Accuracy of Haptic Object Matching in Blind and Sighted Children and Adults

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Abstract. In this study a haptic object matching task is used to examine the accuracy of identification of the object dimensions: texture, weight, volume and exact shape in four different participant groups: congenitally blind adults, sighted adults, congenitally blind children, and sighted children. The results show that age is more influential for the accuracy to identify object dimensions by touch than the visual status.

Keywords: Touch, children, tactual exploration, blind, object dimension.

1 Introduction

Object identification is generally based on visual inspection. One searches for familiar visual features to recognize an object. Normally, a visual glance suffices for this purpose. However, for some people objects have to be explored by other senses, for instance because they lack vision. For blind persons the sense of touch is essential for object identification and manual explorations are necessary for concept development. Prominent object dimensions such as volume, weight, shape and texture, can be distinguished by haptic manipulation alone. Vision is not necessary, although past visual experience might be helpful. Touch also conveys different information about tangible objects than vision. Through haptic exploration one achieves more detailed material information. For instance, texture, compliance and heat flow, are more easily accessible by touch than vision. Compared to vision, relatively little is known about haptic object identification and the developmental trajectories of haptic skills [1].

In the present study, matching objects by different object dimensions is studied in children and adults. An additional aspect of touch that is included in this study, is familiarity with the sense of touch. Congenitally blind persons are more experienced in using touch to identify objects than sighted persons, because they often have to rely on touch because of the absence of sight. One could assume that this experience is an advantage. However, the lack of visual experience to assist the haptic manipulations

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can also be a disadvantage. Visual memory and visual imagery are not available for blind people. This study will focus on the influence of haptic and visual experience on the accuracy to identify object dimensions by touch.

Klatzky, Lederman and Metzger [2] were among the first researchers to describe the way people identify familiar objects by touch. Objects were identified by participants both rapidly and accurately. In a sequel to this study Lederman and Klatzky [3] gave a match-to-sample task to blindfolded participants. Hand movements were observed during object exploration. The haptic strategies depended on the object dimension that was tested. They termed these haptic strategies "Exploratory Procedures" (EPs). Each EP was especially suited for gaining information about certain object dimensions: enclosure for estimating size, unsupported holding for weight, lateral motion for texture, static contact for temperature, pressure for hardness, and contour following for exact shape.

Most studies on the accuracy of judgements on tactile dimensions were carried out with adult participants and not children. One of the few exceptions is a study by Klatzky and colleagues [4] who observed preschool children while judging tool functions of objects. In that experiment, children could apply both visual and haptic exploratory procedures. They showed that children executed specialized exploratory procedures to extract relevant tool properties. The children had an appropriate repertoire of EPs and used these to extract relevant information. They used adult-like patterns of exploration to examine the different dimensions. Based on the results and previous work, they pointed out 'the importance of active haptic exploration in acquiring knowledge about objects, whether or not vision is present' (Klatzky & Mankinen, 2005, 248).

Hatwell [5] studied school-aged children's ability to recognise objects both visually and haptically. She compared the results of congenitally blind and (blindfolded) sighted children on a shape recognition task. The visual performance of 7 years old sighted subjects was superior to that of 12 to 14 years old blindfolded sighted and blind subjects who had to solve the task by touch. Vision seemed to be superior to touch, even in the youngest children. That study highlighted the quantitative differences in performance between haptic and visual recognition of shapes.

Lederman and Klatzky's well known 1987 study [3] was never carried out with children, nor with blind persons. The current study fills this gap and describes the accuracy of performance in the same object matching task by children and adults, both congenitally blind and sighted for the dimensions Texture, Volume, Exact Shape and Weight. Next the experimental design will be described and the results presented with regard to accuracy. The discussion focuses on the effects of blindness and the differences between adults and children.

2 Methods

2.1 Participants

Sixty-one participants took part in the experiment, all naïve to the aims of the experiment. The participants were divided into four groups:

1. 16 congenitally blind adults (mean age = 39)
2. 15 sighted adults, matched on age, gender and level of education with the blind adults (mean age = 39)

3. 15 congenitally blind children, attending mainstream schools (mean age = 9)
4. 15 sighted classmates of the blind children, matched on age, gender and level of education (mean age = 9).

2.2 Material

Four object sets with regard to texture, weight, volume and exact shape were reproduced from the original object sets of Lederman and Klatzky [3] with permission of the authors. All the objects were unfamiliar, meaningless and functionless objects and therefore difficult to label. Each object set consisted of 16 three-dimensional stimuli (see figure 1 for an example).

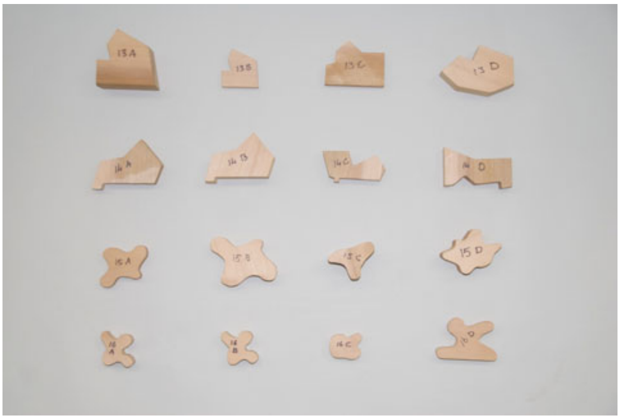

Fig. 1. Object set ‘Exact Shape’, with at the left side the standard objects. The second item in each row shows the test stimulus that matches the standard best on the required dimension, in this example “exact shape”.

Each set comprised of one standard object and three comparison objects, of which one was the best match, but not identical to the standard. By changing irrelevant object dimensions for the task at hand some confusion was purposely introduced into the experiments.

2.3 Procedure

During the experiment, the participant sat opposite the experimenter with a curtain hanging between the participant and the experimenter. As a result, the participant was not able to see the stimuli that were given to him. Participants were asked to put their hands stretched out on the table, with the palms upward. As soon as they received the stimuli in their hands; the participants were allowed to manipulate the objects.

Every condition started with a practice session, in which the participants could practice the procedure of matching one of the objects with the standard. The experimenter first presented a standard object, which they were allowed to explore for one of four object dimensions: texture, weight, volume, or exact shape. Next, the three comparison stimuli were given consecutively and the participants were asked which of the three best matched with the standard. There was no time limit for responding. Participants had to answer verbally after exploring the three comparison stimuli. No feedback was given. The order in which the participants received the stimuli was randomized but blocked per condition. All trials were repeated three times and the mean of the four trials was taken as the dependent variable.

3 Results

Four oneway ANOVAs were carried out on the mean scores of the four tasks with group as the independent variable. The results are shown in figures 2-5.

For all tasks there was a significant main effect for group (Texture: $F(3,57)= 3.370$, $p= 0.025$; Weight: $F(3,57)=3.831$, $p=0.014$; Volume: $F(3,57) =3.677$, $p = 0.017$; and Exact shape: $F(3,57) = 11.432$, $p<0.001$). Post Hoc multiple comparisons

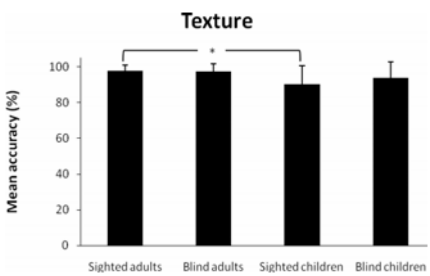

Fig. 2. Mean Percentage Accuracy for Texture. Error bars indicate standard deviations (SD), asterisk indicates significant group difference ($p<0.05$).

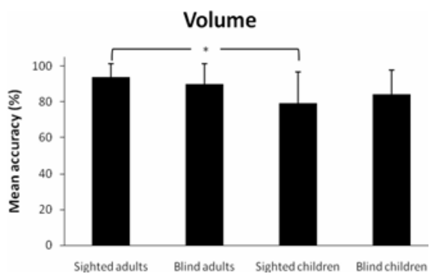

Fig. 3. Mean Percentage Accuracy for Volume. Error bars indicate standard deviations (SD), asterisk indicates significant group difference ($p<0.05$).

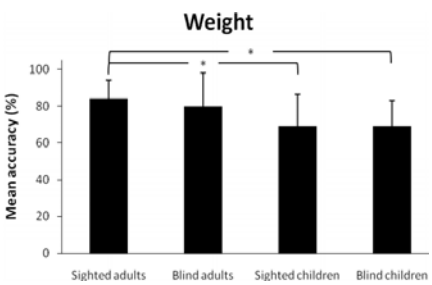

Fig. 4. Mean Percentage Accuracy for Weight. Error bars indicate standard deviations (SD), asterisks indicate significant group differences ($p<0.05$).

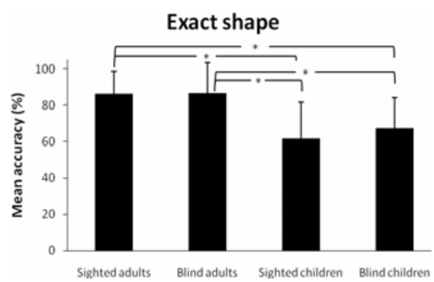

Fig. 5. Mean Percentage Accuracy for Exact Shape. Error bars indicate standard deviations (SD), asterisks indicate significant group differences ($p<0.05$).

with the Tukey test to correct for chance capitalizations showed significant differences between sighted adults and sighted children for Texture (p= 0.035) and for Volume (p=0.016); for Weight between sighted adults and both sighted children (p=0.044) and blind children (p=0.044); and for Exact shape between sighted adults and both sighted children (p<0.001) and blind children (p=0.006), and between blind adults and both sighted children (p<0.001) and blind children (p=0.004).

Correlation analyses between the scores (transformed into Z-scores) of the four groups on the different object dimensions showed that there was just one significant correlation: for the blind children there was a moderately strong correlation between the object dimensions Volume and Exact Shape of $r = 0.56$ ($p = 0.029$).

4 Discussion

The current study partially replicated the classical experiment of Lederman and Klatzky[3] with congenitally blind adults and children and compared them to the performances of sighted adults and children. Four object dimensions were examined (texture, weight, volume and exact shape) with exact replica's of the original objects of Lederman and Klatzky [3]. The accuracy of the different groups on the four object dimensions was examined in a match-to-sample task. The main interest of the present study was to investigate the influence of age and the absence of sight on accuracy.

On all the four object dimensions the children performed significantly poorer on accuracy than the adults. There were no significant differences found between the same age groups of blind and sighted individuals. Age seems more important than the visual status of the participants. Especially 'Exact Shape' appeared to be a significantly more difficult task for children than adults. For the adults 'Weight' was the most difficult object dimension to match followed by exact shape. Exact shape might be difficult for children because of the number of acts necessary to make decisions about exact shape, the fact that their hands are still small or because of immature spatial perception. In the post hoc multiple comparisons there were more significant differences found between the sighted children and adults (texture, weight, volume and exact shape), than between the blind children and sighted adults (weight and exact shape). Age had far more influence on the accuracy to identify object dimensions by touch than visual or tactual experiences.

However, there are some differences in the performances of the blind and sighted groups noticeable. The sighted children and adults performed significantly different on all the object dimensions. The blind children and blind adults performed only significantly different on the dimension 'Exact Shape', which might be explained not only by the tactual strategies they use, but also by the cognitive complexity of the task. Possibly the differences in performance between the sighted and blind children in relation to adults can be explained by the tactual training the blind children received in early childhood. Individual variation is large in both groups of children but also in the group of blind adults. The large variation also explains the lack of significant difference scores.

Accuracy levels in the current study were comparable with the data from Lederman and Klatzky (1987). Texture was easiest to match and Weight the most difficult. In the current study, percentage accuracy for Weight seemed somewhat higher than in the study of Lederman and Klatzky. However, individual variation was also largest for the dimension Weight, so this difference is probably not significant.

Future analyses should make clear which other aspects affect accuracy, such as for instance, response latencies and the use of different Exploratory Procedures.

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