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Tactile Picture Recognition by Early Blind Children: The Effect of Illustration Technique

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This study investigated factors that influenced haptic recognition of tactile pictures by early blind children. Such a research is motivated by the difficulty to identify tactile pictures, that is, two-dimensional representations of objects, while it is the most common way to depict the surrounding world to blind people. Thus, it is of great interest to better understand whether an appropriate representative technique can make objects' identification more effective and to what extent a technique is uniformly suitable for all blind individuals. Our objective was to examine the effects of three techniques used to illustrate pictures (raised lines, thermoforming, and textures), and to find out if their effect depended on participants' level of use of tactile pictures. Twenty-three early blind children (half with a regular or moderate level of use of tactile pictures, and half with either no use or infrequent use) were asked to identify 24 pictures of eight objects designed as the pictures currently used in the tactile books and illustrated using these three techniques. Results showed better recognition of textured pictures than of thermoformed and raised line pictures. Participants with regular or moderate use performed better than participants with no or infrequent use. Finally, the effect of illustration technique on picture recognition did not depend on prior use of tactile pictures. To conclude, early and frequent use of tactile material develops haptic proficiency and textures have a facilitating effect on picture recognition whatever the user level. Practical implications for the design of tactile pictures are discussed in the conclusion.

Keywords: haptic, blind children, practice, thermoforming, raised lines, textures

The haptic manual system is highly efficient when it comes to identifying common real life objects (fork, key, etc.). Identification of common three dimensional (3D) objects is extremely fast and almost error-free in blindfolded sighted adults (Klatzky, Lederman, & Metzger, 1985; Klatzky, Loomis, Lederman, Wake, & Fujita, 1993) and children (Bushnell & Baxt, 1999). A study of Morrongiello et al. (1994) showed that blind subjects performed as well as sighted people in haptic object recognition. Contrary to what has been observed in the haptic identification of 3D objects, studies on the identification of tactile pictures (two dimensional [2D]) revealed low identification rates in blindfolded sighted adults (Heller, Calcaterra, Burson, & Tyler, 1996; Klatzky, Loomis, Lederman, Wake, & Fujita, 1993; Magee & Kennedy, 1980; Scocchia, Stucchi, & Loomis, 2009). Difficulty in recognizing tactile pictures may be related to the inherent constraints of the haptic system. The haptic system has low spatial resolution and a limited perceptual field involving the sequential integration of information which overloads working memory (Hatwell, Streri, & Gentaz, 2003).

Difficulty in recognizing tactile pictures is even more pronounced in blind people (Heller, 1989; Lederman, Klatzky, Chataway, & Summers, 1990; Thompson, Chronicle, & Collins, 2006). Thus, Lederman et al. (1990) asked congenitally blind adults and blindfolded sighted adults to identify 11 2D tactile pictures and 11 3D tactile pictures and showed that congenitally blind identified only 10% of the tactile pictures presented compared with 27% in the blindfolded sighted. Similarly, Thompson et al. (2006), in the first condition of their study, showed that blindfolded sighted adults identified 50% of the tactile pictures presented compared to 13% in the early blind adults. Several authors have attempted to explain these disparities related to visual status by pointing out the lack of understanding and familiarity with the purely visual conventions of

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drawings (Klatzky et al., 1993; Millar, 1975; Thompson et al., 2003, 2006) of blind people and their limited abilities in dealing with visual imagery (Heller et al., 1996; Lederman et al., 1990; Scocchia, Stucchi, & Loomis, 2009; Thompson, Chronicle, & Collins, 2003; Thompson et al., 2006; Warren, 1984; Worchel, 1951). Indeed, visuospatial imagery seems to play a role in tactile pictures recognition (Lebaz, Jouffrais, & Picard, 2012). Finally, several studies have shown that, because of their visual experience (that has a facilitating effect on both the generation and the use of spatial mental imagery), identification performances of the late blind were better than those of the early blind (Heller, 1989; Lederman et al., 1990; Thompson et al., 2006).

Nowadays, tactile graphic material for teaching and education of the visually impaired is becoming easier to access (Hatwell, 2003; Hatwell et al., 2003). The question of the recognition of tactile pictures in blind children appears therefore crucial but very few studies (Pathak & Pring, 1989; D'angiulli, Kennedy, & Heller, 1998) dealt with this topic. In the study of Pathak and Pring (1989), 13-year-old blind children obtained 63% of correct response when asked to select from among three words the one that described a previously explored raised lines drawing and 59% when asked to select the appropriate raised line picture (among three) matching the previously spoken word. Blindfolded sighted children obtained 76% of correct responses in these two conditions.

Currently, the difficulty lies in finding methods of presenting relief drawings that are compatible with the constraints imposed by the slow development of haptic abilities in children (Morrongiello, Humphrey, Timney, Choi, & Rocca, 1994), and with the lack of visual imagery in congenital blindness. Several studies in adults have suggested ways of making tactile pictures more compatible with blindness. For instance, studies by Kennedy and Bai (2002) and Wijntjes, Van Lienen, Verstijnen, and Kappers (2008) showed better identification of large pictures than of small ones. Others have suggested that the ambiguity and complexity of drawing lines and the presence of 3D information complicated tactile picture identification (Kennedy & Bai, 2002; Lederman et al., 1990; Thompson et al., 2003, 2006; Lebaz et al., 2012). Finally, the lack of salient haptic information contained in tactile picture stimuli (Klatzky et al., 1993; Lederman & Klatzky, 1987; Lederman et al., 1990) appears to contribute to poorer identification. A great deal of information is in fact lost when transferring the 3D object to 2D pictures. It has already been shown that the material used to transfer 3D objects to 2D pictures can influence their identification. Indeed, Thompson et al. (2006) showed better recognition by blindfolded sighted adults of uniformly textured pictures than of raised line drawings. Furthermore, a recent meta-analysis (Lebaz, 2011; Picard & Lebaz, 2012) of studies on the identification of tactile drawings in adults showed that the type of paper affected the performance: Swell paper appears to be better for identification than plastic film.

Three main illustration techniques are currently used in the tactile illustration of books: thermoforming, texture, and raised lines. Pictures of thermoformed objects are obtained by vacuum-heating a thin plastic sheet placed on an object or a matrix using a thermoforming machine. The plastic picture obtained follows the contours of the original object precisely. Textured pictures are obtained by assembling several textures (fabrics, foams, paper, etc.). Raised line pictures are produced using paper impregnated with microcapsules of alcohol. When exposed to heat, these burst under the black spaces on the page, thus, increasing the volume of the page in these areas only. Each illustration technique does not, therefore, provide the same kind of information about the real object (3D information, planar contour, textures, etc.). Moreover, the illustration technique might influence the haptic exploratory processing of the object depicted. The raised lines method appears as the less promising technique since it constrains the participants to perform a contour-following exploratory procedure (EP), which is the most sequential and slow exploration, that is, the most taxing use in terms of working memory resources (Lederman & Klatzky, 1987). Conversely, the thermoforming technique of production provides an interesting way to transfer 3D objects to 2D pictures without completely cancelling the relief aspect and thus, without confining the participants to contour-following EP. Indeed, such a design would still promote the EP of enclosure that is appropriate and effective in shape identification (Lederman & Klatzky, 1987). Regarding the textured pictures, several arguments support this technique as the better medium to enhance the process of identification. First, texture affords salient cues for identification (Klatzky et al., 1993). Second, textured pictures provide a twofold source of information, preserving information about contours and adding precious information related to materials that objects are made of, without overloading working memory because shape and materials could be processed in parallel, as testified by the integrative perception of both global (shape) and local (texture) dimensions of objects (cf. Lederman & Klatzky, 1997). In brief, theoretical and procedural arguments claim that identification performances should be better using textured pictures rather than thermoforming or raised lines methods.

Therefore, the present study aimed to determine the role of illustration technique in the tactile identification of pictures by early blind children. Is there a general hierarchy in terms of the difficulties inherent to each illustration technique? More specifically, this study addressed the question of the factors that may modify this hierarchy. In addition, we sought to find out if the effect of illustration technique on tactile picture recognition depended on participants' prior level of use of tactile pictures, because there is evidence of the effect of expertise on spatial skills in blind adults. For instance, Dulin and Hatwell (2006) showed that congenitally blind adults who were already experts in the use of graphic material outperformed late blind nonexpert adults (despite the fact that they benefited from visual experience before blindness occurred). Their results were achieved using a mental rotation task where participants had to match a geometrical figure model with four comparisons figures that were either identical to the model in four possible orientations or were mirror images of it. In summary, the objective of this study was to evaluate the identification of tactile pictures illustrated using three different techniques (thermoforming, textures, and raised lines), and to determine whether the influence of illustration technique on picture identification depended on participants' prior level of use of tactile pictures.

Method

Participants

Twenty-three early blind[1] (11 girls and 12 boys) with no associated disorders aged 10 years 4 months on average (SD = 3 years 4 months) participated in this study (see Table 1). None of the participants who had light perception could discriminate shape or hand movements. Eleven early blind children had regular or moderate use of tactile pictures, and 12 had no or infrequent use of tactile pictures. Level of use was determined using a questionnaire on the frequency of reading tactile pictures by the child at home and at school (see Appendix A). The questionnaire had a 5-point scale (0 = *Never* to 5 = *Everyday*). A mean level of use was calculated from the scores at home and at school (M = 2.78; SD = 1.05). The no or infrequent use group was made up of children below the average and the regular or moderate use group was made up of children above the average. The present study was conducted in accordance with the Declaration of Helsinki. It was conducted with the understanding and the written consent of each participant's parent. It was approved by the local ethics committee of the LPNC (CNRS and University of Grenoble), conducted in accordance with the ethics convention between our academic organization (LPNC-CNRS) and educational organizations for blind people.

Stimuli

Twenty-four stimuli corresponding to eight tactile pictures illustrated using three different techniques (textures, thermoforming, and raised lines) (see Figure 1) were presented to participants. They were presented on a cardboard stand measuring 20 cm × 20 cm. The length of the main axis of each object was 15 cm. Each object was centered on the stand: the distance between the object and the left edge was equivalent to the distance between the object and the right edge, and the distance between the object and the top of the stand was equivalent to the distance between the object and the bottom of the stand. The eight pictures were selected from Snodgrass and Vanderwart's (1980) set of 260 pictures and were adapted and produced by a publisher of tactile pictures ("Les Doigts Qui Rêvent," Talant, France, http://www.ldqr.org/). Our set of pictures has then the particularity of being designed as the pictures currently used in the tactile books for visually impaired children. In our view, the fact that our experimental material is as close as possible to that used by publishers in tactile books allows us to provide reliable and practical applications. In accordance with the Alario and Ferrand (1999) French norms, the pictures from the Snodgrass and Vanderwart's (1980) set used in the present study had a mean name-agreement percentage of 98.25%, and a mean concept-familiarity score of 2.99. To control the kind of objects depicted, manipulability and domain were crossed between pictures, with two depicting handled natural objects (fruit: banana, grapes), and two handled artifacts (kitchen utensils: saucepan, bowl); and two depicting nonhandled natural objects (animals: lion, kangaroo), and two nonhandled artifacts (vehicles: motorbike, helicopter). Handled objects were objects that could be picked up or grasped by the hand.

To examine the relevance of the set of stimuli used in this experiment, we assessed the recognition of our tactile pictures by 10 (four men and six women) blindfolded sighted adults aged 26 years 1 month on average (SD = 3 years 6 months) with the same procedure (see Procedure below). The results showed that on average, 77.5% (SD = 12.45%) of tactile pictures were correctly identified by blindfolded sighted adults with a mean response time of 32.40 s (SD = 15.80 s).

Procedure

Before the test phase, the experimenter asked the adult responsible for the child to complete the questionnaire on the child's level of use of tactile pictures. The study was administered on an individual basis. Participants were told to freely explore a set of tactile drawings of objects using both hands, and to identify each drawing as quickly and accurately as possible.

Before participants started the identification task, the names of the four object categories were given. The 24 tactile pictures were presented to each participant in random order. No feedback was given, regardless of whether or not the answer was correct. If they were unable to identify a picture, participants were told to inform the experimenter when they wished to stop exploring. However, it was explained to the children to always try to give an answer even if this answer did not seem satisfactory and to not hesitate to say what was going through their head. The experimenter registered the participants' response from the time they stopped exploring and gave their final answer. The percentages of correct identification per picture and response times for correct identification were measured.

Results

Preliminary analysis of variances (ANOVAs) on identification rates and response times with use as a between-participants factor and illustration technique as a within-participant factor, and age as a continuous predictor revealed that the age factor was not significant and did not interact with other factors, $F_s < 1$. Therefore, we removed this factor from subsequent analyses. Identification rates and response times were analyzed by 2 (use of tactile pictures: moderate and regular use vs. no and infrequent use) × 3 (illustration technique: thermoforming, textures, or raised lines) ANOVAs with "use of tactile pictures" as a between-subjects factor and "illustration technique" as a within-subject factor.

Identification rates showed that 30.98% (SD = 23.19%) of tactile pictures were correctly identified by children. Results showed that illustration technique had an effect on identification rates, $F(2, 42) = 6.83$, $p < .01$, $\eta^2 = 0.24$. A Tukey's honestly significant difference (HSD) test showed that textured pictures (M = 35.87%; SD = 23.63%) were more accurately recognized than thermoformed (M = 29.89%; SD = 23.76%) ($p < .05$) and raised lines (M = 27.17%; SD = 24.90%) pictures ($p < .01$). For details, Table 2 shows identification rates for each picture as a function of illustration technique. It should be noted that identification performance varied considerably from one picture to another. The correlation results between blind children performance and those of the control group of blindfolded sighted adults indi-

[1] This terminology includes the congenitally blind, and people who became blind in early childhood before the age of one. This generally corresponds to the age retained in the literature.

Table 1
Characteristics of the Early Blind Who Participated in the Experiment

Participant	Gender	Age (year)	Cause of the deficiency	Tactile pictures practice
1	F	16	Glaucoma	Moderate or regular
2	M	15	Cataract	No or infrequent
3	F	6	Glaucoma	Moderate or regular
4	M	13	Cortical blindness	No or infrequent
5	M	6	Retinoblastoma	No or infrequent
6	M	8	Microphtalmia	No or infrequent
7	F	8	Retinoblastoma	No or infrequent
8	M	9	Cataract	Moderate or regular
9	M	9	Retinoblastoma	Moderate or regular
10	M	9	Leukocoria	No or infrequent
11	F	10	Leber's amaurosis	No or infrequent
12	F	15	Unspecified	Moderate or regular
13	F	15	Unspecified	No or infrequent
14	M	12	Unspecified	Moderate or regular
15	F	11	Unspecified	Moderate or regular
16	M	9	Unspecified	Moderate or regular
17	M	9	Unspecified	Moderate or regular
18	F	6	Unspecified	No or infrequent
19	M	14	Unspecified	No or infrequent
20	M	12	Retinopathy	No or infrequent
21	F	10	Unspecified	Moderate or regular
22	F	10	Unspecified	Moderate or regular
23	F	7	Unspecified	No or infrequent

cated that pictures frequently recognized by the blindfolded sighted were also pictures frequently recognized by the blind children ($r = .73$, $p < .05$). Therefore, we investigated whether the variability in identification performance was related to the familiarity—according to the Alario and Ferrand (1999) French norms—of selected pictures. The correlation between picture identification and picture familiarity was not significant in blind children ($r = .43$, $p = .29$) while it was significant in blindfolded sighted adults ($r = .72$, $p < .05$). Otherwise, analysis also revealed that participants with regular or moderate use ($M = 41.67\%$; $SD = 27.18\%$) performed better than participants with no use or infrequent use ($M = 21.18\%$; $SD = 15.47\%$), $F(1, 21) = 5.37$, $p < .05$, $\eta^2 = 0.20$. Results showed that the effect of illustration technique on identification rates did not depend on participants' level of practice, $F(2, 42) < 1$, $p = .42$. Moreover, an item analysis (ANOVA with repeated measures) on identification rates with Presentation of the object (first, second, and third) and Illustration technique (thermoforming, textures, and raised lines) as within-subject factors confirmed an effect of illustration technique on identification rates (MRL = 27.17; SDRL = 24.12; MTH = 29.89; SDTH = 25.18; MTX = 35.87; SDTX = 26.06; $F(2, 14) = 6.09$, $p < .05$) and revealed that participants' performances improve with exposure (MP1 = 26.09%, SDP1 = 22.27%; MP2 = 32.06%, SDP2 = 24,08%, MP3 = 34.78%, SDP3 = 26.37%); $F(2, 14) = 18.87$, $p < .01$]. Finally, it should be noted that Presentation of the object did not interact with illustration technique ($F(4, 28) = 1.69$, $p = .19$).

Response times for correct identification showed that tactile pictures were correctly identified in 13.24 s ($SD = 11.87$) on average. Illustration technique had no effect on response times, $F(2, 42) = 1.67$, $p = .20$. Response times of participants with regular or moderate use ($M = 15.07$; $SD = 14.17$) did not differ significantly from those of participants with no or infrequent use ($M = 11.25$; $SD = 8.48$), $F(1, 41) = 1.94$, $p = .18$. Finally, results showed that the effect of illustration technique on response times did not depend on participants' level of practice, $F(2, 42) < 1$, $p = .53$. Table 3 shows the identification rates and response times for each illustration technique as a function of use level. Finally, the

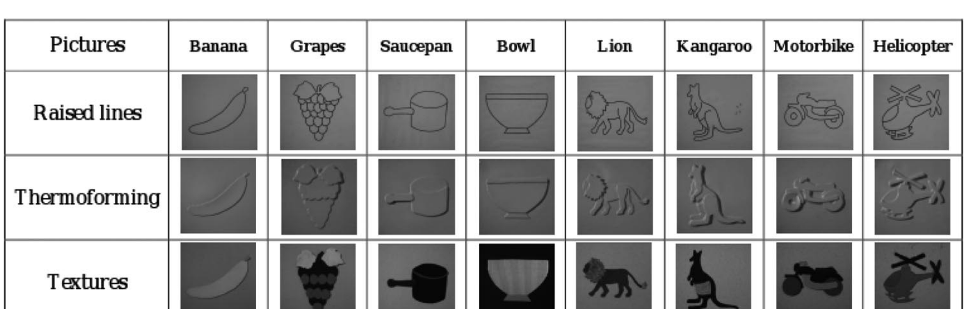

Figure 1. Twenty-four tactile pictures presented to early blind children.

Table 2
Mean Identification Rates (and SD) (%) in Early Blind Children for Each Picture as a Function of Illustration Technique

Picture	Raised lines	Thermoforming	Textures	Total
Banana	82.61 (38.76)	86.96 (34.44)	95.65 (20.85)	88.41 (32.25)
Grapes	17.39 (38.76)	8.70 (28.81)	13.04 (34.44)	13.04 (33.92)
Saucepan	34.78 (48.70)	39.13 (49.90)	43.48 (50.69)	39.13 (49.16)
Bowl	26.09 (44.90)	21.74 (42.17)	21.74 (42.17)	23.19 (42.51)
Lion	13.04 (34.44)	21.74 (42.17)	34.78 (48.70)	23.19 (42.51)
Kangaroo	4.35 (20.85)	8.70 (28.81)	21.74 (42.17)	11.59 (32.25)
Motorbike	21.74 (42.17)	30.43 (47.05)	34.78 (48.70)	28.99 (45.70)
Helicopter	17.39 (38.76)	21.74 (42.17)	21.74 (42.17)	20.29 (40.51)
Total	27.17 (24.90)	29.89 (23.76)	35.87 (23.63)	

correlation coefficient between response times and identification rates was not significant ($r = -.20$, $p = .35$) and revealed that performance did not indicate a speed–accuracy trade-off.

It should be noted that, when focusing on participants' erroneous responses, we noted that many responses were in the correct category, and that the object chosen was sometimes very similar in shape to the expected response (e.g., carrot for banana). This kind of approximate responses was often shared by several participants. When considering these approximate responses as correct, the identification rates reached 40.58% ($SD = 23.31\%$). Approximate responses given per picture are listed and accompanied by their frequencies for each illustration technique in Appendix B.

Discussion

The present study dealt with the haptic recognition of tactile pictures by early blind children. Its objective was to determine if the identification of tactile pictures was influenced by the technique (raised lines, thermoforming, or textures) used to illustrate them. Furthermore, this study sought to determine whether the influence of illustration techniques on picture identification depended on the participants' level of use of tactile pictures.

Our main result showed that illustration technique had an effect on identification performance. Recognition of textured pictures was better than that of thermoformed and raised line pictures. This result corroborates the findings of Thompson et al. (2003) showing that, in blindfolded sighted adults, uniformly textured pictures were recognized better than raised lines pictures. In our study, the fact that textures seemed more appropriate to the identification of tactile pictures could be explained by the fact that textured pictures provided information about material properties and conveyed 3D information because the different textures used to represent objects are not simply juxtaposed next each other to symbolize the different parts of the pictures, but textures are placed on top of one another. This assemblage of different textures could have facilitated the perception of the different components of the picture and thus, enabling better discrimination of the salient elements of the object. This would be consistent with observations of Morrongiello et al. (1994) who showed that with increasing age, children's representation of objects changed from one based predominantly on global shape to one that incorporates specific local parts of objects, and that critical parts (for instance the handle of a cup) played a role in object identification, particularly in older children.

When we considered the approximate responses in the identification rate, it appeared that performance increased to 40%, and that performance for thermoformed pictures were close to performance for textures pictures. Thus, it appears that participants were better at recognizing pictures that provide textures and 3D shape information properties than raised lines pictures that failed to provide these cues to the haptic system. Raised lines pictures would provide far fewer tactile clues about objects than the other techniques. Other authors had explained the difficulties to recognize these pictures by the confusing nature of raised lines (Kennedy, 1993; Thompson et al., 2003). Raised lines pictures would lead to confuse the object foreground and background and to sometimes wrongly believe that certain areas do not constitute part of the object explored. Moreover, as Lederman and Klatzky (1987) pointed out raised lines technique constrains the participants to perform a contour-following exploratory procedure, which is the most sequential and the most taxing in terms of working memory resources. Indeed, in our study, illustration technique might have influence the haptic exploratory processing of object depicted.

The difference in identification rates as a function of illustration technique could also be explained by the graphic complexity. Because the pictures we selected from Snodgrass and Vanderwart's set were adapted and no longer corresponded to the original graphic, we were not able to control the degree of visual complexity. Moreover, Lebaz (2011) showed that tactual complexity was more highly correlated to identification performance than visual complexity. The haptic system is indeed characterized by its sequential processing with subsequent overload of working memory. Thus, the amount of details to be retrieved appears as a factor of

Table 3
Mean Identification Rates (and SD) (%) and Response Times (S) for Correct Answers in Early Blind Children for Each Illustration Technique as a Function of Use Level

	No or infrequent	Moderate or regular	Total
Rates (%)			
Raised lines	15.62 (14.23)	39.77 (28.40)	27.17 (24.90)
Thermoforming	20.83 (14.43)	39.77 (28.40)	29.89 (23.76)
Textures	27.08 (16.71)	45.45 (26.97)	35.87 (23.63)
Total	21.18 (15.47)	41.67 (27.18)	30.98 (23.19)
Times (s)			
Raised lines	13.14 (6.12)	12.47 (6.10)	12.82 (5.98)
Thermoforming	11.38 (8.28)	8.91 (7.45)	10.20 (7.82)
Textures	20.69 (21.90)	12.36 (11.33)	16.71 (17.78)
Total	15.07 (14.17)	11.25 (8.48)	13.24 (11.87)

complexity. Moreover this factor of tactual complexity could explain the fact that identification performance varied considerably from one picture to another. However, tactual complexity cannot be assessed in the same way as visual complexity because it seems to depend not only on the number but also on the salience of details. If we compare, for example, the identification of a picture of a uniformly textured lion to that of a lion as it was textured in our study (with a different texture for the mane), the second picture would appear to be more tactually complex (more components to be perceived). However, identification will probably be easier because of the salience of the mane. To determine the importance of picture complexity, future studies should develop an objective measure of the parameters of pictures complexity.

It could also be argued that the object familiarity could explain the fact that identification performance varied considerably from one picture to another. Indeed, the correlation results showed that identification performance of the control group of blindfolded sighted adults varied according to the object familiarity—according to the Alario and Ferrand (1999) French norms—of selected pictures. Identification performances were higher for pictures with a high degree of familiarity. However, this correlation was not found in the group of blind children and these norms of familiarity are probably irrelevant for this specific population for which experience with some objects could have been limited because of the lack of visual experience. It would have been more relevant to assess the object familiarity for each subject in the experiment in order to assess the effect of familiarity on picture recognition.

It is interesting that, in this study, we obtained identification performance comparable to that observed by Heller et al. (1996), in their study on tactile picture recognition with information on object category. In their study early blind and blindfolded sighted adults obtained 37% and 63% of correct identification, respectively, compared with 30% for blind children and 77% for blindfolded sighted adults in our study. It is also interesting that blindfolded adults performances were correlated to those of blind children. This correlation indicates that the pictures frequently recognized by the sighted were also pictures frequently recognized by the blind. This suggests that similar knowledge of shapes of objects and similar principles of depiction are being used by the blind and the sighted in interpreting pictures. Besides, our results showed that participants with a regular or moderate use obtained higher identification rates than participants with no or infrequent practice. This result is in line with those of Dulin and Hatwell (2006) showing an effect in spatial representations of expertise in the use of tactile graphic material. It could thus be argued that children who have had use with tactual pictures have had more opportunity to develop their tactual exploration skills. However, we cannot clearly conclude that a simple prior use with tactile pictures can improve subsequent recognition and that exposure to tactile picture helps children to develop their knowledge of transcription rules of three-dimensional space into two-dimensional drawings, their tactual skills, or both. Indeed, other factors may be confounded with how we conceptualize the use factor. Indeed, children who are more often exposed to tactile pictures are also likely to have more experience with Braille material and other tactile graphic display suitable for the visually impaired. The use of this material can develop haptic proficiency and efficiency of exploratory procedures. To properly address the issue of the effect of use level with tactile pictures, future studies should take these factors into account.

Our results also showed that the participants' level of use did not interact with the effect of illustration technique on identification rates. Therefore, it seems that the facilitating effect of textures on picture recognition remained stable regardless of the use level. Finally, response times' analyses did not reveal any significant effect of illustration technique or of participants' level of use on tactile picture identification.

To conclude, the results of this study have several practical implications. First, it appeared that early blind children with regular use of tactile pictures were more efficient in their recognition than children who were not familiar with the material. For a blind child, it seems that interpreting tactile pictures is not automatic; it requires use and. tactual exploration skills development over time to help a child explore and interpret tactile pictures. Therefore, it seems crucial to allow blind children to have early training in the use of tactile material and to give them regular opportunities to experience them. Second, the particularity of our study was to test pictures designed in the same way as the pictures currently used in tactile books for visually impaired children, which makes our findings very reliable to envisage practical applications. Results showed that textured pictures were better recognized than other illustration technique. This result is important to consider for publishers of tactile pictures, who tend to give priority to raised lines because they are much easier and faster to produce. Otherwise, in relation with the fact that we traditionally observed in literature a greater ease to recognize real objects than 2D pictures by touch, our result suggests that tactile pictures need to be more like 3D objects to increase their likelihood of recognition. Rather than adding the material property cues of the 3D object, our textured materials convey 3D information because the different textures used to represent objects are not simply juxtaposed next each other to symbolize the different areas, like areas of colors are typically used to separate different "parts" in visual pictures for sighted children. Because the different textures are placed on top of one another, this technique provides information about which texture is in the background or in the foreground in the pictures, giving access to depth information which is central in 3D perception and representation. Textured materials could provide cues about the real 3D object that are central to haptic recognition. Some authors (Thompson et al., 2006) provided the solution to combine the speed and ease of production of raised lines with the presence of 3D information in inventing the TexyForm pictures.

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(*Appendices follow*)

Appendix A

Questionnaire on the Child's Level of Use of Tactile Pictures

1. At school or institution, how often the child had the opportunity to read tactile pictures?

o Every day
o More than once a week
o Once or twice a month
o Less than once a month
o Once a year
o Never

2. At home, how often the child had the opportunity to read tactile pictures?

o Every day
o More than once a week
o Once or twice a month
o Less than once a month
o Once a year
o Never

Appendix B

Approximate Responses Given per Picture Are Listed and Accompanied by Their Frequencies for Each Illustration Technique

		Frequencies		
Picture	Approximate response	Raised lines	Thermoforming	Textures
Banana	Cucumber, carrot	0.04	0.04	0.00
Grapes	Strawberry, pineapple	0.09	0.09	0.09
Saucepan	Spoon	0.04	0.22	0.09
Bowl	Pot, glass	0.17	0.17	0.04
Lion	Horse	0.13	0.26	0.35
Kangaroo	Giraffe	0.09	0.22	0.09
Motorbike	Bike	0.00	0.04	0.04
Helicopter	No approximate response	—	—	—

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