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Haptic-2D: A new haptic test battery assessing the tactual abilities of sighted and visually impaired children and adolescents with two-dimensional raised materials

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ABSTRACT

To fill an important gap in the psychometric assessment of children and adolescents with impaired vision, we designed a new battery of haptic tests, called Haptic-2D, for visually impaired and sighted individuals aged five to 18 years. Unlike existing batteries, ours uses only two-dimensional raised materials that participants explore using active touch. It is composed of 11 haptic tests, measuring scanning skills, tactile discrimination skills, spatial comprehension skills, short-term tactile memory, and comprehension of tactile pictures. We administered this battery to 138 participants, half of whom were sighted ($n = 69$), and half visually impaired (blind, $n = 16$; low vision, $n = 53$). Results indicated a significant main effect of age on haptic scores, but no main effect of vision or Age × Vision interaction effect. Reliability of test items was satisfactory (Cronbach's alpha, $\alpha = 0.51–0.84$). Convergent validity was good, as shown by a significant correlation (age partialled out) between total haptic scores and scores on the B101 test ($r_p = 0.51$, $n = 47$). Discriminant validity was also satisfactory, as attested by a lower but still significant partial correlation between total haptic scores and the raw score on the verbal WISC ($r_p = 0.43$, $n = 62$). Finally, test–retest reliability was good ($r_s = 0.93$, $n = 12$; interval of one to two months). This new psychometric tool should prove useful to practitioners working with young people with impaired vision.

1. Introduction

The psychometric assessment of children and adolescents with impaired vision (i.e., those who are totally blind, legally blind or have low vision) is still challenging, inasmuch as most available instruments rely heavily on sight or were originally designed for sighted participants. The usability of such instruments in persons with impaired vision is therefore subject to debate (Reid, 1995, 2002). Evidence of major dissatisfaction among professionals with current assessment procedures of cognitive abilities in visually impaired persons has been provided by several American surveys (Bauman & Kropf, 1979; Hannan, 2007; Miller & Skillman, 2003). Today, psychologists mostly use the verbal subscale of the Wechsler Intelligence Scale for Children-Revised (WISC-IV-R; Wechsler, 2005) to assess the cognitive functioning of visually impaired children (see Atkins, 2011). However, as its name implies, this verbal subscale does not yield any information about nonverbal reasoning.

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Furthermore, doubts have been expressed about the appropriatness of using some verbal items with visually impaired children, who may be at a disadvantage (and therefore obtain lower scores) compared with their sighted peers (Tillman, 1967). Psychologists also use *handmade* tests (e.g., producing their own tactile versions of existing tests, enlarging characters or increasing constrasts in existing tests), but such tests lack scientific grounding. Thus, psychologists and educationalists working with young people who have a visual disability currently lack efficient assessment instruments. One way of filling this gap would be to develop nonvisual tests that are specifically designed and standardized for visually impaired children.

The haptic modality (i.e., sense of active touch; Gibson, 1966; Revesz, 1950) represents an interesting alternative modality to vision for assessing the perceptual-motor and cognitive functioning of children with impaired vision. This modality plays a key role in the development of blind children (Hatwell, 2003; Withagen, Verloed, Janssen, Knoors, & Verhoeven, 2010). The sense of haptics is particularly effective at processing the material properties of three-dimensional (3D) objects (e.g., texture, hardness, and temperature) and, to a lesser extent, their geometric properties (e.g., shape, size, or volume; Hatwell, Streri, & Gentaz, 2003; Klatzky, Lederman, & Metzger, 1985; Lederman & Klatzky, 2009). The sense of haptics can also be used to process two-dimensional (2D) objects, such as the raised dots in Braille patterns (see Millar, 1997), and the variety of raised-line materials (e.g., geometric shapes, diagrams, graphs, maps, plans, patterns, and outline drawings) that visually impaired children encounter at school or at home in the course of their education. However, owing to the sequential nature of manual haptic exploration, the processing of 2D objects' spatial information is slow and places heavy demands on memory and spatiotemporal integration. As a result, the haptic processing of 2D objects is usually far less effective than that of 3D objects. For example, Klatzky, Loomis, Lederman, Wake, and Fujita (1993) showed that the haptic identification of real objects was clearly superior to that of raised 2D depictions: in their study, blindfolded adults were very fast ($\approx$1–2 s) and accurate (nearly 100%) at identifying common objects by hand (like a comb or an ashtray), whereas they were slower ($\approx$90 s) and far less accurate ($<$30%) at identifying by touch the raised-line drawings of these objects. Despite extensive fundamental research on haptic perception (Klatzky & Lederman, 2009; Lederman & Klatzky, 2009), both applied (psychometric) and developmental studies of haptic functioning in children who are visually impaired remain rare.

A recent literature review of haptic psychometric tests (i.e., tests performed in the haptic modality with no reliance on vision; Mazella, Albaret, & Picard, 2014a) showed that most tests assess adult participants, rather than children. Moreover, these tests are confined to interactions with 3D objects, as opposed to 2D materials. Two categories of tests were identified: tests where active touch is used as a replacement for vision (haptic analogs of mainstream tests such as the Cognitive Test for the Blind (CTB), an analog of the Wechsler Intelligence Scale for Adults; Dial et al., 1990), and tests where active touch is used per se to assess haptic functioning (specialist tests such as the Haptic Sensory Discrimination Test; Dial et al., 1990). Regardless of their category, most of the reviewed tests lacked comprehensive psychometric indices of sensitivity, reliability, and validity. The authors of this review therefore called for the design of new haptic tests incorporating all the properties expected of genuine psychometric tests, and more specifically for the design of developmental haptic test batteries.

To date, two notable psychometric studies of haptic functioning in children who are visually impaired have been conducted from a developmental perspective. The first study was a research project carried out in the Netherlands by Withagen et al. (2005), Withagen and Schellingerhout (2004) and Withagen, Vervloed, Janssen, Knoors, and Verhoeven (2009). These authors developed and validated a psychometric instrument called the Tactual Profile, which assessed the tactual functioning of blind children from ages one to 15. The Tactual Profile consisted of a large set of items (430) measuring the tactual skills required from blind children to perform everyday and school-related activities. The items were arranged according to age level and domain of tactual functioning (sensory, motor, perceptual, and practical). Tactual sensory functioning items (106) assessed passive perception (e.g., tactual awareness, touch sensitivity). Tactual motor functioning items (52) assessed motor proficiency (e.g., tactual exploration, manipulation). Tactual perceptual functioning items (162) assessed the interpretation of tactual information (e.g., perception of detail, discrimination). Finally, practical skills items (110) probed daily life skills involving touch (e.g., touch strategy, linking function to object). This instrument only used 3D materials, and was validated with an original sample of 55 participants. It had both convergent (assessment of intelligence and haptic perception in blind children; Mommers, 1974) and discriminant (verbal subscale of WISC-IV-R) validity, and satisfactory test–retest reliability ($r = 0.94$). Special educationalists working with blind children rated the Tactual Profile as an important and useful instrument, notably because it gave them useful leads for future interventions. However, one major drawback of this instrument was its length (administration time commonly totalled 4–5 h with children over 6 years).

The second study was a research project conducted in Spain by Ballesteros and Bardisa (2002), Ballesteros, Bardisa, Millar, and Reales (2005a) and Ballesteros, Reales, Bardisa, and Muniz (2005b). These authors developed a psychometric instrument called the Haptic Battery, which assessed the development of the perceptual and cognitive abilities involved in haptic processing by visually impaired children (and sighted controls) from age 3 to 16. The Haptic Battery consisted of 14 subtests measuring spatial comprehension (seven subtests), short-term memory (three subtests), object identification (one subtest), raised-shape identification (one subtest), sequential scanning (one subtest), and longer-term coding for new objects (one subtest). This instrument used both 3D and 2D materials, and was validated with an original sample of 119 participants (59 visually impaired, 60 sighted). It had satisfactory internal consistency (Cronbach's alpha, α 0.54–0.88), construct validity (six-factor structure), and age sensitivity. The Haptic Battery took less than an hour to administer. The authors wrote that the Haptic Battery "should prove to be a very useful, as well as valid and reliable instrument" (Ballesteros et al., 2005a, 2005bBallesteros et al., 2005a, 2005b, p. 23). To the best of our knowledge, however, the research project was not taken any further, meaning that this promising instrument's additional psychometric properties (i.e., convergent and discriminant validity, test–retest reliability) were never measured.