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Local and Global Processing in Blind and Sighted Children in a Naming and Drawing Task

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This study investigated the spatial analysis of tactile hierarchical patterns in 110 early-blind children aged 6–8 to 16–18 years, as compared to 90 blindfolded sighted children, in a naming and haptic drawing task. The results revealed that regardless of visual status, young children predominantly produced local responses in both tasks, whereas the production of integrated responses emerged later. Development of local and global processing seems to proceed similarly in the two populations, but local processing continued to occur at high levels over a larger age range in the blind. The possibility of visual mediation is pointed out, as totally blind children tended to process information locally more often than blind children with minimal light perception.

Much of the research conducted in the domain of haptic perception has compared normal-sighted, late-blind (LB), and early-blind (EB) individuals to reveal the role of visual experience and visual imagery in haptic perception (e.g., D'Angiulli & Kennedy, 2001; Dulin & Serrière, 2009; Norman, Norman, Clayton, Lianekhammy, & Zielke, 2004). These studies have concentrated on behavioral performance—for instance, naming pictures in raised-line drawings (Heller, 2002; Heller, McCarthy, & Clark, 2005), the underlying neural substrates of haptic perception (James, Kim, & Fisher, 2007; Streri, Dion, & Mertz, 1996), or individual differences, such as gender effects, in this ability (Vecchi, 2001; Zuidhoek, Kappers, & Postma, 2007).

Another interesting issue in the comparison between haptic and visual perception relates to the differences at the level of global and local processing (Cook & Odom, 1988; Garner, 1974). Berger and Hatwell (1993) showed that analytical strategies predominate over holistic strategies in haptic perception. Developmental trends were also examined by Berger and Hatwell (1996) whose results differed from those obtained in visual studies. In visual perception, access to the local dimensional structure takes longer and demands more attention than access to the global structure and, consequently, occurs later in the course of information processing. In haptic perception, in contrast, access to the global structure of the object occurs at a later stage of processing. Indeed, the sequential local exploratory movements prevent blind people from accessing global information, which therefore needs to be mentally reconstructed later by combining and integrating the particular information gathered locally. The idea that global processing develops later than local processing in haptic perception has found support in the work of Lakatos and Marks (1999), who reported that the ability to distinguish between three-dimensional objects was increasingly based on local features when exploration time decreased. Consequently, at a developmental level, local processing should dominate in haptic perception in young children, whereas older children should process information both locally and globally, a prediction that has received support from a number of studies (Berger & Hatwell, 1996; Schellingerhout, Smitsman, & Cox, 2005; Streri & Féron, 2005). However, to our knowledge, no previous developmental study has as yet addressed this issue in blind individuals.

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The aim of this study was to investigate this issue in blind children by using hierarchical patterns of the type initially proposed by Navon (1977). A Navon pattern is composed of a larger (global) figure (e.g., letter *H*) made up of smaller (local) shapes (e.g., letters *s*). Many researchers have used hierarchical patterns to study visual perception in both adults (e.g., Davidoff, Fonteneau, & Fagot, 2008; Kimchi, 1988, 1992; Kramer, Ellenberg, Leonard, & Share, 1996; Lamb & Yund, 2000; Love, Rouder, & Wisniewski, 1999; Navon & Norman, 1983) and children (e.g., Burack, Enns, Iarocci, & Randolph, 2000; Dukette & Stiles, 1996; Kimchi, Hadad, Behrmann, & Palmer, 2005; Mondloch, Geldart, Maurer, & de Schonen, 2003; Tada & Stiles, 1996; Vinter, Puspitawati, & Witt, 2010). Only one study, however, has focused on the haptic perception of hierarchical patterns in EB and LB participants (Heller & Clyburn, 1993). These authors employed two types of hierarchical stimuli, that is, large Braille patterns (e.g., *R*) made up of smaller, standard-size Braille letters (e.g., *c*) and large geometrical forms made of embossed dots. In this study, the participants were asked to name the explored shapes. The results obtained with the compound Braille stimuli showed that the LB and EB adults mainly gave local responses, although these responses were less frequent in LB (72.5%) than in EB participants (93.8%). LB participants processed information both locally and globally in 25% of cases, whereas none of the EB individuals did so. With the embossed geometrical patterns made of dots, the LB individuals primarily produced local responses (55.5%) and gave global responses at only a lower level (22.2%). By contrast, the EB individuals produced more global (50%) than local (27.7%) responses, whereas blindfolded sighted participants produced integrated (both global and local) responses most often (61.1%), followed by global (16.6%) and local (11.1%) responses. This study demonstrated that visually impaired adults were less capable of integrating local and global information than blindfolded sighted participants. It also revealed the important influence of the material given to blind participants on either local or global processing. However, only adults were tested and the question remains as to whether blind children would also produce predominantly global responses when required to name hierarchical geometrical patterns. We considered this to be quite unlikely, at least in the case of young blind children, considering that access to global information requires the mental reconstruction of information gathered step by step (Heller, 1991; Revesz, 1950).

This study investigated this issue in a large corpus of EB children and blindfolded sighted children. We used both a naming task, as in Heller and Clyburn (1993), and a drawing task. During haptic perception, humans base their classification of an object on its various parts (Klatzky, Lederman, & Mankinen, 2005; Lederman & Klatzky, 1990, 1993; Vinter & Chartrel, 2008). Haptic classification is initially based on separate dimensional features, thus indicating analytical processing, before these local features are subsequently integrated during a global processing stage (Berger & Hatwell, 1993, 1996). We therefore expected children in the younger age groups, regardless of visual status, to produce primarily local responses in the naming task, whereas the older blind children should produce either more global responses, as can be predicted from the Heller and Clyburn's results, or more integrated responses, as expected from the older sighted children.

A drawing task, which is associated with considerable planning and motor requirements (van Sommers, 1989), was used to reveal the extent to which the children were able to coordinate global and local analyses of the patterns. Children may indeed attend to these two components without, however, being able to coordinate them (Dukette & Stiles, 1996; Vinter & Marot, 2007; Vinter et al., 2010). The ability of blind people to draw was studied in depth by Kennedy and his colleagues (D'Angiulli, Kennedy, & Heller, 1998; D'Angiulli, Miller, & Callaghan, 2008; Kennedy, 2003; Kennedy & Juricevic, 2003), who demonstrated that congenitally blind individuals are able to produce contour line drawings that capture the global shape of models. However, Vinter et al. (2010) reported that young sighted children primarily reproduced the local elements of Navon patterns in a visual drawing task, with the production of integrated drawings developing later. We therefore expected young children, regardless of their visual status, to mainly draw the local features of the patterns in a haptic drawing task; only late in childhood would they be able to integrate local and global information in their drawings. Finally, when compared to the naming and drawing performance of control blindfolded sighted children, we expected blind children to produce more local responses than the sighted over a large age range. The integration of local and global processing should be delayed in the blind.

All our hypotheses are based on comparisons involving age or visual status effects. This point is important because the dominance of either local or global processing depends on different characteristics of the stimuli, such as, for instance, sparsity and number of local elements (Kimchi, 1988; Martin, 1979) or the size of the patterns, with local information more likely to dominate in larger images (Sanocki, 1993; Schyns & Oliva, 1994). With regard to these characteristics, the patterns employed in this study were likely to lead to a dominance of global processing in the visual mode. Our comparative hypotheses are based on this observation.

Method

Participants

A total of 110 blind children aged 6–18 years (50 girls, 60 boys) participated in the experiment. They had either been totally blind (World Health Organization [WHO]—Category 5 [cat. 5], i.e., no light perception) or had only minimal light perception (WHO Category 4 [cat. 4], i.e., best visual acuity 1/60) from birth or early infancy before the age of 12 months. (Unfortunately, the exact date of onset of the visual impairment was usually not reported in the children's medical records, which simply indicated "congenital blindness.") They were divided into five age groups with the following characteristics:

- 6- to 8-year-olds: n = 15, M_{age} = 7.5 years, SD = 0.88, 5 girls, 10 boys, n = 10 WHO cat. 4, n = 5 WHO cat. 5; etiologies: cataract (n = 5), glaucoma (n = 3), retinopathy of prematurity (n = 2), optic nerve atrophy (n = 1), and unknown abnormality (n = 4).
- 9- to 10-year-olds: n = 23, M_{age} = 9.4 years, SD = 0.47, 16 girls, 7 boys, n = 13 WHO cat. 4, n = 10 WHO cat. 5; etiologies: cataract (n = 8), retinopathy of prematurity (n = 4), Leber's congenital amaurosis (n = 3), glaucoma (n = 3), anophthalmia (n = 2), optic nerve atrophy (n = 1), and unknown abnormality (n = 2).
- 11- to 12-year-olds: n = 20, M_{age} = 11.7 years, SD = 0.53, 8 girls, 12 boys, n = 12 WHO cat. 4, n = 8 WHO cat. 5; etiologies: cataract (n = 6), Leber's congenital amaurosis (n = 4), retinopathy of prematurity (n = 4), glaucoma (n = 1), trachoma (n = 1), and unknown abnormality (n = 4).
- 13- to 15-year-olds: n = 24, M_{age} = 14.4 years, SD = 0.93, 8 girls, 16 boys, n = 16 WHO cat. 4, n = 8 WHO cat. 5; etiologies: cataract (n = 7), retinopathy of prematurity (n = 3), glaucoma (n = 3), amblyopia (n = 3), anophthalmia (n = 2), microphthalmia (n = 1), optic nerve atrophy (n = 1), and unknown abnormality (n = 4).
- 16- to 18-year-olds: n = 28, M_{age} = 17.6 years, SD = 0.88, 13 girls, 15 boys, n = 17 WHO cat. 4, n = 11 WHO cat. 5; etiologies: cataract (n = 8), retinopathy of prematurity (n = 4), Leber's congenital amaurosis (n = 3), amblyopia (n = 3), microphthalmia (n = 2), glaucoma (n = 2), bilateral retinoblastoma (n = 2), trachoma (n = 1), and unknown abnormality (n = 3).

Sixteen blind children refused to draw the patterns because they did not feel able to perform this task and wanted to avoid being placed in a difficult situation, and one child did not complete the task. The number of participants who performed the drawing task was consequently lower than that reported earlier. Ninety-three blind children aged between 6 and 18 years (40 girls, 53 boys) completed the drawing task. They were also divided into five age groups: 6- to 8-year-olds: n = 12, M_{age} = 7.6 years, SD = 0.76, 4 girls, 8 boys, n = 9 WHO cat. 4, n = 3 WHO cat. 5; 9- to 10-year-olds: n = 15, M_{age} = 9.9 years, SD = 0.50, 11 girls, 4 boys, n = 7 WHO cat. 4, n = 8 WHO cat. 5; 11- to 12-year-olds: n = 16, M_{age} = 12 years, SD = 0.51, 5 girls, 11 boys, n = 9 WHO cat. 4, n = 7 WHO cat. 5; 13- to 15-year-olds: n = 22, M_{age} = 14.4 years, SD = 0.91, 7 girls, 15 boys, n = 14 WHO cat. 4, n = 8 WHO cat. 5; and 16- to 18-year-olds: n = 28, M_{age} = 17.6 years, SD = 0.88, 13 girls, 15 boys, n = 17 WHO cat. 4, n = 11 WHO cat. 5. None of these children performed drawing activities very frequently: Around 20% of them drew on an occasional basis, whereas 80% drew only rarely or infrequently. The youngest children (6–8 years of age) were learning Braille, whereas those in the other age groups regularly practiced Braille reading and writing.

All participants were attending special schools for blind and visually impaired children in six large cities in Indonesia (Jakarta, Bandung, Cimahi, Yogyakarta, Klaten, and Solo). None of them presented any associated disorders of relevance for our study, in particular, psychiatric, cognitive, or neurological disorders. Indeed, they were all enrolled in the school grade that corresponded to their chronological age. They were tested individually at their school. Most of the participants came from families with a medium (38.2%) or low (56.3%) socioeconomic status (SES). However, the children from low-SES families (62 of the 110 blind children) were living in school-organized hostels rather than with their families. The schools that took part in the study were supported either by the Ministry of Social Services in Indonesia or by other social organizations. Informed written consent was obtained from the parents as well as from the directors of the hostels in the case of the children who lived there.

Ninety Indonesian typically developing sighted children were enrolled in the control groups. They were divided into five age groups: 3- to 5-year-olds: $n = 15$, $M_{age} = 4.4$ years, $SD = 0.84$, 7 girls, 8 boys; 6- to 8-year-olds: $n = 18$, $M_{age} = 7.6$ years, $SD = 0.78$, 7 girls, 11 boy; 9- to 10-year-olds: $n = 22$, $M_{age} = 9.7$ years, $SD = 0.62$, 9 girls, 12 boys; 11- to 12-year-olds: $n = 21$, $M_{age} = 11.6$ years, $SD = 0.59$, 7 girls, 14 boys; and 13- to 15-year-olds: $n = 14$, $M_{age} = 14.2$ years, $SD = 0.88$, 6 girls, 8 boys. None of the children were educationally advanced or retarded, and their vision was normal or corrected to normal. Most of the children came from middle-SES families. They were tested individually in a quiet room at their schools. Informed written consent was obtained from the parents of all the children participating in the study.

The experiment was conducted in accordance with the tenets of the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects.

Materials

The tactile hierarchical patterns were made up of small circles or squares forming a large square or circle, with the result that they were similar to those employed in the visual drawing task used in the Vinter et al. (2010) study. A series of pilot studies were run to ensure that these stimuli were designed appropriately. When Braille letters were combined to form the small circles or squares, none of the 16 tested blind children recognized the global or local shapes. When the small local elements were made of embossed dots, as in the Heller and Clyburn (1993) study, more than 60% of the tested blind children still failed to identify the global or local shapes. Although replacing the dots with embossed lines improved performance, more than 20% of the children were still unable to succeed in the test. Finally, in an attempt to reinforce the impression that the local elements constituted small whole shapes (Overvliet, Mayer, Smeets, & Brenner, 2008), the local elements were made of thermoformed block patterns instead of lines. The number of identification errors in the responses fell to < 3%, showing that this type of pattern suited the haptic sensitivity of blind children. Thus, four tactile hierarchical patterns printed as block patterns using thermoformed shapes were employed in the naming and drawing tasks (see Figure 1). The patterns were printed individually on A5 format cards. The length of the sides of the square local elements was 1 cm, and the length of the side of the global shape

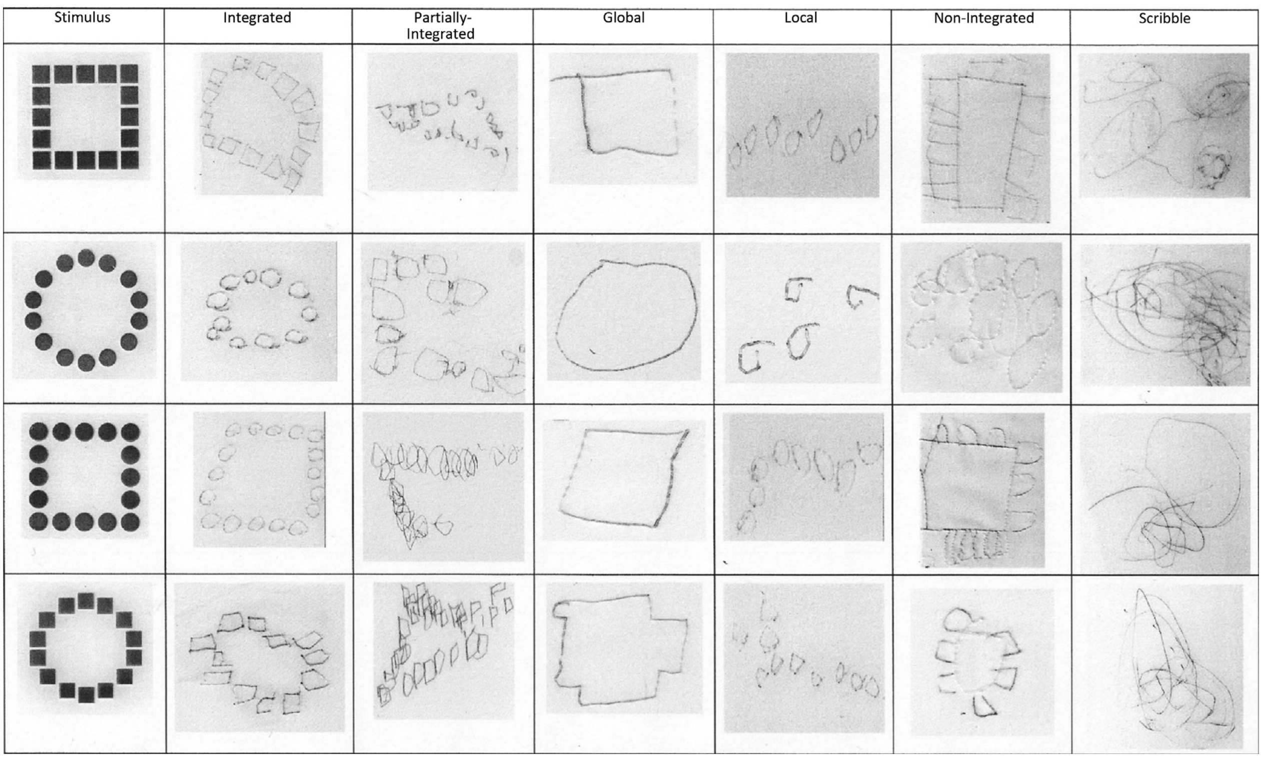

Figure 1. Illustrations of the different types of drawings of the tactile hierarchical patterns produced by the blind children.

was 6 cm. The diameter of the circular local elements was 1 cm and that of the global shape was 6 cm. The height of the thermoformed patterns was 1 mm. The patterns consisted of 14 local circles and 16 local squares, respectively.

In the drawing task, regardless of their visual status, the children were given a Swedish raised-line drawing kit. The drawings were produced using ballpoint pen on Mylar plastic sheets (21 cm × 14.7 cm) placed on a rubberized board (Dycem support, height of 2 mm). The pressure of the ballpoint pen on the plastic sheet produced a raised line (of approximately 0.5 mm in height), thus making it possible to provide haptic feedback during drawing execution. Because most of the blind children were not in the habit of drawing regularly, it was important to ask the sighted children to draw in the same conditions and use the same material.

Procedure

The experiment began with an initial familiarization phase. There were four familiarization stimuli (thermoformed shapes), which consisted of one big circle of 6 cm in diameter, one big square with a side length of 6 cm, five randomly arranged small circles with a diameter of 1 cm, and five small squares with a side length of 1 cm, also arranged randomly. The children were asked to explore the patterns to name the shapes and, during the second part of the familiarization phase, to draw them as accurately as possible using the raised-line drawing kit. The sighted children were told that they would have to complete these tasks without seeing the patterns on the basis of their tactile manual explorations only. Each child wore a blindfold throughout the session. Because some of them seemed disoriented when they were blindfolded, the experimenter gave them time during the familiarization phase to get used to this unusual perceptual condition. The blind and sighted children were also given time to practice drawing with the special drawing kit. Guidance was given by the experimenter if needed (such as verbal guidance during exploration to ensure that exploration was complete, guidance in moving the pen during drawing, and also guidance in the naming of the shape, especially for the youngest children). During the familiarization phase, the experimenter made sure that the children named the patterns of 6 cm diameter or of 6 cm side length "big" and those of 1 cm diameter or of 1 cm side length "small." It was during this familiarization phase that the experimenter identified the blind children who refused to draw the patterns. After the children had named and drawn the four stimuli once, the experimenter tested the participants' understanding by presenting them with the four familiarization patterns again, in a random order, and asking them to name the shape that they perceived together with its size (i.e., big circle, small circles, big square, and small squares). All the children fully explored the shapes and succeeded in this examination phase. The familiarization phase took between 15 and 30 min.

The experimental phase involved a very similar procedure. The children were comfortably seated at a table, and the experimenter placed the card on which the thermoformed pattern was printed on the table at a location aligned with the midline of each child's body. The experimenter helped the children place their hands on the card and asked them to explore the shape of the tactile pattern accurately to name it using precise terminology. The instructions were as follows,

> "We will keep playing the same game. You will have to move your hands and fingers all around the shapes you feel so that you can imagine to yourself how the pattern is made. Tell me exactly what shape you feel and whether it is big or small."

More specific questions were asked depending on the children's responses (see the Data Coding section below). The card was then removed and a second pattern was presented for naming. The patterns were presented in a random order. The responses given by the children were recorded by a second experimenter, who could not see which pattern was placed in front of the child. Due to the familiarization phase, the spontaneous descriptions of the children or their answers to the main experimenter's questions were short and concise, making online coding an easy task. The naming task was followed by an interval of 5–10 min. The experimenter informed the children who were willing to participate in the drawing task that they would now be required to explore patterns accurately to be able to draw them as precisely as possible. They were not informed that the patterns were the same as those already explored in the naming task. The cards were again placed on the table one at a time for exploration. When the children said that they were ready to start drawing, the card was removed, the drawing material was placed at the same location, and the experimenter asked the children to reproduce the pattern as accurately as possible. The four stimuli were presented randomly, one at a time. No guidance or feedback was given during the experimental phase of either the naming or drawing task. The order of the two tasks was fixed. This was due to the fact that during the familiarization phase, we had seen that fewer blind children were willing to draw than to name the patterns. The experimenters were Indonesian postgraduate students who were undergoing professional training as clinical psychologists for handicapped children. They were unaware of the aims of this study.

Data Coding

The verbal responses given by the children in the naming task were coded into four categories as described below:

- *Integrated response:* The children correctly identified both the global and local shapes and their integration, stating that the pattern was a big square made up of small squares or circles, or a big circle made up of small circles or squares.
- *Global response*: The children correctly identified the global shape, but did not mention or describe the local elements. Once the response was provided, the experimenter systematically asked, "Is there anything else you can perceive in this pattern?" When the identification response was global, some of the children said that there was a hole or a space inside the square or the circle, whereas others did not report perceiving anything else. When the children did not spontaneously specify the size of the shape they perceived, the experimenter systematically asked them, "Can you tell me about the size of the square (or circle)?" The response was considered global when the children only mentioned a big square or circle, often accompanied by finger movements tracing the outline of the global shape.
- *Local response*: The children were able to name the local elements without noticing any other shape resulting from the arrangement of these local elements. We used the same process to categorize responses as local as is described earlier for the global responses. The response was considered local when the children only reported perceiving small circles or small squares.
- *Erroneous response*: In a few cases, the children produced erroneous responses (e.g., identification of circles instead of squares or vice versa, identification of meaningful patterns like "stars in the sky"). This response category, however, was rare and was not analyzed further (M = 1.36%, SD = 6.63 of erroneous responses in the blind group; and M = 3.5%, SD = 9.2 in the blindfolded sighted group).

The results of the drawing task were subdivided into six categories as described below and illustrated in Figure 1 for the blind group. Four judges who were unaware of the aims of the experiment (the judges were psychology masters students who received degree credits) independently coded the drawings. Two of them coded the drawings collected from the blind children and the other two coded the drawings produced by the sighted children. The judges were previously trained with the same type of drawings collected by Vinter et al. (2010) in a visual version of the same drawing task. Interrater reliability for the coding of the drawings produced by the 93 blind children was examined using a Cohen's kappa coefficient, which reached 0.77 ($p < .01$). This value was 0.71 ($p < .01$) for the drawings produced by the 90 blindfolded sighted children, thus indicating a substantial level of agreement in both cases. Disagreements were settled before data analysis.

- *Integrated response:* The children drew the overall global shape and the local elements in a correctly integrated response. The sizes, number of elements, regularity of the distance between elements, and accuracy of the angles were not coded, and neither was the accuracy of the global or local shapes.
- *Partially integrated response:* The local elements, partially integrated with the global shape, were present in the drawing. The global shape was frequently left open, or only parts of it were drawn. The local and global shapes were generally greatly distorted.
- *Global response:* The global shape was correctly reproduced as a continuous line and no local elements were drawn. The size of the shape was unambiguously big, when compared to the size of the patterns drawn by the children during the familiarization phase.
- *Local response:* The children reproduced a series of small circles or small squares and the overall global shape was absent. The local elements were either randomly arranged or drawn in lines. There were always at least three elements and these were clearly small in size when compared to the drawings produced by the children during familiarization.
- *Nonintegrated response:* The local elements were drawn juxtaposed with or superimposed on the global shape.

- *Scribbled response:* The drawings were simply scribbled. This response was not observed in the sighted group.

Results

We analyzed each task separately. Nonparametric tests were used because homoscedasticity did not apply in most cases. The Jonckheere trend test (JT value using the R software; free statistical software available at www.r-project.org) was employed to test ordered alternatives of performance across age groups. This test can reveal significant differences between age groups and simultaneously test whether these differences follow an increasing or a decreasing trend. The Mann–Whitney test (*U* value) was used to compare the blind and sighted groups or the two blind groups, and the Wilcoxon signed-rank test (*T* value) was employed to test differences between frequencies of responses within a group.

Results From the Naming Task

Figure 2 indicates the frequencies of integrated, local, and global naming responses as a function of age for the two groups of children. As shown in Figure 2a, the number of integrated responses increased significantly across age in the blind group, JT = 3,357, $p < .001$, and in the control group, JT = 2,328.5, $p < .001$. In the blind group, there were no significant differences between the 6–8 and 9–10 years of age groups, $U = 164$, n1 = 15, n2 = 23, $p > .70$. Note that the development of integrated responses appeared delayed in the blind children. All comparisons between children of the same age from the two groups showed that the blind children produced significantly less integrated responses than their sighted counterparts, *p*s $< .05$. It was only at 13–15 years of age that blind children displayed as many integrated responses as the 6- to 8-year-old sighted children, $U = 200$, n1 = 24, n2 = 18, $p > .60$. At

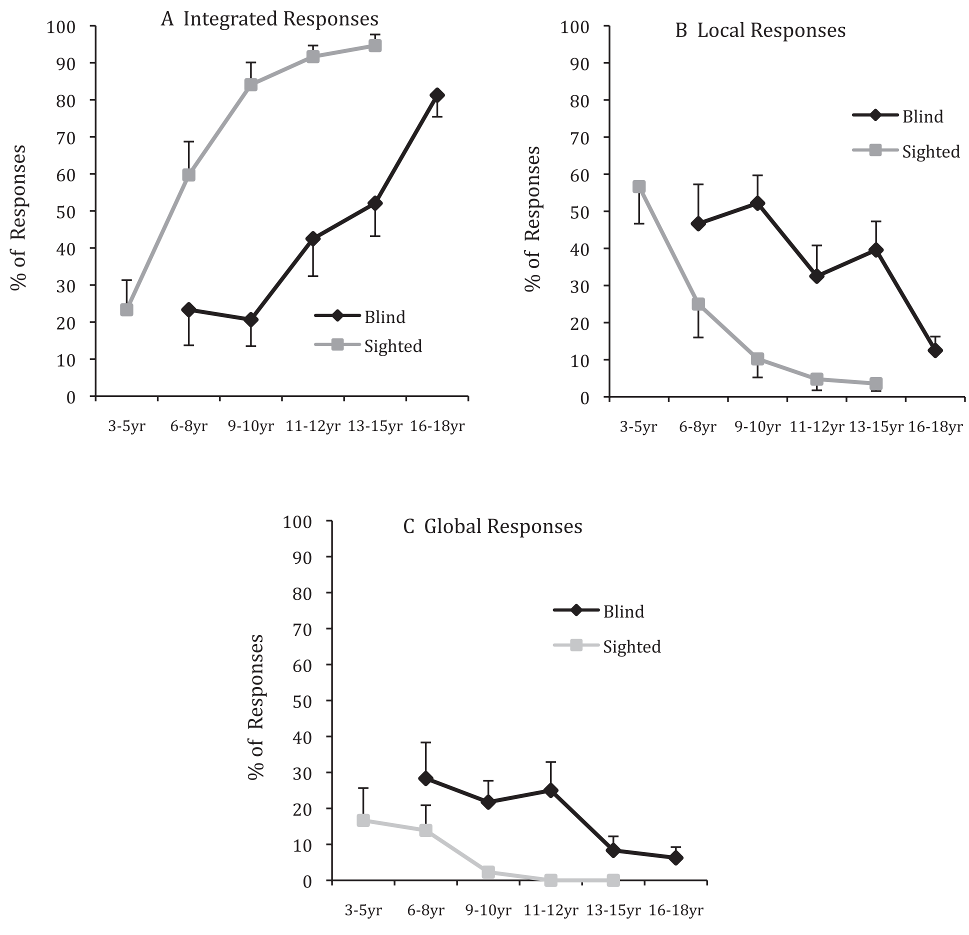

Figure 2. Age-related change in the frequencies of integrated responses (a), local responses (b), and global responses (c) in blind children and blindfolded sighted children.

around 16–18 years of age, the blind children showed performance similar to the level recorded at 13–15 years of age in the controls, $U = 164.5$, n1 = 28, n2 = 14, $p > .30$.

Variations as a function of age also characterized the local responses in the blind and sighted children as depicted in Figure 2b. These responses decreased between 6 and 8 years of age (47%) and 16–18 years of age (12.5%) in the blind group, JT = 1,730.5, $p < .001$. A significant decreasing pattern also characterized the development of local responses in the sighted group, JT = 1,039, $p < .001$. All comparisons between children of similar ages revealed that the blind children showed significantly more local responses than their sighted counterparts, *p*s < .01. However, the 16- to 18-year-old blind children did not differ from the 13- to 15-year-old sighted children in their production of local responses, $U = 156$, n1 = 28, n2 = 14, $p > .30$, indicating that they attained a similar level of performance.

Finally, Figure 2c shows that the frequencies of global responses decreased significantly across ages in the blind group, JT = 1,911.5, $p < .01$, but this decreasing trend was only marginally significant in the blindfolded sighted group, JT = 1,400, $p = .07$. Around 28% of the blind 6- to 8-year-olds gave a global response and this percentage dropped to 6% at 16–18 years of age. Similarly in the sighted group, 17% of the naming responses provided by the 3- to 5-year-olds were global, whereas no such responses were observed at 11–12 years of age. Although, the developmental pattern was similar in the two groups, a delay was observed between them, with the global responses decreasing later in the blind children. Regardless of age, the blind ($M = 16.4\%$) produced significantly more global responses than the sighted ($M = 6.1\%$), $U = 3{,}898$, n1 = 110, n2 = 90, $p < .01$. However, in both the blind and sighted groups, global responses were less frequent than local responses, $T = 548.5$, $z = 3.5$, $p < .01$, and $T = 141$, $z = 2.8$, $p < .01$, respectively.

Our blind group included both totally blind children (WHO cat. 5, $n = 42$, $M_{age} = 12.6$ years, $SD = 3.3$ years) and children with minimal light perception (WHO cat. 4, $n = 68$, $M_{age} = 12.9$ years, $SD = 3.6$ years). We wondered whether this minimal residual visual function might have an impact on the children's analysis of the haptic hierarchical patterns. Figure 3 shows the distribution of the different types of naming responses across the two degrees of blindness.

Although the totally blind children tended to produce integrated responses less frequently than those with minimal light perception, the difference failed to reach significance, $U = 1{,}206$, n1 = 68, n2 = 42, $p = .17$. By contrast, the difference in local responses was significant, $U = 1{,}067$, n1 = 68, n2 = 42, $p < .05$. Totally blind children analyzed the patterns locally more often than those having minimal light perception. These results indicate that the proportions of local responses might be a function of both age and WHO category in the blind group. To control for age, we conducted an analysis of covariance (ANCOVA) on these proportions, with age (in months) as a continuous factor and WHO category as a categorical factor. After controlling for the significant age effects, beta coefficient = .505, $F(1, 107) = 37.8$, $p < .01$, the WHO category was significant for the local responses, beta coefficient = .14, $F(1, 107) = 3.7$, $p < .05$.

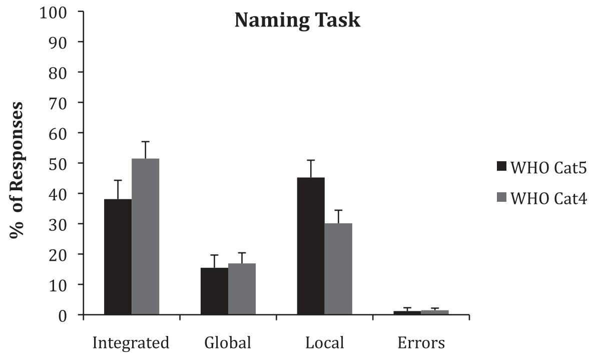

Figure 3. Percentages of the different types of naming responses as a function of the levels of blindness WHO Cat5 = World Health Organization Category 5; WHO Cat4 = World Health Organization Category 4.

Results From the Drawing Task

Five of the 12 blind children aged 6–8 years, 1 of the 15 aged 9–10 years, and 1 of the 22 aged 13–15 years produced scribbles. They were excluded from the analysis. Figure 4 presents the frequencies of occurrence of the different response categories obtained in the drawing task as a function of age for the two groups of children. The results for the nonintegrated responses were not reported because they were rarely produced regardless of visual status, in < 3% of the cases on average.

Significant differences between ages were obtained for the integrated responses in the blind group (Figure 4a), the Jonckheere test revealing a significant increasing pattern, JT = 1,894, $p < .01$. None of the blind 6- to 8-year-olds drew integrated patterns, whereas 48.4% of the drawings produced by the 11- to 12-year-olds were integrated, $U = 14$,

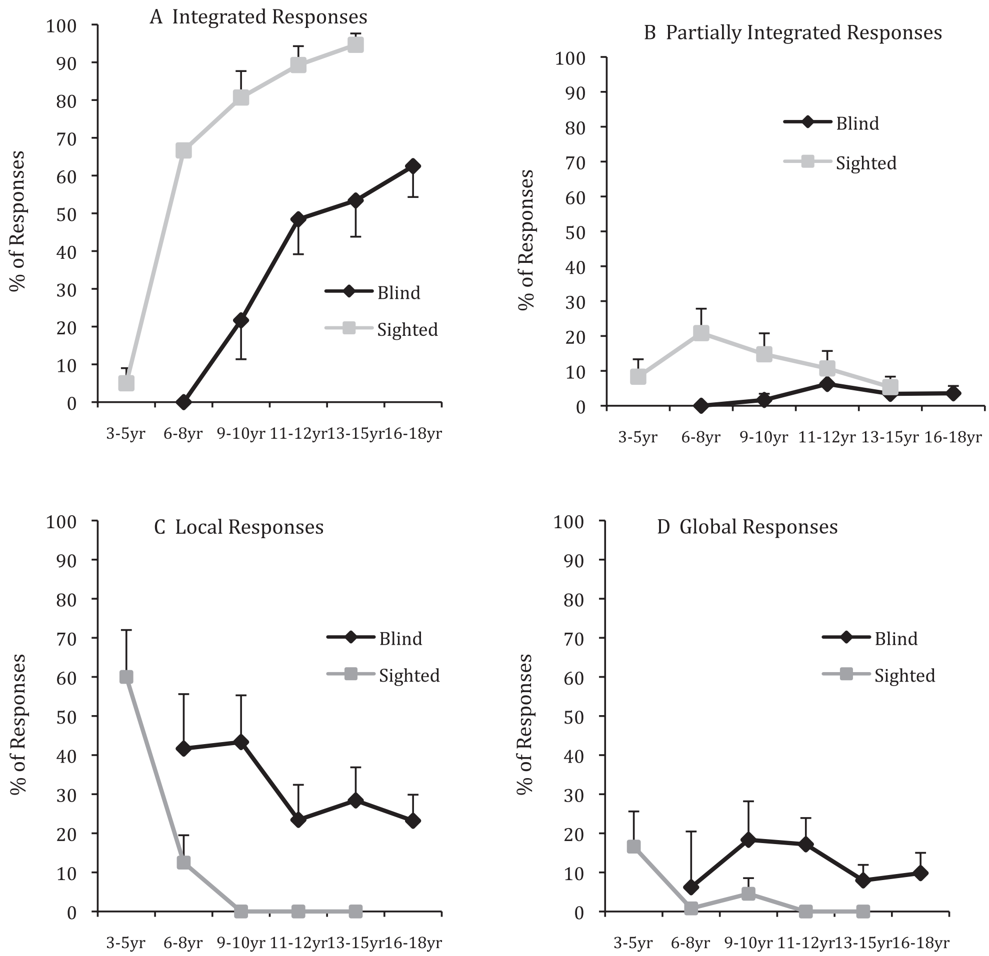

Figure 4. Age-related change in the frequencies of integrated drawing responses (a), partially integrated drawing responses (b), local drawing responses (c), and global drawing responses (d) in blind children and blindfolded sighted children.

n1 = 7, n2 = 16, $p < .01$. This percentage then increased slowly to reach 62.5% at 16–18 years of age. A similar developmental pattern was obtained in the blindfolded sighted group, JT = 2,296, $p < .01$, with only 5% of the 3- to 5-year-olds' drawings being integrated; this proportion reached 67% at 6–8 years of age, $U = 36$, n1 = 15, n2 = 18, $p < .01$, and was close to 95% at 13–15 years of age. At corresponding ages, the blind children drew integrated patterns less often than their sighted counterparts, *p*s < .01. This was even the case when the oldest blind children were compared to the oldest sighted children, $U = 122$, n1 = 28, n2 = 14, $p < .05$.

The occurrences of partially integrated responses (Figure 4b) were, on average, very low in the blind group ($M = 3.5\%$) and they did not vary as a function of age, Kruskal–Wallis test, $H(4, n = 86) = 2.8$, $p = .60$. There were also no significant overall differences between age groups in the blindfolded sighted group, Kruskal–Wallis test, $H(4, n = 90) = 3.8$, $p = .43$, despite their progressive decrease between 6 and 8 years of age ($M = 22\%$) and 13–15 years of age ($M = 7\%$).

Like the integrated responses, the local responses (Figure 4c) also followed a similar developmental pattern regardless of visual status. These responses were frequently produced by the youngest age groups and then decreased significantly with age in the blind group, JT = 1,180, $p < .05$, as well as in the blindfolded sighted group, JT = 1,186, $p < .01$. The local responses disappeared totally at 9–10 years of age in the sighted, whereas they were still present at a nonnegligible level ($M = 23.2\%$) at 16–18 years of age in the blind children. At all ages, the blind children made more local drawings than their sighted counterparts, *p*s < .01, and the 16- to 18-year-old blind children still produced more local drawings than the 13- to 15-year-old sighted children, $U = 126$, n1 = 28, n2 = 14, $p < .05$. Finally, the production of integrated drawings became more frequent than that of local drawings at 11–12 years of age in the blind group, $T = 38$, $z = 2.1$, $p < .05$, and at 6–8 years of age in the sighted group, $T = 2.5$, $z = 3.8$, $p < .01$.

In neither group was the production of global responses very common, as Figure 4d illustrates. None of the age trends was significant (*p*s > .10). However, the global drawings were more frequently realized by the blind ($M = 11.5\%$) than by the sighted ($M = 3.9\%$), $U = 3{,}453$, n1 = 93, n2 = 90, $p < .05$. They disappeared completely at 11–12 years of age in the sighted children, and continued to be produced at a low level (around 10%) by the blind children between 13 and 18 years. Moreover, the blind and the sighted children produced global drawings less often than local drawings, $T = 244$, $z = 3.2$, $p < .01$ and $T = 148$, $z = 2.1$, $p < .05$.

In the same way as for the naming task, we checked whether the presence of minimal light perception had an impact on the drawings produced by the blind children. Figure 5 presents the results.

The same tendencies as observed in the naming task emerged in the drawing task: The totally blind children tended to produce local drawings more often and integrated drawings less often than the blind children with minimal light perception, although the differences were only marginally significant in both cases, $U = 809$, $z = -1.78$, n1 = 56, n2 = 37, $p = .07$, and $U = 812$, $z = 1.76$, n1 = 56, n2 = 37, $p = .07$, respectively. An ANCOVA with age (in months) as a continuous factor and WHO category as a categorical factor was run on these proportions. After controlling for the significant age effect, beta coefficient = .41, $F(1, 90) = 18.3$, $p < .01$, the WHO category factor just attained significance for the integrated responses, beta coefficient = .215, $F(1, 90) = 4.92$, $p = .05$.

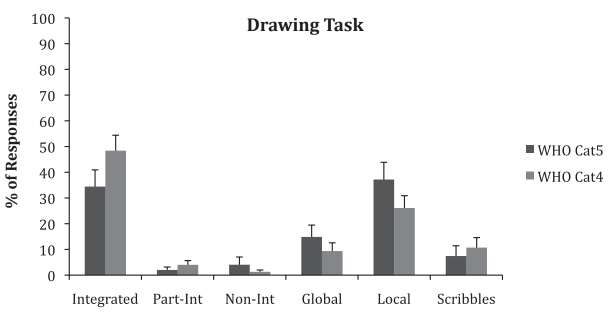

Figure 5. Percentages of the different types of drawing responses as a function of the levels of blindness. WHO Cat5 = World Health Organization Category 5; WHO Cat4 = World Health Organization Category 4; Part-Int = partially integrated; Non-Int = nonintegrated.

Discussion

The aims of this study were to investigate the type of processing—local or global—that predominates in blind children as a function of their age, whether these children would be able to integrate and coordinate the two types of information in the tasks we selected, and the extent to which their performance differs from that of blindfolded sighted children. The results yielded by the naming and drawing tasks were quite similar across ages, regardless of visual status, thus confirming the validity of the drawing task as a way of addressing this issue, even in blind individuals.

The two tasks revealed that the blind children mainly produced local responses at the younger ages studied between 6 and 10 years and that the proportion of local responses decreased with age without, however, disappearing totally. Indeed, around 20% of the drawings produced by the blind 16- to 18-year-olds were still local in nature. The same type of development characterized the blindfolded sighted group, with local responses initially predominating in both tasks. These results are consistent with the literature dealing with haptic perception. Berger and Hatwell (1996) concluded that dimensional local relations organize haptic perceptual classification in young sighted children. Lakatos and Marks (1999) reported that blindfolded sighted adults, who were asked to judge whether two objects were the same or not, relied more heavily on local than on global features during the initial stages of haptic exploration. Heller and Clyburn (1993) showed that blind adults produced more local than global or integrated responses when required to name compound Braille stimuli. The demonstration of the initial dominance of local processing at early ages is also consistent with the literature dealing with visual perception (e.g., Dukette & Stiles, 1996; Kimchi et al., 2005; Kramer et al., 1996; Poirel, Mellet, Houdé, & Pineau, 2008; Vinter et al., 2010).

Different explanations have been suggested to account for the initial local processing dominance. It could be related to differential rates of development between the left and right hemispheres (Molfese & Segalowitz, 1988) or to attentional functioning in young children who attend more to parts than to the whole (Tada & Stiles, 1996). Moreover, just as some authors have argued that incomplete processing of visual scenes might result from reduced oculomotor exploration, which involves only the incomplete processing of the patterns (Kowler & Martins, 1982; Poirel et al., 2008), it is possible that initial local processing dominance in haptic tasks may, at least in part, result from incomplete haptic exploration in young children. It therefore seems important that future research should record the precise manual procedures employed by children when they explore haptic hierarchical patterns, even though Lakatos and Marks (1999) reported that no procedure was associated with a predominant emphasis on either local or global features when sighted adults were required to judge whether two haptically explored patterns were identical or not. In our study, we ensured that the children actively moved their hands and fingers to explore the patterns as such movements are important for the extraction of shape information (Kalagher & Jones, 2011; Lederman & Klatzky, 1987). However, the fact that active movements have been performed does not guarantee that the appropriate information has been collected.

The initial phase of local processing dominance seemed to persist for longer in the blind than in the blindfolded sighted children. Indeed, whereas the local responses disappeared at 7–8 years of age in the drawing task in the sighted children, in the blind children who performed the same task, it was only at 11–12 years of age that the local responses decreased significantly compared to the level observed at 6–8 years of age. The stronger dominance of local processing observed in the blind children cannot be attributed to the fact that they drew using haptic feedback only, as the sighted children explored and drew the patterns in the same conditions as the blind children. Furthermore, the blind children also produced local responses over a longer period of development than the sighted children in the naming task. This tendency was therefore not restricted to drawing. It could be argued that the exploratory procedures developed with age by blind children are less efficient than those developed by sighted children, with the result that the former collect only partial information for a longer period of time. However, in a recent study, it was found that children aged 7 years or 11 years with a visual handicap outperformed age-matched sighted children in the haptic exploration of bidimensional tactile images (Vinter, Fernandes, Orlandi, & Morgan, 2012). The stronger dominance of local processing in blind children is therefore unlikely to be due to potential deficits in peripheral information-gathering activities as compared to sighted children, although we cannot totally rule out this hypothesis.

Other hypotheses are more plausible. As already pointed out, global information cannot be accessed immediately during haptic perception as it can be in the visual mode. The sequential exploratory movements collect piecemeal information that needs to be mentally combined and integrated to construct images of whole objects, via processes that are dependent on both attention and memory (Hochberg, 1986; Loomis, Klatzky, & Lederman, 1991; Revesz, 1950). Thus, access to the global shape of unknown patterns requires highly developed mental capabilities for the coordination and integration of information, and these capabilities need time to develop. Indeed, if we compare the drawing performance of our blindfolded sighted group in the haptic drawing task with that of sighted children of a similar age in a visual drawing task (Vinter et al., 2010), it can be seen that the disappearance of local responses is delayed by nearly 2 years. Local responses disappeared at 6 years of age in the visual drawing task, and at 7–8 years of age in the haptic drawing task. Although this comparison must be treated with caution, it helps highlight the specific difficulty in going beyond local processing in haptic perception.

Furthermore, this study showed that this delay was considerably greater when the blind children were compared with the sighted children, regardless of the task. The Heller and Clyburn (1993) study found that even blind adults still encountered more difficulties than sighted adults in integrating local and global information when they had to name tactile Navon patterns. It is likely that in our tasks, the blindfolded sighted children processed haptic information as described in the image mediation model (Lederman & Klatzky, 1987), that is, by translating the sequentially collected haptic information into visual images. They would thus benefit from the ease with which global shapes can be apprehended in the visual modality and the integration process would therefore be facilitated. By contrast, blind children seem to operate in accordance with the direct haptic apprehension model described by Lederman and Klatzky (1987) and would therefore make use only of the processing mechanisms available to the haptic system. Accessing global information related to unknown hierarchical patterns and integrating it with local information would place much greater mental and attentional demands on blind than on blindfolded sighted individuals, thus causing the observed developmental lags.

Our results showing an effect of the degree of blindness on the production of local responses appears to be consistent with this framework. The totally blind children produced more local naming responses and tended to produce more local drawings than the blind children who had minimal light perception. This suggests that a minimal residual visual capacity helps children go beyond local processing and tends to facilitate the integration of local and global information. Similar findings have been reported in a number of studies, revealing that a residual visual capacity associated with haptic skills leads to better performance in spatial recognition tasks (Heller, 2002; Passini, Proulx, & Rainville, 1990; Ungar, Blades, Spencer, & Morsley, 1994).

The global responses were produced at a lower level than local responses in both the blind and sighted groups. Unlike Heller and Clyburn (1993) who reported that EB adults named the global shape more often than the local elements when exploring embossed dot patterns, at no stage during our study did we observe a predominance of global over local responses in the blind children. These discrepancies were probably due to differences in the material employed to build the tactile Navon patterns, with larger sized local elements being used in our study. Thus, for both blind and sighted individuals, the size of the local elements could be a factor that enhances either local or global processing (Sanocki, 1993; Schyns & Oliva, 1994). Nevertheless, our findings revealed that on each task, blind children displayed greater proportions of local as well as global responses than the blindfolded sighted children. In our view, this highlights the specific difficulty encountered by the blind in integrating both types of information.

Finally, beyond the lags observed between blind and sighted children, this study revealed that the development of local and integrated responses followed similar trends in the two groups. Local responses were initially produced at a high level before falling in frequency. In both groups and tasks, integrated responses were observed only infrequently in the younger age groups before increasing in frequency with age. Integrated responses became the blind children's predominant response category in both tasks by 11–12 years of age, and by 7–8 years of age for the sighted children. Given that integrating local and global information in the analysis of spatial patterns requires an understanding of part–whole relations, the slow progression of these integrated responses in the blind group confirms the findings of a study that assessed the tactile functioning of congenitally blind children and reported that items measuring the understanding of part–whole relations were among those that these children found difficult to master (Withagen, Vervloed, Janssen, Knoors, & Verhoeven, 2010).

In conclusion, it is important to point out that as this experiment is the first to investigate how blind children process local and global information in tactile Navon figures, replications are needed to confirm our main finding that the development of local and global processing seems to proceed in similar ways in sighted and blind children, but local processing continues to occur at high levels over a larger age range in the blind. As the use of different types of tactile Navon patterns may lead to different patterns of local–global dominance, as is clear from the comparison of our results with those of Heller and Clyburn (1993), it will be important to test whether our findings generalize to other stimuli and to define the stimulus characteristics that either favor or impede local and global processing in haptic perception.

References

Berger, C., & Hatwell, Y. (1993). Dimensional and overall similarity classification in haptics: A developmental study. *Cognitive Development*, *8*, 495–516.

Berger, C., & Hatwell, Y. (1996). Developmental trends in haptic and visual free classifications: Influence of stimulus structure and exploration on decisional process. *Journal of Experimental Child Psychology*, *63*, 447–465.

Burack, J. A., Enns, J. T., Iarocci, G., & Randolph, B. (2000). Age differences in visual search for compound patterns: Long vs. short range grouping. *Developmental Psychology*, *36*, 731–740.

Cook, G. L., & Odom, R. D. (1988). Perceptual sensitivity to dimensional and similarity relations in free and rule-governed classification. *Journal of Experimental Child Psychology*, *45*, 319–338.

D'Angiulli, A., & Kennedy, J. M. (2001). Children's tactual exploration and copying without vision. *International Journal of Rehabilitation Research*, *24*, 233–234.

D'Angiulli, A., Kennedy, J. M., & Heller, M. A. (1998). Blind children recognizing tactile pictures respond like sighted children given guidance in exploration. *Scandinavian Journal of Psychology*, *39*, 187–190.

D'Angiulli, A., Miller, C., & Callaghan, K. (2008). Structural equivalences are essential, pictorial conventions are not: Evidence from haptic drawing development in children born completely blind. *Psychology of Aesthetics, Creativity, and the Arts*, *2*, 20–33.

Davidoff, J., Fonteneau, E., & Fagot, J. (2008). Local and global processing: Observations from a remote culture. *Cognition*, *108*, 702–709.

Dukette, D., & Stiles, J. (1996). Children's analysis of hierarchical patterns: Evidence from similarity judgement task. *Journal of Experimental Child Psychology*, *63*, 103–140.

Dulin, D., & Serrière, C. (2009). Special needs education in the blind population: Effects of prior expertise in raised line drawings on blind people's cognition. *Procedia—Social and Behavioral Sciences*, *1*, 549–553.

Garner, W. R. (1974). *The processing of information and structure*. Hillsdale, NJ: Erlbaum.

Heller, M. A. (1991). Haptic perception in blind people. In M. A. Heller & W. Schiff (Eds.), *The psychology of touch* (pp. 239–261). Hillsdale, NJ: Erlbaum.

Heller, M. A. (2002). Tactile picture perception in sighted and blind people. *Behavioral Brain Research*, *135*, 65–68.

Heller, M. A., & Clyburn, S. (1993). Global versus local processing in haptic perception of form. *Bulletin of the Psychonomic Society*, *31*, 574–576.

Heller, M. A., McCarthy, M., & Clark, A. (2005). Pattern perception and pictures for the blind. *Psicológica*, *26*, 161–171.

Hochberg, J. (1986). Representation of motion and space in video and cinematic displays. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human performance: Vol. 1. Sensory processes and perception* (pp. 22.21–22.64). New York: Wiley.

James, T. W., Kim, S., & Fisher, J. S. (2007). The neural basis of haptic object processing. *Canadian Journal of Experimental Psychology*, *61*, 219–229.

Kalagher, H., & Jones, S. S. (2011). Developmental change in young children's use of haptic information in a visual task: The role of hand movements. *Journal of Experimental Child Psychology*, *108*, 293–307.

Kennedy, J. M. (2003). Drawings from Gaia, a blind girl. *Perception*, *32*, 321–340.

Kennedy, J. M., & Juricevic, I. (2003). Haptics and projection: Drawings by Tracy, a blind adult. *Perception*, *32*, 1059–1071.

Kimchi, R. (1988). Selective attention to global and local levels in the comparison of hierarchical patterns. *Perception and Psychophysics*, *43*, 189–198.

Kimchi, R. (1992). Primacy of wholistic processing and global/local paradigm: A critical review. *Psychological Bulletin*, *112*, 24–38.

Kimchi, R., Hadad, B., Behrmann, M., & Palmer, S. E. (2005). Microgenesis and ontogenesis of perceptual organization: Evidence from global and local processing of hierarchical patterns. *Psychological Science*, *16*, 282–290.

Klatzky, R. L., Lederman, S. J., & Mankinen, J. M. (2005). Visual and haptic exploratory in children's judgments about tool function. *Infant Behavior & Development*, *28*, 240–249.

Kowler, E., & Martins, A. J. (1982). Eye movements of preschool children. *Science*, *215*, 997–999.

Kramer, J. H., Ellenberg, L., Leonard, J., & Share, L. J. (1996). Developmental sex differences in global-local perceptual bias. *Neuropsychology*, *10*, 402–407.

Lakatos, S., & Marks, L. E. (1999). Haptic form perception: Relative salience of local and global features. *Perception & Psychophysics*, *61*, 895–908.

Lamb, M. R., & Yund, W. E. (2000). The role of spatial frequency in cued shift of attention between global and local forms. *Perception & Psychophysics*, *62*, 753–761.

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

Lederman, S. J., & Klatzky, R. L. (1990). Haptic classification of common objects: Knowledge-driven exploration. *Cognitive Psychology*, *22*, 421–459.

Lederman, S. J., & Klatzky, R. L. (1993). Extracting object properties through haptic exploration. *Acta Psychologica*, *84*, 29–40.

Loomis, J. M., Klatzky, R. L., & Lederman, S. J. (1991). Similarity of tactual and visual picture recognition with limited field of view. *Perception*, *20*, 167–177.

Love, B. C., Rouder, J. N., & Wisniewski, E. J. (1999). A structural account of global and local processing. *Cognitive Psychology*, *38*, 291–316.

Martin, M. (1979). Local and global processing: The role of sparsity. *Memory and Cognition*, *7*, 476–484.

Molfese, D. L., & Segalowitz, S. J. (Eds.). (1988). *Brain lateralization in children*. New York: Guilford.

Mondloch, C. J., Geldart, S., Maurer, D., & de Schonen, S. (2003). Developmental changes in the processing of hierarchical shapes continue into adolescence. *Journal of Experimental Child Psychology*, *84*, 20–40.

Navon, D. (1977). Forest before the trees: The precedence of global features in visual perception. *Cognitive Psychology*, *9*, 353–383.

Navon, D., & Norman, J. (1983). Does global precedence really depend on visual angle? *Journal of Experimental Psychology: Human Perception and Performance*, *9*, 955–965.

Norman, J. F., Norman, H. F., Clayton, A. M., Lianekhammy, J. L., & Zielke, G. (2004). The visual and haptic perception of natural object shape. *Perception & Psychophysics*, *66*, 342–351.

Overvliet, K. E., Mayer, K. M., Smeets, J. B. J., & Brenner, E. (2008). Haptic search is more efficient when the stimulus can be interpreted as consisting of fewer items. *Acta Psychologica*, *127*, 51–56.

Passini, R., Proulx, G., & Rainville, C. (1990). The spatio-cognitive abilities of the visually impaired population. *Environment and Behavior*, *20*, 227–252.

Poirel, N., Mellet, E., Houdé, O., & Pineau, A. (2008). First came the trees, then the forest: Developmental changes during childhood in the processing of visual local-global patterns according to the meaningfulness of the stimuli. *Developmental Psychology*, *44*, 245–253.

Revesz, G. (1950). *The psychology and art of the blind*. London: Longmans Green.

Sanocki, T. (1993). Time course of object identification: Evidence for a global to local contingency. *Journal of Experimental Psychology: Human Perception and Performance*, *19*, 878–898.

Schellingerhout, R., Smitsman, A. W., & Cox, R. F. A. (2005). Evolving patterns of haptic exploration in visually impaired infants. *Infant Behavior & Development*, *28*, 360–388.

Schyns, P. G., & Oliva, A. (1994). From blobs to boundary edges: Evidence for time and spatial scale dependent scene recognition. *Psychological Science*, *5*, 195–200.

Streri, A., Dion, A., & Mertz, C. (1996). Hemispheric asymmetry in infancy: Global or local processing of objects in the haptic mode. *Infant Behavior & Development*, *19*(Suppl. 1), 766.

Streri, A., & Féron, J. (2005). The development of haptic abilities in very young infants: From perception to cognition. *Infant Behavior & Development*, *28*, 290–304.

Tada, W. L., & Stiles, J. (1996). Developmental change in children's analysis of spatial patterns. *Developmental Psychology*, *32*, 951–970.

Ungar, S., Blades, M., Spencer, C., & Morsley, K. (1994). Can visually impaired children use tactile maps to estimate directions? *Journal of Visual Impairment & Blindness*, *88*, 221–233.

van Sommers, P. (1989). A system for drawing and drawing-related neuropsychology. *Cognitive Neuropsychology*, *6*, 117–164.

Vecchi, T. (2001). Visuo-spatial processing in congenitally blind people: Is there a gender-related preference? *Personality and Individual Differences*, *30*, 1361–1370.

Vinter, A., & Chartrel, E. (2008). Visual and proprioceptive recognition of cursive letters in young children. *Acta Psychologica*, *129*, 147–156.

Vinter, A., Fernandes, V., Orlandi, O., & Morgan, P. (2012). Exploratory procedures of tactile images in visually impaired and blindfolded sighted children: How they relate to their consequent performance in drawing. *Research in Developmental Disabilities*, *33*, 1819–1831.

Vinter, A., & Marot, V. (2007). The development of context sensitivity in children's graphic copying strategies. *Developmental Psychology*, *43*, 94–110.

Vinter, A., Puspitawati, I., & Witt, A. (2010). Children's spatial analysis of hierarchical patterns: Construction and perception. *Developmental Psychology*, *46*, 1621–1631.

Withagen, A., Vervloed, M. P. J., Janssen, N. M., Knoors, H., & Verhoeven, L. (2010). Tactile functioning in children who are blind: A clinical perspective. *Journal of Visual Impairment & Blindness*, *104*, 43–54.

Zuidhoek, S., Kappers, A. M. L., & Postma, A. (2007). Haptic orientation perception: Sex differences and latelarization of functions. *Neuropsychologia*, *45*, 332–341.