The severity of the visual impairment and practice matter for drawing ability in children

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ABSTRACT

Background and aims: Astonishing drawing capacities have been reported in children with early visual impairments. However, most of the evidence relies on single case studies. Hitherto, no study has systematically jointly investigated, in these children, the role of (1) the severity of the visual handicap, (2) age and (3) practice in drawing. The study aimed at revealing the specificities of the drawing in children deprived from vision, as compared to children with less severe visual handicap and to sighted children performing under haptic or usual visual control.
Method: 148 children aged 6–14 years had to produce 12 drawings of familiar objects. 38 had a severe visual impairment, 41 suffered from low vision, and 69 were sighted children performing either under visual condition or blindfolded under haptic control.
Results: Recognizability and other characteristics of the drawings were highly dependent on the child's degree of vision and level of drawing practice, and progressed with chronological age more clearly in the sighted children or those with low vision than in those deprived of vision.
Conclusion: The study confirmed that all groups showed significant drawing ability, even the group totally deprived of visual experience. Furthermore, the specificities of the drawings produced by visually-impaired children appeared clearly related to their practice and the severity of their visual impairment. This should incite parents and professionals to encourage these children to practice drawing as early as possible.

What this paper adds?

To our knowledge, this is the first study to include a high number of children with early visual impairments (from birth for most of them, before 14 months of age for some of them), without associated cognitive or psychiatric disabilities, thus offering the opportunity to study at the same time, in this population, the influence of important determinants in drawing: the severity of the visual handicap, the level of drawing practice and age. Also the comparison of the production of visually-impaired children with that of blindfolded sighted children producing their drawings in the same conditions as the former has rarely been reported in the literature, even though this control makes it possible to partly disentangle the role played by constraints related to execution processes and by specificities of mental representations guiding drawing.

The study demonstrates that although the loss of vision did not prevent drawing, as visual acuity falls, drawings became less recognizable, showed more element positioning errors and disconnections between segments; they were more likely to be made up of juxtaposed parts, and contained fewer contour lines. However, the comparison with blindfolded sighted children suggests that what remained typical of those deprived from vision is the production of stick representations of juxtaposed elements, each depicting a

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particular part of an object. Furthermore, as previously reported in the literature, practice greatly improved drawings in visually-impaired children, and did specially influence the drawing characteristics typical of children without vision. This suggests that giving these children the opportunity to regularly practice drawing from an early age could greatly compensate for their vision loss with regard to this ability.

1. Introduction

Drawing is a fascinating ability, as it entails the coordination of processes involving multiple components of cognition and emotion, such as perception, long and short-term memory, spatial processing, motor planning and control, motivation or affective states. Not surprisingly, the investigation of drawing studies has been extended to individuals with various handicaps or pathologies affecting one or more of these components (e.g. Clements & Barrett, 1994; Farran & Dodd, 2015; Jolley, O'Kelly, Barlow, & Jarrold, 2013). There is, however, one handicap for which an investigation of drawing skills might at first glance appear of little interest: the case of visual impairment. Drawing requires individuals to successfully transform three-dimensional objects into two-dimensional configurations that appropriately capture the overall shape and specific details of the object. A priori, this can hardly be done without vision. Although numerous studies have reported that the loss of vision can be compensated for by the recruitment of the remaining intact sensory systems which enable visually-impaired individuals to accurately process spatial information (e.g., Collignon, Voss, Lassonde, & Lepore, 2009), producing drawings appears to be quite challenging for them.

Despite this, a few researchers have demonstrated that they are capable of both producing and interpreting tactile or haptic pictures (that is, thermoformed, textured or raised line pictures) and that they can make appropriate use of lines as indicators of an object's contours (e.g., D'Angiulli, 2007; Heller, 1989; Kennedy, 1993; Millar, 1975). These researchers argued that some representational graphic principles are universal. The edges and corners of surfaces are indeed perceived both by the eye and the hand, so that, as claimed by several authors (e.g. Heller & Kennedy, 1990; Kennedy, 1993), the visual and haptic systems can provide equivalent information about the contours and other spatial properties of objects. Some astonishing performances have been reported in certain case studies showing that early[1] visually-impaired individuals, with practice, are capable of producing foreshortening, oblique projection, converging lines, perspective, and of implementing different points of view as well as movement in their drawings (e.g. Kennedy, 2003; Kennedy & Juricevic, 2003, 2006). In line with these findings, several studies conducted into other aspects of spatial cognition have confirmed that visual experience is not a necessary condition for the development of complex spatial mental images (e.g., Cattaneo & Vecchi, 2011; Cornoldi & Vecchi, 2000).

However, most authors acknowledge that the drawings produced by individuals with visual impairments are usually rough, elementary representations of the depicted objects, and are less recognizable than those of sighted children (D'Angiulli & Maggi, 2003; Heller, Calcaterra, Tyler, & Burson, 1996; Kennedy, 1993). For the sake of illustration, Millar (1975) reported poorer performance in children with congenital visual impairments asked to draw a man when compared with blindfolded sighted children drawing with the same tactile material as those deprived of vision, or with sighted children performing in the usual visual condition. Thus, even though astonishing drawing capacities are sometimes observed, it is likely that, on average, children with early visual impairments will exhibit poorer drawing performance than age-matched sighted children, whether they are blindfolded or not. This expectation is in line with numerous findings revealing severe difficulties in visually-impaired individuals when they are asked to process spatial information (e.g., Pasqualotto & Newell, 2007; Postma, Zuidhoek, Noordzij, & Kappers, 2008). Further, their infrequent exposure to pictures, typically, and a priori little practice of drawing certainly equally prevent the development of drawing skills. Several factors may indeed help enhance the quality of their drawing production.

One of these factors is the degree of severity of the visual impairment. Comparing drawing performance between children deprived from vision and children suffering from low vision enabled us to explore to what extent the degree of severity of the visual impairment directly impacted the quality of their drawings. Given that some studies have indicated that even highly degraded visual information can be sufficient to allow individuals with low vision to perform better than those without vision in different visuospatial tasks (e.g., Vecchi et al., 2006), we expected that the greater their visual handicap, the less recognizable the drawings produced by the children would be.

As shown by Millar (1975), the poor performance of children with severe visual impairments may also be a consequence of the material conditions in which they are asked to produce their drawings. In most cases, they use the Swedish raised-line drawing kit with special plastic sheets on which the pressure of a ballpoint pen results in raised lines of less than 1 mm in height. In such a condition, the only available feedback during and after the execution of the drawing is haptic in nature, and is therefore less detailed, precise and efficient than visual feedback (Lederman & Klatkzy, 1987; Lederman and Klatzky, 2009). In the present study, we introduced two groups of sighted children as controls. One group produced drawings in the usual visual condition, whereas the other drew blindfolded using the haptic drawing material. Some errors, similar to those observed in children with visual impairment, may occur in drawings produced by blindfolded sighted children, due to the poor spatial resolution of the haptic information (Loomis & Lederman, 1986) and arguably, to the greater demands on working memory processes resulting from the necessity to coordinate sequential incoming haptic information in the course of drawing execution (Warren, 1984).

Two other types of factors warrant attention when dealing with drawing ability. First, drawing performance clearly evolves with age, as widely investigated in sighted children (e.g. Cox, 1986; Freeman, 1980; Lange-Küttner & Vinter, 2008; Willats, 2005), but less often in children with visual impairments. In the Millar study (1975) on human figure drawing, there was no clearly identifiable

[1] Early: means an onset at the time of birth or shortly after, in the course of the first year of life.

improvement in performance of children deprived of vision between 6 and 8 years of age, whereas this improvement was noticeable when the 6-year-olds were compared to the children of 9–11 years of age. Bin and Chuen-Jiang (2010) revealed a slow and less complex development in the drawing of cubes and cylinders by individuals without vision as compared to sighted persons. The former did not achieve the final stages of development observed in sighted children, except one who benefited from visual experience until 9 years of age and had prior experience with drawing.

The second factor that warrants attention is related to practice, and the role of this factor has been a concern in participants with visual impairments. Beyond differences in levels of performance, D'Angiulli and Maggi (2003) suggested that drawing in children with congenital visual impairments may develop, through practice, similarly to the way it does in sighted children. In their study, after 9 months of practice, 12-year-old visually-impaired children produced drawings comparable to those obtained from 4- to 8-year-old sighted children. In a follow-up analysis, D'Angiulli, Miller and Callaghan (2008) demonstrated that these drawings displayed a greater structural complexity as practice increased, in much the same way as they do during the development of sighted children. Thus, the present study was aimed to tackle the main following questions: Can drawing ability be observed at a meaningful level when a quite large number of children with early visual impairments and no other associated disorders is studied? Is it possible to identify characteristics that are specific to the drawings produced by children deprived of vision? To what extent is drawing performance in these children impacted by their level of practice of this ability and by their chronological age? The study will establish that it is indeed mainly a function of the severity of their visual handicap and of their level of practice.

2. Method

2.1. Participants

A total of 148 children aged 6–14 years were included in the study, 79 of them were early visually impaired children (44 girls) and 69 were sighted (40 girls). They were generally from middle class families (74.3%). Thirty-eight children were totally deprived of vision (World Health Organization −WHO- category 5, no light perception, n = 13) or had only minimal light perception (WHO category 4, best visual acuity 1/60, n = 25) from birth for 35 of them or early in infancy (n = 2 onset before 6 months of age, n = 1 onset at around 14 months of age). Forty-one children were suffering from low vision (WHO category 1, moderate low vision, best visual acuity 3/10, n = 19; WHO category 2, severe low vision, best visual acuity 1/10, n = 12; WHO category 3, profound vision loss, best visual acuity 1/20, n = 10), from birth for most of them (n = 38, and n = 3 with an onset before 12 months of age). These 79 visually impaired children were divided into four age groups (6–7 years, 8–9 years, 10–11 years and 12–14 years).

The children with visual impairments did not have any associated disorders of relevance for our study, in particular psychiatric or cognitive disorders. They were enrolled in the school grade that corresponded to their chronological age. Etiologies of the visual impairment were available for 67 out of the 79 children. These took the form of congenital cataracts (n = 10), retinopathy of prematurity (n = 10), Leber's congenital amaurosis (n = 9), congenital glaucoma (n = 9), severe myopia (n = 7), optic nerve atrophy (n = 6), amblyopia (n = 6), retinitis pigmentosa (n = 5), retinoblastoma (n = 5), microphthalmia (n = 5), and anophthalmia (n = 4). We asked the parents to code their child's current level of practice in drawing on a 5-point scale (level 1 = no practice at all, level 2 = rare practice, level 3 = 1 or 2 times a month, level 4 = 1 or 2 times a week, level 5 = almost daily practice). The control groups consisted of 69 typically developing sighted children aged 6–14 years, also divided into 4 age groups. Thirty-two of them produced their drawings in the usual visual condition, using regular sheets of paper, while 37 children were blindfolded and drew in a haptic condition using the Swedish drawing kit. Their vision was normal or corrected to normal. They were enrolled in the school grade that corresponded to their chronological age. We checked that their level of drawing practice, coded by their parents, did not differ as a function of the drawing condition to which they were assigned, $t(67) < 1$, $p > 0.50$. The main characteristics of the different groups of children are summarized in Table 1.

Table 1 revealed two interesting points with regard to drawing practice. Gathering levels 1 and 2, the number of children without noticeable practice was much higher in the group without vision (12 out of 38) than in the two sighted groups (6 out of 69), $\chi^2(1) = 9.2$, $p < 0.01$. However, a high proportion of visually impaired children did practice drawing quite regularly (levels 3–5), enabling the investigation of the relationship between drawing performance and practice. Furthermore, gathering levels 3, 4, and 5, practice decreased with age in the two sighted groups (100% in the youngest, 81.25% in the oldest) and in the group with low vision (100% to 78.6%), while it remained stable (or even slightly increased with age) in the group with vision loss (66% to 75%). This difference may very well be due to specific educational interventions in the last group, encouraging these children to draw.

Whether visually impaired or not, the children were tested individually at home or at school. Informed written consent was obtained from the parents of each child. 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.

2.2. Material

The children either produced their drawings on white sheets of paper (A5 format, one drawing per sheet of paper) with black or colored pencils or used a Swedish raised-line drawing kit. The visually impaired children were free to choose the material they were most familiar with. Twenty-eight of them decided to draw with the Swedish raised-line drawing kit, including almost all (12 out of 13) children with no light perception, and half of those with minimal light perception (13 out of 25). This variable was thus largely redundant with the severity of the visual handicap. The sighted children produced their drawings with imposed material, either white sheets of paper (visual drawing condition) or the Swedish raised-line drawing kit (haptic drawing condition). In the latter case, the

17

Table 1
Main characteristics of the four children's groups involved in the experiment.

	Age group	Number	Sex	Mean age (SD) yrs,mths	Hand used for drawing	WHO visual category (N)	Drawing Practice (N)	Use of Mylar material or paper
Group	6–7 yrs	6	4 girls 2 boys	M = 7,1 (0,59)	3 left 3 right	C4 = 4 C5 = 2	L2 = 2 L3 = 1 L4 = 2 L5 = 1	3 Mylar 3 Paper
	8–9 yrs	11	8 girls 3 boys	M = 8,9 (0,67)	2 left 9 right	C4 = 8 C5 = 3	L1 = 2 L2 = 3 L3 = 1 L4 = 2 L5 = 3	9 Mylar 2 Paper
with	10–11 yrs	9	7 girls 2 boys	M = 11 (0,52)	0 left 9 right	C4 = 6 C5 = 3	L2 = 2 L4 = 5 L5 = 2	5 Mylar 4 Paper
no/minimal light perception	12–14 yrs	12	7 girls 5 boys	M = 13,2 (1,1)	2 left 10 right	C4 = 7 C5 = 5	L1 = 1 L2 = 2 L3 = 5 L4 = 3 L5 = 1	8 Mylar 4 Paper
Low Vision	6–7 yrs	10	5 girls 5 boys	M = 7,2 (0,37)	1 left 9 right	C1 = 4 C2 = 4 C3 = 2	L3 = 1 L4 = 6 L5 = 3	10 Paper
	8–9 yrs	7	5 girls 2 boys	M = 8,7 (0,70)	1 left 6 right	C1 = 3 C2 = 1 C3 = 3	L3 = 2 L4 = 4 L5 = 1	2 Mylar 5 Paper
Group	10–11 yrs	10	3 girls 7 boys	M = 10,8 (0,47)	1 left 9 right	C1 = 5 C2 = 1 C3 = 4	L2 = 1 L3 = 3 L4 = 4 L5 = 2	10 Paper
	12–14 yrs	14	9 girls 5 boys	M = 13,6 (0,95)	2 left 12 right	C1 = 7 C2 = 6 C3 = 1	L1 = 1 L2 = 2 L3 = 4 L4 = 6 L5 = 1	1 Mylar 13 Paper
Sighted Group	6–7 yrs	8	3 girls 5 boys	M = 7,2 (0,31)	1 left 7 right		L4 = 6 L5 = 2	Paper
	8–9 yrs	8	5 girls 3 boys	M = 8,8 (0,59)	0 left 8 right		L3 = 3 L4 = 3 L5 = 2	Paper
Visual Condition	10–11 yrs	8	4 girls 4 boys	M = 11,2 (0,22)	2 left 6 right		L2 = 1 L3 = 2 L4 = 5	Paper
	12–14 yrs	8	5 girls 3 boys	M = 13,4 (0,70)	1 left 7 right		L2 = 1 L3 = 3 L4 = 4	Paper
Sighted Group	6–7 yrs	8	5 girls 3 boys	M = 7,1 (0,59)	1 left 7 right		L3 = 1 L4 = 5 L5 = 2	Mylar
	8–9 yrs	11	7 girls 4 boys	M = 8,9 (0,63)	1 left 10 right		L3 = 3 L4 = 5 L5 = 3	Mylar
Haptic Condition	10–11 yrs	10	6 girls 4 boys	M = 10,8 (0,62)	2 left 8 right		L2 = 2 L3 = 3 L4 = 4 L5 = 1	Mylar
	12–14 yrs	8	5 girls 3 boys	M = 13 (0,85)	0 left 8 right		L2 = 2 L3 = 3 L4 = 3	Mylar

Abbreviations: WHO categories: C1 = moderate low vision; C2 = severe low vision; C3 = profound vision loss; C4 = participants with minimal light perception; C5 = participants without light perception.
Drawing Practice: L1 = no practice at all; L2 = rare practice; L3 = 1 or 2 times a month; L4 = 1 or 2 times a week; L5 = almost daily practice.

drawings were produced using a ballpoint pen on Mylar plastic sheets (21 cm × 14.7 cm), one drawing per plastic sheet placed on a rubberized board (Dycem support, 2 mm height). The pressure of the ballpoint pen on the plastic sheet produced a raised line (between approximately 0.5 and 0.7 mm height), thus providing haptic feedback during drawing execution.

2.3. Procedure

The children were comfortably seated in front of a table and were instructed that they had to produce drawings of familiar objects. The experimenter told the children assigned to the haptic condition that they would wear a blindfold and draw in an unusual condition. They were shown how to use the raised-line drawing kit (both while seeing or while wearing the blindfold), and they were given some free time to practice in this condition. The duration of the familiarization period was variable, ranging from a few minutes to around 15 min.

All the children were asked to produce 12 drawings of animate entities (man drawing, animals: dog, fish and bird) and inanimate objects (objects that can be held in the hand: toothbrush, glass and banana; tangible objects that cannot be held in the hand: tree, house and bed; non-manipulable objects, sources of strong tactile sensations: sun and rain[2]). These objects were familiar to the children, and they did not present a complex geometrical structure that would make drawing difficult. They corresponded to a range of tactile experiences due to their diversity of shapes, sizes and textures. Finally, they had a high imageability value according to available databases (however restricted to sighted people, as no database existed for visually-impaired people). All of them rated above 4.5 on the Bonin et al., 5-point scale (2003) for instance.

The order in which the 12 drawings were requested was randomized for each child. For each drawing, the experimenter asked the child: “Can you draw a….?” None of the children refused to draw and no feedback was given to them on their performance.

2.4. Data coding

Two raters unaware of the age and visual status of the children who produced the drawings worked independently and coded the variables defined below (see Fig. 1 for illustrations). They were trained together to apply the criteria before they started to code the drawings with the small sample of drawings gathered in Fig. 1, and were then tested with different series of 10 randomly extracted drawings until they reached 80% of agreement. Inter-rater reliability for the coding of each variable was examined using Cohen’s Kappa coefficient, which varied from 0.74 to 0.85 ($p_s < 0.05$). This indicated a high level of agreement in all cases (Landis & Koch, 1977). Disagreements were settled before data analysis.

*the degree of recognizability of the drawing (low = 0 – the coder was unable to tell what was represented in the drawing; medium = 0.5–the coder identified some parts of the drawing and could only guess its identity; high = 1). The raters knew the complete list of the 12 drawings produced, but not the specific title of each one. The percentage of inter-rater agreement was 87%. Illustrations in Fig. 1A;

*the presence of positioning errors of elements relative to each other or to the overall shape (e.g., arms anchored in the head; percentage of inter-rater agreement: 85%). This variable was not coded for the banana and the rain. Illustrations in Fig. 1B;

*whether the drawing was made up of juxtaposed elements (each mark depicting an element of the represented object) instead of a single integrated shape (percentage of inter-rater agreement: 89%). This variable was not coded for the rain and the banana. Illustrations in Fig. 1C;

*whether the correctly positioned elements were disconnected or not (disconnected = 1; mixture = 0.5; connected = 0): the shape was integrated but the segments were not connected to one another (percentage of inter-rater agreement: 81%). This variable was not coded for the rain, the sun and the banana. Illustrations in Fig. 1D;

*whether volumes were reproduced with sticks instead of closed curves standing for surfaces (mainly sticks = 1; mixture = 0.5; mainly surfaces = 0, percentage of inter-rater agreement: 80%). This variable was not coded for the rain and the sun. Illustrations in Fig. 1E;

*whether contour lines were used to draw the overall shape or profile of the object (percentage of inter-rater agreement: 79%). This variable was not coded for the rain and the sun. Illustrations in Fig. 1F.

2.5. Statistical analysis

Insofar as we were not interested in the effect of object category, we averaged the coded variables across the 12 drawings for each child and obtained various scores of mean occurrences ranging from 0 to 100% (or 0 and 1). Nonparametric tests were used because homoscedasticity did not apply in most cases. The Kruskal-Wallis test (H value) was employed to test overall differences due to Visual Status (no vision: no or minimal light perception, low vision, sighted in visual condition, blindfolded sighted in haptic condition), Age (6–7 years, 8–9 years, 10–11 years and 12–14 years) and WHO categories (5 levels). The Mann-Whitney test (U value) enabled performance to be compared when 2 levels were of interest. Correlations between drawing practice and different criteria of drawing performance were computed with the Kendall test (τ value).

[2] Of course, the sun and the rain can also be perceived visually, like the other objects, and their shapes can be described verbally. We qualified the inanimate objects according to the type of direct hand-object relationships they enable.

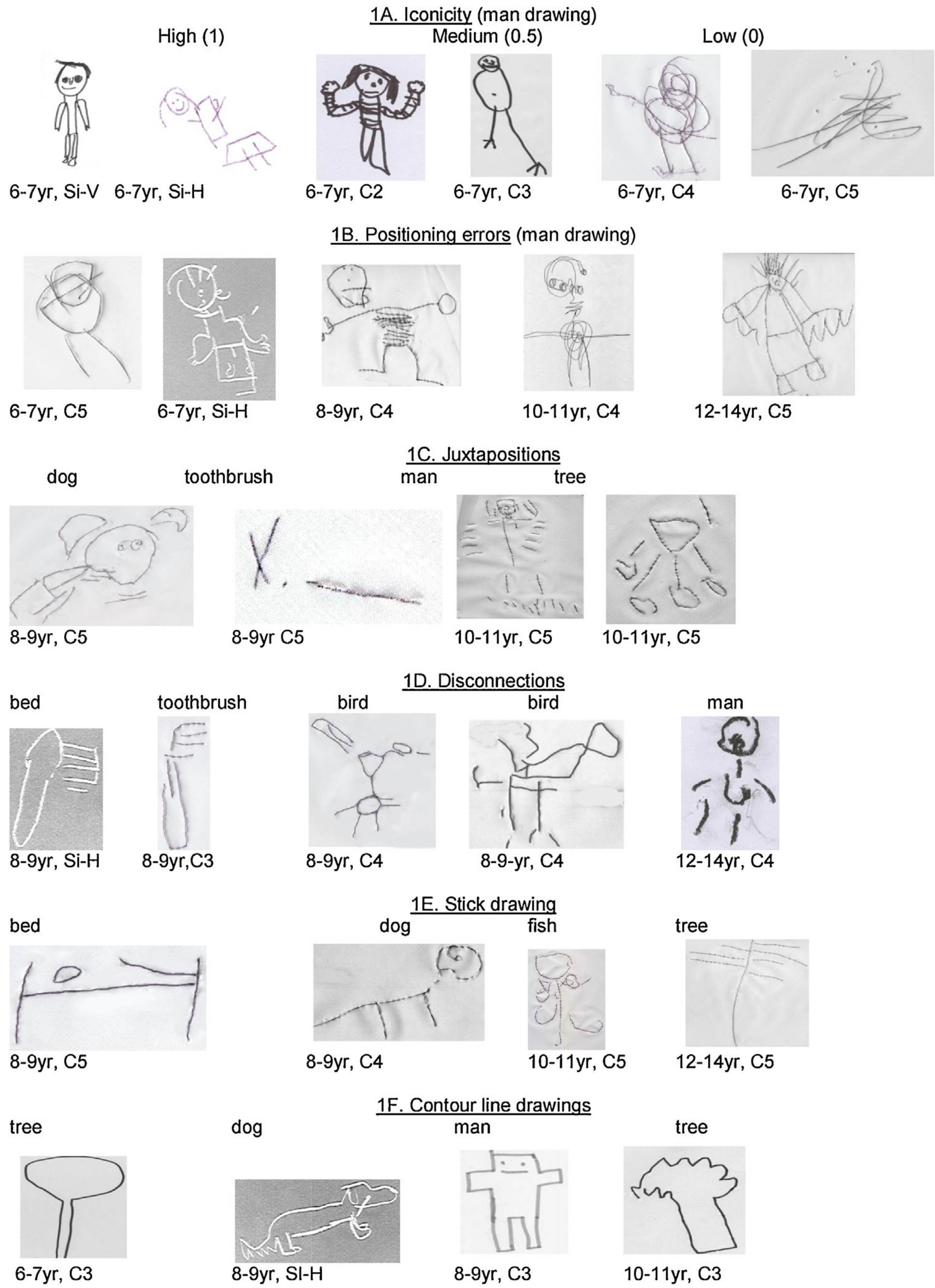

Fig. 1. Illustrations of the different criteria with drawings made by children with a visual handicap or not (C1 = moderate low vision; C2 = severe low vision; C3 = profound vision loss; C4 = participants with minimal light perception; C5 = participants with no light perception; Si-H = blindfolded sighted participants in the haptic condition; Si-V = sighted participants in the visual condition).

3. Results

3.1. Degree of recognizability and positioning errors

First of all, it is worth reporting that all groups produced recognizable drawings, including the group of children with no vision who, regardless of age, obtained a mean score of recognizable drawings of 0.41, indicating an ability to draw. In comparison, the blindfolded sighted group performing in the haptic task reached a 0.70 score of recognizability. The Kruskal-Wallis test revealed significant Visual Status, $H(3, N = 148) = 20.6$, $p < 0.001$, and Age differences, $H(3, N = 148) = 34$ $p < 0.001$.

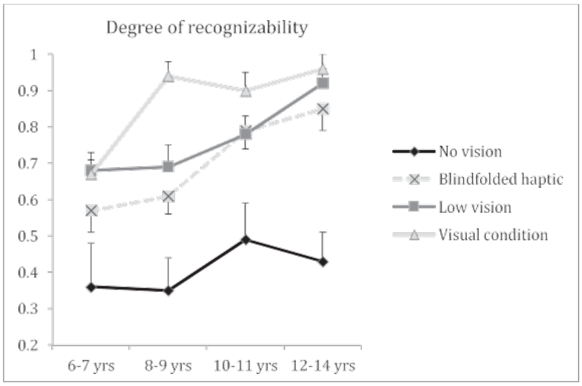

Fig. 2. Evolution with age of the degree of recognizability of the drawings made by the four child groups. Values are means with standard error bars.

As shown in Fig. 2, the children without vision (or at best minimal light perception) produced the drawings that were the most difficult to recognize. The sighted children in the visual condition outperformed those who drew blindfolded under haptic control (Mann-Whitney test, U = 336, N1 = 32, N2 = 37, $p < 0.01$), with the latter producing drawings that were no easier to recognize than those of the children with low vision (Mann-Whitney test, $p > 0.10$). The recognizability of the drawings differed significantly as a function of age, regardless of visual status, moving from 0.57 at 6–7 years of age to 0.79 at 12–14 years of age. However, the developmental trend was much less pronounced in the group with no vision. In this latter group, the difference between the levels observed in the two youngest age groups (M = 0.36, SD = 0.28) and that recorded in the two oldest (M = 0.45, SD = 0.30) failed to reach significance (Mann-Whitney test, $p > 0.20$).

A more fine-grained analysis of the role of the severity of the visual handicap was carried out. A Kruskal-Wallis test run with the WHO category factor revealed significant differences between categories, H(5, N = 148) = 36.4, $p < 0.001$, and Fig. 3A showed that the greater the visual handicap, the less recognizable the drawings were. Even the difference between the drawings made by the children in WHO category 4 (minimal light perception, M = 0.50, SD = 0.27) and those in WHO category 5 (no light perception, M = 0.23, SD = 0.24) was noticeable, U = 70, N1 = 25, N2 = 13, $p < 0.01$, whereas the Mann-Whiney test did not indicate any significant differences between the first 3 categories, $p_s > 0.20$.

The correlation between recognizability and drawing practice reached significance in the 38 children with vision loss, Kendall's $\tau = 0.31$, p = .005, but failed to yield significance in the 41 children with low vision, $\tau = 0.18$, p = .10, as well as in the 69 sighted

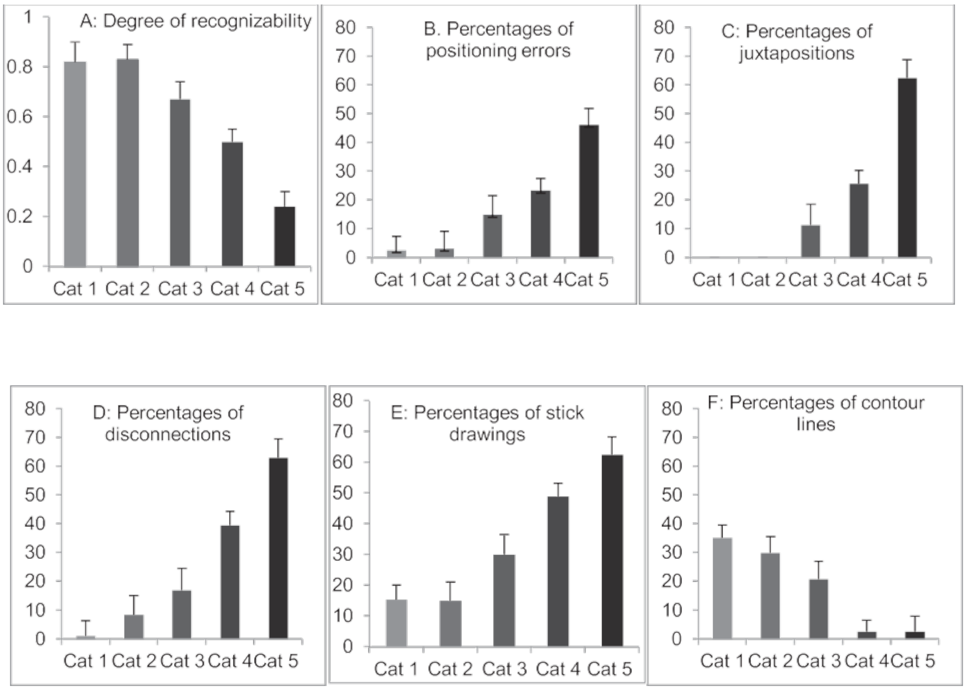

Fig. 3. Frequency of occurrence of different drawing criteria as a function of the WHO (World Health Organization) visual categories. Values are means with standard error bars.

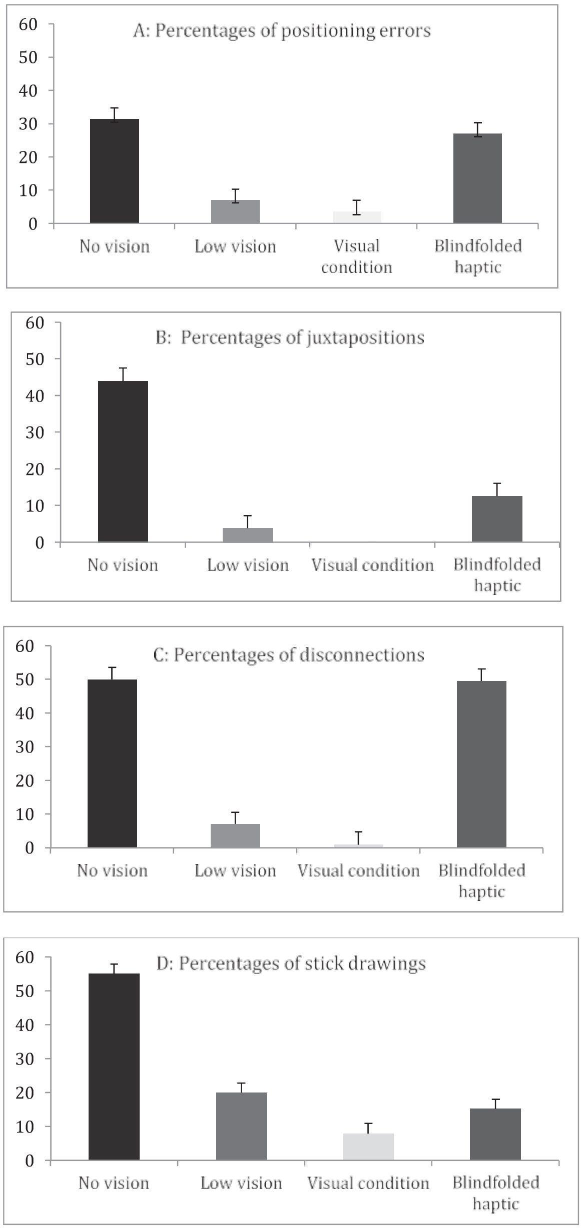

Fig. 4. Frequency of occurrences of different drawing criteria in the four child groups. Values are means with standard error bars.

children, τ = 0.12, p = .12.

The production of element positioning errors was a function of Visual Status, H(3, N = 148) = 64.7, p < 0.001, but not of Age, H (3, N = 148) = 5.6, p = .13. As Fig. 4A shows, positioning errors were produced almost solely by the children deprived of vision and the blindfolded sighted children assigned to the haptic task, with no significant difference between these two groups, U = 64, N1 = 38, N2 = 25, p = .56.

As illustrated in Fig. 3B, the occurrence of positioning errors increased as the level of vision decreased, H(5, N = 148) = 41.85, p < 0.001, although the children with moderate and severe low vision made very few positioning errors (M = 2.9%, SD = 1.1%), no more than the sighted children drawing in the visual condition (M = 3.6%, SD = 1.4%). Children who did not perceive light (WHO category 5), introduced significantly more positioning errors in their drawings than the children who could perceive light (WHO category 4), U = 78, N1 = 13, N2 = 25, p < 0.01. Furthermore, these errors just failed to be significantly negatively related to their level of drawing practice, τ= −0.18, p = .09.

3.2. Juxtapositions, disconnections, stick drawings and contour lines

As clear in Fig. 4B, the children deprived of vision drew the different parts of the depicted entity juxtaposed with one another significantly more often than the other groups did, $H(3, N = 148) = 71.2$, $p < 0.001$. This feature appeared to be characteristic of the former group. The percentage of juxtapositions in the blindfolded sighted group ($M = 12.6\%$, $SD = 16.2\%$) was similar to that obtained for the children with profound vision loss (WHO category 3, $M = 11.25\%$, $SD = 31.4\%$), but was much lower than that of children with no or minimal light perception (WHO categories 4 and 5, respectively $M = 25.7\%$, $SD = 24.2\%$ and $M = 62.4\%$, $SD = 31.1\%$). Age did not yield significant differences, $p = .64$. Fig. 3C shows that the degree of severity of the visual handicap induced significant differences, $H(5, N = 148) = 62$, $p < 0.001$, with no cases of juxtaposition being reported in the drawings made by the children with severe or moderate low vision, and significantly less occurrences in the children who could perceive light than in those totally deprived of light perception, $U = 61.5$, $N1 = 25$, $N2 = 13$, $p = .002$. Among these 38 children deprived of vision, those with the greatest drawing practice were those who produced the fewest drawings with juxtaposed elements, $\tau = -0.35$, $p < 0.001$. The presence of disconnections between drawn segments was significantly influenced by the child's visual status, $H(3, N = 148) = 86.5$, $p < 0.001$, as indicated in Fig. 4C. This was frequent in the participants with no or minimal light perception, and rare in those with low vision and in sighted children, except when they drew blindfolded in the haptic condition. The WHO visual category factor induced significant differences, $H(5, N = 148) = 41.8$, $p < 0.001$, as Fig. 3D shows. The correlation between the level of drawing practice and the frequency of disconnections reached significance in the children without vision, $\tau = -0.45$, $p < 0.001$.

One feature that appeared to be quite characteristic of these latter participants was the occurrence of stick drawings, $H(3, N = 148) = 66$, $p < 0.001$. Half of their drawings contained stick representations, while this was the case in only around 15% of the productions of the blindfolded sighted children in the haptic condition (Fig. 4D). This behavior was negatively correlated with their level of drawing practice, $\tau = -0.33$, $p < 0.01$. Fig. 3E illustrates the significant differences related to the WHO visual category factor, $H(5, N = 148) = 65$, $p < 0.001$. These children with no or minimal light perception produced significantly more stick drawings than the children with low vision, $U = 203$, $N1 = 38$, $N2 = 41$, $p < 0.001$. Age did not yield significance, $H(3, N = 148) = 1.1$, $p = .78$.

These results are consistent with the fact that the children deprived of vision did not often draw using contour lines, as confirmed by a significant Visual Status effect, $H(3, N = 148) = 49.8$, $p < 0.001$, which was complemented by a significant Age effect, $H(3, N = 148) = 27$, $p < 0.001$. Fig. 5 presents these findings.

Contour lines increased with age in all the groups, apart from the group deprived of vision where age did not induce significant differences, $H(3, N = 48) = 3.6$, $p = .30$. Though the blindfolded haptic group used contour lines more often than the former group, $U = 187$, $N1 = 37$, $N2 = 38$, $p < 0.001$, they employed this drawing strategy significantly less often than the sighted children in the visual condition, $U = 392.5$, $N1 = 37$, $N2 = 32$, $p < 0.05$. Moreover, a fall-off in the use of this strategy at 12–14 years of age was observed in the sighted children drawing under haptic control. Fig. 3F shows the significant differences induced by the WHO visual category factor, $H(5, N = 148) = 48.2$, $p < 0.001$, and highlights the scarcity of contour lines in the children with no or minimal light perception (categories 4 and 5), in comparison to the children with low vision (categories 1–3), $U = 256$, $N1 = 38$, $N2 = 41$, $p < 0.001$. $p < 0.05$. No other significant effects were observed.

4. Discussion

The literature provides numerous convincing pieces of evidence that testify to unexpected drawing capacities in children with visual impairments (e.g., Kennedy, 1993). Though Kennedy (1993) tested children who were unpracticed in drawing, the extent to which these clear findings are representative of the general capacities of visually-impaired individuals or, on the contrary, of those who are highly motivated to draw and do so regularly, remains unclear. With a few exceptions (e.g. Millar, 1975), there have been no drawing studies that have enlisted a significant number of visually-impaired participants with different levels of visual handicap or of drawing practice. The aim of the present study was to provide a more analytical overview of drawing abilities in children who had a total or partial lack of vision, in order to relate specific drawing characteristics to various levels of degraded visual information. Furthermore, increasing the number of participants enabled us to study the impact of their level of practice in this skill as well as the

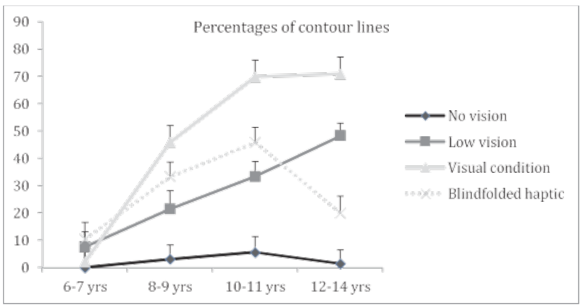

Fig. 5. Frequency of use of contour lines in the children's drawings as a function of age and visual status. Values are means with standard error bars.

chronological age-related development of different drawing criteria in both children deprived of vision and children with low vision. As suggested by Kennedy and collaborators, our study confirmed that vision is not a pre-requisite for drawing. When asked to draw 12 familiar objects, the children who had no light perception and those benefitting from minimal light perception produced drawings that were recognizable, by sighted persons, at a level of 40% on average, given knowledge of 12 options. This percentage is similar to that reported by D'Angiulli and Maggi (2003). As illustrated in Fig. 1, these children used lines to roughly copy the shapes of the objects, corroborating other findings that demonstrate that visual imagery is not necessary in order to activate the spatial representations that can guide drawing (e.g. D'Angiulli & Maggi, 2003; Heller & Kennedy, 1990; Vinter, Fernandes, Orlandi, & Morgan, 2012). The spatial understanding about objects that is needed to drive drawing from memory (as required in our task) derives from tactile, auditory or conceptual information, as well as from degraded visual information for children with low vision (Cornoldi & Vecchi, 2000). In line with this, the language used by children deprived of vision to describe similar familiar objects appears to refer largely to tactile and auditory attributes (Vinter, Fernandes, Orlandi, & Morgan, 2013). Following Cattaneo and Vecchi (2011), it can be argued that the most economical account of such results is to consider that individuals with severe visual impairments mentally consider the shapes of the objects as they progress in their drawing, merging all these sources of information together. However, our experiment also showed that their drawings were less recognizable, for sighted persons, than those produced by the other children. What factors are involved in this issue?

Both visual status and drawing practice are evident in our findings. We will discuss the effect due to the severity of the visual impairment first. To our knowledge, this is the first study to show that as visual acuity falls, drawings as those required in our study become less recognizable, include fewer elements, contain more element positioning errors and disconnections between drawn segments, are more likely to be made up of juxtaposed parts, themselves represented as stick configurations, and use fewer contour lines. Some of these findings have already been reported when visually impaired children were compared to sighted ones, in particular with regard to positioning errors and disconnections (Kennedy, 1993; Millar, 1975), but not as a function of a large diversity of degrees of severity of the visual impairment. In most cases, the data reported in Figs. 2 and 4 support the hypothesis of a huge gap between drawings of individuals deprived of vision (WHO categories 4 and 5) on the one hand and of individuals with low vision (categories 1 and 2 particularly) on the other hand, of whom drawings did not differ, for most criteria, from those of sighted children. Although the loss of vision did not prevent drawing abilities, the level of severity of the visual impairment determined the degree of recognizability of the produced drawings. This finding is similar to others reporting that participants with low vision outperformed those deprived of vision in spatial tasks (Blanco & Travieso, 2003; Cattaneo & Vecchi, 2011). Even significantly degraded visual information can "make the difference" and, when associated with haptic information, can enable individuals with a visual handicap but residual vision to perform spatial tasks adequately.

The comparison with the blindfolded sighted group that performed the haptic task permits a better understanding of some of the characteristics of the drawings produced by the group with severe visual impairments. Drawing under haptic feedback led the drawers to reduce the number of elements included in their productions, which, moreover, contained disconnected segments and element positioning errors (see also Millar, 1975). All these features are presumably induced by the lower spatial resolution of tactual compared to visual information (e.g., Dassonville, 1995), by the narrow tactile perceptual field even when multiple fingers are used (Loomis, Klatzky, & Lederman, 1991). It may also be due to the sequential nature of this mode of perception, which imposes a considerable load on working memory (Revesz, 1950) and affects the way information is mentally reconstructed in individuals with vision loss (Cattaneo et al., 2008). Following this line of analysis, the decrease in the use of contour lines at 12–14 years of age in the blindfolded haptic group probably indicates a strategic adaptation to the task constraints, preventing the overloading of working memory as a result of a continuous drawing movement performed under haptic control. Note however that this use of stick drawings could likely decrease if the blindfolded sighted children drawing with the Swedish kit would be extensively trained.

What then remained typical of the drawings of children with no or minimal light perception? Only they produced more than half of their drawings as stick representations of juxtaposed elements, each depicting a particular part of an object (e.g. legs, arms, wings), as if they had in mind a list of elements to include in their drawings (Millar, 1975). As a consequence, the spontaneous use of contour lines was extremely rare. They tended to draw the object's elements piece by piece, which were, nevertheless, sufficiently well combined relative to one another for the resulting overall configuration to be recognized in 40% of cases on average. Note that prior teaching strategy or exposure effects are not likely to account for this result. We are ignorant of tactile illustrated books that contain tactile pictures depicted as stick configurations, and drawing in this way was not taught in the centers our visually impaired children attended.

However, our findings also revealed that these characteristics of their drawings were dependent on their level of practice. The production of visually impaired children with current regular drawing practice were more recognizable, contained more elements, were less piecemeal, with fewer disconnections and stick configurations than those who had rare or null practice. The impact of practicing spatial skills has already been pointed out (e.g., D'Angiulli & Maggi, 2003; Dulin & Hatwell, 2006; Ittyerah, 2009). Likova (2012) provided impressive illustrations of improvements in the drawings of an adult with congenital visual impairment after training, and performed an fRMI analysis to demonstrate that the primary visual cortex of this participant exhibited rapid changes during learning, becoming massively activated as drawing from tactile memory was enhanced (see also Amedi et al., 2008). This high cross-modal plasticity of the brain after specific stimulations or experience is evidently involved in the astonishing drawing competencies sometimes exhibited in individuals deprived of vision who intensively practice this skill. It is likely that the low level of contour lines use in children deprived from vision in our study is a consequence of both limited drawing practice and reduced exposure to pictures during their childhood: would they have been given more opportunity, their performance would have been more close to that of sighted children, as claimed by Warren (1984) with regard to different perceptuo-motor, cognitive and social skills. In this vein, guessing that children with vision loss will have, in the future, major exposure to pictures and increased practice in drawing, we can wonder if their drawings will still be different from those made by sighted individuals. Our data incite us to think that it will no longer be the case.

Finally, while our results showed an age-related development on a number of drawing criteria in the sighted as well as in the children with low vision, the developmental trends in the children with the most severe visual impairments were tenuous. Their number with a high level of drawing practice in each age group was unfortunately too low in our experiment to permit an assessment of drawing development in these selected children. Despite this, the age-related development of recognizability tended to suggest that the developmental trends were similar in the sighted and visually impaired children, although undoubtedly slower in the latter, especially in those with vision loss. Be that as it may, we can also ask whether it might not be somewhat questionable to expect drawing behavior to develop in similar ways in sighted children and children with the most severe visual impairments. If children build representations of objects that are anchored in their specific perceptual experience, children deprived of vision should tend to integrate features inaccessible through their own perceptual experience in their drawings only in response to explicit instructions (see, for instance, Heller, Kennedy, & Joyner, 1995, for a demonstration of the influence of explicit instructions in haptic drawing recognition). Alternatively, it may be that children deprived of vision feel the continuity, proportion and limb-positions of objects veridically, and that the presence of disconnections or juxtapositions in drawings has to do with drawing practice, not with specific perception of objects.

In conclusion, the present study demonstrated that "the less one sees, the less well one draws" (from sighted persons' point of view), though drawing is a spatial skill that individuals without vision can definitely develop. Furthermore, drawing practice can help them develop drawing skills. This important finding could encourage parents, caregivers and teachers to increase drawing opportunities for children deprived of vision, as producing drawings is one important media of communication between one self and the others, and contributes to cognitive development (e.g. Freeman, 1980; Willats, 2005). In further studies, it could be interesting to study if severely visually-impaired children are able to identify their own drawings, whether these drawings are judged as recognizable or not by sighted persons. If the errors in drawings that made them not recognizable are mainly due to insufficient practice, they should not recognize them better than sighted persons would.

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