Haptic Tests for Use with Children and Adults with Visual Impairment: A Literature Review

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Abstract

We sought to provide a quantitative overview of haptic tests, so as to identify what has been done in this area so far, and discuss possible avenues for the future design of haptic tests for use with persons with visual impairment. We reviewed 24 haptic psychometric tests, that is, tests performed in the haptic modality, with no reliance on vision. We found that haptics (i.e., tactilo-kinesthetic perception or the sense of active touch) has been used in two different ways: first, to assess nonverbal/practical intelligence, replacing vision in haptic analogs of mainstream tests (e.g., tactile adaptations of Wechsler performance scales); second, to assess, per se, the quality of haptic functioning in specialized tests (e.g., Tactual Profile, Haptic Test Battery). In both cases, we found that only a limited number of tests had been standardized for children and/or were developmental tests. We also noticed an overwhelming use of 3D material in the tests, and a general lack of a comparison group (blindfolded sighted participants) during the standardization process. We discuss the usefulness of designing developmental haptic test batteries to assess 2D haptic functioning in visually impaired and sighted children.

Introduction

Psychometric tests are part of the basic toolkit available to psychologists to assess the personality, knowledge, skills and attitudes of individuals with reference to a standard population. They are used in many areas, including education, therapy, recruitment, academic achievement, and counseling. As the vast majority of psychometric assessment tools rely on the visual modality, their usability in persons with visual impairment (i.e., those who are totally blind, legally blind or have low vision) still provokes controversy (see Reid, 1994, 1995). Several American surveys (Bauman & Kropf, 1979; Hannan, 2007; Miller & Skillman, 2003) have quantified the use of and satisfaction with measures of cognitive abilities applied to visually impaired individuals. These studies concluded that there is considerable dissatisfaction among professionals with current assessment procedures, with doubts being expressed as to their appropriateness for use with visually impaired children and adults. In the UK, Atkins (2011) recently reviewed a range of psychometric tests that have been developed for use with visually impaired people in the education and employment fields, the majority based on tests for sighted people (e.g., Wechsler intelligence scales). According to Atkins, visually impaired individuals are potentially disadvantaged by the use of these tests, the nonverbal aspects of the tests being particularly problematic, owing to their reliance on visual images, and the limitations or difficulties of adapting the visual material using haptic models.

Haptics (i.e., tactilo-kinesthetic perception) plays a key role in our cognitive and perceptual development (Hatwell, Streri, & Gentaz, 2003). Tactilo-kinesthetic perception results from the stimulation of the skin, together with the muscles, joins, and tendons, due to active exploratory hand movements (Hatwell et al., 2003; Revesz, 1950). Haptic perception usually occurs under conditions of active touch, when the subject's hand or skin contacts an object (see Gibson, 1966). Therefore it is common to equate haptics with the sense of active touch. Note however that in some very specific cases, haptic exploration can also occur under

conditions of passive touch, when the subject's hand or skin is guided by an external agency (a machine or the experimenter) across an object (see e.g., van Doorn, Dubaj, Wuillemin, Richardson, & Symmons, 2012). Haptics is the first sense to develop in the womb (see Heller & Schiff, 1991; Heller & Gentaz, 2013), and an important modality used by infants and young children to acquire information about their environment (Bushnell & Boudreau, 1991). Haptics is also fundamental to the development of children with visual impairments, allowing them to gain knowledge about the outside world and function as independently as possible in their everyday lives (Hatwell, 2003; Withagen et al., 2010). In both children and adults, this modality is particularly effective in the perception of the material properties of three-dimensional (3D) objects as well as in their manipulation (Gentaz, 2009; Hatwell, et al., 2003; Lederman & Klatzky, 2009). But it can also be used to process two-dimensional (2D) raised-line materials, such as diagrams and graphics (e.g., Lederman & Campbell, 1983), maps and plans (e.g., Espinoza & Ochaita, 1998), shapes and geometric patterns (e.g., Bailes & Lambert, 1983 ; Picard, Lebaz, Jouffrais, & Monnier, 2010), or pictures of common objects (e.g., D'Anguilli & Kennedy, 1998; Picard, Albaret, & Mazella, 2013; see also Picard & Lebaz, 2012 for a literature review). Haptics therefore represents an alternative modality to vision for the psychometric assessment of cognitive and perceptual-motor abilities, and may be specifically suitable for assessing visually impaired individuals whose "perceptual experience is haptic rather than visual" (Ballesteros, Bardisa, Millar, & Reales, 2005, p. 11).

So far, however, tests based on haptics have not been specifically reviewed, thus limiting our understanding of how the sense of active touch has been used as the assessment modality for cognitive and perceptual-motor abilities. Unlike most previous studies, which have either undertaken surveys (on the use of and satisfaction with tests for blind people), or else examined psychometric tools in general (with no specific focus on haptics), the present study was intended to provide a *quantitative* review of haptic psychometric tests. We defined

haptic tests as tests that are performed in the haptic (or tactilo-kinesthetic) modality, with no reliance on vision, and which are therefore potentially usable in the case of visual impairment. More specifically, the aim of this literature review was to identify the main characteristics of the haptic test landscape (i.e., what has been done thus far), and to discuss possible avenues for future research and for the design of haptic tests aimed at visually impaired persons (i.e., what should be done next).

Method

A search of scientific databases (e.g., PsycINFO, PubMed, Google Scholar, Science Direct) yielded 24 tests published over the past 66 years that matched our inclusion criteria: tests performed in the haptic modality (active or guided conditions of touch, with no reliance on vision); publication in a scientific journal and/or manual; stimulation of the cognitive and perceptual-motor sphere; use of tactile (i.e., manually explorable) 2D or 3D material; participation of visually impaired individuals (legally blind or totally blind) and/or blindfolded sighted individuals; and reporting of validity and/or reliability measures. Psychometric tests that assessed knowledge, academic achievement (including braille reading skills), or purely kinesthetic, or purely cutaneous, or motor skills were not taken into account.

We considered tests produced over a particularly long timespan, as we took the year in which the very first haptic test (Tactual Performance Test, 1947) was made available as our starting point. The quality of psychometric tests has, of course, changed considerably in the course of these 66 years. As underlined by previous American surveys, psychometric tests published before 1990 are now seldom used with visually impaired individuals, for a variety of reasons (e.g., highly complex and stressful items, lengthy testing times, high production costs, cumbersome or childish materials). We decided, however, not to exclude any *old* tests from our corpus, in order to gain a truly comprehensive picture of the haptic test landscape.

Results

An examination of the corpus (see Table 1) revealed that this field has generated a great deal of activity, starting in the 1950s-70s (11 tests) and continuing in the 90s (5 tests), with a fresh wave of tests published since the early 2000s (8 tests). The majority of these tests (58 percent, *n* =14/24) have originated from the US, the remainder coming from Europe (30 percent; Netherlands, UK, France, Spain) and Asia (12 percent; Japan, India, Taiwan). Within Europe, the Dutch are particular interested in the assessment of visually impaired people (three tests developed in 1974, 1993, and 2009). English is the main standardization and assessment language, and so far, very few tests have been translated and adapted to other cultures.

(Insert Table 1 about here)

As can be seen in Table 1, fewer than half the tests (46 percent, *n* = 11/24) are specialized tests developed directly for the haptic modality. The majority (54 percent, *n* = 13/24) are analogs, that is, famous mainstream tests adapted from the visual to the haptic modality. These mainstream tests include the Kohs Block Design Test (four haptic versions: 1960, 1966, and twice in 2002), the Wechsler intelligence scales (three haptic versions: 1964, 1990, and 1993), Raven's Progressive Matrices (two haptic versions: 1964 and 2007), the D48 (one haptic version: 1968), the Boehm Test of Basic Concepts (one haptic version: 1977), the TONI (one haptic version: 1989), and the Wisconsin Card Sorting Task (one haptic version: 2004). They were all designed and standardized for visually impaired participants. Tests belonging to this category are mostly assumed to measure nonverbal or practical intelligence in individuals with visual impairments, relying either on a single skill (e.g., the ability to distinguish and copy patterns in the haptic versions of the Kohs Block Design Test) or else on multiple Wechsler-based performance subtests (six subtests in the Haptic Intelligence Scale for Adult Blind, 1963; five subtests in the Cognitive Test for the Blind,

1990; eight subtests in the ITVIC, 1993). Regardless of the category, all haptic tests involved an active condition of touch (there were no haptic tests with a guided touch).

Only a minority of the specialized haptic tests (3/11) are intended to be used as part of a neuropsychological assessment that does not specifically target visually impaired people. These three tests are the Tactual Performance Test from the Halstead battery (1947), which measures possible deficits in tactile perceptual skills associated with frontal lesions, the Hand Active Sensation Test (2006), which measures tactile functioning in stroke survivors, and the Manual Tactile Tests for hands with sensory deficits (2012), which measures haptic discrimination skills in adults with carpal tunnel syndrome (median entrapment neuropathy). The eight remaining haptic tests were designed specifically to assess visually impaired adults (Vocational Intelligence Scale for the Adult Blind, 1964; Tactual Reconstruction Pegboard, 1966; Haptic Sensory Discrimination Test, 1990) or children (Roughness Discrimination Test, 1965; Mommers Test, 1974; Vithoba Paknikar Performance Test, 1981; Haptic Test Battery, 2002; Tactual Profile, 2009). These tests are intended to measure the quality of haptic functioning, including haptic discrimination skills, haptic spatial perception, and memory in sighted or visually impaired individuals. Again, depending on the test, the quality of haptic functioning is assessed either through reliance on a single skill (e.g., the ability to discriminate textures in the Roughness Discrimination Test, 1965) or else via multiple performance subtests organized into broad categories (six categories of tests in the Haptic Test Battery, 2002; four categories of tests in the Tactual Profile, 2009).

The tests listed in Table 1 have generally been standardized for adults (age range: 16-85 years), and are primarily suited to assessing adult participants. It is noticeable that only a third of the tests have been standardized for children (age range: 0-16 years), and/or are developmental tests. Furthermore, comparisons between visually impaired and sighted (blindfolded) participants during the standardization process is certainly not the rule of thumb,

as just one test-the Haptic Test Battery (2002)-included both sighted and visually impaired participants so that norms would be available for both groups. Another striking feature of this corpus is the overwhelming use of 3D material (3D objects, shapes, and textured blocks): 62.5 percent of the tests feature 3D material, and 2D material (2D raised shapes, textures, or raised-line shapes) is present in only 37.5 percent of them. Finally, not all the tests in Table 1 have all the statistical properties required for a genuine psychometric test. Although measures of convergent validity (i.e., degree to which scores on a test correlate with scores on other tests that are supposed to measure the same construct) are often reported (70 percent of tests), the same cannot be said for discriminant validity (i.e., degree to which scores on a test do not correlate with scores on other tests that are not supposed to measure the same construct), which is reported in only 8 percent of cases (2/24). The two tests reporting both convergent and discriminant validity measures are contemporary American and Dutch tests, developed in 2007 (3D Haptic Matrix test of nonverbal reasoning) and 2009 (Tactual Profile).

Conclusion

This literature review shows that haptic tests represent a relatively large area that is still evolving. Unsurprisingly, these tests are mostly, albeit not exclusively, American, and intended for a visually impaired population. Interestingly, the tests can be divided into two main categories: haptic analogs of mainstream tests, where active touch is used *as a replacement for vision* to assess nonverbal/practical intelligence; and specialized tests, where active touch is used *per se* to assess the quality of haptic functioning. Regardless of type, the tests predominantly assess adult participants (rather than children) and are generally confined to haptic interactions with 3D materials (as opposed to 2D materials). Overall, the tests lack cross-cultural validation, comparison data with sighted peers, and comprehensive psychometric indices.

The haptic test landscape therefore presents rather a mixed picture. On the one hand, the specialized tests that have emerged so far appear to offer tremendous potential, representing an alternative to the much-criticized haptic analogs of mainstream tests. More important, they appeal to a sensory modality that is fundamental for those with visual impairments in their daily life activities. On the other hand, there are noticeable drawbacks to some tests, arising from missing psychometric properties (i.e., convergent/discriminant validity measures are not systematically reported), that may impair their quality. There is also a tendency to design assessment tools for adults, and a reliance on 3D material, meaning that the field's full potential has yet to be realized.

Perspectives

We suggest that the design of specialized haptic tests incorporating all the properties expected from genuine psychometric tests, plus a comparison group (blindfolded sighted peers), should be promoted without further delay. A comparison group is both useful for theory (understanding haptic functioning with impaired and unimpaired vision) and/or application (designing tests that are usable irrespective of visual status). More specifically, we believe that it would be useful to design developmental haptic tests to assess 2D haptic functioning in visually impaired children. Currently, only a limited number of assessment tools for visually impaired pupils take age-related changes in their haptic skills into consideration. Moreover, due to the overwhelming use of 3D material in haptic tests, the quality of 2D haptic functioning in visually impaired children has yet to be investigated. While the use of 3D assessment material appears both ecological and suited to the haptic modality (Lederman & Klatzky, 2009), we cannot ignore the fact that visually impaired individuals are extensively exposed to 2D materials. From an early age, they learn to interact haptically with 2D materials, including raised dots (braille) and a wide variety of raised-line

pictures (e.g., symbols, graphs, maps, drawings) both at home and at school (Kirby & D'Anguilli, 2011). School children develop skills with more and more sophistication with these kinds of representations (e.g., perspective drawing, metaphoric pictures; see Kennedy, 1993). Accordingly, designing a developmental 2D haptic test battery would fill an important gap in the field of haptic tests for use with visually impaired children.

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Table 1. Main characteristics of the corpus of 24 psychometric tests using the haptic modality (ranked by year of initial publication).

Year of initial publication	Name of Test	Authors (Country)	Original language	Original visual version	Participants	Age range	Sample size	Material	Tasks	Measured abilities	Measures of convergent/ discriminant validity	Developmental test	Testing Time
1947	Tactual Performance Test	Halstead (USA)	English	None	Blindfolded sighted children & adults	5-85 yrs	≥ 200	3D shapes (geometric forms)	Replace blocks according to model	Tactile perceptual skills, tactile-spatial memory	-	No	30-60 min
1960	Ohwaki-Kohs Block Design Test	Ohwaki et al. (Japan)	Japanese (+ English)	Khos Block Design Test	Visually impaired adults (blind)	6-21 yrs	50-100	3D textured blocks	Arrange blocks according to model	Nonverbal intelligence	Convergent (WAIS)	Yes	60-90 min
1963	Vocational Intelligence Scale for the Adult Blind	Jones (USA)	English	None	Visually impaired adults (blind)	20-50 yrs	≥ 200	2D raised shapes (geometric forms)	Find shape that matches the standard	Tactile perception, shape recognition	Convergent (WAIS)	No	30-60 min
1964	Haptic Intelligence Scale for Adult Blind	Shurrager & Shurrager (USA)	English	Wechsler Adult Intelligence Scale (WAIS)	Visually impaired adults (blind)	16-64 yrs	≥ 200	3D objects, 3D shapes, 2D raised shapes (geometric forms)	6 subtests: digit symbol; object assembly; block design; object completion; pattern board; bead arithmetic	Nonverbal intelligence	Convergent (WAIS)	Yes	> 90 min
1964	Tactual Progressive Matrices	Anderson & Belz (USA)	English	Raven's Progressive Matrices	Visually impaired adults (blind)	16-64 yrs	100-200	2D raised shapes (geometric forms)	Select correct piece to complete matrix	Nonverbal intelligence	Convergent (WAIS)	No	30-60 min
1965	Roughness Discrimination Test	Nolan & Morris (USA)	English	None	Visually impaired children	5-6 yrs	-	2D raised textures	Discriminate textures	Tactile perception	-	No	< 30 min
1966	Stanford-Ohwaki-Kohs Tactile Block Design Test	Suinn et al. (USA)	English	Khos Block Design Test	Visually impaired adults	*M* = 39 yrs	≥ 200	3D textured blocks	Arrange blocks according to model	Nonverbal intelligence	Convergent (WAIS)	No	60-90 min
1966	Tactual Reconstruction Pegboard	Gruber (USA)	English	None	Visually impaired adults (blind)	20-50 yrs	≥ 200	3D objects	Place pegs on board; reconstruct board as in model	Manual dexterity, spatial understanding	Convergent (WAIS)	No	< 30 min
1968	D48 Test	Gough & Domino (UK)	English	D48	Visually impaired adults	≥ 18 yrs	-	3D objects	Find missing domino	Nonverbal intelligence	Convergent (WAIS)	No	> 90 min

1974	Mommers Test	Mommers (Netherlands)	Dutch	None	Visually impaired children (blind)	7-13 yrs	100-200	2D raised-line shapes (geometric forms)	Discriminate shapes, object sizes, spatial orientation and roughness	Haptic intelligence	-	Yes	-
1977	Tactile Test of Basic Concepts	Caton (USA)	English	Boehm Test of Basic Concepts	Blindfolded sighted children	4-7 yrs	50-100	2D raised-line shapes (drawings of common objects)	Find picture that corresponds to stated object or situation	Concept comprehension	Convergent (BTBC)	Yes	< 30 min
1981	Vithoba Paknikar Performance Tests for the blind	Paknikar (India)	Hindi	None	Visually impaired children & adults (blind)	8-22 yrs	≥ 200	3D objects	Discriminate shape, texture, and weight	Nonverbal intelligence	-	Yes	-
1989	Tactile TONI	Ducan et al. (USA)	English	TONI	Visually impaired adults (blind)	19-50 yrs	< 50	2D raised-line shapes (geometric forms)	Choose right figure to complete the series	Nonverbal intelligence	Convergent (WAIS)	No	60-90 min
1990	Cognitive Test for the Blind-Non-visual performance subtests	Dial et al. (USA)	English	Wechsler Adult Intelligence Scale (WAIS)	Visually impaired adults (blind)	18-69 yrs	≥ 200	3D objects, shapes (geometric forms) and textures	5 subtests: haptic category learning; haptic category memory, haptic memory recognition; pattern recall; spatial analysis	Nonverbal intelligence	Convergent (WAIS)	No	90 min
1990	Haptic Sensory Discrimination Test	Dial et al. (USA)	English	None	Visually impaired adults	18-69 yrs	≥ 200	3D shapes (geometric forms) and textures	Discriminate size, texture, shape and spatial configuration	Tactile discrimination, short-term tactile memory	-	No	-
1993	Intelligence Test for Visually Impaired Children-Non-visual performance subtests	Dekker (Netherlands)	English (+ Dutch-German)	Wechsler Intelligence Scale for Children (WISC)	Visually impaired children & adults (blind)	6-15 yrs	100-200	3D objects and shapes (geometric forms)	8 subtests: name learning; digit span; exclusion of figures; figural analogies; figure perception; block design; puzzles; map and plan questions.	Nonverbal intelligence	Convergent (WAIS)	Yes	-
2002	Adapted Kohs Block Design Test	Reid (UK)	English	Khos Block Design Test	Visually impaired adults (blind)	16-64 yrs	50-100	3D textured blocks	Arrange blocks according to model	Practical intelligence, tactile-spatial reasoning	Convergent (WAIS)	No	-
2002	B-101-DV	Thiebaut et al. (France)	French	Kohs Blocks Design Test	Visually impaired adults (blind)	16-59 yrs	≥ 200	3D textured blocks	Arrange blocks according to model	Practical intelligence, tactile-spatial reasoning	Convergent (B53 & BLS4)	No	< 30 min

2002	Haptic Test Battery	Ballesteros et al. (Spain)	Spanish	None	Visually impaired (blind) & blindfolded sighted children	3-16 yrs	100-200	3D objects and shapes, 2D raised-line shapes (geometric forms)	6 categories of tests: spatial comprehension; short-term memory; raised-shape identification; haptic exploration; long-term coding for new objects	Haptic perception and memory	-	Yes	30-60 min
2004	Tactile Wisconsin Card Sorting Test	Beauvais et al. (USA)	English	Wisconsin Card Sorting Test	Visually impaired adults	*M* = 55 yrs	< 50	2D raised textures and shapes (geometric forms)	Find rules for matching cards with different key cards	Executive functions	Convergent (WAIS)	No	-
2006	Hand Active Sensation Test	Williams et al. (USA)	English	None	Stroke survivors & blindfolded sighted adults	32-84 yrs	50-100	3D objects	Match objects by weight and texture	Haptic perception	-	No	< 30 min
2007	3D Haptic Matrix test of nonverbal reasoning	Miller et al. (USA)	English	Raven's Progressive Matrices	Visually impaired adults (blind)	18-79 yrs	< 50	3D objects	Complete matrix	Nonverbal cognitive abilities (haptic spatial ability)	Convergent (CTB-spatial tasks); discriminant (verbal IQ)	No	-
2009	Tactual Profile	Withagen et al. (Netherlands)	Dutch (+ German, English)	None	Visually impaired children (blind)	0-16 yrs	50-100	3D objects	4 categories of tests: tactile sensory functioning; tactile motor functioning; tactile perceptual functioning; practical skills	Tactile functioning	Convergent (Mommers test), discriminant (WIPPSI)	Yes	> 90 min
2012	Manual Tactile Tests for hands with sensory deficits	Hsu & Kuo (Taiwan)	Chinese	None	Carpal tunnel syndrome & blindfolded sighted adults	15-55 yrs	100-200	3D objects	Discriminate objects by weight, texture, and shape	Haptic discrimination skills	Convergent (SWM, M2PD, S2PD)	No	-

Note. In the Participants column, (blind) indicates that the sample of visually impaired participants included totally blind subjects.