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Intelligence Testing For Persons With Visual Impairments: Haptic Matrices Intelligence Assessment

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INTELLIGENCE TESTING FOR PERSONS WITH VISUAL IMPAIRMENTS:
HAPTIC MATRICES INTELLIGENCE ASSESSMENT

by

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This dissertation, submitted by Heather A. Pedersen in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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ABSTRACT

This study further examined internal consistency reliability and convergent-divergent validity of a three dimensional haptic matrix completion task as a measure of non-verbal intelligence for persons with low or no vision. Sixty-six UND undergraduates completed the prototype Haptic Matrices Intelligence Assessment (HMIA) and the Wechsler Adult Intelligence Scale 4th Edition (WAIS-IV), as well as several other tasks. Convergent validity was previously established for the HMIA with the Raven's Advanced Progressive Matrices. However, the HMIA was designed for use in clinical settings to complement or replace popular assessment tools that are inappropriate for use with visually-impaired examinees. Therefore, ecological validity was examined (via convergent validity) with an instrument more commonly used in clinical applications (e.g. the WAIS-IV). Utilizing the WAIS-IV allowed for more reliable estimates of criteria constructs and examination of the precise constructs underlying HMIA task performance. Additional tasks that related more directly to manual-motor components of HMIA performance were also used to examine the effects of haptic ability on test scores. The HMIA was found to assess non-verbal abstract reasoning abilities, haptic spatial performance, and working memory skills. Further research is warranted with individuals with visual impairments.

CHAPTER I

INTRODUCTION

Intelligence has been a controversial construct since it was first developed and rigorous theoretical debate continues regarding its nature and expression, as theories of cognitive abilities continue to evolve. The assessment of intelligence and cognitive functioning is also a developing field. One aspect of this field that has been neglected is availability of equitable testing for individuals with low, or no, vision. The purpose of this review and proposed research is to further the field with respect to fair assessment of intelligence for people with visual impairment. It will begin with a general overview of intelligence, followed by a review of the measures available for assessment of intelligence for the low vision population, which demonstrates the need for measures of non-verbal intelligence. The factors affecting intelligence testing will be addressed. Finally, research to date on a proposed measure of non-verbal intelligence will be reviewed, and a plan for further validation described.

Intelligence Defined

According to Sternberg (1997), intelligence was variously defined in a 1921 survey of scholars. Some of the more common elements were "higher level abilities," the ability to learn, and the ability to adapt to one's environment. In a 1986 survey, the common elements were "higher level abilities," culturally bound behaviors, and executive processes (Sternberg, 1997). Intelligence, as a *broad* construct, has been

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controversial (Fraser, 1995; Miele, 2002) and difficult to define (e.g., Gardner, 1985).

Discrete process-oriented definitions of "intelligent behavior" (Sternberg, 1997), often in

very specific contexts (e.g., Carpenter, Just, & Schell, 1990), are less controversial and

more readily operationalized, though their broad applicability is more limited. Notions of

"emotional intelligence" (Goleman, 1995) emphasize self-control and regulation of

behavior, and "social intelligence" (Greenspan & Shanker, 2004), embed academic

problem-solving in a larger context of competence (see also Gardner, 1985).

Theorists have devised various means of defining and conceptualizing

intelligence, and many, if not most, agree on the multi-faceted nature of intelligence (cf.

Herrnstein & Murray, 1994). Some theories are based upon hierarchical taxonomies,

others on information processing models. Hierarchical theories of intelligence (as

opposed to information processing models) will be discussed here, as they are the models

that often underlie the intelligence assessment batteries most widely utilized in clinical

practice (Camara, Nathan, & Puente, 2000; Watkins, Campbell, Nieberding, & Hallmark,

1995). The hierarchical Gf-Gc theory (Carroll, 1993; McGrew & Flanagan, 1998)

underlies the popular Woodcock Johnson Tests of Cognitive Abilities (WJ-III-COG;

Woodcock, McGrew, & Mather, 2001; cf. Woodcock, 1990). The theory behind the

Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997) is "implicitly

hierarchical" (Zachary, 1990, p.279), as is the model underlying the Stanford-Binet

Intelligence Scales (Sattler, 2001; Thorndike, Hagen, & Sattler, 1986). What is often

debated among those who have developed these theories is the presence of an

overarching functional construct that unifies one's intellectual abilities. One way to

examine intelligence theories is by dividing them into two general groups, those that are

based on the idea that intelligence is a unitary construct and those that were developed based on the idea that intelligence is multi-faceted.

Theories of intelligence

 "Few topics in psychology are as controversial as the question of the

continued utility of the construct of general intelligence and, in particular,

the notion of a global IQ" (Zachary, 1990, pp.286).

Intelligence as a unitary construct is supported psychometrically by the "positive manifold," the apparent positive correlation among all measures of cognitive abilities (Hunt, 1997). Charles Spearman is perhaps the most well known theorist to support this concept, and was the first to demonstrate it empirically (Hunt, 1997). He developed a two-factor theory with *g* as the overarching intelligence factor and *s* representing the specific abilities of the individual (Spearman, 1927). *g* is composed of three distinct processes: introspection, "education of relations," and "education of correlates" (Horn & Noll, 1997). These three processes work together to form a functionally singular construct, which is a measure of the individual's overall cognitive abilities and essentially determines the extent to which that person can succeed. However, many theorists critiqued Spearman's *g*, based on later applications of factor analysis, which revealed a multi-faceted construct of intelligence (Carroll, 1997b; Fruchter, 1954). Horn & Cattell (1966; Horn, 1985) first identified two broad factors: "crystallized" (Gc) and "fluid" (Gf) intelligence, with a third factor, later identified loosely as "visualization" ability (McGrew & Flanagan, 1998). Increasingly sophisticated factor-analytic procedures led to the development of more complex hierarchical factor- models, with debates continuing

about the utility of or even presence of an overarching construct (i.e., "*g*"; cf. Reeve &

Hakel, 2002). Some have argued that *g* is merely a mathematical and statistical artifact

(Gould, 1996; Sternberg, Wagner, Williams, & Horvath, 1995) and is not a particularly

useful construct. This argument has not been widely supported (Carroll, 1997a; Jensen,

1980; Jensen & Weng, 1994). Others theorize that "multiple intelligences'" is a more

accurate and useful manner of examining an individual's intelligence.

Thurstone (1938), among others, developed a structural model of intelligence

composed of primary factors (or "multiple intelligences"), which were inductive

reasoning, deductive reasoning, practical problem solving, verbal comprehension,

associative short term memory, spatial relations, perceptual speed, numerical facility, and

word fluency (Horn & Noll, 1997). While Thurstone originally found no statistical

support for a general intelligence, others who reworked his data did find support (Carroll,

1997b). Eysenck (1979) determined that there is strong evidence for a hierarchical model

of intelligence that has a level for general cognitive ability, *g*, which varies between

individuals. For example, subtests of the Wechsler Adult Intelligence Scales, Fourth

Edition (WAIS-IV) positively inter-correlate and analytic models are most suggestive of

a single underlying factor, presumably *g*. However, when factors are allowed to correlate,

(i.e., nonorthogonal rotation), a four-factor model emerges (Sattler, 2009).

A hierarchical theory was developed from these primary abilities in which there

was a level of general intelligence, however when this general factor was removed, the

abilities could be divided into two main factors, labeled verbal-educational and spatial-

practical-mechanical (Eysenck, 1979; Sattler, 2001). This division was commonly seen

and used in intelligence testing, specifically in the Wechsler's system of intelligence

testing were labeled Verbal and Performance (Wechsler, 1997). The hierarchy in WAIS-III did make the distinction between Verbal and Performance IQ (VIQ and PIQ, respectively); both were measured and utilized to provide a rounded and accurate assessment of the individual's intelligence. However, the performance-verbal distinction was eliminated in the third revisions of two Wechsler tests (Wechsler Intelligence Scale for Children, 4th Edition; Wechsler, 2003; Wechsler Adult Intelligence Scale, 4th Edition, Wechsler, 2008). While the labels of PIQ and VIQ are removed from the test, both factors will likely be calculated by clinicians with a more traditional mindset, given the history of VIQ and PIQ interpretation (e.g., Kaufman, 1990). Even with the removal of the VIQ and PIQ labels, intelligence assessment batteries have not ceased to examine both verbal and non-verbal aspects of intelligence. It is still recognized as essential to examine a wide variety of cognitive abilities to most accurately assess the array of abilities comprising intelligence. The current edition of the WAIS (i.e. WAIS-IV) reflects the finer-grained analysis within verbal and nonverbal domains that is now preferred by test-developers and clinicians. For example, with respect to Wechsler scales, verbally-mediated subtests that previously comprised the VIQ factor are now grouped into two separate factor ("Index") scores, reflecting working memory and higher-order conceptual verbal reasoning. Likewise, nonverbal (visual) subtests that previously comprised the PIQ factor are now grouped into two separate factors reflecting visual-motor decision speed and nonverbal reasoning. A more detailed description of these factors and their constituents are provided later in this document. Interestingly, a new bifurcation has appeared in the most recent WAIS, with one factor representing *both* verbal and visual problem-solving ability, and the other representing "automaticity"

(working memory and processing speed) across verbal and nonverbal domains (Wechsler, 2008). However, this higher-order structure appears purely heuristic, as it lacks factor analytic support (Sattler, 2009).

The commonly described "Gf-Gc" or "CHC" theory (Horn & Noll, 1997; McGrew & Flanagan, 1998) encompasses both the unitary and multi-dimensional constructs of intelligence. The theory was developed to "replace, expand, or supplement previous theories of the structure of cognitive abilities, such as Thurstone's (1938) theory of primary mental abilities" (Carroll, 2005, p. 71). The theory proposes a three-stratum model. Stratum III represents general intelligence (*g*), Stratum II represents broad abilities (a factor grouping of Thurstone's primary mental abilities), and Stratum I represents narrow abilities (Carroll, 2005). Horn & Noll (1997) reported that the broad abilities were grouped into nine general factors. Fluid reasoning (Gf) was a measure of reasoning in novel situations. Acculturation knowledge or crystallized knowledge (Gc) was a measure of the individual's general knowledge base. Short term memory (Gsm) measured the ability to gather and keep information available for short periods of time. Long term memory (Glr) was a measure of the individual's ability to consolidate and retrieve information at a later time. Visual processing (Gv) and auditory processing (Ga) measured the ability to process visual and auditory stimuli respectively. Processing speed (Gs) and correct decision speed (CDS) measured the individual's ability to process information quickly. Quantitative knowledge (Gq) measures the ability to understand and apply numerical concepts. Stratum I abilities are those specific abilities necessary for success with Stratum II abilities. For example, visualization skills are an important set of abilities that contribute to visual processing (Gv).

Sternberg (1997) states that one needs to be cautious when attempting to define intelligence. A distinction should be made between intelligence, intelligent behavior, and tested intelligence. He suggests that intelligence has "a common core of mental processes that manifests itself behaviorally in different ways in different contexts" (p. 1031). Another way of viewing these distinctions is that intelligent behavior is rooted in a certain minimal amount of intelligence (Zachary, 1990, p. 278). Intelligence testing is an attempt to measure intelligence through the observation of various behaviors. Although the information is imperfect, it is nonetheless useful.

As stated previously, intelligence psychometrics is based primarily on the hierarchical models of intelligence, as opposed to the information processing theories (e.g., Sternberg, 1977). Tests were originally developed from these theories for placement purposes: to place children in the "correct" learning environment, to place Army recruits in the appropriate position, and so forth. Today, intelligence tests are used for a variety of purposes, however, more and more they are being used for assessment purposes to determine "better uses of intact functions, as well as rehabilitating or bypassing impaired functions" (Matarazzo, 1992, p. 1007), i.e., in neuropsychological applications (Lezak, 1995).

Measures of Intelligence for Individuals with Visual Impairments

"Intelligence tests are simply samples of behaviors. For the reason it is wrong to speak of a person's IQ. Instead, we can refer only to a person's IQ on a specific test. . . Because the behavior samples are different for different tests, one must always ask, "IQ on what test?" (Salvia & Ysseldyke, 1988).

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Different tests measure different, though related, abilities or constructs. That is why knowledge of the test being used is crucial to the interpretation of intelligence test data. There are several widely used intelligence batteries that assess an individual's overall intelligence, one such battery is the current Woodcock-Johnson Tests of Cognitive Abilities (WJ-III-COG; Woodcock, et al., 2001). The WJ-III-COG is based on the Gf-Gc model; subtests measure seven of the nine factors (the two remaining factors, quantitative abilities and correct decision speed, are not measured with this battery). Subtests load onto each of the seven measured Stratum II abilities and the Stratum II abilities are combined to obtain an estimate of general intelligence. Factor analysis has supported the use of this intelligence battery (Woodcock, 1990), although this test of intelligence has not been used much, if at all, with individuals with visual impairments (Bauman & Kropf, 1979; Miller & Skillman, 2003). In addition, the Stanford-Binet Intelligence Scales (Thorndike, et al., 1986) has been proven useful for measuring intelligence (Sattler, 2001), but it also is not widely utilized with individuals with visual impairments (cf. Bauman & Kropf, 1979; Miller & Skillman, 2003).

David Wechsler is considered one of the fathers of intelligence testing. His standardized assessments are based on the assumption that intelligence is a global mental capacity, much like Spearman's *g*, and that this global capacity was an "aggregate" of various abilities and skills, some of which may be significant strengths for an individual, while others may be relative weaknesses (Zachary, 1990).

The model of intelligence underlying the Wechsler intelligence tests is hierarchical, with the Full Scale IQ at the top of the hierarchy and the Index scores below them (Wechsler, 2008). The Verbal Comprehension and Perceptual Reasoning indices

are scores for intelligence mediated via verbal or non-verbal abilities, respectively. This theoretical model is supported by both factor analytic and criterion-related validity studies (Lichtenberger & Kaufman, 2009; Sattler, 2009).

Verbally-mediated intelligence

As noted previously, the labels of "VIQ" and "PIQ" have fallen out of use with the new edition of the WAIS. However, it is still an important distinction in that intelligence can and should be assessed via verbal and non-verbal means. The adaptation of intelligence tests for use with individuals with visual impairments has been to simply use the subtests of the Wechsler tests that do not require visual stimuli and disregard the subtests that do. The advantages of this system is that no adaptations are necessary for use (Anastasi, 1988; Coveny, 1976) and no significant differences were found between the scores of individuals with sight and those without (Vander Kolk, 1977a), except for Digit Span and Comprehension. Digit Span measures working memory and blind children were found to score higher on this subtest (see also Smits & Mommers, 1976). Comprehension measures incidental knowledge, such as social judgment and "culturally loaded knowledge" (Kaufman & Lichtenberger, 1999, p. 95). Blind children were found to score lower on the Comprehension subtest (Smits & Mommers, 1976). This may be due to item bias (Tillman, 1967), as blind children may not have the same exposure to information as sighted children. While the intelligence patterns assessed by verbal measures are different between sighted and blind individuals (Vander Kolk, 1987), the verbal measure itself has appeared to be a respected and useful tool among professionals (Groenveld & Jan, 1992; Miller, 1977; Smits & Mommers, 1976; Vander Kolk, 1977a),

and is commonly used to assess cognitive abilities of persons with visual impairments (Miller & Skillman, 2003).

The populations consisting of individuals with low-vision and or no-vision are heterogeneous, but despite that, Vander Kolk (1977a) found no significant differences in intelligence (as measured by the WAIS) based on congenital versus adventitious blindness, degree of vision, sex, or residential versus sighted school attendance. This finding is qualified in that it applied only to individuals scoring "above that of the general population" (p. 782). This indicates that new norms may not be necessary for that population, but the finding may not generalize to individuals scoring at or below the population mean. The Verbal scales are highly correlated with an individual's opportunities for previous learning (Bauman, 1975). This is particularly important because individuals who are visually impaired may not have benefited as much from traditional classroom teaching, due to their sensory deprivation (Nelson, Dial, & Joyce, 2002). Also, it has been noted that low-vision populations may develop language differently and/or at a different rate than sighted populations. One example of this idiosyncratic language development is "verbalism", reflecting an often literal or rote interpretation of word meaning (Dimcovic & Tobin, 1995; Vander Kolk, 1977b). Differential language development makes the reliance on verbal tests insufficient.

Sole reliance on a truncated version of a full battery of tests that are used to assess intelligence is inadequate and, arguably, unethical when attempting to measure the cognitive abilities of any individual. Factor analysis has shown that intelligence test performance for low-vision populations also loads onto two significant factors, verbal and performance intelligence (Daugherty & Moran, 1982; Miller, 1977). Federal law and

practice guidelines in both clinical and educational settings require the use of the most

fair and appropriate test available, irrespective of the examinee's demographic

characteristics (American Psychological Association, 1992; National Association of

School Psychologists, 1995; US Department of Education, 1995). It has been recognized

that relying only on one aspect of intelligence (such as sole use of the Verbal scale for

individuals with visual impairments or only the Performance scale for individuals who

did not speak English) is inadequate; research is needed to broaden the measures

available to clinicians so as to more fully assess the low-vision population (Goldman,

1970).

Nonverbally-mediated intelligence

The scales on Wechsler's tests were designed for individuals with no visual

impairments to assess non-verbal ability, namely visual-spatial and abstract reasoning, as

well as processing speed through the use of visual stimuli (Kaufman & Lichtenberger,

1999). Even if an individual retains some visual acuity, their performance on the vision-

based subtests is somewhat reduced (Groenveld & Jan, 1992) and it is difficult, if not

impossible, to determine if poor performance was due to lack of necessary visual acuity

or non-verbal ability (Reid, 1997).

The process of using the subtests administered verbally and some other

performance based test of intelligence for those with visual impairments is common

practice (Bauman & Kropf, 1979; Miller & Skillman, 2003; Reid, 1997) and thought to

be necessary to accurately assess persons with low vision (Dekker, Drenth, Zaal, &

Koole, 1990). Other tests have been created to fill in this "performance ability gap",

usually by adapting tests created for individuals with no visual impairments (Reid, 1997).

Assessment of non-verbal intelligence with low vision populations requires using

one's hands to obtain information haptically. "Haptics" refers to active touch, which is

an integration of passive tactile stimulation, active motor planning and behavior, and

spatial perception necessary to gain information through one's hands.   For example,

recognition of a Braille letter, pressed onto a stationary finger tip, does not require haptic

ability because motor activity is not involved. However, Braille *reading* is a haptic task,

as that requires recognition of tactile stimulation, motor planning, and spatial perception

(Miller, et al., 2007).

One of the first attempts at assessing non-verbal intelligence in the low vision

population was the Interim Hayes-Binet (Hayes, 1942; see also Gilbert & Rubin, 1965).

It was noted that the verbal scales of the WISC provided comparable results (Gilbert &

Rubin, 1965) and it was later superseded by Perkins-Binet Test of Intelligence.   The

Perkins-Binet was published in two forms, Form U, for use with individuals with some

residual vision, and Form N, for use with individuals with no usable vision. However,

the test was found to assess the same abilities that the WAIS verbal scales measure

(Coveny, 1976). Also, it had a long administration time, the manuals were incomplete

and unclear, it had poor psychometric properties (the SD was up to 2.46 times greater

then the WISC-R verbal intelligence standardization), and there was no technical data in

the manuals (Gutterman, Ward, & Genshaft, 1985).

The Intelligence Test for Visually Impaired Children (ITVIC) is a combination of twelve haptic and verbal subtests that are based on Thurstone's primary factors. This test was only standardized in Holland (Dekker, et al., 1990), and is currently not used by assessors in the U.S. (Miller & Skillman, 2003).

The Blind Learning Aptitude Test (BLAT) is a haptic measure available for use with children aged six through 16. It consists of line and dot patterns, embossed plastic pages, which the participant must resolve by selecting a missing element from a set of distracters, similar to Raven's Progressive Matrices (Raven, Raven, & Court, 1993). The BLAT was intended to measure the child's capacity for learning (Newland, 1979), not what the child has already learned (which is highly correlated with V-IQ), though it is highly correlated with educational achievement. It also appears to be culturally neutral (Newland, 1990). However, the BLAT is currently out of print (Miller, 2000).

The Haptic Intelligence Scale for Adult Blind (HISAB) is based on the Wechsler Performance scales (Dauterman, Shapiro, & Suinn, 1967; Reid, 1997) and contains six subtests: Digit Symbol, Object Assembly, Block Design, Object Completion, Pattern Board, and Bead Arithmetic (Coveny, 1976). Individuals with some residual vision are required to wear blacked out glasses and the manual provides one standardization table for both blind individuals and blindfolded partially sighted individuals (Dekker, Drenth, & Zaal, 1991). The HISAB has a long administration time, no normative data for individuals under the age of 16, is costly, and fairly cumbersome (Bauman, 1975). Also, it receives a mixed rating for usefulness from psychologists (Baunman & Kropf, 1979). The HISAB has long been out-of-print. Its norms, and many of its test stimuli, are

outdated. For example, one subtest requires that the examinee identify a part missing from, in two separate items, a rotary-dial telephone and a garter.

The D48 is a test comprised of tactile dominos with which the individual performs problems defined by progression rules. It was found to be difficult and stressful for subjects and was not recommended for use (Domino, 1968).

The (Stanford) Ohwaki-Kohs Block Design Test is based on the Kohs Block Design Test and required the test-taker to copy a previously presented series of blocks. In this test the colors on the blocks were replaced with fabric to distinguish textures (Suinn, 1966). However, it lacks psychometric data and it has low discrimination value among poor performers. It also has been found that the normal wear and tear of the blocks compromise the tactile textures (Suinn, Dauterman, & Shapiro, 1965). Psychologists had mixed ratings for usefulness for this test (Baunman & Kropf, 1979) and a common complaint is that it is overly reliant on a single skill, which is distinguishing and copying patterns (Bauman, 1975).

The Cognitive Test for the Blind (CTB; Dial, et al., 1990) is a series of tests, such as Spatial Analysis (in which the individual uses small shapes to create a larger shape) and Haptic Category Learning (in which the individual attempts to deduce rules governing correct responses to tactile stimuli). It is used to examine abstract reasoning skills (MacCluskie, Tunick, Dial, & Paul, 1998) and is reported to be culturally neutral and have better discrimination value for the visually impaired population (Nelson, et al., 2002). However, it is expensive and has a long administration time (Dial, et al., 1990).

Factors Affecting Intelligence Testing

As shown, there is an unmet need for measures of non-verbal intelligence for individuals with low vision. Sole reliance on verbal assessment measures is inadequate and potentially unethical. Current measures of non-verbal intelligence are out of print, cumbersome, costly, overly difficult or stress-inducing, or are simply inadequate measures. In general, professionals are not generally satisfied with current measures of intelligence for low vision populations (Miller & Skillman, 2003).

While current measures are inadequate, the development of a measure for non-verbal intelligence is a daunting task. There are a variety of factors that can affect psychological testing, especially performance intelligence testing. Physiological factors, such as differences in evoked action potentials and reaction times (Matarazzo, 1992) and personality factors (Wechsler, 1943) can influence intelligence scores. However, these factors are not specific to low vision populations. There are a variety of problems that one encounters when testing people with low vision that are not an issue with other examinees. These factors can be divided into two general categories: variables affecting non-verbal (performance) intelligence scores and personal variables unique to the individual and their specific visual-developmental history.

Variables affecting non-verbal intelligence

There are some variables that should be considered when testing the non-verbal intelligence of persons with low, or no, vision. Non-verbal scores can be altered in the low vision population by different abilities that may not be related to intelligence, such as visualization, spatial relations, and haptic discrimination.

Visualization refers to the individuals' ability to "picture" the stimuli in their mind. It has been demonstrated that the ability to visualize stimuli is "functionally equivalent" to perceiving stimuli (Cooper, 1995; Kosslyn, 1994; Podgomy & Shepard, 1978), suggesting that the ability to visualize may improve performance on tests of intelligence, specifically tasks that involve tactile forms (Davidson, Appelle, & Pezzmenti, 1981; Worchel, 1951) and spatial perception (Bigelow, 1991; Cratty, 1967; Potter, 1995; Worchel, 1951). Visualization is composed of two components, passive storage and active maintenance (Vecchi, Monticelli, & Cornoldi, 1995). The passive storage is directly related to short term and working memory. The active maintenance component of visualization has been demonstrated to be compromised in congenitally blinded individuals (Vecchi, et al., 1995).

Spatial abilities have been shown to be equivalent between low vision individuals and sighted individuals in small scale tasks (Birns, 1986; Klatzky, Colledge, Loomis, & Cicinelli, 1995), while large scale tasks (e.g., mapping tasks) are problematic for low vision individuals (Bigelow, 1991). Problems that occur in analyzing spatial relations can be minimized, if not abolished completely, by the ability to "check" the stimuli and assess accuracy (Hollins & Kelley, 1988).

Haptic discrimination refers to the ability to distinguish texture, size, shape, and / or configuration of various stimuli. Measures of haptic discrimination (e.g. Haptic Visual Discrimination Test; McCarron & Dial, 1976) are correlated with measures of cognitive function (McCarron & Horn, 1979). However, the ability to distinguish furry from rough, though critical for the expression of nonverbal intelligence, is not nonverbal

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intelligence per se. This fact requires any test of intelligence to be able to *further* assess

intelligence beyond that assessed by a haptic discrimination task.

<div align="center">*Personal variables*</div>

There are a number of variables that are unique to the individual that may

influence non-verbal intelligence testing. The following factors should be considered

when testing this population: origin of blindness, differential developmental timeframes,

age of onset, and time since impairment. The relationship between the causes of

blindness (e.g. disease, underdevelopment of some aspect of the visual system, etc.) and

intelligence has been little researched, so the effects of this particular variable is largely

unknown (Thinus-Blanc & Gaunet, 1997).

Sighted and blind individuals have been found to develop sensori-motor abilities

at differing rates. Blind individuals do not fully develop their spatial representational

abilities until age 17, while sighted individuals are fully developed by age 14 (Ochai'ta &

Huertas, 1993). This delay creates a situation in which there needs to be caution in

interpreting intelligence scores, especially performance based scores.

Age of onset is relevant as there seem to be developmental differences between

individuals born with no usable vision and those who are blinded adventitiously (i.e.,

after birth). Some evidence suggests that blind children outperform sighted children on

verbal memory measures, such as the Digit Span subtest on the WISC, and that

congenitally blind children outperform adventitiously blinded children (Hull & Mason,

1995; see also Smits & Mommers, 1976; Tillman & Bashaw, 1968). It has also been

found that congenitally blind individuals outperform adventitiously blinded individuals in

<div align="center">17</div>

spatial and visualization tasks (Birns, 1986), as well as in haptic discrimination tasks (Davidson, et al., 1981). However, Worchel (1951) found that adventitiously blinded individuals outperform congenitally blind individuals when applying visual imagery to spatial tasks. Research on visualization skills seem to indicate that there is a critical period in development in which the child can develop visuo-spatial skills; children who do not have the opportunity for that development fall behind their sighted counterparts or must rely on alternative cognitive abilities to solve spatial problems.

Time since impairment addresses the issue of whether adventitiously blinded individuals learn over time to adapt to their impairment and how this changes the expression of cognitive abilities (e.g. intelligence scores). There has been very little research into this variable. One obstacle is the fact that vision loss does not always occur instantaneously; it is often gradual and makes defining the exact onset of blindness difficult. Worchel (1951) found that the ability to visualize spatial relationships erodes as the time since impairment increases. Also, the advantage that congenitally blinded individuals have in haptic discrimination tasks (as noted above) diminishes as adventitiously blinded individuals received more exposure to the stimuli (Davidson, et al., 1981).

<center>Haptic Matrix Completion Tasks</center>

Haptic matrices, or "matrix completion tasks", are one manner in which the non-verbal intelligence gap could be bridged. Several tools of this type have been developed. The Tactile Test of Nonverbal Intelligence (TONI) is a matrix completion task in which the subject is asked to choose which design completes the pattern of designs on the page.

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It is a non-verbal test of cognitive ability that assesses problem solving and does not correlate significantly with tests of verbal ability. However, it has been noted that the stimuli can be too complex or fine to perceive. It also has a long administration time and may be too difficult for individuals with below normal intelligence (Duncan, Wiedel, Prickett, Vernon, & Hollingsworth-Hodges, 1989).

The Tactile Progressive Matrices (Anderson, 1964; Rich & Anderson, 1965) was an attempt to create a tactile version of the matrices tests (e.g., Raven's Progressive Matrices; Raven, et al., 1993). It was determined to be unsuitable for use with people with some residual vision (Dauterman, et al., 1967), had a long administration time (Duncan, et al., 1989), had poor concurrent validity, and was too unwieldy to be practical. It was also never in wide circulation, because it was too expensive to mass produce (Taylor & Ward, 1990).

Miller, et al. (2007) conducted a pilot test of a three dimensional haptic matrices and found that it correlated with convergent measures, such as the verbal subtests of the Wechsler Adult Intelligence Scales (WAIS-III; Wechsler, 1997) and the performance scales of the Cognitive Test for the Blind (CTB; Dial, et al., 1990). However, with 21 participants, the sample in the pilot study was not large enough to embody the range of demographic variables that are relevant to performance on cognitive tests. Further, pilot test items were developed intuitively, without empirically-verified principles guiding test construction.

Haptic Matrices Intelligence Assessment (HMIA)

Pedersen (2009) created a new set of matrices designed for haptic administration, the Haptic Matrices Intelligence Assessment (HMIA). This is an instrument patterned after the well-respected Raven's Progressive Matrices (Raven, Raven, & Court, 1998) and measures non-verbal or performance intelligence through a haptic, rather than visual, modality. Specifically, it measures inductive reasoning, a component of non-verbal intelligence, as it does not rely on declarative knowledge (Carpenter, et al., 1990).

Pedersen (2009) established the basic reliability and validity of the HMIA. Reliability was established with an acceptable level of internal consistency (Cronbach's alpha = .74; Cronbach, 1951). Both convergent and divergent validity were established, as measured with the Raven's Advanced Progressive Matrices (RAPM), Tactual Performance Test (TPT), and WAIS-III Vocabulary subtest. With respect to convergent validity, it was shown that haptic efficiency, as measured by the TPT, and non-verbal intelligence, as measured by the RAPM, were both significant predictors of HMIA scores. Importantly, the RAPM accounted for a significant portion of the variance *above and beyond* that accounted for by the TPT, suggesting that the correlation between HMIA and RAPM is more due to non-verbal intelligence than haptic efficiency. With respect to discriminant validity, HMIA performance was found to be more highly correlated with RAPM scores than with either WAIS-III Vocabulary or TPT scores, suggesting that the HMIA is more a measure of non-verbal intelligence than either verbal intelligence or haptic efficiency.

The RAPM has been found to be more culturally neutral than the Wechsler's performance scales (Groth-Marnat, 2003) and the HMIA was created based on the rules derived from the RAPM items. Because of this, the RAPM was used as a comparison to the HMIA in the first pilot study. However, the RAPM is not typically used in clinical settings, because, for several reasons, other instruments are favored by clinicians. Due to this, further research is necessary to firmly establish external and ecological (with respect to actual clinical practice) validity for the HMIA. In addition, the relationships found between scores on the HMIA and haptic processes were somewhat unusual. These relationships should be examined to more fully explain the constructs contributing to HMIA performance.

<center>Purpose of the Study</center>

The purpose of this research was to further pilot this measure of non-verbal intelligence for individuals with visual impairments, the HMIA. The hypotheses tested in this research were aimed at examining the external and ecological validity of the HMIA. This was done through correlations with other measures of cognitive ability (convergent and divergent concurrent validity). As noted previously, while the Raven's Advanced Progressive Matrices is often used in research, it is rarely used in a clinical setting as other instruments are typically favored. The HMIA was initially designed by the researcher for use in the clinical setting. The Wechsler scales are well-established and respected tools for assessing intelligence in clinical settings. The Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV; Wechsler, 2008) was used to more firmly establish external and ecological validity of the HMIA. In addition, the index scores provided more reliable estimates of criteria constructs. Correlational analyses with these

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subtests allowed for a more detailed examination of the constructs underlying task performance on the HMIA. Several additional tasks utilizing the HMIA were also administered to further examine the impact of haptic abilities or processes on HMIA performance.

CHAPTER II

METHODS

Participants

Based on power analyses (see below), at least 60 undergraduate students from the

University of North Dakota, Grand Forks were required. Seventy-one students

participated; however, data from four of these participants were not useable (e.g., the

participant had to leave the session early or the researcher was unable to finish the

protocol in the time allotted) and one participant's age fell outside of the age range

required (see below). This left data from sixty-six participants (18 male, 48 female) that

were included in the analyses (age $M = 19.39$, $SD = 1.69$; see table 1).

Table 1. *Descriptive Statistics*

	Mean (SD)		Mean (SD)
Age	19.39 (1.69)	FSIQ	103.48 (8.68)
Education	13.30 (1.12)	PRI	103.11 (11.52)
NFC	12.24 (17.89)	VCI	101.91 (9.57)
GEFT	11.12 (5.51)	WMI	100.85 (11.27)
HS	238.89 (46.71)	PSI	106.44 (10.89)
HSP	220.48 (106.68)	MR	10.44 (2.44)
HMIA	10.64 (3.18)		

Volunteers received extra credit in their undergraduate psychology classes. To be included in the study, participants needed both hands and arms intact with little or no loss of tactile sensitivity or manual-motor function, be able to understand spoken English, and be in the age range of 18 to 75 years (inclusive). It has been found that intelligence mediated by non-verbal abilities tends to decrease with age, while performance on verbally mediated intelligence tests is more stable over time (Kaufman & Lichtenberger, 1999). Primary correlational/regression analyses involved participants within an age range with relatively stable fluid intelligence (18 to 35). WAIS-IV standard scores are age-adjusted to account for population-wise changes in various abilities across the lifespan. In contrast, HMIA scores, lacking population norms, are not. Therefore, large age-related effects on abilities measured by both tests would likely confound estimates of linear relationship (regression or correlation) between the two. Thus, we intended to limit the possible age-related effects by limiting analysis to those participants in the more Gf-stable age range (18 to 35 years old).

Measures

Data was collected using one form and several measures: the Haptic Matrices Intelligence Assessment (HMIA, the experimental measure), the WAIS-IV (Wechsler, 2008), and several tasks that related more directly to manual-motor components of HMIA performance.

Informed Consent (Appendix A)

The Informed Consent Form contained information relevant to their involvement: an invitation to participate, identification of the institute and researcher's involved,

description of the study's purpose, statements regarding the voluntary nature of the study as well as compensation available for participation (e.g. extra credit in an undergraduate psychology class), description of the measures being used, and a list of possible risks and benefits involved in participating. The consent form was developed following guidelines published by UND's Institutional Review Board.

Demographic Questionnaire (Appendix B)

This questionnaire recorded participant's demographic information, such as age, gender, ethnicity, level of education, cognitive or tactile impairment, and other relevant information that may impair cognitive or attentional abilities (Heaton, Miller, Taylor, & Grant, 2004; Kaufman, 1990; Strauss, Sherman, & Spreen, 2006; Vander Kolk, 1977b).

Need for Cognition (NFC) Questionnaire (Appendix C)

This questionnaire assesses an individual's enjoyment of and tendency to engage in activities that require sustained mental effort (Cacioppo & Petty, 1982). It consists of 18 items which the participants will apply to themselves and rate using a Likert-scale of nine points ranging from Very Strong Agreement to Very Strong Disagreement (Cacioppo & Petty, 1984). In this study, it provided an estimate of the participant's motivation, as they were being asked to engage in problem solving requiring sustained mental effort.

Group Embedded Figures Test (GEFT)

Field independence and field dependence refer to the extent to which an individual perceives the parts that make up the whole picture (field independence) or

perceives the whole pictures without the specific parts (field dependence; Witkin, Moore, Goodenough, & Cox, 1977). These concepts are related to an individual's problem-solving style. A person who is field independent tends to approach a problem in an analytical, step-by-step fashion. An individual who is field dependent tends to view a problem as a unified gestalt, and may have difficulty ignoring stimulus configuration when trying to attend to details. The Group Embedded Figures Test (GEFT) is one method to assess whether an individual approaches problems in a more field independent or field dependent manner (Oltman, Raskin, & Witkin, 1971). It consists of 25 items in which the individual is asked to find a target shape within a larger, more complex, image.

Haptic Matrices Intelligence Assessment (HMIA)

This is the experimental measure. The HMIA itself consists of an 11" x 11" board with nine vertical pegs arranged in a 3x3 pattern. Eight different block types, defined by (a) round vs. square *shape*, (b) large vs. small *size*, and (c) "flat" vs. "3-D" *dimension*, are stacked on the vertical posts to create the haptic patterns. It has been found that circles and squares (translated three dimensionally into spheres, cubes, and "flattened" spheres and cubes) are among the easiest shapes to discriminate (Witkin, Oltman, Chase, & Friedman, 1971). This makes these shapes ideal for use in the HMIA. The matrices for the instrument is based on the five types of rules derived from the Raven's matrices (see Table 2; Pedersen, 2009): constant in a row, quantitative pairwise progression, figure addition or subtraction, distribution of three values, and distribution of two values (Carpenter, et al., 1990). These rules were applied to the three categories of figures within the HMIA (size, shape, and dimension), of which there are two values (big / small, circles / squares, and flat / three dimensional). The only rule not used from Carpenter, et

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al.'s (1990) rule taxonomy was distribution of three values, as the categories in the HMIA only have two values. Also, because there are three categories to which each rule can apply (size, shape, and dimension), some items on the HMIA contain more than one rule. Twenty-eight items were developed with the taxonomy of rules, eight of which were dropped because they were deemed too difficult, leaving 20 items for the HMIA (see Table 3).

It has been found that as a problem becomes more complex greater effort is required to solve the item, as it places more demands on the individuals' working memory to track goals and subgoals en route to a solution (Carpenter, et al., 1990). As in the Raven's Progressive Matrices, this progression also assesses "intellectual efficiency" (Mills, et al., 1993). In a similar manner, the 3 x 3 matrices in the HMIA were developed progressively. As the participant solves more items, they become successively more difficult as more rules are added to each matrix. To solve each item, the participant determined the correct type and order of the beads to occupy the bare post in the matrix.

Table 2. *A Taxonomy of Rules [1] in the Raven Test as Exemplified by HMIA Items*
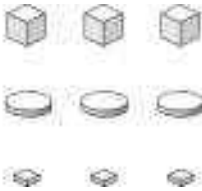
Rule [1]	Description [1]	Example HMIA Item	HMIA Rule
Constant in a Row	The same value occurs throughout a row, but changes down a column…		"Same" Rule; All attributes are constant in a row: *SAME (Size) x SAME (Shape) x SAME (Dim)*

Table 2 cont.

Distribution of two values	Two values from a categorical attribute are distributed though a row; the third value is null…		"2/3" Rule; Here, the Dimension attribute (two flat, one 3D) varies within rows: *SAME (Size) x SAME (Shape) x 2/3 (Dimension)*
Distribution of three values	Three values from a categorical attribute (such as figure type) are distributed through a row…	No HMIA Example [2]	Only two values are utilized for each category in the HMIA
Quantitative Pairwise Progression	A quantitative increment or decrement occurs between adjacent entries in an attribute such as size, position, or number…		Progression Rule: *Number of blocks decreases across each row.*
Figure Addition or Subtraction	A figure from one column is added to … or subtracted from another figure to produce the third…		Additive Rule *Elements in rows/columns add together to yield the far right (row) or bottom (column) post*

[1] Taken from Carpenter, Shell, & Just, 1990

[2] This rule could not be applied to the HMIA, because each attribute (Shape, Size, Dimension) has only two alternatives (round vs. square, large vs. small, flat vs. 3D)

Table 3. *Haptic Matrices Intelligence Assessment (HMIA)*

	HMIA Matrices	HMIA Rule	Carpenter, et al. (1990) Rule
1		SAME (Size) x SAME (Shape) x SAME (Dimension)	Constant in a row (size, shape, and dimension)
2		SAME (Size) x SYM (Shape) x SYM (Dimension)	Constant in a row (size) Distribution of two values (shape and dimension)
3		Additive Rule *Two of the elements in a row/column are combined to yield the third (all rows/columns add to six)*	Figure addition or subtraction

Table 3 cont.

4		Progression Rule	Quantitative pairwise progression
5		Additive Rule *Two of the elements in a row/column are combined to yield the third* w/ Additional Rule: 1. *large or round always in the middle vertically*	Figure addition or subtraction
6		Progression Rule	Quantitative pairwaise progression

Table 3 cont.

7		SAME (Size) x SAME (Shape) x 2/3 (Dimension)	Constant in a row (shape and size) Distribution of two values (dimension)
8		Progression Rule	Quantitative pairwise progression
9		SAME (Size) x SAME (Shape) x SYM (Dimension)	Constant in a row (size and dimension) Distribution of two values (shape)

Table 3 cont.

10		Progression Rule	Quantitative pairwise progression
11		Additive Rule *Two of the elements in a row/column are combined to yield the third* w/ Additional Rule: 　1. *Shape, Size, & Dimension all SAME*	Figure addition or subtraction
12		Additive Rule *Two of the elements in a row/column are combined to yield the third* w/ Additional Rule: 　1. *Small or round always on top*	Figure addition or subtraction

Table 3 cont.

13		Additive Rule *Two of the elements in a row/column are combined to yield the third* w/ Additional Rule: *1. Small ball always on top*	Figure addition or subtraction
14		Additive Rule *Elements in rows/columns add together to yield the far right (row) or bottom (column) post First (far left / top) element stacks on top of second to yield third (far right / bottom)*	Figure addition or subtration
15		SAME (Size) x 2/3 (Shape) x 2/3 (Dimension)	Constant in a row (dimension) Distribution of two values (shape and size)

Table 3 cont.

16		SYM (Size) x 2/3 (Shape) x 2/3 (Dimension)	Distribution of two values (shape, size, and dimension)
17		Progression Rule	Quantitative pairwise progression
18		Additive Rule *Elements in rows/columns add together to yield the far right (row) or bottom (column) post* *Square always on top*	Figure addition or subtraction

Table 3 cont.

19			SAME (Size) x SYM (Shape) x 2/3 (Dimension)	Constant in a row (size) Distribution of two values (shape and dimension)
20			Additive Rule *Down columns or across rows, post on the bottom or far right has a cube in one of four vertical Positions if a cube appears in that position on a post above (columns) or to the left (rows)*	Figure addition or subtraction

Two strategies can be used to solve the matrices in both the Raven's and the

HMIA (Miller et al., 2007): a verbal / analytical / sequential approach (i.e. field

independent approach) or a visual / simultaneous approach (i.e. field dependent

approach). The first approach is one in which the individual elements of the matrix are

compared to find the pattern, in other words, the pattern is deconstructed to assess the

change in individual elements or their components, then combined to find a solution. The

second approach takes in the matrix as a whole to deduct which is the missing piece,

much like a gestalt (Miller, 2000; Sattler, 2001). However, more visualization skill (i.e.,

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mental imagery) may be necessary on the tactile version of the matrices than on the Raven's, as the individual must visualize the pattern either piece by piece (for the verbal / analytical / sequential approach) or as a whole (for the visual / simultaneous approach). Miller, et al. (2007) found that individuals who processed haptic matrix boards in a simultaneous "visual" fashion (that is, they "pictured" the board in their mind) performed better then those who utilized the sequential approach. As previously stated, there are two components of visualization necessary for these haptic tasks, passive storage and active maintenance. Passive storage has been shown to be equivalent for sighted and low vision individuals (Hull & Mason, 1995), while active maintenance is compromised in congenitally blind individuals (Vecchi, et al. 1995). This may necessitate norm corrected scores for this population; however, that is beyond the scope of the current research.

Haptic efficiency tasks

In addition to the prototype items, the HMIA materials were used to examine the impact of haptic efficiency on test performance. Two aspects of haptic efficiency were measured: haptic speed and haptic-spatial performance. Haptic speed refers to the simple, rapid, placement of blocks, with little demand for spatial perception or memory. Haptic-spatial performance refers to the rapid placement of blocks, where spatial information must be processed, stored in short-term memory, and used effectively Thus, two successive levels of haptic efficiency were assessed.

To measure simple haptic speed (HS), examinees placed blocks on each of the nine pegs as quickly as possible. The examinee was required to do this eight times, once with each block type, and the presentation order of the various block types were

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randomized to account for learning effects. The time required to complete each of the eight haptic speed tasks was combined into a composite score of haptic speed for use in statistical analysis, i.e., to partial out haptic speed from the relationship between HMIA and WAIS-IV scores.

Haptic spatial performance (HSP) was also assessed utilizing the HMIA materials. This was done by placing one of each of the eight different blocks onto eight predetermined pegs in an apparently random arrangement. The participant then placed one identical block on each of the blocks as quickly as possible (i.e., matching blocks by type and location on the board). This was repeated four times. The time required to complete each of the four trials was combined into a composite score of haptic spatial performance for use in statistical analyses, i.e., partialing more complex haptic-spatial ability from the relationship between HMIA and WAIS-IV scores. The degree of co-linearity between HS and HSP was used to determine whether one or both would be used to statistically control for haptic efficiency in these analyses.

Wechsler Adult Intelligence Scales, Fourth Edition (WAIS-IV)

The WAIS-IV (Wechsler, 2008), as mentioned previously, is based upon a hierarchical model of intelligence in which the full scale IQ (FSIQ) is the score considered to be most representative of general intelligence. Abilities represented by the FSIQ may be decomposed into four indices: Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and Processing Speed Index (PSI). Each index score is created by summing the scaled scores of specific subtests. There are ten core subtests with an additional five supplementary subtests that

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are combined to create each index score. While the PIQ and VIQ distinction was dropped from the WAIS hierarchy with the fourth edition of the test, the procedure of measuring more than one aspect of intelligence to ascertain one's general ability level is still intact. The PRI and VCI are the two indices that most closely match the original constructs of PIQ and VIQ, respectively. The PRI is a measure of non-verbal, or performance, intelligence. Specifically, it assesses "perceptual and fluid reasoning, spatial processing, and visual-motor integration" (p. 128; Wechsler, 2008). In comparison to the WAIS-III Perceptual Organization Index (which is the index score equivalent to the PRI), visual attention has been de-emphasized, making non-verbal reasoning a more prominent construct within the PRI (Wechsler, 2008). The PRI is the index score most closely related to the constructs underlying the experimental measure, the HMIA. It is composed of three core subtests (Matrix Reasoning, Visual Puzzles, and Block Design) and two supplementary subtests (Figure Weights and Picture Completion).

Matrix Reasoning (MR) assesses inductive-deductive reasoning, an aspect of non-verbal abstract reasoning, and higher-order thinking more generally (Carroll, 1993). It involves classification and visual spatial abilities, knowledge of part-whole relationships, simultaneous processing and perceptual organization. In this test, the examinee selects the correct response out of five options that best completes the matrix, or pattern series. Matrix Reasoning is the subtest in which the examinee is asked to solve puzzles in much the same manner as in the HMIA; s/he must induce a general rule, or set of rules, by comparing and contrasting exemplars of the rule(s), and must then deduce the missing element by applying the rule(s) induced. Therefore, it is this subtest that theoretically assesses the constructs underlying the HMIA. However, they are not an exact match in

task demands. When solving items in this subtest, the examinee can rely on either deductive or inductive reasoning, that is, the examinee can use the possible answers to solve the pattern (deductive reasoning) or they can solve the pattern without the possible answers provided for each item (inductive reasoning). The HMIA relies on inductive reasoning alone, as no possible answers are provided for the examinee to utilize in solving the item. That is, the MR subtest provides aids to deduction by way of a set of possible solutions, while the HMIA does not. The extent to which examinees use either deductive or inductive reasoning to solve the items on MR may determine the strength of the relationship between this subtest and the HMIA. If examinees' primarily use inductive reasoning when solving the items, as opposed to deductive reasoning, the relationship between the two tests will be stronger. Similarly, the extent to which individual subtest items *demand* inductive versus deductive thinking may predict the degree of relationship with other items, either on the MR subtest or the HMIA.

Visual Puzzles (VP) also assesses deductive reasoning, as well as visual spatial abilities and organization, that is, the ability to "anticipate relationships among parts" (p. 14; Wechsler, 2008). The examinee is required to select the three correct responses out of six options that, when assembled, would recreate the stimuli puzzle. Block Design (BD) assesses concept formation, an aspect of non-verbal reasoning. It involves visual perception and organization in addition to constructional abilities. The examinee is asked to re-create red and white designs utilizing blocks. Figure Weights (FW) assesses quantitative and analogical reasoning. The examinee views several scales, one of which is unbalanced. The individual uses the information gathered from the balanced scale to select the response option that would balance the unbalanced scale. The last subtest

assessing PRI constructs is Picture Completion (PC). It assesses visual perception and organization, as well as recognition of essential details. The examinee views pictures in which there is an important piece missing and is asked to identify the missing piece.

The remaining three indices, the VCI, WMI, and PSI, are expected to be related to HMIA performance because of the "positive manifold," the apparent positive correlation among all measures of cognitive abilities (Hunt, 1997), although they are expected to be correlated to a lesser degree. The VCI is a general measure of verbal intelligence and language abilities. It is composed of three core subtests (Similarities, Vocabulary, and Information) and one supplementary subtest (Comprehension). The Similarities subtest taps into verbal concept formation and reasoning. It requires the examinee to describe how two common objects or ideas are alike. The Vocabulary subtest assesses verbal concept formation also, as well as word knowledge. Information is designed to measure general factual knowledge and consists of the examinee answering questions about a large range of topics. Finally, in the Comprehension subtest, the examinee also answers questions about a range of topics related to social principals and norms. It assesses verbal reasoning and conceptualization.

The WMI is a measure of one's ability to capture and hold information in short term memory while performing mental manipulations on the information. It is composed of two core subtests (Digit Span and Arithmetic) and one supplementary subtest (Letter-Number Sequencing). Digit Span assesses rote memory and working memory. In the rote memory task the examinee recalls a sequence of numbers (Digit Span Forward). In the two working memory tasks the examinee manipulates the sequence of numbers and recalls them in reverse order (Digit Span Backwards) and in sequential order (Digit Span

Sequencing). In the Arithmetic subtest, the examinee mentally solves a series of arithmetic word problems within a limited time frame. Letter-Number Sequencing is much like Digit Span Sequencing, in that the examinee manipulates a sequence of numbers and letters, and then recalls them, separately, in sequential order.

Finally, the PSI is a measure of how quickly one can scan, sequence, or discriminate visual information. These tests assess processing speed as well as short-term visual memory, visual discrimination, and psychomotor speed. It is composed of two core subtests (Symbol Search and Coding) and one supplementary subtest (Cancellation). The Symbol Search subtest requires the examinee to scan target shapes and determine if a target shape is in a group of searched symbols. Coding requires the examinee to copy symbols that are paired with numbers. In the Cancellation subtest the examinee crosses out predetermined shapes from a group of distracter shapes.

Procedures

Adult (18 to 75 years old, inclusive) participants were solicited through SONA, an online sign-up program for research being conducted through the Psychology department at the University of North Dakota. Volunteers signed up for designated time slots, with each session lasting up to three hours. When the experimenter and participant met, the participant was asked to (a) give their informed consent, (b) complete the Questionnaire Packet (i.e. the Demographic and Need for Cognition [NFC] questionnaires; Appendices B and C, respectively), (c) complete the Group Embedded Figures Test [GEFT], (d) complete the HMIA haptic efficiency and prototype items, and (e) complete the WAIS-IV.

The Informed Consent (Appendix A) was summarized for the participant, per the Informed Consent Script in the Procedures (Appendix D). A printed copy of the Informed Consent was given to the participant to read and any questions he or she had were answered by the experimenter. The participant was asked to sign the Consent Form, which was witnessed by the experimenter. An unsigned copy of the Informed Consent form was made available to the participant for their records if they chose.

Following the informed consent procedure, the participant was asked to fill out the Demographic and Need for Cognition (NFC) questionnaires. The Questionnaires Script in the Procedures was used for these administrations. Next, the Group Embedded Figures Test (GEFT) was administered per the standardized administration instructions provided in the manual (Oltman, Raskin, & Witkin, 1971). Any questions were addressed by the experimenter.

The HMIA (tasks assessing both haptic speed and haptic spatial performance, as well as the prototype) and the WAIS-IV were administered in counterbalanced order to minimize possible learning and fatigue effects (i.e., odd participation codes received the HMIA tasks then the WAIS-IV, while even participation codes received the WAIS-IV then the HMIA tasks). The WAIS-IV was administered per guidelines in the administration and scoring manual (Wechsler, 2008). Each task utilizing the HMIA was introduced per their respective scripts in the Procedures. Each script gave a brief overview of the task, instructions for completion of the items, and allowed the participant to ask any questions necessary to clarify the instructions. Answers and times for each test were recorded by the experimenter on the appropriate protocol form.

The tasks involving the HMIA were administered using a type of "puppet screen"; that is the participant worked through a curtain that blocks visual access. Prior to administration, the experimenter verified that the participant was comfortable with their hands being guided by the experimenter when necessary. The experimenter then followed the scripts outlined in the Procedures. Following the administration of the final test, the participant was asked if there were any final questions or concerns about the testing procedure. Subsequent to their departure, extra credit was provided via the online system, SONA.

CHAPTER III

RESULTS

Data from five subjects were removed from analyses based on incomplete data sets (four participants) and age restrictions (one participant). As noted above, possible age-related effects were eliminated by limiting analysis to those participants in the more Gf-stable age range (18 to 35 years old). No learning effects were found with respect to HMIA and WAIS-IV administration order. The effect of test administration order (i.e., whether the participant was administered either HMIA or WAIS-IV first) had no effect on HMIA ($t[64] = .20, p > .05$), FSIQ ($t[64] = -.75, p > .05$), PRI ($t[64] = -.43, p > .05$), or MR ($t[64] = .40, p > .05$).

Hypotheses

The hypotheses tested in this research related to the convergent and divergent validity of the HMIA, as assessed by correlations with convergent and discriminant criterion measures. To this end, the primary hypotheses examined in this study were the following:

H_1: Cronbach's alpha $_{HMIA} \geq .70$ (Internal consistency reliability)

H_2: r $_{HMIA.FSIQ} > r$ $_{HMIA.HS}$ (Discriminant validity)

H_3: r $_{HMIA.FSIQ} > r$ $_{HMIA.HSP}$ (Discriminant validity)

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H_4: $r_{\text{HMIA.PRI}} > r_{\text{HMIA.VCI}}$ (Discriminant validity)

H_5: $r_{\text{HMIA.PRI}} > r_{\text{HMIA.WMI}}$ (Discriminant validity)

H_6: $r_{\text{HMIA.PRI}} > r_{\text{HMIA.PSI}}$ (Discriminant validity)

H_7: $r_{\text{HMIA.MR}} > r_{\text{HMIA.HS}}$ (Discriminant validity)

H_8: $r_{\text{HMIA.MR}} > r_{\text{HMIA.HSP}}$ (Discriminant validity)

H_9: $R^2_{\text{HMIA·PRI,HS,HSP}} \geq .50$ (Convergent validity)

H_{10}: $R^2_{\text{HMIA·PRI,HS,HSP}} > R^2_{\text{HMIA·HS,HSP}}$ (Discriminant validity)

H_{11}: $R^2_{\text{HMIA·MR,HS,HSP}} \geq .50$ (Convergent validity)

H_{12}: $R^2_{\text{HMIA·MR,HS,HSP}} > R^2_{\text{HMIA·HS,HSP}}$ (Discriminant validity)

Hypotheses described above as tests of discriminant validity (H_2 through H_8, H_{10}) reflect Campbell and Fiske's (1959) "third common-sense desideratum" (p. 83).

H_1: Cronbach's alpha $\geq .70$

H_1 addressed internal consistency utilizing Cronbach's alpha (Cronbach, 1951). The HMIA was expected to have a satisfactory level of reliability with internal consistency above .70 ($\square \geq .70$), as suggested by Groth-Marnat (2003). Pedersen (2009) found a Cronbach's alpha of .74 for the HMIA with a similar sample. The current sample had a Cronbach's alpha of .71, which is similar to that previously found and indicates satisfactory internal consistency of the HMIA. Examining the correlations between HMIA items and WAIS-IV indices and subtests indicated that some items may be better

measures of nonverbal intelligence, as they were more correlated with PRI, MR, and

subtests that were measures of nonverbal intelligence (see table 4).

Table 4. *HMIA and WAIS-IV Correlations*

	FSIQ	VCI	PRI	WMI	PSI	BD	Sim
HMIA Total	.55**	.23	.59**	.45**	.06	.49**	.08
Item 1	.15	.01	.16	.05	.10	.12	-.17
Item 2	.21	.20	.30*	.04	-.08	.23	.09
Item 3	.36**	.18	.41**	.30*	.15	.33**	.14
Item 4	.25*	.10	.16	.21	.01	.21	-.01
Item 5	.12	-.07	.28*	.13	.01	.22	-.12
Item 6	.49**	.33**	.30*	.35**	.18	.15	.20
Item 7	.37**	.11	.59**	.17	.01	.47**	.05
Item 8	.33**	.15	.38**	.22	.09	.43**	.12
Item 9	.13	.07	.22	.12	-.10	.19	.07
Item 10	.25*	-.06	.34**	.22	.03	.33**	-.18
Item 11	.34**	.38**	.36**	.19	-.14	.28*	.20
Item 12	.16	-.09	.03	.22	.23	-.02	-.02
Item 13	.25*	.14	.27*	.26*	-.03	.19	.16
Item 14	.25*	.13	.20	.21	.11	.18	.04
Item 15	.16	-.01	.23	.22	-.21	.25*	-.04
Item 16	.08	.14	.15	.07	-.17	.12	.10
Item 17	.04	.21	.05	.03	-.16	-.04	.18
Item 18	-.04	-.12	-.07	.13	.03	-.02	-.28*
Item 19	.04	-.07	.06	.03	.10	.04	-.10
Item 20	.16	-.03	.12	.21	.15	.09	-.01

Table 4 cont.

	DS	MR	Voc	Arit	SS	VP	Info	Cod
HMIA Total	.39**	.48**	.23	.38**	.07	.45**	.24	.02
Item 1	.04	.17	.05	.06	.21	.09	.14	-.00
Item 2	.07	.21	.24	-.02	-.04	.28*	.14	-.07
Item 3	.28*	.30*	.14	.23	.18	.34**	.14	.09
Item 4	.15	.14	-.03	.22	.03	.05	.26*	-.03
Item 5	.08	.31*	-.02	.14	.01	.14	-.02	.01
Item 6	.31*	.28*	.26*	.30*	.08	.28*	.31*	.20
Item 7	.18	.42**	.21	.11	.07	.51**	.05	-.05
Item 8	.22	.08	.15	.17	.08	.39**	.08	.07
Item 9	.08	.12	.14	.13	-.06	.23	-.02	-.11
Item 10	.21	.27*	-.18	.17	.17	.23	.20	-.10
Item 11	.13	.30*	.42**	.20	-.24	.27*	.28*	-.01
Item 12	.26*	.07	-.01	.12	.14	.03	-.13	.25*
Item 13	.19	.28*	.12	.26*	-.09	.17	.06	.02
Item 14	.20	.17	.27*	.17	.09	.14	.02	.11
Item 15	.17	.17	-.02	.19	-.19	.14	.04	-.18
Item 16	-.01	.12	.03	.13	-.11	.11	.16	-.17
Item 17	.01	.09	.13	.04	-.07	.05	.16	-.21
Item 18	.17	-.15	.02	.05	.07	-.02	.01	-.03
Item 19	.03	.16	-.11	.04	.09	-.04	.06	.09
Item 20	.21	.12	-.17	.13	.22	.08	.05	.07

*p < .05; ** p < .01

$$H_2: r_{HMIA.FSIQ} > r_{HMIA.HS}$$

H_2 stated that HMIA scores will correlate more highly with general intelligence, as measured by the WAIS-IV (FSIQ score), than with haptic speed (HS). Correlations of

subtests within the WAIS-IV with FSIQ range from .44 to .78, with an average

correlation of .69. It was expected that HMIA would correlate with the FSIQ in a

comparable manner. Therefore, it was expected that the difference between HMIA's

correlation with FSIQ would be significantly greater ($p < .05$) then the absolute value of

HMIA's correlation with HS, with a difference of .33 or greater (per calculations based

upon Fisher z transformation of r; Cohen, 1988; p. 110). Of note, FSIQ was expected to

be positively correlated with HMIA scores and haptic speed was expected to be

negatively correlated with the HMIA scores, as greater haptic speed corresponds to

smaller task latency. This was expected as the HMIA has been shown to be assessing

intelligence, above and beyond haptic speed (Pedersen, 2009). Haptic speed was likely to

be correlated to some degree with the HMIA scores, owing to the haptic nature of the

HMIA; however, the HMIA was expected and thought to be more of a measure of

intelligence than a measure of haptic speed.

Analyses showed a correlation of HMIA with FSIQ of .55 ($p < .01$; see table 5)

and a correlation of HMIA with HS of -.23, creating a difference of .32. This lends

support to the test's discriminant validity with respect to simple haptic-motor speed in the

absence of vision; however, it does not meet strict statistical criteria.

$$H_3: \text{r}_{HMIA.FSIQ} > \text{r}_{HMIA.HSP}$$

Similar to H_2, H_3 stated that HMIA scores would correlate more highly with

intelligence, as measured by the WAIS-IV (FSIQ score), than with our measure of haptic

spatial performance (HSP). As noted above, the average correlation of subtests within

the WAIS-IV with FSIQ is .69 and HMIA was expected to correlate with the FSIQ in a

comparable manner. Therefore, it was expected that the difference between HMIA's correlation with FSIQ would be significantly greater ($p < .05$) then the absolute value of HMIA's correlation with HSP, with a difference of .33 or greater (per calculations based upon Fisher z transformation of r; Cohen, 1988; p. 110). Of note, FSIQ was expected to be positively correlated with HMIA scores and haptic spatial performance was expected to be negatively correlated with the HMIA scores, as greater haptic spatial performance corresponds to shorter task latency. Haptic spatial performance was likely to be correlated to some degree with the HMIA scores, owing to the haptic nature of the HMIA; however, the HMIA was expected and thought to be more of a measure of intelligence than a measure of haptic spatial performance.

Table 5. *Instrument Correlations*

	VCI	PRI	WMI	PSI	MR	HS	HSP	HMIA	NFC	GEFT
FSIQ	.60**	.76**	.69**	.42**	.58**	-.21	-.48**	.55**	.33**	.56**
VCI	--	.35**	.25*	-.10	.27*	-.04	-.30*	.22	.40**	.34**
PRI		--	.32**	.18	.75**	-.27*	-.44**	.59**	.30*	.66**
WMI			--	.30*	.23	-.15	-.30*	.45**	.20	.27*
PSI				--	.12	-.22	-.27*	.05	-.06	.10
MR					--	-.19	-.40**	.48**	.22	.36**
HS						--	.45**	-.23	-.02	-.35**
HSP							--	-.46**	-.17	-.37**
HMIA								--	.40**	.38**
NFC									--	.23
GEFT										--

*$p < .05$; ** $p < .01$

HMIA's correlation with FSIQ was .55 ($p < .01$) and HMIA's correlation with HSP was -.46 ($p < .01$; see table 5), with a difference of .09. This indicates that the HMIA does assess intelligence on a general level (a la FSIQ); however, the test requires more haptic spatial abilities then previously hypothesized. This analysis does not support the test's discriminant validity with respect to more complex haptic-spatial efficiency.

$$H_4: r_{HMIA.PRI} > r_{HMIA.VCI}$$

H_4 stated that HMIA scores would correlate more highly with non-verbal intelligence, as measured by the WAIS-IV (PRI score), than with verbal intelligence (WAIS-IV VCI score). Of all the subtests of the WAIS-IV, the HMIA was thought to be most similar to the Matrix Reasoning subtest (MR). MR correlates with the PRI at .82 (Sattler, 2009). However, for many reasons (e.g., the HMIA is haptically-mediated while both MR and PRI are visually-mediated; MR, unlike HMIA, requires no manual-motor skills; PRI is calculated from, among other subtest scores, MR; etc.), the HMIA was expected to correlate less with PRI than does MR. Therefore, the average correlation of WAIS-IV PRI subtests with PRI was used as an estimate of common variance, as opposed to the MR correlation with PRI. Correlations of PRI subtests within the WAIS-IV with PRI range from .55 to .86, with an average correlation of .75. It was expected that HMIA would correlate with PRI in a comparable manner. Therefore, it was expected that the difference between HMIA's correlation with PRI would be significantly greater ($p < .05$) than HMIA's correlation with VCI, with a difference of .30 or greater (per calculations based upon Fisher z transformation of r; Cohen, 1988; p. 110).

HMIA's correlation with PRI was .59 ($p < .01$) and with VCI was .22 ($p > .05$; see table 5), with a difference between the two correlations being .37. This supports the idea that the HMIA measures performance, or non-verbal, intelligence as opposed to verbal intelligence. The solution process of the HMIA is not inherently verbally mediated and perceptual-spatial processes are required, rather then verbal reasoning. This supports the HMIA's discriminant validity, with respect to verbal intelligence.

$$H_5: r_{HMIA.PRI} > r_{HMIA.WMI}$$

H_5 stated that HMIA scores would correlate more highly with non-verbal intelligence WAIS-IV PRI score) than with working memory (WAIS-IV WMI score). As noted above, the average correlation of subtests within the WAIS-IV with PRI is .75 and HMIA was expected to correlate with PRI in a comparable manner. Therefore, it was expected that the difference between HMIA's correlation with PRI will be significantly greater ($p < .05$) than HMIA's correlation with WMI, with a difference of .30 or greater (per calculations based upon Fisher z transformation of r; Cohen, 1988; p. 110). Working memory was expected to be correlated somewhat with HMIA scores, as holding and manipulating information is necessary to some degree when completing this task (and because of the well-established intercorrelation of cognitive tasks generally). However, one of the WMI subtests is timed. Because the HMIA is not timed, working memory was expected to play a smaller part in the composition of HMIA scores than non-verbal intelligence.

HMIA's correlation with PRI was .55 ($p < .01$) and with WMI was .45 ($p < .01$; see table 5), with a difference between the two correlations being .10. This supports the

idea that the HMIA measures performance, or non-verbal, intelligence more so than working memory. However, the analysis does not meet strict statistical criteria necessary to state that the HMIA is *more* of a measure of non-verbal intelligence than working memory. This does not support HMIA's discriminant validity, with respect to working memory.

$$H_6: r_{HMIA.PRI} > r_{HMIA.PSI}$$

H_6 stated that HMIA scores would correlate more highly with non-verbal intelligence (WAIS-IV PRI score) than with processing speed (WAIS-IV PSI score). Again, the average correlation of subtests within the WAIS-IV PRI with PRI is .75 and HMIA was expected to correlate with PRI in a comparable manner. Therefore, it was expected that the difference between HMIA's correlation with PRI would be significantly greater ($p < .05$) then HMIA's correlation with PSI, with a difference of .30 or greater (per calculations based upon Fisher z transformation of r; Cohen, 1988; p. 110). Similar to working memory discussed in H_5, processing speed was expected to be correlated somewhat with HMIA scores. It is possible that the quicker an individual completes each item, the smaller the chance of giving up on the item. Again, because the HMIA is not time-limited, processing speed was expected to play a smaller part in the composition of HMIA scores than non-verbal intelligence.

HMIA's correlation with PRI was .55 ($p < .01$) and with PSI was .05 ($p > .05$; see table 5), with a difference between the two correlations being .50. This supports the idea that the HMIA measures performance, or non-verbal, intelligence more so than visual-

motor processing speed. This supports HMIA's discriminant validity, with respect to visual-motor processing speed.

$$H_7: r_{HMIA.MR} > r_{HMIA.HS}$$

H₇ stated that HMIA scores would correlate more highly with a test of non-verbal intelligence (WAIS-IV Matrix Reasoning subtest score; MR) than with haptic speed (HS). Pedersen (2009) found that HMIA correlated with RAPM at .66 ($p < .05$). It was expected that HMIA would correlate with MR in a comparable manner due to the similar nature of the tasks. Therefore, it was expected that the difference between HMIA's correlation with MR would be significantly greater ($p < .05$) then HMIA's correlation with HS, with a difference of .37 or greater (per calculations based upon Fisher z transformation of r; Cohen, 1988; p. 110). Again, because of the similar nature of the two tasks (HMIA and MR), it was expected that the HMIA would be assessing comparable constructs as MR (namely, inductive-deductive reasoning) and would be more related to MR than haptic speed.

HMIA's correlation with MR was .48 ($p < .01$) and with HS was -.23 ($p > .05$; see table 5), with a difference between the absolute value of the two correlations being .25. This supports the idea that the HMIA measures performance, or non-verbal, intelligence more so than haptic speed. However, the analysis does not meet strict statistical criteria necessary to state that the HMIA is *more* of a measure of non-verbal intelligence than haptic speed. This does not support HMIA's discriminant validity, with respect to simple haptic-motor speed in the absence of vision.

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$$H_8: r_{HMIA.MR} > r_{HMIA.HSP}$$

H8, similar to H7 above, stated that HMIA scores would correlate more highly with a test of non-verbal intelligence (MR) than with haptic spatial performance (HSP). It was expected that the difference between HMIA's correlation with MR (estimated to be approximately .66, as stated in H7) would be significantly greater ($p < .05$) then HMIA's correlation with HSP, with a difference of .37 or greater (per calculations based upon Fisher z transformation of r; Cohen, 1988; p. 110). As noted previously, because of the similar nature of the two tasks (HMIA and MR), it was expected that the HMIA would be assessing comparable constructs as the MR subtest and would be more related to MR than haptic spatial performance.

HMIA's correlation with MR was .48 ($p < .01$) and with HSP was .46 ($p < .01$; see table 5), with a difference between the two correlations being .02. This does not support the idea that the HMIA measures performance, or non-verbal, intelligence more so than haptic spatial performance. This does not support HMIA's discriminant validity, with respect to more complex haptic-motor spatial ability in the absence of vision.

$$H_9: R^2_{HMIA \cdot PRI, HS, HSP} \geq .50$$

H9 stated that a regression model with HMIA scores as the dependent variable (DV) and independent variables (IVs) of non-verbal intelligence (WAIS-IV PRI), haptic speed (HS), and haptic spatial performance (HSP) would yield a large R^2, specifically .50 or greater. This hypothesis acknowledged that haptic processes (both speed and spatial performance) were relevant in assessing visually impaired individuals, owing to the unsuitability of visually-based instrumentation, and the increased reliance of visually-

impaired persons on haptic ability. In other words, while the HMIA was designed to assess non-verbal intelligence, haptic processes also contribute to HMIA scores.

Analysis showed that this model yielded a R^2 of .40, which does not allow the rejection of the null. While this was a statistically significant model ($F = 13.85, p < .01$; see table 6), it does not meet the strict statistical thresholds set by the researchers and does not support the construct validity of the HMIA.

$$H_{10}: R^2_{HMIA \cdot PRI, HS, HSP} > R^2_{HMIA \cdot HS, HSP}$$

H_{10} is closely related to H_9. If HMIA scores reflected both intelligence and haptic processes as expected, then it was reasonable to anticipate that HMIA measured a significant amount of intelligence above and beyond haptic processes. H_{10} spoke to construct validity more precisely than H_9. The extent to which H_{10} was true determined the extent to which the HMIA could be considered a measure of non-verbal intelligence, distinct from other, task-relevant, abilities (i.e., haptic abilities). As stated previously, it was believed that HMIA is a measure of intelligence, rather than a measure of haptic processes. Therefore, this hypothesis stated that an augmented model, with non-verbal intelligence (WAIS-IV PRI), haptic speed (HS), and haptic spatial performance (HSP) as IVs, would yield significantly greater R^2 than a more parsimonious model with haptic speed (HS) and haptic spatial performance (HSP) only as IVs. That is, in a stepwise regression with HMIA as DV, and HS and HSP scores entered first and PRI entered second as IVs, a significant change in R^2 would be observed at the second step.

As stated above, a model with PRI, HS, and HSP as IVs yielded a R^2 of .40 ($F = 13.85, p < .01$; see table 6). A model with only HS and HSP yielded a R^2 of .21 ($F =$

8.79, $p < .01$; see table 6), which leaves a difference in R^2 of .19. While this was a statistically significant model, it does not meet the strict statistical thresholds set by the researchers (see Power Analysis, below). Results do not support the discriminant validity of the HMIA with respect to simple haptic efficiency, and, thereby, the applied utility of controlling for simple haptic efficiency when measuring nonverbal intelligence in a haptic modality.

$$H_{11}: R^2_{HMIA\cdot MR,HS,HSP} \geq .50$$

H_{11} stated that a regression model with HMIA scores as the dependent variable (DV) and independent variables (IVs) of a test of non-verbal intelligence (WAIS-IV MR), haptic speed (HS), and haptic spatial performance (HSP) would yield a large R^2 ($\geq .50$). The reasoning for this hypothesis was the same as hypothesis H_9, above. It acknowledged that haptic processes (both speed and spatial performance) are relevant in assessing visually impaired individuals, owing to the unsuitability of visually-based instrumentation. In other words, while the HMIA was designed to assess non-verbal intelligence, haptic processes are also contributing to the scores of this measure.

Analysis showed that this model yielded a R^2 of .32, which does not allow the rejection of the null. While this was a statistically significant model ($F = 9.79$, $p < .01$; see table 6), it does not meet the strict statistical thresholds set by the researchers and does not support the construct validity of the HMIA.

Table 6. *Summary of Regression Models for Variables Predicting HMIA Scores*

Hypothesis 9	Predictors	B	SE B	β
	HS	0.001	0.008	0.015
	HSP	-0.008	0.004	-0.257*
	PRI	0.133	-0.030	0.481**

Note. $R^2 = .40$; $F(1, 65) = 13.85$, $(p < .01)$.

Hypothesis 11	Predictors	B	SE B	β
	HS	-0.002	0.008	-0.026
	HSP	-0.009	0.004	-0.314*
	MR	0.458	0.149	0.351**

Note. $R^2 = .32$; $F(1, 65) = 9.79$, $(p < .01)$.

Hypotheses 10 & 12	Predictors	B	SE B	β
	HS	-0.002	0.008	-0.031
	HSP	-0.013	0.004	-0.452**

Note. $R^2 = .21$; $F(1, 65) = 8.79$, $(p < .01)$.

*p < .05; ** p < .01

$$H_{12}: R^2_{HMIA \cdot MR, HS, HSP} > R^2_{HMIA \cdot HS, HSP}$$

H_{12} closely related to H_{11}. If HMIA scores reflected both intelligence and haptic processes as expected, then it was reasonable to anticipate that HMIA measured a significant amount of intelligence above and beyond haptic processes. The reasoning for this hypothesis was the same as hypothesis H_{10}, above. As stated previously, it was believed that HMIA is a measure of intelligence, rather than a measure of haptic

processes. Therefore, this hypothesis stated that an augmented model, with a test of non-verbal intelligence (WAIS-IV MR), haptic speed (HS), and haptic spatial performance (HSP) as IVs, would yield significantly greater R^2 than a more parsimonious model with haptic speed (HS) and haptic spatial performance (HSP) only as IVs. That is, in a stepwise regression with HMIA as DV, and HS and HSP scores entered first and PRI entered second as IVs, a significant change in R^2 would be observed at the second step.

As stated above, a model with MR, HS, and HSP as IVs yielded a R^2 of .32 ($F = 9.79$, $p < .01$; see table 6). A model with only HS and HSP yielded a R^2 of .21 ($F = 8.79$, $p < .01$; see table 6), which leaves a difference in R^2 of .11. While this was a statistically significant model, it does not meet the strict statistical thresholds set by the researchers (see Power Analysis, below). Results do not support the discriminant validity of the HMIA with respect to simple haptic efficiency, and, thereby, the applied utility of controlling for simple haptic efficiency when measuring nonverbal intelligence in a haptic modality.

Additional Analyses

Impact of multicollinearity (HS and HSP)

Due to that fact that HS and HSP are highly correlated ($r = .45$, $p < .01$; see table 5), the above results from the hypotheses involving multiple regression (i.e., H_9 through H_{12}) may be overly emphasizing the impact of haptic abilities, as both variables measuring these abilities are in each regression equation. Collinearity diagnostics indicated that multiple regression equations with both HS and HSP had high degrees of multicollinearity (eigenvalues of .17 and less, variance proportions of .51 and above).

Therefore, hypotheses were analyzed again after HS and HSP were combined into one variable (Myers and Well, 2003; p. 598). Results did not show significant difference from those previously discussed. Stepwise multiple regression analyses revealed that HS on it's own never met criteria for inclusion (criteria: probability of F to enter < .05; probability of F to remove > .11) in any of the above mentioned hypotheses, indicating that HSP is a better measure of haptic abilities when being used as a predictor of HMIA scores. However, results were analyzed again using only HSP and were again not significantly different from those results presented above.

Item analyses

To possibly increase reliability and validity of the measure, an alternative scoring system was developed. Errors made by participants were analyzed and a two-point scoring system was created by allotting two points to those answers that were correct based on the rules utilized to produce the matrices (see Tables 1 and 2) and allotting one point to those "wrong" answers that were used consistently by 25% or more of the participants. The rationale being that there was a consistent method by which those participants came up with the recurring erroneous answers, making the given answer a plausible response. The above described hypotheses were analyzed using the new scoring system. While this scoring method increased Cronbach's alpha to .74 (from .71), the results for the other hypotheses were not significantly changed (either in a supporting or opposing fashion).

Motivational variations

It is possible that differential motivation to complete complex tasks could

confound results. The Need for Cognition (NFC) questionnaire was used to quantify the

relationships between the individual's motivation and their scores on the WAIS-IV and

the HMIA. The NFC score was used as an additional IV in the regression analyses, so as

to determine its effect on WAIS-IV and HMIA and to more fully understand the

relationships between the IVs and DVs. A model with PRI, HS, HSP, and NFC as IVs

yielded a R^2 of .45 ($F = 12.46$, $p < .01$; see table 7).

Table 7. *Summary of Regression Model for Motivational Variables Predicting HMIA Scores*

Predictors	B	SE B	β
HS	-0.001	0.007	-0.009
HSP	-0.007	0.003	-0.237*
NFC	0.041	0.018	0.232*
PRI	0.114	0.031	0.414**
Note. $R^2 = .45$; $F (1, 65) = 12.46$, ($p < .01$).			
Predictors	B	SE B	β
HS	-0.003	0.008	-0.048
HSP	-0.008	0.004	-0.276*
NFC	0.050	0.018	0.284**
MR	0.391	0.144	0.300**
Note. $R^2 = .39$; $F (1, 65) = 10.04$, ($p < .01$).			

*$p < .05$; ** $p < .01$

Additionally, in a second model with MR, HS, HSP, and NFC as IVs yielded a R^2 of .39 ($F = 10.04$, $p < .01$; see table 7). NFC was a variable which significantly contributed to both models at least at a level of $p < .05$, which indicates that motivational factors related to problem solving were impacting HMIA scores. More motivation within an individual that they reported having at problem solving resulted in an increase in performance on the experimental measure, HMIA.

Field independence

It is also possible that differences in field independence could confound results. The Group Embedded Figures Test (GEFT) was used to determine if the individual approached problems to be solved in a manner characterized by field independence (i.e., analytical, step-by-step) or field dependence (i.e., viewing the problem as a whole or a gestalt). This was used to determine the magnitude of the relationship between problem solving style and WAIS-IV or HMIA scores.

The GEFT was significantly correlated with the HMIA ($r = .37$, $p < .01$), HS ($r = -.35$, $p < .01$), HSP ($r = -.37$, $p < .01$), FSIQ ($r = .56$, $p < .01$), PRI ($r = .66$, $p < .01$), VCI ($r = .34$, $p < .01$), WMI ($r = .26$, $p < .05$), and MR ($r = .36$, $p < .01$; see table 5). Multiple regression was used to further examine the relationships among these variables. A model with PRI, HS, HSP, and GEFT as IVs predicting HMIA as a DV yielded a R^2 of .40 ($F = 10.29$, $p < .01$). A model with MR, HS, HSP, and GEFT yielded a R^2 of .34 ($F = 7.91$, $p < .01$). The GEFT was not a significant predictor in either model ($p > .05$; see table 8).

Table 8. *Summary of Regression Model for Field In/Dependence Predicting HMIA Scores*

Predictors	B	*SE* B	β
HS	-0.000	0.008	0.005
HSP	-0.008	0.004	-0.258*
GEFT	-0.032	0.078	-0.055
PRI	0.142	0.038	0.515**
Note. $R^2 = .40$; $F(1, 65) = 10.29$, $(p < .01)$.			
Predictors	B	*SE* B	β
HS	0.001	0.008	0.011
HSP	-0.009	0.004	-0.287*
GEFT	0.094	0.069	0.163
MR	0.404	0.153	0.309*
Note. $R^2 = .34$; $F(1, 65) = 7.92$, $(p < .01)$.			

*$p < .05$; ** $p < .01$

Assumptions of Multiple Regression

The assumptions of multiple regression are that the variables are normally distributed, linear in their relationships with one another, and homoscedastic in their variability. With respect to normality, HS, HSP, and HMIA were all found to be positively skewed ($p > .05$) and GEFT, NFC, FSIQ, PRI, VCI, WMI, PSI, and MR were not skewed ($p < .05$). Kurtosis was normal ($p < .05$) for all of the variables, with the exception of HSP. With respect to linearity and homoscedacity, scatterplots were examined with DV and IVs. FSIQ, PRI, HSP, and NFC were largely linear and

homoscedastic. MR and HS were non-linear. Overall, this indicates that some caution is warranted in interpreting the data analyses.

Power Analysis

Power analysis (Cohen, 1988; p.134) showed that, with $\square$ = .05, at least 60 participants were needed to obtain sufficient power (.80) to determine if there was a difference between correlation coefficients (see H_2 through H_8, above). This was determined with the Fisher's z transformation of Pearson rs for the determination of statistically significant differences of correlations. Additionally, with this number of participants, power was .94 when determining if 50% of the variance in the HMIA was accounted for by the PRI or MR, HS, and HSP (see H_9 and H_{11}, above). This also provided sufficient power to detect a change in R^2 of .25 or greater when PRI or MR scores are added to the regression equation with HS and HSP scores (see H_{10} and H_{12}, above; Cohen, 1988, p. 416). These calculations made from Cohen (1988) were confirmed with G*Power (Faul, Erdfelder, Lang, &, Buchner, 2007).

CHAPTER IV

DISCUSSION

Data from the current study indicate that more development is needed on the

HMIA in order for it to be utilized as a measure of non-verbal intelligence for individuals

with visual impairments. Analyses of internal consistency showed the measure to be

reliable; however, an alpha falling within the .70 to .79 is considered to be minimally

sufficient for research purposes, while an alpha of .85 and above is considered to be a

prerequisite for clinical applications (Groth-Marnat, 2003). Therefore, further changes

may be necessary to the items on the HMIA so as to improve internal consistency and

increase their dependence on one construct (i.e., nonverbal intelligence).

Analyses regarding convergent and divergent validity were somewhat

inconclusive. The HMIA was found to be more of a measure of general intelligence (i.e.,

FSIQ) and non-verbal abilities (i.e., PRI and MR) than of visual-motor processing speed

or verbal abilities. Working memory was found to be more associated with HMIA scores

then previously theorized. Haptic speed was not correlated significantly with HMIA

scores and was not found to be a significant contributor to HMIA scores when analyzed

with multiple regression. However, HMIA scores were found to be more reliant on

haptic spatial performance then previously hypothesized.   While correlational analyses

revealed intellectual abilities in general (i.e., FSIQ) and non-verbal abilities specifically

(i.e., PRI and MR) to be *more* associated with HMIA scores, strict statistical criterion

were not met to be able to reliably assume HMIA is more of a measure of non-verbal intelligence than of haptic spatial performance. Multiple regression analyses demonstrated similar results as the correlational analyses.   Thus, convergent validity was established with respect to intelligence in general and non-verbal abilities specifically. Divergent validity was established with respect to haptic speed, processing speed, and verbal abilities; however, divergent validity was not sufficiently established with respect to working memory or haptic spatial performance. HMIA assesses non-verbal abstract reasoning abilities (i.e., PRI and MR), haptic spatial performance, and working memory skills.

With respect to working memory having more impact on HMIA scores then previously hypothesized, it should be noted that Arithmetic (which was one criterion measure used to assess working memory) has been found to cross load onto constructs other than working memory when confirmatory factor analysis was used. Benson, Hulac, & Kranzler (2011) found that Arithmetic loaded onto working memory (Gsm) as well as fluid intelligence (Gf) (see also Ward, Bergman, & Hebert, 2011). This may have muddied the results involving working memory and its impact on HMIA scores.

As noted above (q.v., Introduction, Variables affecting non-verbal intelligence), children with visual impairments have been shown to be superior then sighted children on some working memory tasks (e.g., Digit Span; see also Smits & Mommers, 1976). Also, due to these individual's more extensive experience with haptics, this population may be reasonably expected to outperform sighted individuals on haptic tasks. This may cause the impact of working memory on HMIA performance to decrease, as the individual with no vision may not struggle with this aspect of the test as much. These issues (i.e., the

psychometric properties of Arithmetic and the heightened working memory abilities of those individuals with visual impairments) may potentially make the HMIA a *more* valid measure for individuals with visual impairments then was found within this study.

Additionally, motivational factors were impacting HMIA scores. Due to the length of testing during this experiment (i.e., three to four hours required) and the population from which the sample was taken (i.e., undergraduate students), it is thought that the participants may not have had the proper motivation to stay focused and engaged throughout the entire testing session, thus lowering their effort level and influencing the score of the experimental measure.

Finally, the level of one's field independence or field dependence did was not a significant contributor to HMIA scores, indicating that this construct is not a relevant one when interpreting HMIA scores. However, GEFT was highly correlated with most of the scores and constructs of interest in this study. About 14% of variance was shared between GEFT and HMIA. It is possible that the participants use visualization skills to solve HMIA items by picturing the stimuli in their "mind's eye". The skills necessary to do this mental visualization could be related to the ability assessed by the GEFT, namely the ability to mentally manipulate visual images (i.e., differentiate embedded figures from the gestalt). Research has demonstrated that individuals who have visual impairments can also use mental imagery to represent visual information (Cattaneo & Vecchi, 2011). This suggests that individuals both with sight and without may use similar visualization and mental manipulation skills when approaching this assessment measure.

It should be noted that the statistical cut-offs (e.g., $p < .05$) created for purposes of research are somewhat arbitrary and results that indicate sub-threshold levels of significance might be best viewed as "trends". Also, this sample being individuals in college may have created the somewhat leptokurtic spread of the scores (e.g., FSIQ, see table 4) as compared to the scores' standard presentation, which could have affected the results adversely. Considering this and the results of this study, the next logical step is to perform a pilot study of this measure with participants from the population of individuals with visual impairments, controlling for such things as education. Studied with an existing measure of nonverbal intelligence (e.g., CTB; Dial, et al., 1990) would allow for the assessment of convergent construct validity within the population of interest. Additionally, it may be useful to assess criterion validity, i.e., to determine what this measure can predict (e.g., academic achievement, vocational aptitudes, other practical measures of nonverbal intelligence, etc.), as this would help determine in what setting this measure is most clinically useful. A pilot study would also allow the researcher to see if working memory and haptic spatial performance are as problematic for people with visual impairments as they were for people without visual impairments. If indeed working memory and haptic spatial performance do not impact HMIA scores as severely with the population who have visual impairments, the HMIA does show promise of being used as a test of non-verbal intelligence for individuals with visual impairments.

APPENDICES

INFORMED CONSENT
HMIA: TESTING FOR PERSONS WITH VISUAL IMPAIRMENTS

University of North Dakota, Grand Forks   **Department of Psychology**
215 Corwin-Larimore, Box 8380   Grand Forks, ND 58202
Primary Investigator: Heather Pedersen   **Contact Information:** heather.pedersen@und.edu

• You are being invited to participate in a research study being conducted at the University of North Dakota (UND) through the Psychology Department because you are an undergraduate at UND. The purpose of this study is to develop a measure of non-verbal cognitive skills for use with individuals with visual impairments. Currently, there is a lack of measures available for assessing these skills in the visually impaired population.

• If you consent to participate in this study, you will be asked to complete the following items, which should take approximately four (4) hours:
- Demographic Questionnaire: a questionnaire requesting information about yourself that is related to cognitive and haptic performance.
-NFC Questionnaire: a questionnaire requesting you to rate agreement or disagreement regarding yourself on eighteen statements.
- WAIS-IV: a standardized measure of cognitive abilities, in which you will be asked to solve various types of problems.
-Haptic Matrices Intelligence Assessment (HMIA): the measure under investigation, in which you will be asked to complete several tasks and puzzles without the use of vision.

• For participation in this study, you will receive extra credit for the hours that you spend participating in your undergraduate psychology class.

• Participation in this study is voluntary. You have the right to withdraw at any time with no penalty of any kind and any time already spent in participation will receive the appropriate amount of extra credit.

• This study poses minimal risk. However, because tests of cognitive abilities are often challenging, people completing these tests may occasionally feel embarrassed by their performance. It is very important to remember that these tests are designed so that *everyone* has at least *some* difficulty with *some* of the items. You can expect that some of the items will be very easy, and some will be very difficult. All we ask is that you do your very best, and that you do not allow yourself to become discouraged. Because the target measure is experimental, no individual test scores will be released to participants. However, you may contact the Principal Investigator for a summary of the research results, once the study is completed.

• While there are no direct benefits to you, your participation may contribute significantly to improving intelligence assessments for individuals with visual impairments.

• If you have any questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach research staff, or you wish to talk with someone else.

• Your responses are strictly confidential. All written and spoken information obtained from you will be held in the strictest confidence. Randomly assigned participant id numbers will be used to identify the data you provide. Identifying information will not be associated with your data when it is presented in the written report. Consent forms will be stored in a locked storage container and destroyed after a minimum of three years.

• A copy of this form will be made available to you and any questions that you have, now or later, will be answered.

I have read the above and agree to the terms stated. I agree to participate in the study.

_____
Participant's Signature   Date   Witness's Signature   Date

DEMOGRAPHIC QUESTIONNAIRE

Today's Date:_____   **Age**:_____   **Birth Year:**_____

Gender (circle): M / F   **Highest level of education:**

_____Elementary school

Ethnicity: _____Some high school

_____African American   _____High school diploma / GED

_____Caucasian   _____Some college: # yrs:_____

_____Native American   _____Bachelor's degree

_____Other: _____   _____Some graduate college

_____Master's degree

_____Ph.D.

Check any of the following that apply to you:

Have you *ever* been diagnosed with . . .

_____Diabetes

_____Multiple Sclerosis

_____Other chronic medical conditions.

Describe:_____

_____Depression; if YES, are you *currently* depressed? ☐ Yes ☐ No

_____Anxiety (such as panic attacks, phobias, or PTSD): Describe:_____

_____Attention Deficit Hyperactivity Disorder (ADHD)

_____Learning Disability: (circle) math, reading, or other_____

_____Other psychiatric diagnoses.

Describe:_____

_____Sensory problem with hands/fingers (such as numbness, tingling, stiffness, or pain).

Describe:_____

_____Vision problem. If so, is it corrected with glasses? (circle) Y / N

Describe:_____

_____Head injury.

Describe:_____

_____Taking medications.

Describe:_____

NFC QUESTIONNAIRE

Describe the extent to which you agree with each statement using the following scale:

+4 = very strong agreement
+3 = strong agreement
+2 = moderate agreement
+1 = slight agreement
 0 = neither agreement nor disagreement
 -1 = slight disagreement
 -2 = moderate disagreement
 -3 = strong disagreement
 -4 = very strong disagreement

       1. I would prefer complex to simple problems.

       2. I like to have the responsibility of handling a situation that requires a lot of thinking.

       3. Thinking is not my idea of fun.

       4. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.

       5. I try to anticipate and avoid situations where there is likely a chance I will have to think in depth about something.

       6. I find satisfaction in deliberating hard and for long hours.

       7. I only think as hard as I have to.

       8. I prefer to think about small, daily projects to long-term ones.

       9. I like tasks that require little thought once I've learned them.

       10. The idea of relying on thought to make my way to the top appeals to me.

       11. I really enjoy a task that involves coming up with new solutions to problems.

       12. Learning new ways to think doesn't excite me very much.

       13. I prefer my life to be filled with puzzles that I must solve.

       14. The notion of thinking abstractly is appealing to me.

       15. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.

       16. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.

       17. It's enough for me that something gets the job done; I don't care how or why it works.

       18. I usually end up deliberating about issues even when they do not affect me personally.

Procedures

INFORMED CONSENT SCRIPT:

Experimenter: "You are being invited to participate in a research study being conducted here at UND through the Psychology Department. The purpose of this study is to develop a measure of non-verbal cognitive abilities for individuals with visual impairments.

"If you consent to participate in this study, you will be asked to (1) complete a set of questionnaires about yourself, (2) complete a set of puzzles with your hands, without the use of vision, and (3) complete a standardized test that measures an array of cognitive skills. This will take about 3-4 hours.

"You will receive extra credit in your undergraduate psychology class for the hours you participate. Your participation is voluntary and you will not be penalized if you decide to withdraw. You will receive extra credit for any time you do spend participating.

"This study poses minimal risk. However, because tests of cognitive abilities are often challenging, people completing these tests may occasionally feel embarrassed by their performance. It is very important to remember that these tests are designed so that *everyone* has at least *some* difficulty with *some* of the items. You can expect that some of the items will be very easy, and some will be very difficult. All we ask is that you do your very best, and that you do not allow yourself to become discouraged. Because the target measure is experimental, no individual test scores will be released to participants. However, you may contact the Principal Investigator for a summary of the research results, once the study is completed.

"Your responses are strictly confidential. All written, spoken, and videotaped information obtained from you will be held in the strictest confidence. Please read over this Informed Consent." - - - "Do you have any questions about anything on the Informed Consent?" - - - "Please sign and date at the bottom." - - - "Would you like a copy of the Informed Consent?"

QUESTIONNAIRES SCRIPT:

Experimenter: "Please fill this questionnaire out, if you have any questions about any of the items, be sure to ask. If you don't feel comfortable answering any of them, go ahead and leave the item blank."
<Allow the participant time to complete the Demographics Questionnaire.>

Experimenter: "Please fill this questionnaire out. Using this scale, from +4 to -4, please indicate how strongly you agree or disagree with each statement, as applied to you. Any questions?"
<Allow the participant time to complete the NFC Questionnaire.>

GEFT SCRIPT:
< Per GEFT Manual administration instructions.>

NOTE: Odd participation codes – administer HMIA then the WAIS-IV
          Even participation codes – administer WAIS-IV then the HMIA

<u>**HAPTIC MATRICES INTELLIGENCE ASSESSMENTS' SCRIPT**</u>:

<The first time the participant is introduced to the HMIA board provide this orientation. Position the participant at the puppet screen and verify that it's okay with the participant to guide their hands when necessary.>

Experimenter: "In front of you on the table is a board. This is the size and shape of it. *<Move participant's hand around edge of board>* On the face of the board are nine pegs, with three across and three down. *<Move their hand across face of board>*

<u>**Haptic Speed Script**</u>:
<Administer the eight haptic efficiency tasks once with a different block each time, using the appropriate counterbalanced order per the participant code. Start the stop watch when the participant first touches the blocks or board and stop it when the participant indicates they are done with an item.>

Experimenter: "You will be asked to place one these blocks" *<guide participant's hands to the pile of blocks to their right>* "on each of the nine pegs as quickly as you can. Only one block goes on each peg. Any questions?
        "Ready . . . go!"
<Record time necessary to complete first task.>

Experimenter: "Now you are going to place one of <u>these</u> blocks" *<guide participant's hands to the pile of blocks to their right>* "on each of the nine pegs as quickly as you can. Any questions?
        "Ready . . . go!"
<After the participant completes the first two tasks, reiterate the instructions as necessary until all eight tasks are complete.>

<u>**Haptic Spatial Performance Script**</u>:
<Administer the four haptic spatial awareness tasks once with a different configuration of blocks each time. Start the stop watch when the participant first touches the blocks or board and stop it when the participant indicates they are done with an item.>

Experimenter: "Here in the box on your right are blocks of various shapes and sizes. *<Guide the participant's hand to each block in the box as you describe them>* There are large cubes and small cubes, large spheres and small spheres, large flattened circles and small flattened circles, and large flattened squares and small flattened squares.
        "On the board in front of you, eight of the nine pegs each have a different block on them. You will stack an identical block on each of the blocks already on the board as quickly as you can. For example, if there is a large cube on the peg, place a large cube on top of it. If a peg does not have a block on it, do not place a block on that peg. Any questions?
        "Ready . . . go!"
<Record time necessary to complete first task.>

Experimenter: "Now, like before, eight of the nine pegs have a different block on them, but the blocks are in different locations. Like before, stack an identical block on each of the blocks already on the board as quickly as you can. If a peg does not have a block on it, do not place a block on that peg. Any questions?
        "Ready . . . go!"
<After the participant completes the first two tasks, reiterate the instructions as necessary until all four tasks are complete.>

HMIA Script:

<FOR EACH ADMINISTRATION: Start the stop watch when the participant first touches the blocks or board and stop it when the participant indicates they are done with an item. Record the time for each item.>

Experimenter: "Here in the box on your right are blocks of various shapes and sizes. *<Guide the participant's hand to each block in the box as you describe them>* There are large cubes and small cubes, large spheres and small spheres, large flattened circles and small flattened circles, and large flattened squares and small flattened squares.
   "You will be presented a series of problems. They will consist of these blocks arranged in a pattern on the nine pegs, but the lower right peg will be empty. In every problem you use the same method of working. You look along each row and decide what the missing figure should be like. You look down each column and decide again. You need to figure out which blocks go on the empty peg and in what order they are supposed to be. Use the blocks beside you to construct your answer on the empty peg.
   "The problems begin to get more difficult as you continue with the test, but just do the best you can throughout the test. Any questions?
   "For example, which block would go on the empty peg for this problem? Make sure you feel the entire board when doing these."
<Administer sample A>

<If the participant gets it correct:>
Experimenter: "That's correct."

<If the participant gets it incorrect:>
Experimenter: "That's incorrect. You see, all the blocks are the same down each row, and all the blocks are the same down each column, so a large cube would go on the empty peg." *<Place the correct block on the empty peg and allow the participant to feel the board with the correct answer>* "Any questions?"

<Administer problems 1-20. Do not tell the participant if they are correct or incorrect for each item. Encourage an attempt if the participant indicates that s/he does not know.>

WAIS-IV SCRIPT:
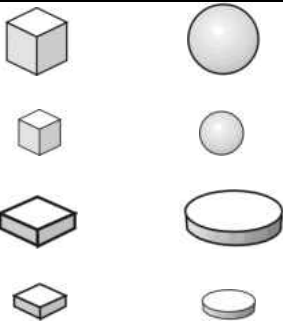
<Per WAIS-IV Manual administration instructions.>

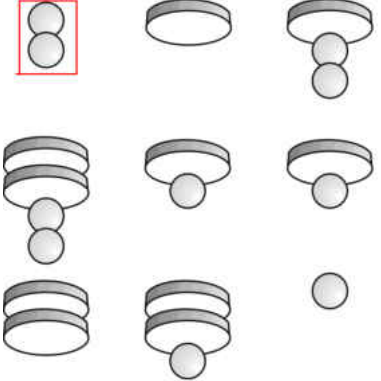**Haptic Matrices Intelligence Assessment (HMIA)**: **PARTICIPANT ID #:**_____

Haptic Speed: Order:_____

	A		B		C		D

	Time:		Time:

Haptic Spatial Performance:

<Place a block on each location. The client is to place identical blocks on top of the prearranged blocks.>
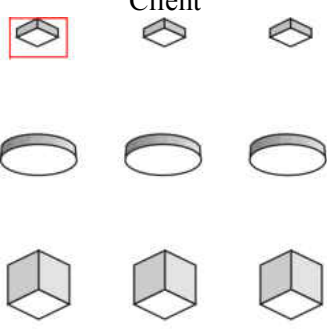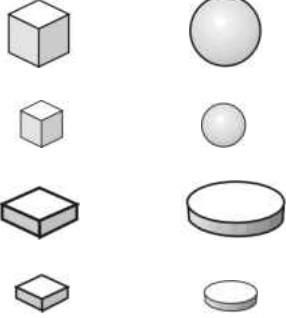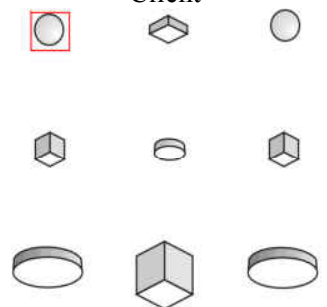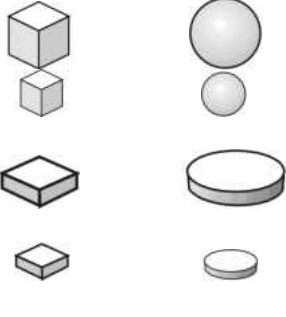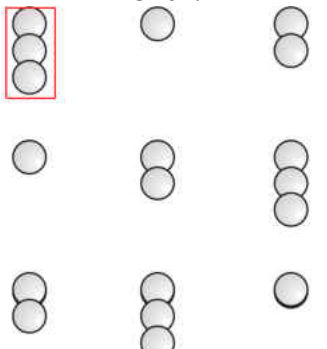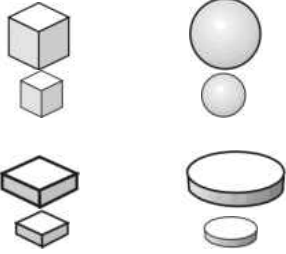
		Arrangement	Time:			Arrangement	Time:
1		Client		3		Client	
		Experimenter				Experimenter	
2		Client		4		Client	
		Experimenter				Experimenter	
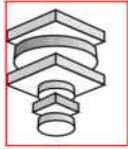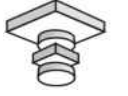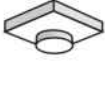
76
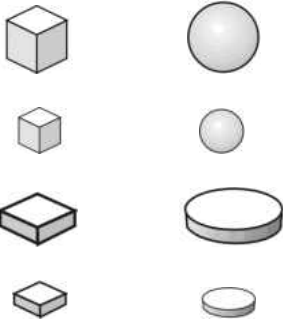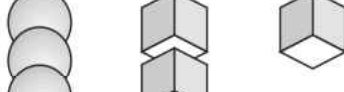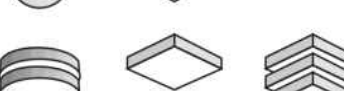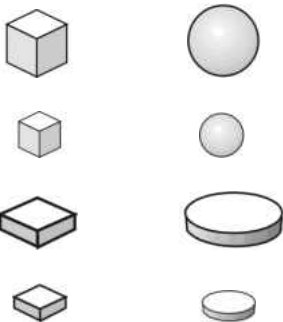
Haptic Matrices Intelligence Assessment (HMIA): **PARTICIPANT ID #:**_____

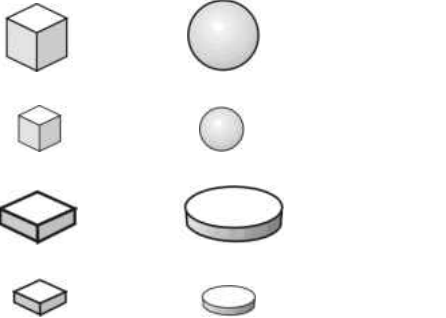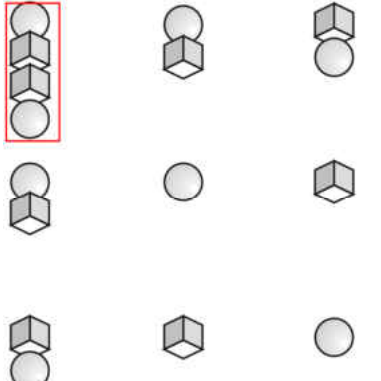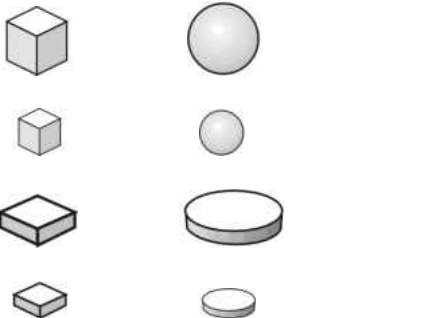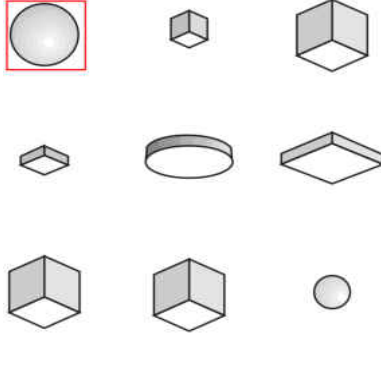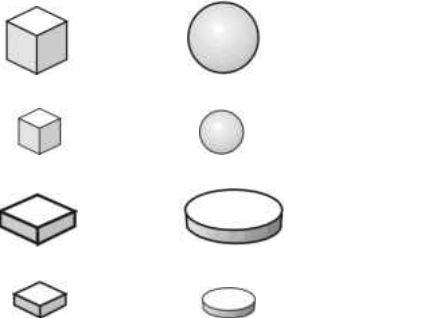<u>*<When recording a stocked shapes response, label "1" as the BOTTOM shape on the post.>*</u>
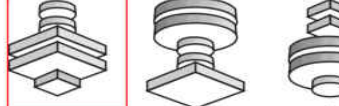
Item	Correct response	Participant's response	Time:
A	Large square		n/a
1			
2			
3			
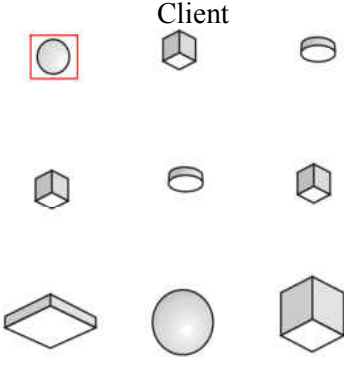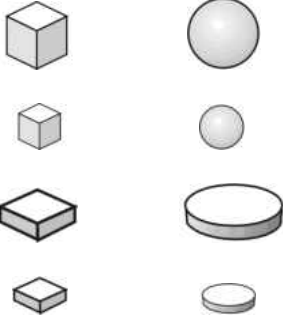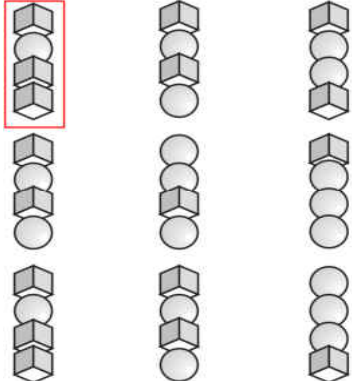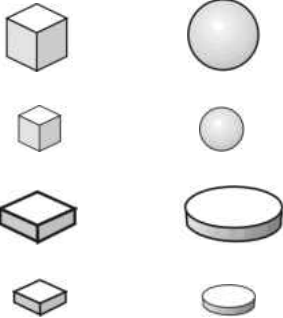
Item		Participant's response	Time:
4	Client Experimenter		
5	Client Experimenter		
6	Client Experimenter		

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Item		Participant's response	Time:
7	Client Experimenter		
8	Client Experimenter		
9	Client Experimenter		

Item		Participant's response	Time:
10	Client Experimenter		
11	Client Experimenter		
12	Client Experimenter		

Item		Participant's response	Time:
13	Client Experimenter		
14	Client Experimenter		
15	Client Experimenter		

Item		Participant's response	Time:
16	Client Experimenter		
17	Client Experimenter		
18	Client Experimenter		

Item		Participant's response	Time:
19	Client Experimenter		
20	Client Experimenter		

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