to perform skilled movements), academic skills (such as reading, writing, spelling, and arithmetic), visuoperception, visuospatial skills (such as visual pattern recognition or mental rotation of shapes), reasoning and problem solving, executive functions (such as planning, organization, cognitive flexibility, and self-awareness), and mood and personality functions (Sohlberg & Mateer, 2001).

Although not originally designed to detect neurocognitive dysfunction, the Wechsler Adult Intelligence Scale (WAIS) and its later revisions have often comprised the backbone of a comprehensive neuropsychological assessment (Lezak, et al. 2004). For example, in developing their seminal neuropsychological battery, Halstead and Reitan emphasized inclusion of the Wechsler scales (Groth-Marnat, 2000). The Wechsler intelligence scales are well suited for neuropsychological assessment since, in addition to being well standardized and well matched to U.S. census data, many of the domains covered within the scales such as working memory, processing speed, abstract reasoning, and attention are of relevance to neurocognitive assessment (Groth-Marnat, 2000). Indeed, it is well demonstrated that moderate to severe ABI results in reduced scores on intellectual testing (Sohlberg & Mateer, 2001).

From the early 1950's through the early 1980's, over 30 studies were published utilizing the Wechsler scales to identify cognitive deficits associated with unilateral brain damage such as ABI secondary to stroke (Lawson & Inglis, 1983). Indeed, David Wechsler, in his "hold/no hold" hypothesis, attempted to identify a "brain damage" profile by comparing performance between subtests thought to be sensitive to neurological insult with those theorized to be resistant to the effects of brain injury (Groth-Marnat, 2000). Such a classification scheme failed to capture the high degree of heterogeneity in performance among brain injured individuals since the various types of brain injuries and other critical factors elude a formulaic brain injury profile. Although a valid “brain damage” Wechsler profile was not identified, the Wechsler scales have emerged as reliable and objective sources of information relevant to neuropsychological abilities and prediction of environmental functioning (Groth-Marnat, 2000). In addition to their widespread clinical use, the Wechsler intelligence scales are commonly used in neuropsychological research in order to identify cognitive patterns associated with various syndromes (Groth-Marnat, 2000).

In earlier versions of the Wechsler scales, the Verbal and Performance IQs were traditionally interpreted to differentiate between right and left hemisphere damage; specifically, a relative deficit in Performance IQ was considered to reflect right hemisphere impairment and a relative deficit in Verbal IQ to reflect left hemisphere impairment (Groth-Marnat, 2000). Although such differences have indeed been demonstrated in empirical studies, VIQ-PIQ discrepancies across left hemisphere and right hemisphere lesion groups often lack statistical significance (Bornstein & Matarazzo, 1982). Although specialization of the left cerebral hemisphere for language and the right hemisphere for non-verbal abilities (such as visuospatial integration) is well established (Funnell, Corballis, & Gazzaniga, 1999; Reuter-Lorenz & Miller, 1998), the weak correlation between lesion lateralization and VIQ-PIQ discrepancies is likely due to the fact that PIQ subtests involve linguistically mediated processes and often imply an expectation for verbal responses (Lawson & Inglis, 1983). The quest for lesion lateralization based VIQ-PIQ discrepancy, however, is now moot since the Verbal IQ and Performance IQ groupings have been supplanted by four-factor grouping in the WAIS-

IV. The four factors allow subtest performance to be clustered into four index scores (Verbal Comprehension, Perceptual Organization, Working Memory, and Processing Speed).

A study cited in the WAIS-IV Technical and Interpretative Manual examined the WAIS-IV performance of 22 individuals (ages 20-44 years) with history of recent moderate or severe TBI. Mean full-scale, index, and subtest scores were compared to a group of matched controls. Large effect sizes were found across Full Scale IQ, Perceptual Organization Index, and Processing Speed Index, with Processing Speed Index demonstrating the largest effect size (Coalson & Raiford, 2008). Similarly, an analysis of the data from the seven clinical studies presented in the WAIS-III/WMS-III Technical Manual revealed a significant weakness in the Processing Speed Index relative to the other three WAIS-III indices among individuals with TBI (Hawkins, 1998). Such findings are consistent with the long-held observation that individuals with ABI demonstrate significant difficulties on subtests that rely on non-verbal "fluid" abilities (such as novel problem solving) and speeded performance (Sohlberg & Mateer, 2001).

On a subtest level, the study cited in the WAIS-IV manual revealed a large effect size between the TBI and matched control groups across the Symbol Search, Figure Weights, Visual Puzzles, Arithmetic, and Matrix Reasoning subtests, and a moderate effect size across the Block Design, Digit Span, Information, Coding, Letter-Number Sequencing, Cancellation, and Picture Completion subtests (Coalson & Raiford, 2008). Similarly, Prigatano observed lower performance on the Coding subtest, a non-verbal test of processing speed, among TBI patients (Prigatano, 1999). These findings demonstrate the utility of the Wechsler scales in discriminating brain-injured and non-brain injured individuals, consistent with theory-driven predictions that identify select Wechsler subtests with the cognitive sequelae associated with ABI.

Since neuropsychologists are often called upon to assess individuals with various disabilities secondary to acquired brain injuries and other neuromedical disorders, they are frequently compelled to depart from standardized procedures in order to accommodate for the disabilities with which these patients commonly present (Lee, Reynolds, & Willson, 2003). In fact, failure to take the patient's disabilities into account during neuropsychological testing can seriously compromise the validity of the data collected during the assessment. For instance, the Wechsler scales were developed to detect individual variance across multiple domains of intellectual skills within the normal population. This has been accomplished by sampling a broad range of cognitive tasks that utilize various input and output modalities. On the Block Design subtest, for example, the examinee must visually perceive (input) and manually manipulate (output) the test stimuli. Other input/output dyads include the requirement to hear verbal instructions and vocalize a verbal response, such as on the Similarities subtest, in which the examinee must hear the examiner administer two words and then explain to the examiner how the two words are related. While the approach of measuring a range of cognitive abilities via a variety of input/output modalities is an effective way of measuring intellectual skills for non-disabled individuals, the approach is flawed when the methodology is applied to the assessment of disabled examinees. When instruments designed for non-disabled persons are used to assess disabled persons, the disabled person's constellation of disabilities may interact with the input/output demands of the instrument, thereby biasing the findings (Tulsky et al., 2003).

This interaction between the disabled examinee's limitations and the input/output demands of the given instrument produces a distortion known as construct-irrelevant variance (Tulsky et al., 2003). Each neuropsychological instrument or subtest is designed to measure one or more constructs. For example, the Coding subtest, which requires the examinee to use a key to rapidly copy symbols paired with numbers, assesses (among other things) the construct of processing speed (Coalson & Raiford, 2008). However, rather than constituting a pure measure of processing speed, the Coding subtest contains construct-irrelevant variables (i.e., variables that are merely incidental to task completion) such as visual acuity and visual-motor coordination. If the individual completing the Coding subtest has blurred or double vision, or impaired fine motor skills, he or she is likely to perform poorly on the subtest. His or her low score on this task alone, however, cannot be interpreted to reflect impaired processing speed since construct-irrelevant variance was introduced by the visuoperceptual and visuomotor aspects of the task (Tulsky et al., 2003). Under these conditions, the neuropsychologist may choose to modify the task vis-à-vis the examinee's disabilities in order to remove construct-irrelevant variance (Lee et al., 2003).

The potential for construct-irrelevant variance frequently occurs during the neuropsychological assessment of individuals who have sustained CVA. Such individuals commonly present with co-morbid neuromotor impairment such as hemiparesis or complete hemiplegia, often involving dysmobility of the dominant hand (Ryan & Tree, 2007). This presents a challenge when administering tasks with motor components, including many of the WAIS-IV Perceptual Reasoning and Processing Speed subtests. Since these tasks require examinees to manually manipulate stimulus materials, patients with motor problems are at a distinct disadvantage when completing these tasks (Groth-Marnat, 2000; Tulsky et al., 2003). Under such conditions, non-dominant hand administration (NDA) must often be employed (Ryan & Tree, 2007).

Although NDA appears to be a profound departure from the standard administration procedures, researchers have found that the NDA modification does not always result in significant performance differences. For instance, one study demonstrated inter-manual equivalence on the Japanese Trail Making Test, a pencil-and-paper target sequencing task (Toyokura, Ishida, Watanabe, Okada, & Yamazaki, 2003). Similarly, an early study that investigated the effects of NDA on WAIS Performance subtests found that non-dominant hand performance on select subtests with substantial motor involvement (Block Design, Picture Arrangement, and Object Assembly) was comparable to dominant hand or dual handed administration (Briggs, 1960). A 2007 study reinvestigated the effects of non-dominant hand administration on Wechsler subtests using the 1997 updated Wechsler Intelligence Scale- Third Edition (WAIS-III; Wechsler, 1997). In that study, 58 normal volunteers (college students) completed the Digit Symbol-Coding, Block Design, Picture Arrangement, Symbol Search, and Object Assembly subtests using either the standard administration procedure (SA) or non-dominant hand administration (NDA). Consistent with Briggs' earlier findings (1960), the 2007 study found no significant differences between SA and NDA performance on the Block Design, Picture Arrangement, and Object Assembly subtests (Ryan & Tree, 2007).

In many cases, however, departure from standardization is associated with significant differences in performance, thereby invalidating the use of normative data to derive standardized scores (Lee et al., 2003). For example, a reading comprehension task might be modified for a visually impaired patient such that the examinee is asked to listen to passages prior to answering questions rather than read the passages from a visually presented stimulus. Under the modified administration conditions, the normative data might over- or underestimate the individual's performance since the task demands of the normative sample (i.e. passage reading) are different than the modified task demands (i.e. passage listening).

Even subtle alterations in standard administration procedures can result in significant performance differences. For instance, fourth graders were able to recite significantly more digits on the Wechsler Digit Span subtest when the examiner dropped voice inflection on the final digit as compared to when the examiner placed uniform emphasis across digits (Hagan, Durham, & Shannon, 1977). Similarly, visual presentation of the digits on a computer screen significantly reduced the number of digits accurately recalled as compared to performance under standard auditory administration conditions (Beaumont, 1985).

Interestingly, the direction in which modifications alter performance can be counter-intuitive (Lee et al., 2003). For example, there are two administration procedures commonly employed for the Rey-Osterrieth Complex Figure Test; one involves handing the examinee a different colored pen upon completion of each aspect of a complex geometric figure and in the other, the examinee is uninterrupted as he or she copies the entire figure with one pencil. A study investigating the differences between these two administrations (drawing on data collected from 100 inpatients and outpatients) found that patients in the switching condition performed better than the patients in the uninterrupted condition, despite the intuitive prediction that switching would compromise performance (Ruffolo, Javorsky, Tremont, Westervelt, & Stern, 2001). It is also noteworthy that although modifications are meant to facilitate task completion for individuals with disabilities, they are sometime associated with reduced performances as compared to unmodified conditions (Elliott, Kratochwill, & McKevitt, 2001).

Directly relevant to the present study, NDA performance has been associated with significant performance differences for certain Wechsler tasks. Briggs' 1960 study found that the average scaled score for NDA performance was 3.2 points lower than the average standard administration (SA) scaled score for the WAIS Digit Symbol-Coding subtest. Likewise, Ryan and Tree (2007) found that NDA produced an average scaled score disadvantage of 4.04 points on the WAIS-III version of the same subtest. Ryan and Tree also found a disadvantage of 1.62 scaled score points for NDA on the Symbol Search subtest of the WAIS-III (the subtest was not investigated by Briggs since it was not included in the WAIS at the time of his study).

Accordingly, the literature demonstrates that departure from standard administration procedures can impact test performance and invalidate the use of normative data for modified administrations. Furthermore, the magnitude and direction of performance differences associated with administration departures may be contrary to logical predictions. Accordingly, normative data cannot be justifiably used to interpret scores from a modified administration in the absence of direct empirical evidence of the equivalency of the alternative procedure or an empirically validated modification to the normative data.

The Ethical Principles of Psychologists and Code of Conduct (American Psychological Association, 2002) highlights the responsibility to modify procedures in order to accommodate disability. For example, article 3.01 (Unfair Discrimination) states, “In their work-related activities, psychologists do not engage in unfair discrimination based on age, gender, gender identity, race, ethnicity, culture, national origin, religion, sexual orientation, disability, socioeconomic status, or any basis proscribed by law.” Similarly, Title IV of the Civil Rights Act of 1964, Title IX of the Educational Amendments of 1972, Section 504 of the Rehabilitation Act of 1973, and Title II of the Americans with Disabilities Act of 1990 require that individuals with disabilities have access to a variety of assessment processes and settings (Tulsky et al., 2003). Accordingly, to simply omit the assessment of a particular domain (such as processing speed) or to leave tasks unmodified and thereby introduce construct-irrelevant variance vis-à-vis a patient’s disability would apparently constitute disability discrimination, since both professional ethics and federal legislation require the clinician to modify procedures in order to accommodate for disability.

While professional ethics and legislation require clinicians to accommodate for disabilities, in light of the literature discussed above, departure from standardization may compromise validity. This creates a dilemma since professional ethics also mandate that psychologists “use assessment instruments whose validity and reliability have been established for use with members of the population tested.” (American Psychological Association, 2002, 9.02 Use of Assessments). Accordingly, when an individual with neuromotor impairment presents for neuropsychological assessment, the clinician’s ethic to accommodate and modify is apparently contraindicated by the ethic to preserve psychometric validity.

The tension between the need to accommodate and the need to utilize valid assessment procedures has been expressed in the clinical literature. In his text Neuropsychological Assessment in Clinical Practice, Groth-Marnat (2000) writes:

> Patients with motor problems (e.g. hemiplegia of the dominant hand, or any condition that compromises speed or coordination) are particularly at risk for being penalized for slow motor output…However, [the Wechsler Coding subtest]is an excellent neuropsychological task and should still be administered…(p.169)

Moreover, the lack of resolution concerning this tension is also evident. Referring to the Wechsler Symbol Search subtest, Groth-Marnat (2000) writes:

> A patient with a severe motor handicap could, however, complete this task in a nonstandard manner by scanning each line and then dictating "yes" or "no" to the examiner, although scores so obtained would not be comparable with the standard administration. (p.178)

The Standards for Educational and Psychological Testing, published by the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education (1999) reflect a movement towards resolving this specific dilemma. The *Standards* addresses both the need to modify testing procedures in order to accommodate individuals with disabilities and the imperative to provide evidence for the validity of test scores yielded from a modified administration (Lee et al., 2003). Practically, this means that subjecting specific modifications to empirical analysis will allow researchers and clinicians to uphold both the value of accommodating individuals with disabilities and the imperative to base conclusions on psychometrically sound procedures. The current investigation is in concert with this aspiration, as it will attempt to provide parameters within which the WAIS-IV normative data can be used to derive standardized scores from NDA performances.

Briggs studied the effects of non-dominant hand administration on WAIS subtests in 1960. Ryan and Tree conducted a study in 2007 that investigated the same phenomenon in order to reevaluate past findings in light of publication of the updated Wechsler Adult Intelligence Scale-Third Edition (WAIS-III). Following the same trend, the current study will compare mean performance between standard administration (SA) and non-dominant administration (NDA) groups in light of publication of the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; 2008). Several WAIS-IV updates are particularly relevant to potential SA-NDA discrepancies including a reduced emphasis on time bonuses for the Block Design visuomotor construction task, enlarged symbols and a revised format for the pencil-and-paper Symbol Search and Coding subtests, and the addition of a new pencil-and-paper task, the Cancellation subtest (Coalson & Raiford, 2008).

In addition to reexamining NDA effects in light of WAIS-IV updates, this study will expand upon Ryan and Tree's work by generating NDA correction factors which may be applied to scores produced by individuals completing WAIS-IV tasks with their non-dominant (i.e. pathologically dominant) hand. This will be accomplished by comparing mean performance between a standard administration group (SA) and a non-dominant hand administration group (NDA) across the WAIS-IV Block Design, Symbol Search, Coding, and Cancellation subtests. In concert with the aspirations set forth in *The Standards,* this will equip researchers and clinicians with a psychometrically sound procedure for offering accommodations based on disability.

A potential threat to validity of such a procedure is the likelihood that correction factors appropriate for right-hand dominant individuals using their left hand will not be valid for left-hand dominant individuals using their right hand. Although it is common practice to group these potentially heterogeneous groups together (i.e. the normative data available for most psychomotor tasks use the designation "dominant hand" and "non-dominant hand" without sub-grouping based on which hand is dominant), there is strong evidence that contraindicates this practice. Namely, left-handers demonstrate less inter-manual discrepancy than do right-handers and (correspondingly) left-hand dominant individuals perform better with their non-preferred hand than do right-hand dominant individuals (Judge & Stirling, 2003; Steenhuis & Bryden, 1999). Because the literature demonstrates that the degree of discrepancy between dominant and non-dominant hand performance varies depending on hand preference, the current study will limit its investigation to SA versus NDA performance among right-hand dominant individuals. This leaves the question of NDA performance discrepancy among left-handers for future research.

Method

Participants

Participants in this study consisted of 58 non-neurologically impaired, right-hand dominant adults. Participation in the study was voluntary. Requests for participation were made at community events and from the waiting room of an Atlanta area physician. Participants recruited from the latter source included both non-neurologically or motorically impaired patients and accompanying non-patients. Right-hand dominance was established by verifying an exclusive preference for right-hand writing and by observing preferred writing hand during completion of the informed consent documentation. This method is highly correlated with formal measures of handedness classification (Judge & Stirling, 2003). Individuals were excluded from the study if they reported history of neurological injury or illness, impairment in either upper extremity, or if an anticipated need for clinical neuropsychological evaluation was identified (so as to reduce the risk of biasing future clinical assessments). A small chocolate was provided to each participant as a nominal compensation for time and effort.

Of this group, 29 individuals were selected to complete the subtests according to standard administration procedures, as outlined in the WAIS-IV administration guidelines (SA group) and 29 individuals completed the subtests using their non-dominant (i.e. left) hand (NDA group). Participants were randomly assigned to either group (SA or NDA) based on the identification number assigned to each participant (odd identification numbers were assigned to the SA group, even numbers to the NDA group). Each participant completed the Block Design, Symbol Search, Coding, and Cancellation Subtests in that order.

The demographic variables age, sex, race, education, occupation, and region were used to derive an estimated Performance IQ for each participant, according to the regression equation proposed by Barona, Reynolds, and Chastain (1984). This procedure was implemented in order to evaluate the comparability between the SA and NDA groups and the likelihood that between-group differences were due to the independent variable (i.e. administration method) and not an artifact of subject-related factors (such as a difference in intellectual abilities).

Of the 29 SA participants, 19 were male and 10 were female. 27 were Caucasian and 2 were African American. Mean age was 31.52 years (SD=8.53), mean level of education was 15.83 years (SD=2.14), and mean estimated Barona Performance IQ was 107.55 (SD=5.28). Of the 29 NDA participants, 20 were male and 9 were female. 27 were Caucasian and 2 were African American. Mean age was 36.14 years (SD=11.93), mean level of education was 15.69 years (SD=2.25), and mean estimated Barona PIQ was 108.44 (SD=4.73). Demographic data for SA and NDA groups can be found in Tables 1 and 2, respectively.

Table 1

Demographics of SA group (n=29)

Age (in years)		Education (in years)		Barona Estimated PIQ	
M	SD	M	SD	M	SD
31.52	8.53	15.83	2.14	107.55	5.28

Table 2

Demographics of NDA group (n=29)

Age (in years)		Education (in years)		Barona Estimated PIQ	
M	SD	M	SD	M	SD
36.14	11.93	15.69	2.25	108.44	4.73

Materials

The study used the standard WAIS-IV stimuli and test record forms for the Block Design, Symbol Search, Coding, and Cancellation subtests. Descriptions of the relevant subtests are provided in Table 3, as they appear in the WAIS-IV Administration and Scoring Manual (Coalson & Raiford, 2008):

Table 3

Relevant WAIS-IV subtest descriptions

Subtest	Description
Block Design	Working within a specified time limit, the examinee views a model and a picture, or a picture only and uses red-and-white blocks to re-create the design.
Symbol Search	Working within a specified time limit, the examinee scans a search group and indicates whether one of the symbols in the target group matches.
Coding	Using a key, the examinee copies symbols that are paired with numbers within a specified time limit.
Cancellation	Working within a specified time limit, the examinee scans a structured arrangement of shapes and marks target shapes.

Procedure

Each participant signed an informed consent document prior to collection of demographic information and administration of testing. All 4 subtests were administered to each participant in a single session. Subtest administration order was consistent within and across groups and administration order followed the chronological sequence of the subtests found in the WAIS-IV Administration and Scoring Manual (Wechsler, 2008) such that Block Design was administered first, followed by Symbol Search, Coding, and then Cancellation.

Administration procedures for the Standard Administration (SA) group followed the standardized guidelines detailed in the WAIS-IV Administration and Scoring Manual (Wechsler, 2008). For the NDA group, participants were instructed to complete tasks with their non-dominant (left) hand. Participants were immediately redirected if they began to use their dominant hand. The examiner provided minimal motor assistance to facilitate fluid task performance, such as stabilizing the response booklet and flipping pages, in order to more closely approximate the administration procedures that would accompany clinical assessment of an individual with dysmobility of one hand. All tasks were administered by either the primary investigator or a research assistant who received thorough training in the study protocol, recruitment methods, and test administration. Initial administrations by the research assistant were observed by the primary examiner and all scoring was rechecked by the primary examiner in order to ensure adherence to standardized and experimental protocols.

Mean raw and scaled scores for each subtest were compared between SA and NDA groups. This allowed us to determine the extent to which NDA impacted performance across the Block Design, Symbol Search, Coding, and Cancelation subtests. This between-subtests design was utilized in order to avoid practice effect biases associated with repeated-measures designs.

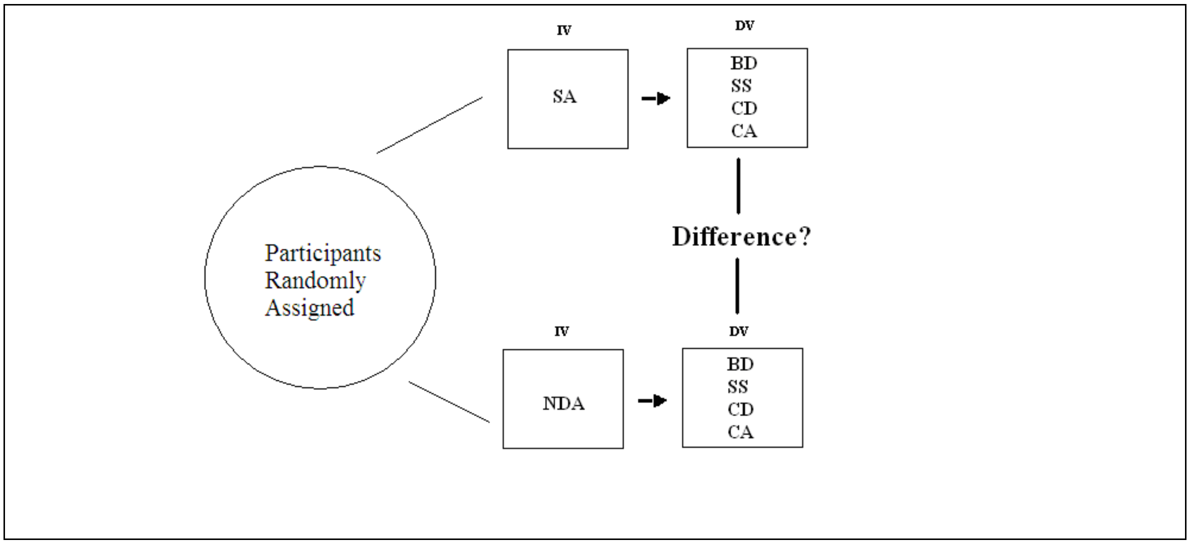

Figure 1. Between-subjects design

Results

Demographic variables and Barona estimated PIQ values were compared between SA and NDA groups in order to establish between group equivalence. The SA and NDA groups did not significantly differ on age, $t(56) = -1.70$, $p = .096$, years of education, $t(56) = .239$, $p = .812$, or Barona estimated PIQ, $t(56) = -.680$, $p = .499$.

T tests for independent samples (SA vs. NDA groups) were conducted for each of the four subtests for both raw and scaled scores. Sample size differences and inter-subject variance was low, thereby justifying use of pooled t tests, making comparisons more sensitive to changes in administration technique (Bordens & Abbott, 2005).

For the Block Design (BD) subtest, neither raw nor scaled scores were significantly different between SA and NDA groups, $t(56) = .812$, $p = .420$; $t(56) = .362$, $p = .718$. Mean scaled score was only 0.28 points lower for the NDA group as compared to the SA group.

For the Symbol Search (SS) subtest, both raw and scaled scores were significantly different between groups, $t(56) = 4.56$, $p < .001$; $t(56) = 4.29$, $p < .001$. The mean NDA scaled score was 3.24 points lower than mean SA scaled score for this subtest.

For the Coding (CD) subtest, both raw and scaled scores emerged as significantly different between groups, $t(56) = 4.40$, $p < .001$; $t(56) = 3.81$, $p < .001$. The NDA disadvantage was 3.03 Scaled Score points for the Coding Subtest.

For the Cancellation (CA) subtest, neither raw nor scaled scores were significantly different between groups, $t(56) = .844$, $p = .402$; $t(56) = .442$, $p = .661$. The mean NDA disadvantage was only 0.28 scaled score points for this subtest. Raw and scaled score comparisons across the 4 subtests are summarized in Table 4.

Table 4

Means, Standard Deviations, and t tests for SA and NDA groups for both raw and scaled scores across the four WAIS-IV subtests.

	SA		NDA			
Variables	M	SD	M	SD	t(56)	Sig. (2-tailed)
Block Design- raw	47.21	11.62	44.62	12.62	.812	.420
Block Design- Scaled Score	10.93	2.81	10.66	2.98	.362	.718
Symbol Search- raw	37.72	8.58	28.52	6.68	4.56	.000
Symbol Search- Scaled Score	11.86	3.17	8.62	2.56	4.29	.000
Coding- raw	79.66	15.96	60.41	17.34	4.40	.000
Coding- Scaled Score	11.59	2.92	8.55	3.13	3.81	.000
Cancellation- raw	37.17	9.57	35.41	5.86	.844	.402
Cancellation- Scaled Score	8.93	2.84	8.66	1.80	.442	.661

NDA correction factors were generated for each of the four subtests, for both raw and scaled scores. The task in creating a correction factor was to find a numerical constant that would convert an NDA score into its SA counterpart. For example, the mean SA scaled score for the Block Design subtest was 10.93 and the mean NDA scaled score for the Block Design subtest was 10.66. When the NDA score (10.66) is multiplied by 1.025, the product (10.9265) approximates the SA score. That numerical constant (1.025) is the correction factor for converting NDA Block Design scaled scores into expected SA Block Design scaled scores. Accordingly, 8 correction factors were derived in all (one scaled score correction factor and one raw score correction factor for each of the 4 subtests). The correction factors were calculated by subtracting the mean NDA score (scaled or raw) from the mean SA score, dividing the difference by the mean NDA score, and adding 1 to the quotient.

In certain clinical settings, actual NDA scores (scaled or raw) can be multiplied by the appropriate NDA correction factor to arrive at an expected SA score (scaled or raw). The corrected scores could be applied to the normative data to generate standardized scores (such as scaled scores, index scores, or IQ scores). The parameters within which the NDA correction factors may be justifiably used will be discussed below. The NDA correction factors for each of the examined subtests are listed in Table 5.

Table 5

NDA correction factors for four WAIS-IV subtests.

Subtest	Correction Factor- by scaled score	Correction Factor- by raw score
Block Design	1.025	1.058
Symbol Search	1.376	1.323
Coding	1.355	1.319
Cancellation	1.031	1.050

If a significant interaction effect existed between sex and administration (meaning if the extent to which administration method impacted scores differed between the sexes), then a singular correction factor could not be applied to both males and females. An Analysis of Variance (ANOVA) was therefore employed for each of the four subtests to determine the extent to which sex and administration may have differentially impacted subtest performance. The dependent variable was subtest scaled score and the independent variables were sex and administration. Although sex significantly impacted subtest performance for the Symbol Search, $F(1,54) = 4.692$, $p = 0.35$, Coding, $F(1,54) = 9.664$, $p = .003$, and Cancellation, $F(1,54) = 5.145$, $p = .027$ subtests, no significant sex by administration interaction effects were observed for the Block Design, $F(1,54) = .824$, $p = .368$, Symbol Search, $F(1,54) = 1.563$, $p = .217$, Coding, $F(1,54) = 3.429$, $p = .070$, or Cancellation subtests, $F(1,54) = .975$, $p = .328$. ANOVA scaled score comparisons across the 4 subtests are summarized in Tables 6 through 9.

Table 6

Two factor ANOVA for Block Design scaled scores.

Source	SS	df	MS	F	P-value
Sex	.980	1	.980	.114	.736
Admin	3.485	1	3.485	.407	.526
Sex • Admin	7.055	1	7.055	.824	.368
Error	462.232	54	8.560		

Table 7

Two factor ANOVA for Symbol Search scaled scores.

Source	SS	df	MS	F	P-value
Sex	36.064	1	36.064	4.692	.035
Admin	157.801	1	157.801	20.531	.000
Sex • Admin	12.015	1	12.015	1.563	.217

Table 8

Two factor ANOVA for Coding scaled scores.

Source	SS	df	MS	F	P-value
Sex	73.714	1	73.714	9.664	.003
Admin	151.350	1	151.350	19.842	.000
Sex • Admin	26.155	1	26.155	3.429	.070
Error	411.890	54	7.628		

Table 9

Two factor ANOVA for Cancellation scaled scores.

Source	SS	df	MS	F	P-value
Sex	27.022	1	27.022	5.145	.027
Admin	2.515	1	2.515	.479	.492
Sex • Admin	5.119	1	5.119	.975	.328
Error	283.613	54	5.252		

Discussion

Non-dominant hand administration produced scores that were statistically comparable to standard administration conditions for the Block Design and Cancellation subtests. These findings are consistent with prior studies that have demonstrated that the Block Design subtest does not appear to be significantly altered by NDA (Briggs, 1960; Ryan & Tree, 2007). Prior studies did not investigate NDA difference for the Cancellation subtest, as this was a novel addition to the recently published WAIS-IV.

The current study also found that non-dominant hand administration indeed resulted in significant score reductions for the Coding and Symbol Search subtests, consistent with prior findings (Briggs, 1960; Ryan & Tree, 2007). The degree of NDA discrepancy, however, varied between studies. For example, for the Coding subtest, Briggs found a 3.20 scaled score point NDA disadvantage, Ryan and Tree found a 4.04 point NDA disadvantage, and the current study found a 3.03 point NDA disadvantage. Similarly, for the Symbol Search subtest, Ryan and Tree found a 1.62 scaled score point NDA disadvantage while the current study found an NDA scaled score point disadvantage of 3.24 (Briggs did not investigate the Symbol Search subtest since it was not included in the Wechsler battery at the time of his study). The revisions in subtest format between the studies (WAIS, WAIS-III, and WAIS-IV) may account for some of the variability in the degree of NDA disadvantage between studies.

Despite the relative consistency across the current and past findings, a parsimonious explanation for why certain subtests were more vulnerable to the effects of NDA than were others remains illusive. Ryan and Tree found that while the Symbol Search subtest was vulnerable to a mere 1.62 scaled score point NDA disadvantage, the Digit Symbol-Coding (i.e. Coding in the WAIS-IV) subtest was vulnerable to a much greater NDA effect, with a mean scaled score difference of 4.04 (2007). They asserted that the disparity in degree of NDA vulnerability was related to the degree to which motor skills constituted a significant component of the task. For example, while Symbol Search requires the examinee to make simple slash marks with a pencil, Digit-Symbol Coding requires the examinee to pencil-draw a series of novel geometric symbols. Under these conditions, a much greater NDA effect seems predictable. By extension, while Block Design, Object Assembly, and Picture Arrangement certainly require motor skills, other required skills such as visuospatial reasoning, pattern analysis, and part-to-whole recognition likely account for greater variance in task performance than do the tasks' simple motor components. Accordingly, inter-manual equivalence has been consistently demonstrated for those subtests.

However, this seemingly parsimonious explanation (i.e. NDA discrepancy depends on the relative degree of manual-motor demands) does not accurately predict the impact of NDA. For example, in the current study, although the Symbol Search and

Cancellation subtests both involve similar motor demands (creating pencil-drawn slash marks) and similar non-motor demands (speeded visual search and attention to visuospatial detail), a significant NDA effect was not observed for Cancellation yet was observed for Symbol Search. It is possible that the short administration time of the Cancellation tasks (45 second intervals) verses the relatively long administration time of the Symbol Search task (120 seconds) accounts for the discrepancy (i.e. if the administration time of the Cancellation subtest was longer, perhaps a significant NDA effect would emerge).

However, even this less parsimonious explanation (i.e. degree of manual-motor skill involvement plus administration time) still fails to account for all inter-manual discrepancies observed on Wechsler tasks. For instance, both Ryan and Tree (2007) and Briggs (1960) found that mean non-dominant hand performance was higher than mean dominant hand performance for the Object Assembly subtest! Accordingly, it is likely that performance scores reflect the convergence and interaction of multiple factors which may include task demands, hand utilization, and functional specialization of the cerebral hemispheres (Ryan and Tree, 2007), thus making predictions or even explanations of NDA discrepancies premature until a more thorough understanding of these factors is achieved.

The current findings were used to generate correction factors for each of the WAIS-IV subtests that involve salient manual-motor components. For a clinical situation in which NDA is called for, the NDA raw or scaled score can be multiplied by the appropriate correction factor in order to arrive at an expected SA raw score or scaled score. The expected SA raw or scaled score can then be applied to the normative data in order to derive standardized scores (scaled scores, index scores, and IQ scores). Because there is evidence that inter-manual discrepancies interact with hand dominance (see Judge & Stirling, 2003; Steenhuis & Bryden, 1999), the correction factor value will likely depend upon hand dominance. Accordingly, separate NDA correction factors should be derived based on hand dominance. Since only right-hand dominant individuals were included in this preliminary study, the proposed correction factors cannot be justifiably applied to left-hand dominant individuals. Determining the extent to which NDA impacts task performance among left-handers (and the generation of left-hand dominant NDA correction factors) remains for future research.

The current study attempted to correct for the effects of NDA by comparing SA performance with NDA performance among 58 non-impaired individuals. The clinical validity of the current findings, however, is contingent upon the degree to which the NDA performance of the sample (i.e. individuals without neuromotor impairment) approximates clinical NDA performance (i.e. NDA performance among individuals with dysmobility of the dominant-hand).

Indeed, there is reason to suspect that as more time elapses since onset of dysmobility, the less the NDA performance of the sample will reflect clinical NDA performance. For example, it has been demonstrated that while non-impaired individuals exhibit 19% more activity in their dominant arm than in their non-dominant arm, stroke survivors exhibit 300-600% more activity in their unaffected arm as compared to their affected arm (Vega-Gonzales & Granat, 2005). In other words, following impaired use of one arm, an individual will demonstrate a pronounced overuse of the unaffected arm, irrespective of premorbid hand dominance. It seems likely that this pronounced overuse would lead to improvement in motor efficiency over time. It also seems likely that the contrast between premorbid and post-injury arm efficiency would be most pronounced when the overused arm is the pre-morbidly non-dominant extremity (e.g. a previously non-dominant left hand presently called upon to function as a primary hand). Under such circumstances, the NDA performance of an individual who has been using (i.e. overusing) his or her unaffected arm for a year would likely exceed the NDA performance of a non-impaired individual who is ill-practiced at using his or her non-dominant hand. If such a practice effect indeed follows prolonged over-use, the current correction score (which corrects for non-overused NDA performance) would not be valid for an individual with long-standing dysmobility of the dominant hand and associated overuse of the non-dominant hand. Under such circumstances, the currently proposed correction factors would overcorrect for NDA differences and thereby generate inflated scores. In light of this possibility, the clinical use of the correction factors should be limited to recently injured individuals. While this is a limitation in the applicability of the findings, newly injured patients do reflect a large portion of those who present for clinical evaluation.

Another limitation to the applicability of the findings is the fact that the degree to which a raw score correction factor will change the scaled score varies across age groups. For example, the raw score correction factor for the Symbol Search subtest is 1.323. For a 16 year old, an NDA raw score of 35 (scaled score = 10) would be corrected to 46.305 (scaled score = 15). Therefore, at age 16, the correction results in a 5 scaled score point change. For a 45 year old, an NDA raw score of 31 (scaled score = 10) would correct to 41.013 (scaled score = 14), resulting in a change of 4 scaled score points. At age 75, an

NDA raw score of 22 would become 29.106, resulting in a 3 point scaled score change and at age 85, a raw score of 16 would become 21.168, resulting in a 2 point scaled score change. For this reason, the scaled score correction factor offers a more robust correction than does the raw score correction factor since the degree to which the scaled score correction factor changes the scaled score is consistent across age groups. For example, for the Symbol Search subtest (scaled score correction factor = 1.376), a scaled score of 10 will always be corrected to a scaled score of 13.76 (a 3.76 scaled score point change) irrespective of age group.

Although there is justification for clinical use of the currently proposed correction factors (for recently injured formerly right-hand dominant individuals), more research is needed to establish the degree to which the corrected subtest scores accurately reflect the neuropsychological domain targeted by that subtest. Indeed, the *Standards* recommend that the process of modifying a test in consideration of disability should involve piloting the task on individuals with similar disabilities (American Educational Research Association et al., 1999). This is a sound recommendation and points to a logical next step towards the goal of establishing the validity of the NDA correction. For example, NDA corrected Symbol Search and Coding subtest scores could be used to generate a Processing Speed Index (PSI) score; however the extent to which an NDA corrected PSI score correlates to other well established measures of speed of mental processing remains unknown. Future research could examine the degree to which an NDA corrected PSI score correlates with other tasks that involve significant processing speed demands without manual-motor involvement. For example, the Paced Auditory Serial Addition Test (PASAT) and the Stroop tests have been shown to be sensitive to cognitive slowing and do not require manual-motor movement (Lezak, et al. 2004). Other tasks such as the Symbol Digit Modalities Test (SDMT) oral administration and the WMS-III Mental Control subtest also require rapid mental processing and are free of manual-motor demands (Spreen & Strauss, 1998; Wechsler, 1997). Strong correlations between such measures and the NDA corrected PSI would demonstrate the concurrent validity of the currently proposed correction.

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