Tactile Functioning in Children Who Are Blind: A Clinical Perspective

Ans Withagen, Mathijs P. J. Vervloed, Neeltje M. Janssen, Harry Knoors, and Ludo Verhoeven

Abstract: This study of 48 children with congenital blindness who attended mainstream schools focused on the tactile and haptic skills they needed in typical academic and everyday tasks. The results showed that, in general, the children mastered such tactile tasks, but some items posed special problems.

Touch is essential for children who are blind to gather information about their surroundings and to perform everyday tasks. Touch gives information not only on the characteristics of objects, such as their shape, size, and texture, but on the functional aspects of objects, such as the possibility that they can be used as tools. Moreover, in the everyday lives of children who are blind, haptic skills are indispensable for functioning as independently as possible. Children who are blind have to solve tasks differently from children who are sighted because they have to use touch instead of vision to obtain information. Moreover, ordinary tasks that are easily performed by using vision may be complex when they are performed by using touch (Jansson, 2008). From a pedagogical perspective, it is essential to teach children who are blind all the possible and relevant strategies to help them cope with everyday challenges (McLinden & McCall, 2002), especially since most children who are blind are mainstreamed in regular schools, where they face a reasonable number of tactile challenges whenever they try to solve academic tasks by touch instead of vision.

Researchers in psychophysics and psychology also have a theoretical interest in touch and blindness. People who are blind have to adapt to lives without sight. This situation is fundamentally different from the situation of any blindfolded participant in an experiment on the relationship between perception and action. Several studies have shown that perception and action are narrowly linked in the haptic sense, more than in the other senses (Hatwell, 1978; Hatwell, Orliaguet, & Brouty, 1990; Hatwell, Streri, & Gentaz, 2003). Exploratory actions seem to determine what is perceived and how it is perceived. An example is the distinction between

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active and passive touch. According to Heller (1984, 1989, 1991, 2000a, 2000b) and Heller and Meyers (1983), active touch is especially important for performing tasks involving the perception of forms or during manipulation of objects to obtain information about them, whereas passive touch can be an effective strategy for the perception of known forms of limited size.

With regard to the exact nature and development of the tactile skills of people who are blind, knowledge is rather limited, which is a real drawback, since touch is so important for them. However, because of recent neurocognitive and behavioral studies (Hatwell et al., 2003; Heller, 2000a, 2000b, 2006; Merabet et al., 2007), knowledge of touch has increased. What follows are a few examples to illustrate this point.

Haptic exploration was studied in depth by Jones and Lederman (2006), Klatzky, Lederman, and Metzger (1985), and Lederman and Klatzky (1987, 1996). These studies showed how remarkably fast and accurate the haptic identification of a wide range of objects is. They identified exploratory procedures, that is, specific manual behaviors that are used to gain information about the properties of objects (such as size, weight, texture, temperature, hardness, and the exact shape). They also observed two phases in exploratory strategies: nonspecific exploratory procedures and specific exploratory procedures. The nonspecific exploratory procedures (like enclosure), give global information about objects, whereas the specific procedures (such as following contours) give more or less exact information about objects. Note that most of Lederman and Klatzky's research was conducted with adults who were sighted and blindfolded so as to exclude vision as a source of information. But the results of their studies cannot be automatically generalized to people who are congenitally or adventitiously blind, since people who can see are still capable of using visual experience, visual memory, and visual imagery while they are blindfolded.

Millar (1994, 2006) studied the role of touch in spatial coding and spatial representation by people who are blind. One of her main conclusions was that the complete absence of vision reduces the information about external reference cues and informational redundancy, meaning that there is less overlap with input from the other senses. This finding implies that people who are blind have to use body-centered cues, rather than external cues, to solve spatial tasks.

Millar (1997, 2006) also studied braille reading. After analyzing the tactile skills that are necessary for fluent braille reading, she concluded that the importance of familiarity, practice, and experience is evident in tactile discrimination. Millar (2008) reached a similar conclusion with regard to the understanding of space; that is, for spatial coding, it is crucial to get information from reference cues. She assumed that spatial processes are activities of the organism that integrate input from diverse sources to act as reference cues. Spatial coding integrates input from diverse sources. For persons who are blind, Millar's theory stresses the importance of exploring and scanning hand movements during spatial tasks. The body-centered cues, which people who are blind generally use in spatial tasks, may increase the accuracy of the recall of distance and location.

Both Heller (2006) and Kennedy (2000) studied the perception of pictures by people who are blind (see also Kennedy, Gabias, & Nicholls, 1991; Kennedy & Juricevic, 2006). When these persons were assessed with raised-line pictures, they were often able to recognize sketches and outline drawings, even those that were drawn in perspective. Astonished by this finding, these researchers subsequently studied different modes and aspects of picture representations: tactile space, outline drawings, perspective, and metaphors. Kennedy (2006) showed that touch allows people to understand outline drawings and that in persons who are blind, the development of drawing occurs in similar ways as in persons who are sighted. Furthermore, Kennedy showed that the geometry of perspective that is used to make outline pictures is largely the same for both touch and vision, although the concept of perspective is more well defined in vision than in touch.

Despite an increase in fundamental studies on touch, applied studies of the tactile functioning of individuals who are blind are still rare. Moreover, a developmental perspective on tactile functioning is generally lacking. As a result, there is no consensus among clinicians whether touch skills are at risk for persons who are blind and whether touch skills should be stimulated or trained. What is known is that people who are congenitally blind outperform people who became blind at a later age with regard to their braille reading speed, probably because touch acuity diminishes with age (Jansson, 2008). With this point in mind, it seems wise to start intervention at an early age, as was promoted by Marek (1999, 2000), who developed materials for people who are blind to teach the specific tactile skills and spatial insights. But again, whether training is necessary and effective has still to be proved.

In the study presented here, we assessed the tactile functioning of children from birth to age 12 with congenital blindness. Our assessment tool was the Tactual Profile, an instrument that is designed to evaluate the tactile skills of children who are blind with regard to tactile sensory functioning, tactile motor functioning, and tactile perceptual functioning (Withagen et al., 2005).

Methods

Participants

Participants were recruited from the records of all institutes and schools for students who are visually impaired in the Netherlands and Flanders. Children were included who had visual acuities of less than 5/100 from birth, attended mainstream schools, ranged in age from birth to age 16, had a proper understanding of the Dutch language, and had no additional impairments. An inspection of school records revealed a total of 110 potential participants. The school records proved to be unreliable in 14 cases, leaving 96 potential participants, of whom 51 agreed to participate (response rate 53%). Only 3 children aged 12–16 were recruited. Since this sample of 3 was considered too small to be included in the study, these children were excluded. As a result, 48 children who ranged in age from birth to age 12 were included in the final sample (see Table 1 for the characteristics of the participants).

Instruments

The Tactual Profile consists of items that are graded according to age level and are divided into three domains of tactile

Table 1
Characteristics of the participants.

Age group	Boys *n*	Girls *n*	Total, by age *n*	Mean age level (in months)
A (Birth to 2 years)	3	3	6	16
B (2–4 years)	5	10	15	36
C (4–6 years)	6	6	12	57
D (6–9 years)	5	1	6	93
E (9–12 years)	3	6	9	124
Total	22	26	48	65

functioning (tactile sensory, tactile motor, and tactile perceptual) and one domain of practical skills. The instrument is based on direct observation of the items by the administrator. The tactile skills of the children are scored as mastered or not mastered. Only items that were directly observed by the administrator were included in the study. Therefore, the practical skills items were not analyzed, because the results of these items were based on verbal responses of the parents and were not direct observations.

After items for children aged 12 and older and the practical skills items were excluded, the total number of items in the analyses totaled 303, divided over five different age groups: birth to 2 years, 2–4 years, 4–6 years, 6–9 years, and 9–12 years. Each domain is divided into different categories, but not every category has the same number of items for each age group. Tactile sensory functioning (106 items) consists of categories that incorporate all the perceptual components involved in touch, for instance, tactile awareness, touch sensitivity, and proprioception. Tactile motor functioning (52 items) consists of categories that require proficiency in motor skills, including tactile exploration, manipulation, and two-handedness. Tactile perceptual functioning (162 items) consists of categories that refer to the interpretation of tactile information, such as tactile discrimination, tactile-spatial perception, part-whole relationships, and the third and second dimensions.

Psychometric properties of the Tactual Profile are published in more detail elsewhere (Janssen, Withagen, & Vervloed, 2005; Schellingerhout & Withagen, 2002; Withagen & Schellingerhout, 2004; Withagen, Vervloed, Janssen, Knoors, & Verhoeven, in press). In short, face validity and content validity were determined by the ratings of experts. Subsequently, the item pool was adjusted in a second version of the Tactual Profile and studied in 50 children for construct validity, level of difficulty, and reliability. Reliability and construct validity turned out to be moderate to good (see Janssen et al., 2005; Withagen et al., in press).

Procedure and setting

The research followed the tenets of the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects. Prior to the study, informed consent was obtained from the parents of all the participants, and the study was ethically approved by the Independent Review

Board, an Amsterdam-based certified ethical review board. Examinations were performed by three trained administrators who were all familiar with children who are blind. Procedural reliability was ensured by organizing regular meetings with the administrators to discuss and check the administration and scoring of the Tactual Profile.

In the Tactual Profile, the items were divided over different age groups. In clinical use of the Tactual Profile, each child would receive the items belonging to his or her age group. To be able to find the skills that are the most difficult, half the group was also given items belonging to a younger age group, and the other half were given items belonging to an older age group. This way, it was possible to gather more information on the children's tactile skills.

Prior to the assessment, the forms for general data and warning signals were filled in with the parents of the young children (birth to 4 years) or the teachers of the older children (aged 5–12 years). For each child, the general data contained information about date of birth, etiology, additional diagnoses, residual vision, preferred sense, and background information. The warning signals consisted of items concerning complicating factors in tactile functioning, for instance, questions about overregistration (overreaction and tactile defensiveness) or underregistration (insensitivity) of tactile stimuli.

Children in age group A (birth to 2 years) were observed at home in the presence of their parents. Those in age group B (2–4 years) were observed at either a day care center or at home. All the children in the age groups C (4–6 years), D (6–9 years), and E (9–12 years) were assessed at their mainstream schools. The duration of the testing period depended on the number of items for each age group and the child's alertness and motivation, and ranged from 1.5 to 3.5 hours. During the assessment, no time restrictions were imposed on the participants.

Results

To describe success or failure in tactile functioning, we calculated levels of difficulty for each item, that is, the percentage of participants who succeeded in passing an item. Typical levels of difficulty between 0 and 0.10 (too difficult) and between 0.90 and 1 (too easy) are thought to be nondiscriminatory. In our sample, no item had a level of difficulty between 0 and 0.10, so none was too difficult for the participants. Of the 303 items, 51 (17%) had a difficulty level of 1, meaning that all the participants passed these items, and 25 (8%) items had difficulty levels between 0.90 and 1. As a result 76 (25%) items posed no problem at all. Most of these easily mastered items with difficulty levels between 0.90 and 1.0 were in age group A, namely, 39 items (51% of all items with difficulty levels between 0.9 and 1.0).

Next, we looked at difficulty levels of lower than 0.70, since we were interested not in extreme individual cases, but in more general strengths and weaknesses in the tactile functioning of children who are blind. We chose the more conservative cutoff value of 0.70 instead of 0.90 because of the small sample sizes as a consequence of the fact that not every item was offered to children in all the age groups. Of the total of 303 items, there were 73 (24%) items with difficulty levels of lower than 0.70 when the children were

Table 2
Failed items, by age level and domain of tactile functioning (numbers; percentages in parentheses).

Age group	Number of items	Tactile sensory	Tactile motor	Tactile perceptual	Total
A (Birth to 2 years)	85	1	1	–	2 (2.4)
B (2–4 years)	36	1	1	–	2 (5.6)
C (4–6 years)	60	–	1	8	9 (15.0)
D (6–9 years)	68	1	–	3	4 (5.9
E (9–12 years)	54	1	–	1	2 (3.7
Total	303	4 (3.8%)	3 (5.9%)	12 (8.1%)	19 (6.3)

tested only with items for their own age group. To be sure that an item was really difficult for children who are blind, we added an extra criterion; 30% or more of the children in the subsequent age group had to fail that item, too. A total of 19 items were not passed by 30% or more of the children in two age groups. The variation of these 19 items is depicted for each age group in Table 2.

Table 3 lists the difficult items for each tactile domain, that is, items with difficulty levels of 0.70 or lower. Items for 4- to 6-year-old children proved to be especially difficult. Given the small number of participants, no statistical analysis could be performed to group these 19 difficult items. Descriptively, some categories were discernable in these 19 items. Items that were difficult refer to recognizing and naming an object (8, 9, 19), recognizing the function or common use of an object (15, 16), comparing and matching objects (11), and searching for an object (6). All these items appeal to play; imitation; and working memory or mental acts, such as imagery, comparing, and matching.

A number of items also refer to touch strategies that children have to learn, such as reading braille with six fingers (3), using mobility strategies (feeling the height of an obstacle on the ground with one's feet, 7), or engaging in constructive play (4, 5). The items in the category part-whole relationships (15, 16, 17) refer to concept development. Table 4 shows the distribution for each age group and quartile of the number of participants who failed these items. Two children failed all 19 difficult items and performed poorly over the total range of the Tactual Profile. As can be seen in Table 4, most children failed more than 50% of the 19 difficult items. Thus, these 19 items were not difficult for just a few single cases, but for the majority of the participants.

We also studied the effect of different eye diseases and gender on the scores of the 19 difficult items. There were 20 (44%) participants with Leber's congenital amaurosis; other eye diseases were represented by smaller numbers of children, for example, microphthalmia (n = 5), retinopathy of prematurity (n = 5), anophthalmia (n = 4), and retinoblastoma (n = 3). No clear relationship was found between eye disease or gender and the 19 difficult items.

Discussion

From the results of this study, one could conclude that children who are congenitally blind and have no additional impairments master roughly 94% of the tactile

Table 3
Items with difficulty levels lower than 0.70.

Number	Category	Age (in years)	Description of the item	Level of difficulty: Age group	Level of difficulty: Next older age group
1	Body awareness	6–9	Observer is facing the child and puts both hands on his or her own waist: “Can you copy this?” (copying hand positions)	0.65	0.66
2	Touch sensitivity	2–4	Shows touch sensitivity with the entire face or parts of the face (for example, brushes an object along the check or feels furniture with the forehead)	0.43	0.17
3	Touch sensitivity	9–12	Can read braille with six fingers (index fingers, middle fingers, ring fingers)	0.44	0.43
4	Proprioception	Birth to age 2	Clasps object (such as a teddy bear or a rattle) tightly against the body using hands or feet, sitting down or standing up	0.50	0.50
5	Tactile exploration	Birth to age 2	Plays alternately with both hands and feet in combination with the mouth (for instance, grabs own foot with own hand or sucks own toes)	0.67	0.67
6	Large and nearby space	2–4	Searches, through touch, for an object that is behind another object (such as a ball behind a chair or a doll behind a couch)	0.50	0.64
7	Large and nearby space	4–6	Searches, by touching with a foot, for differences in height (for example, while standing upright next to a bench or curb)	0.55	0.50
8	Recognizing	4–6	Is capable of recognizing the object that is presented twice, in a sequence of four small distinguishable objects (wooden playing fruit or Tactilo shapes)	0.32	0.25
9	Recognizing	4–6	Is capable of recognizing the shape that is presented twice, in a sequence of four flat distinguishable shapes (see material box)	0.41	0.25
10	Discrimination	6–9	Can feel a deviation in the outline of a linear drawing (see exemplary sheet)	0.50	0.42
11	Discrimination	6–9	Can locate matching shapes, despite distracting textures (see material box)	0.34	0.59
12	Constructing or reproducing	4–6	Can create a row around a frame on the outer border (such as a burl board or Ministeck)	0.59	0.50
13	Constructing or reproducing	6–9	Can reproduce an arrangement after an example (such as a square, with a ”bit” missing, made from multiple Lego bricks or a row of Duplo stones, with a double row of stones in two places)	0.25	0.50
14	Constructing or reproducing	9–12	Can copy a shape after an example on a Ministeck board (see exemplary picture)	0.50	0.36
15	Part-whole relationships	4–6	Identifies a whole on the grounds of a part (such as the spout of a teapot or grandpa’s eyeglasses)	0.55	0.00
16	Part-whole relationships	4–6	Knows, by touching, which part belongs to which whole (for example, a shoelace with a shoe or a peel with an orange)	0.59	0.50
17	Part-whole relationships	4–6	Recognizes sections as part of a whole shape (for instance, a half and a whole apple or a sandwich and a loaf of bread)	0.28	0.50
18	Tactile spatial perception	4–6	Can localize an identical stimulus on both a flat horizontal and an upright surface (see exemplary worksheets)	0.55	0.50
19	Tactile language	4–6	Can name the material of which an object is made (such as wood, plastic, or paper)	0.55	0.50

tasks they encounter in their everyday lives. However, there is some small individual variation. Children in age group C (4–6 years) mastered 85% of the items, while children in age group A (birth to 2 years) had command over 97.6% of the items. The tasks in the domain of tactile sensory functioning were mastered best. These items refer to the more basic components of touch, such as tactile awareness and touch sensitivity, both necessary requirements for performing higher haptic tasks. Most failures were in the domain of tactile

Table 4
Number of children, by age group and quartile, for the 19 difficult items.

Age group	Number of children	0–25%	25–50%	50–75%	75–100%
A (Birth to 2 years)	6	2	0	3	1
B (2–4 years)	15	2	3	4	6
C (4–6 years)	12	1	2	5	4
D (6–9 years)	6	0	0	2	4
E (9–12 years)	9	0	0	6	3

perceptual functioning, where cognition and higher mental processes play a more important role. Note that these items are not purely tactile. Tactile experiences, memory, and acquired strategies for learning influence the performance of a task. Overall, one may conclude that touch is not a severe problem for children who are blind, but there are some areas that need attending to.

In the study, children in the age group from birth to 2 years performed the tasks best; they failed only two items. However, the number of participants in the youngest age group consisted of five children aged 1 to 2 and only one child younger than 1 year (average age of 16 months). The age distribution in this age category was, therefore, not optimal, which could explain the low number of failed items. At this age level, cognition plays a minor role in the assignments, but sensory-motor development is important (Bloch & Bertenthal, 1990; Hatwell et al., 2003). For children who are blind, tactile exploration is necessary for receiving proper information about their environments. Schellingerhout (1998) concluded that infants who are blind seem to be more biased toward exploration on the basis of what they feel than on the basis of what they hear. This finding shows the importance of the tactile sense in early childhood and the need to monitor and stimulate it, although one could wonder whether touching is really at risk of being underdeveloped in this age group since individual variation might be large and few tasks are mandatory in this age group.

In our study, children aged 4–6 performed the worst. They failed 15%, but mastered 85%, of the items. Items measuring tactile basic skills and conditions for more complex tasks, namely, tactile sensory and tactile motor skills, were performed well by these children. However, the children often failed eight items in the tactile perceptual domain. Several possible explanations for this finding can be given. First, within this age group, there is a large variation in the amount of school experiences (such as familiarity with teaching procedures, tasks, situations, and tests). Second, some children in this age group may have found the verbal instructions for some items difficult to understand, especially the items in the category of recognition. The instructions for these items may have to be simplified for the Tactual Profile to be a suitable instrument. Third, the results for the children in age group C were negatively influenced by one child who performed poorly.

Next, we focused on the other items with difficulty levels of lower than 0.70. Millar (2006, 2008) described the sense of touch in combination with movement as an important source of information regarding spatial information. She emphasized the importance of exploring and scanning movements in spatial tasks for persons who are blind. In our study, the participants performed relatively well on most tactile spatial tasks. Only one item in the category tactile spatial perception (33 items in total) was not mastered by 70% or more of the participants. So, on the basis of these findings, one could conclude that tactile spatial perception seemed to pose no problems for the participants.

Three of the 14 items in the category constructing or reproducing were not mastered by 70% of the participants. The skills necessary for these three items (12, 13, 14) require the use of proper scanning techniques. Apparently, these skills do not appear spontaneously, but have to be offered and trained. The scanning techniques and the use of body-centered cues may be important practice material because they are necessary to perform "reconstructing skills" properly. Millar underlined the use of these body-centered cues for people who are blind, in contrast to the use of external cues, which people who are sighted use to solve spatial tasks. Clinical observations during the execution of the task seem to support this theory. We found that Item 14, in which the participants were asked to copy a shape after an example, was mastered only by children who used adequate scanning strategies with body-centered cues.

The concept of part-whole relations (items 15, 16, and 17) develops with age and a child's increased tactile experiences. From an early intervention point of view, knowing whether this concept is lacking is important for planning intervention. Whether the lack of part-whole skills is due to the lack of experience or to individual variation in acquiring the necessary tactile skills is not known, since clinical information about the tactile history of each child was not available. On the basis of clinical experience, we think that the lack of experience may be responsible. If this is true, then intervention should first consist of offering more opportunities to explore part-whole relations.

The basic exploratory actions and manual activities that are necessary for gathering information about form and space, described by Hatwell (1978; see also Hatwell et al., 1990; Hatwell et al., 2003), were performed quite well in this study. However, items referring to object-recognition, for which the perception of shape and memory are necessary, proved to be more difficult. No clear conclusion can be given for the fact that the identification of objects is sometimes problematic. Possibly, the combination of exploring objects and memory is too difficult. But as we mentioned earlier, the verbal instruction could also have been too difficult or lacked the proper kind of instructions.

In the study, no time restrictions were imposed on the children so as to have optimal conditions for the participants to carry out the tasks. Under these circumstances, the participants mastered about 94% of the skills. However, in everyday life, time restrictions are sometimes imposed on the performance of tasks, such as most academic tests. It would therefore be interesting to study the performance of the Tactual Protocol items with time constraints and to see whether this performance differs from the performance under optimal conditions, that is, no time restrictions.

In summary, in this study, roughly 94% of the tactile skills that were thought to be necessary for performing academic tasks and daily living skills were mastered by the participants. This is a positive finding. Flemish and Dutch children who are blind, with no additional impairments, master nearly all the tactile prerequisites of academic and everyday tasks spontaneously, and no subsequent formal teaching or intervention is necessary. Only 19 items proved to be too difficult for more than 70% of the participants. For these 19 items, we need to design intervention plans, since a reasonable number of children who are blind do not master these items on their own.

If one wants to design a tactile or haptic test, the 76 items with difficulty levels between 0.90 and 1 could be deleted, since they were nondiscriminatory and, as a result, add no useful information. The 19 difficult items from this study should definitely be included in the test. Until such a test is available, one could consider using a shortened version of the Tactual Profile consisting of only the 19 difficult items. For future research, it would also be interesting to administer the Tactual Profile to people who are deaf-blind and to compare their profiles with those of children who are congenitally blind and have no additional disabilities. Another interesting line of research would be to enroll people who are blind in haptic experiments. Several theories on touch and haptics have been derived from experiments with sighted people who were blindfolded. It would be interesting to study the performance of persons who are congenitally blind on similar tasks. The findings of such a study have the potential to greatly increase knowledge of touch and haptic development.

References

Bloch, H., & Bertenthal, B. I. (1990). *Sensory-motor organizations and development in infancy and early childhood.* Dordrecht, the Netherlands: Kluwer Academic.

Hatwell, Y. (1978). Form perception and related issues in blind humans. In R. Held Herschel, W. Leibowitz, & H. Teuber (Eds.), *Perception* (pp. 489–519). New York: Springer-Verlag.

Hatwell, Y., Orliaguet, J. P., & Brouty, G. (1990). Effects of object properties, attentional constraints and manual exploratory procedures on haptic perceptual organization: A developmental study. In H. Bloch & B. I. Bertenthal (Eds.), *Sensory motor organizations and development in infancy and early childhood* (pp. 315–335). New York: Kluwer Academic.

Hatwell, Y., Streri, A., & Gentaz, E. (2003). *Touching for knowing: Cognitive psychology of haptic manual perception.* Amsterdam: John Benjamins.

Heller, M. A. (1984). Active and passive touch: The influence of exploration time on form recognition. *Journal of General Psychology, 110,* 243–249.

Heller, M. A. (1989). Texture perception in sighted and blind observers. *Perception and Psychophysics, 45*, 49–54.

Heller, M. A. (1991). Haptic perception in blind people. In M. A. Heller & W. Schiff (Eds.), *The psychology of touch* (pp. 239–262). Hillsdale, NJ: Lawrence Erlbaum.

Heller, M. A. (2000a). Conclusions: The San Marino discussion. In M. A. Heller (Ed.), *Touch, representation and blindness* (pp. 183–215). Oxford, England: Oxford University Press.

Heller, M. A. (2000b). Introduction: The theoretical context of the dialog. In M. A. Heller (Ed.), *Touch, representation and blindness* (pp. 1–27). Oxford, England: Oxford University Press.

Heller, M. A. (2006). Picture perception and spatial cognition in visually impaired people. In M. A. Heller, & S. Ballesteros (Eds.), *Touch and blindness: Psychology and neuroscience* (pp. 49–73). Mahwah, NJ: Lawrence Erlbaum.

Heller, M. A., & Meyers, D. S. (1983). Active and passive tactual recognition of form. *Journal of General Psychology, 108,* 225–229.

Jansson, G. (2008). Haptics as a substitute for vision. In M. A. Hersh & M. A. Johnson (Eds.), *Assistive technology for visually impaired and blind people* (pp. 135–166). London: Springer.

Janssen, N. M., Withagen, A. J., & Vervloed, M. P. J. (2005). Tactual Profile: Reliability and validity of the instrument. In *Vision 2005* (International Congress series 1282, pp. 596–600). Amsterdam: Elsevier.

Jones, L. A., & Lederman, S. J. (2006). *Human hand function*. New York: Oxford University Press.

Kennedy, J. M. (2000). Recognizing outline pictures via touch: Alignment theory. In M. A. Heller (Ed.), *Touch, representation and blindness* (pp. 67–99). Oxford, England: Oxford University Press.

Kennedy, J. M., Gabias, P., & Nicholls, A. (1991). Tactile pictures. In M. A. Heller & W. Schiff (Eds.), *The psychology of touch.* (pp. 263–299). Hillsdale, NJ: Lawrence Erlbaum.

Kennedy, J. M., & Juricevic, I. (2006). Form, projection and pictures for the blind. In M. A. Heller & S. Ballesteros (Eds.), *Touch and blindness: Psychology and neuroscience* (pp. 73–95). Mahwah, NJ: Lawrence Erlbaum.

Klatzky, R. L., Lederman, S. J., & Metzger, V. A. (1985). Identifying objects by touch: An "expert system." *Perception & Psychophysics, 37*, 299–302.

Lederman, S. J., & Klatzky, R. L. (1987). Hand movements: A window into haptic object recognition. *Cognitive Psycholgy, 19*, 342–368.

Lederman, S. J., & Klatzky, R. L. (1996). Action for perception: Manual exploratory movements for haptically processing objects and their features. In A. Wing, P. Haggard, & R. Flanagan (Eds.), *Hand and brain: Neurophysiology and psychology of hand movements* (pp. 431–446). San Diego, CA: Academic Press.

Marek, B. (1999). A blind child in an English language classroom. *Network: A Journal for English Language Teacher Education, 2*(1), 3–8.

Marek, B. (2000, July). *Does a stone look the way it feels?* Paper presented at the European International Council for the Education of People with Visual Impairment Conference in Krakow, Poland.

McLinden, M., & McCall, S. (2002). *Learning through touch: Supporting children with visual impairment and additional difficulties.* London: David Fulton.

Merabet, L. B., Swisher, J. D., McMains, S. A., Halko, M. A., Amedi, A., Pascual-Leone, A., & Somers, D. C. (2007). Combined activation and deactivation of the visual cortex during tactile sensory processing. *Journal of Neurophysiology, 97,* 1633–1641.

Millar, S. (1994). *Understanding and representing space: Theory and evidence from studies with blind and sighted children.* Oxford, England: Clarendon Press.

Millar, S. (1997). *Reading by touch*. London: Routledge.

Millar, S. (2006). Processing spatial information from touch and movement: Implications from and for neuroscience. In M. A. Heller & S. Ballesteros (Eds.), *Touch and blindness: Psychology and neuroscience* (pp. 25–48). Mahwah, NJ: Lawrence Erlbaum.

Millar, S. (2008). *Space and sense.* East Sussex, England: Psychology Press.

Schellingerhout, R. (1998). *Surface texture as a source of haptic spatial information for blind children.* Unpublished doctoral dissertation, Radboud University, Nijmegen, the Netherlands.

Schellingerhout, R., & Withagen, A. J. (2002). *Tactiel profiel, validatie onderzoek 2001* [Tactual Profile, validation study 2001]. Huizen, the Netherlands: Visio.

Withagen, A. J., Baerwaldt, I., Blok, A. G., Ekkens, I. E., Hamelink, A., & Vervloed,

M. P. J. (2005). *Tactual Profile (manual).* Kortenhoef, the Netherlands: Xsites BV.

Withagen, A. J., & Schellingerhout, R. (2004). Tactual Profile: An assessment procedure for tactual functioning in children and adolescents: Validation of the instrument. In S. Ballesteros & M. Heller (Eds.), *Touch, blindness and neuroscience* (pp. 323–333). Madrid: Uned Press.

Withagen, A., Vervloed, M. P. J., Janssen, N. M., Knoors, H., & Verhoeven, L. (in press). The Tactual Profile: An assessment procedure for tactual functioning of children who are blind. *British Journal of Visual Impairment*.

Ans Withagen, M.A., *special education specialist, Royal Visio, National Foundation for the Visually Impaired and Blind, Oud Bussummerweg 76, 1272 RX Huizen, the Netherlands; e-mail: <answithagen@visio.org>.* ***Mathijs P. J. Vervloed, Ph.D.,*** *assistant professor, Behavioural Science Institute, School of Educational Science, Radboud University Nijmegen, Postbus 9104, 6500 HE, Nijmegen, the Netherlands; e-mail: <m.vervloed@pwo.ru.nl>.* ***Neeltje M. Janssen, M.A.,*** *special education specialist, Royal Visio, National Foundation for the Visually Impaired and Blind, the Netherlands; e-mail: <neeltjecox@hotmail.com>.* ***Harry Knoors, Ph.D.,*** *professor, Royal Kentalis and Behavioural Science Institute, School of Educational Science, Radboud University Nijmegen, the Netherlands; e-mail: <h.knoors@viataal.nl>.* ***Ludo Verhoeven, Ph.D.,*** *professor, Behavioural Science Institute, School of Educational Science, Radboud University Nijmegen, the Netherlands; e-mail: <l.verhoeven@pwo.ru.nl>. Address all correspondence to Withagen.*

