Picard, D., Albaret, J-M., Mazella, A., "Haptic identification of raised-line drawings by children, adolescents, and young adults: An age-related skill", Haptics-e, the electronic journal of haptic research, Vol. 5, No. 2, 24-Jul-2013.

HAPTIC IDENTIFICATION OF RAISED-LINE DRAWINGS BY CHILDREN, ADOLESCENTS AND YOUNG ADULTS: AN AGE-RELATED SKILL (Short Paper)

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ABSTRACT

Past research involving adult participants has consistently shown that the identification of raised-line drawings through haptics was challenging. In the present study, we used a developmental approach to assess whether this skill was related to age and haptic short-term memory capacity. To that end, we asked sighted children, adolescents, and young adults to identify raised-line drawings of common objects by touch. We also measured their haptic short-term memory capacity. Results showed that picture identification scores and memory spans both improved significantly with age. Interestingly, memory scores accounted significantly for the variability in picture identification scores. These findings suggest that identifying raised-line drawings through haptics is an age-related skill. Improvement in haptic short-term memory capacity may play a role in the development of that skill.

1. INTRODUCTION

Raised-line pictures [6] are tangible pictures that are perceptible to the fingers. These pictures are potentially interesting bi-dimensional stimuli for haptics. People may use their sense of active touch to explore and identify a variety of tactile pictures. Past research asking participants to identify raised-line pictures of common objects [4-5, 7, 9, 12-18, 22, 24-28] has mostly involved adult participants, and has consistently shown that this task was challenging. For sighted as well as for blind people, past research has revealed low identification rates (about 30-40%) and long response times to naming (about 90 seconds) (for reviews see [8, 10]). What makes the identification of tactile pictures of common objects so difficult for individuals is still not entirely clear (for a recent review see [20]).

Lederman et al. [16] described tactile picture identification as a three-stage process. Stage 1 (encoding) refers to the acquisition of shape information over space and time through haptics. Stage 2 (mental elaboration) refers to the construction of a mental image of what is haptically perceived. Finally, stage 3 (concept identification and naming) refers to the retrieving of object representations and names that match the constructed mental image. A variety of factors may affect each of these stages, and account for the difficulties to identify tactile pictures.

There is ample evidence that image characteristics significantly affect shape acquisition under haptics [12-15, 22, 25]. For instance, Kalia and Sinha [12] found that symmetry and complexity of pictures correlated with their recognition. Several studies also suggested that manual exploration strategies affect the encoding of raised-line information [5, 18, 27]. For instance, D'Anguilli et al. [5] showed an advantage of a guided exploration of tactile images in sighted children having poor exploration skills. The elaboration of a mental image of what is haptically perceived partly depends on imagery abilities [15-16]. For instance, Lebaz et al. [15] showed that high visuospatial imagers outperformed low visuospatial imagers in a haptic picture identification task. Finally, the availability of semantic information about the pictures significantly affects concept identification. Heller et al. [9] showed that identification performance improved remarkably when categorical information was given about the tactile pictures.

Despite the numerous studies on raised-line drawing identification, none of them has yet examined this skill from a developmental point of view. D’Anguilli and coworkers [5] have assessed children’s ability to identify raised-line drawings of common objects. However, these authors did not explore behavioral changes with age. Therefore, the issue of whether haptic identification of raised-line drawings is an age-related skill has not been addressed so far.

Taking a developmental perspective into account is relevant to our understanding of the mechanisms underlying haptic picture perception. Indeed, most authors assume that memory demands represent an important part of the problem in tactile picture identification (see in particular [16-17]). Haptic exploration is sequential in nature and operates with a narrow field of view. As a result, temporally separated samples of information need to be stored serially in short-term memory in order to make sense of what is haptically processed. Haptic short-term memory capacity is thus one likely key factor operating at stage 1 (encoding). It may have direct influence on the serial storage of haptically perceived information; it may thereby constraint later identification performance. Haptic short-term memory increases during childhood up to adulthood [1, 21]. Therefore, under the hypothesis that haptic short-term memory plays a key role in tactile picture processing, we predicted that haptic picture identification performance will improve with age. We also predicted that haptic short-term memory capacity will be a significant predictor of variation in picture identification performance. We designed the present study to test these predictions.

2. METHOD

2.1. Participants

Thirty-nine sighted individuals (20 females/19 males) took part in the study on a voluntarily basis. They pertained to three age groups: children (5-7 years, mean age = 6 years 2 months, n = 13), adolescents (13-17 years, mean age = 15 years 9 months, n = 13), and young adults (20-25 years, mean age = 23 years, n = 13). We used the 10-item version of the Edinburgh handedness questionnaire to determine participants’ manual preference. On the whole sample, 4 participants (10%) had a left manual preference; the other had a right manual preference.

2.2. Materials

Materials in the picture identification task were 10 different raised-line pictures depicting common objects. Figure 1 shows the picture set. Table and spoon served as familiarization stimuli; these pictures have been used previously by Heller et al. [9]. The test stimuli included: banana, apple (fruits); dog, butterfly (animals); sock, shoe (clothes); car, bicycle (vehicles). The test pictures were simplified versions of pictures from [23]. Side-view pictures were in a left profile (see [19]). According to a French data basis for (visual) picture naming [3], children as young as five could name accurately all the depicted objects. The pictures were each on a separated page (landscape format) in a booklet, and fit within the page area. Maximum picture size was 19 x 25 cm.

Materials in the shape span task were 6 different raised-line geometrical shapes as (average individual size was 2 x 2 cm). The shapes appeared linearly by series of one to six shapes in a booklet. Figure 2 shows a six-shape series. We constructed series such that (i) one given shape appeared only once a time in a given series, (ii) the location of a shape varied across the series, and (iii) the last shape of a series differed from the first shape of the following series. The booklet comprised 2 x 6 test series (there were two trials for each test series), plus 1 additional series for practice.

We produced the raised-line versions of pictures and shapes on Swell paper with a heating machine. We used heat-sensitive paper because Swell paper has high resolution and line quality [11]. We also used an apparatus with an opaque curtain mounted on an inverted U-shape vertical armature. This apparatus permitted participants to put their hand below the curtain, while preventing them from seeing the raised-line material behind the curtain.

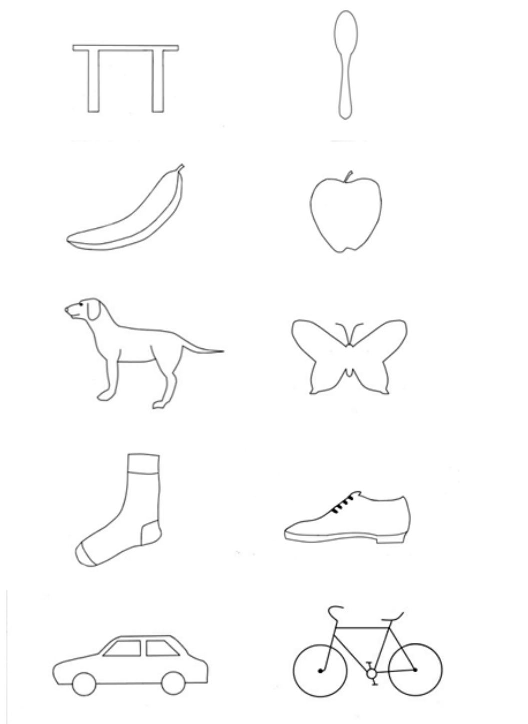

Figure 1. Corpus of drawings used in the picture identification task.

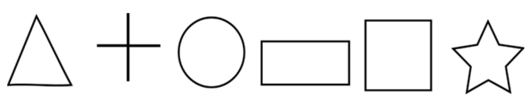

Figure 2. Example of a six-shape series to be recalled in order in the shape span task.

2.3. Procedure

The session was individual. Participants performed two successive tasks (counterbalanced order) involving their manual haptic skills, with a 5 min break between the two tasks.

In the picture identification task, participants freely explored a set of 10 raised-line drawings of common objects using both hands. They had to identify each drawing as quickly and accurately as possible. We gave them a maximum of 2 min for each picture. Following the procedure used by Heller et al. [9], we told participants the appropriate superordinate category name (e.g., fruits, vehicles) prior to the presentation of each of the drawings. We selected this option because pre-tests without semantic cues revealed floor performance in children. We gave no feedback, regardless of whether or not the verbal response was correct. The first two pictures of the booklet were practice items, so as to familiarize participants with the task. None of the participants had previous experience with tactile pictures. For each picture, we used a binary coding of the responses: 1 point if correct, 0 if not. We calculated a score for picture identification task as the total number of correctly identified pictures (min 0, max 8).

In the shape span task, participants used the index finger of their dominant hand to explore series of increasing size (1 to 6 items) of raised-line shapes. For each series, they explored and memorized the shapes one at a time from left to right (with no possible return back to a previously explored shape). Once they had explored a series in its full, they immediately recalled the name of the shapes in order. We gave no feedback, regardless of whether or not the verbal responses were correct. The task continued until participants failed to recall in a correct order two series of a given size. Score for the shape span task corresponded to size of the largest series of shapes recalled in correct order (min 0, max 6).

3. RESULTS

The distribution of scores significantly deviated from normality for each task (Shapiro-Wilk tests, all *p*s < 0.05). We therefore used non parametric tests with an alpha level of 0.05 for all statistical analyses. Kruskall-Wallis ANOVAs were used with age group as a between-subject variable for each task. We run additional Mann-Whitney U tests to test further between-group differences. We corrected the reported p-values for multiple-comparisons using a Holm correction [2]. Manual preference, order and sex were not significant factors of variation for shape span or picture identification scores. Therefore these factors are not discussed below.

Table 1. Scores by task for each age group.

Task	Picture identification	Shape span
Children	Median = 3.00 Mean = 2.62 SD = 1.66	Median = 1.50 Mean = 1.31 SD = 0.33
Adolescents	Median = 6.00 Mean = 5.54 SD = 1.39	Median = 4.50 Mean = 4.46 SD = 1.03
Adults	Median = 7.00 Mean = 6.92 SD = 0.95	Median = 6.00 Mean = 5.73 SD = 0.39

Scores at the picture identification task differed significantly according to age group, $H(2, N = 39) = 25.37$, $p < 0.001$. As shown in Table 1, children identified a lower number of pictures (Median = 3.00) than adolescents (Median = 6.00) ($p < 0.001$); and adolescents also scored lower than adults at this task (Median = 7.00) ($p < 0.05$). Percent of correct identification was 32.75% for children, 69.25% for adolescents, and 86.5% for adults. A linear regression analysis indicated that age in months was a significant predictor of variation for picture identification scores ($R^2 = 0.62$, $F(1, 37) = 61.84$, $p < 0.001$). Figure 3A illustrates the relationship between age and picture identification scores.

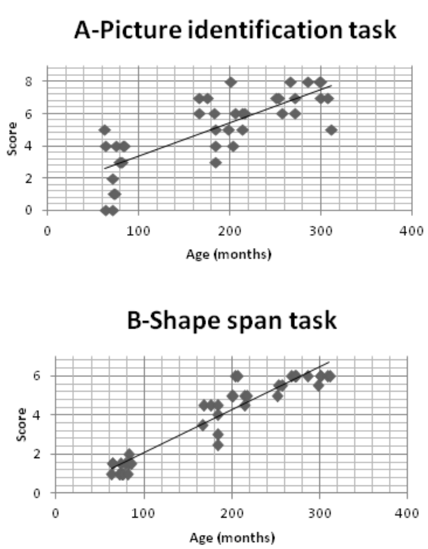

Figure 3. Relationships between age in months and individuals scores at the picture identification task (A), and shape span task (B).

Scores at the shape span task varied significantly according to age group, $H(2, N = 39) = 30.96$, $p < 0.001$. As shown in Table 1, children obtained lower spans (Median = 1.50) than adolescents (Median = 4.50) ($p < 0.001$); and adolescents also scored lower than adults (Median = 6.00) ($p < 0.001$). A linear regression analysis indicated that age in months was a significant predictor of variation for shape span scores ($R^2 = 0.89$, $F(1, 37) = 317,87$, $p < 0.001$). Figure 3B illustrates the relationship between age and memory spans.

We finally ran a forward stepwise multiple regression analysis to assess whether short-term memory span was a significant variable affecting picture identification score. We tested the following linear regression model: identification score = constant + age in months + shape span scores. The resulting R-square value was significant: $R^2 = 0.62$, $F(2, 36) = 29.06$, $p < 0.001$. Shape span scores accounted significantly for the variability ($\beta = 0.41$, $t(36) = 2.14$, $p < 0.05$). The contribution of age in months to the variance was marginally significant ($\beta = 0.36$, $t(36) = 1.89$, $p = 0.06$).

4. CONCLUSION

This study is the first study to assess haptic identification of raised-line drawings in a developmental perspective. In line with our predictions, we found an age-related improvement in picture identification scores. Whereas children could identify about one third of the pictures, adolescents and young adults were able to name correctly 69 to 86% of the picture set, on the average. High scores obtained by our young adults are in line with those reported by Heller et al. [9]. There was an important variation in identification performance between items (see also [13, 15, 17]). Interestingly, items ranked in a similar order of difficulty for each age group.

Congruent with previous research measuring haptic short-term memory [1, 21], we found an age-related improvement in shape span scores. Our results closely fit in with those obtained by Ballesteros et al. [1] using a dot span task (serial recall of series of tactile dominos) with children and adolescents aged 3-16 years. In line with our predictions, we found that haptic short-term memory capacity was a significant predictor of variation for picture identification performance. This finding suggests that short-term memory capacity is important for the haptic identification of raised-line pictures.

We conclude from this developmental study that the identification of raised-line drawings through haptics is an age-related skill. Our data suggest that improvement in haptic short-term memory capacity plays a role in the development of that skill. However, the possibility that memory in general, or other cognitive changes with age, also account for the age-related improvement in tactile picture identification scores cannot be ruled out. Specifically, a visual control condition would be useful to assess the contribution of visual short-term memory to tactile picture recognition. Future research might also extend this work to blind children, who were shown to perform higher in a raised-line pictures identification task [5], and to have larger-size spans [1], than their sighted peers under haptics.

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