Effect of Visual and/or Haptic Experience on Haptic 3D Model Recognition

Tetsuya Watanabe [1[0000-0002-4014-5437]] Kazunori Minatani [3[0000-0001-9077-113X]], and Masakazu Iwamura [3[0000-0003-2508-2869]]

[1] Niigata University, 950-2181 Niigata, Niigata, Japan
[2] National Center for University Entrance Examinations, 153-0041 Meguro, Tokyo, Japan
[3] Osaka Metropolitan University, 599-8531 Sakai, Osaka, Japan
t2.nabe@eng.niigata-u.ac.jp

Abstract. Our research question is whether there is any difference in haptic recognition, i.e. understanding what the 3D models represent by the sense of touch, between early blind and late blind people. To investigate it, we took the opportunity of a Zoom symposium on our 3D model making and delivering service. Prior to the symposium we sent out two 3D models to 48 blind and visually impaired attendees without telling what they were. After the symposium, we emailed a questionnaire to them on the understanding of the models and the attributes of the attendees, and received the answers from 32 people. The average correct rates for each model were 75% and 50%. The effect of visual, tactile, and hearing experience as well as the age and usage history of hearing and/or tactile senses on the correct rates were examined, but their effects were not explicitly shown by the numbers because of the inadequate research design. Rather, their comments on the grounds for recognition suggest that recognition of 3D models is the conclusion logically drawn by combining a few shape features, and finding these features relies more on prediction than the ability of tactile sense.

Keywords: Haptic Recognition, 3D Model, Early Blind, Late Blind.

1 Introduction

For blind and visually impaired people to understand the shapes of things that they want to know, we are doing a 3D model making and delivering service using 3D printers to their demands [1]. While doing this service, questions were raised as to whether there is any difference between early and late blind people in haptic recognition of 3D models. It is generally assumed that early blind people are better at haptic object recognition than late blind people because they have used haptics for long times in their everyday lives [2]. On the other hand, late blind people have had the experience of seeing actual objects, which may be useful for recognizing the shapes of the models. If there are differences between them in the way they understand 3D models through the sense of touch, then it may be necessary to modify the way in which models are created and presented to them.

The researches on the effect of visual experience on haptic shape recognition focused on the orientation in which the objects were presented. The sighted participants' performance deteriorated when the objects were presented in non prototypical orientations whereas that of early blind participants was unaffected [3], [4]. These researches used geometrical shapes either embossed or made of blocks. However, we want to know the effect of visual experience on recognizing real objects which can be found in everyday life, including on TV and on Web. We therefore decided to investigate the effects of different attributes of blind people on haptic recognition of 3D models.

2 Method

2.1 Zoom Symposium on 3D Models

Since 2020, we have held Zoom symposiums every half a year on our 3D model making and delivering service [1]. The numbers of the symposium audience exceeded 100, and more than half of them were blind and visually impaired people. Before each symposium, we sent one or two 3D-printed models to the blind and visually impaired audience who had requested them. We used one of these symposiums to investigate the research question.

2.2 Procedure

Prior to the symposium that was held on August 8, 2020, two 3D models were sent out to each blind and visually impaired attendee. The models sent were a coronavirus and either one of two sizes of sphinx: large (140 mm L × 58 mm W × 83 mm H) and small (half these dimensions), or a snail (77 mm L × 32 mm W × 33 mm H). The 3D data of them were downloaded from a 3D data site, Thingiverse and put to a 3D printer, Ultimaker S3, with PLA white filament (Fig. 1).

Of the three kinds of models, the coronavirus was named as such when sent. The other model was unnamed and sent without telling the recipient what it was. The large sphinx was sent to 17 people, the small sphinx was sent to 9 people, and snails were sent to 23 people (Small size sphinxes were made to shorten the time to print). In all, models were sent out to 48 people.

The recipients were finally told what models they had been sent at the symposium on August 8. However, by this time some of them appeared to have already been told by their sighted family members what these models represented.

On September 4, after the symposium, we emailed a questionnaire to the 48 people to whom the models had been delivered. They were given a week to email back their replies. The contents of the questionnaire related to haptic recognition were as follows.

1. What model did you receive in addition to the coronavirus model?
2. What did you think this model represented before being told?
3. What features of the model led you to the answer you gave to question 2?
4. Had you ever seen the actual object (sphinx or snail) depicted by the model, or a photograph of this object?

5. Had you ever touched the actual object (sphinx or snail) depicted by the model, or a model of this object?
6. Had you ever read or heard about the object (sphinx or snail) you received?
7. When did you start getting information from the outside through your sense of hearing or touch (rather than sight)? Answer in any way you like, for example "since birth", "since primary school", "since I was X years old", or "since X years ago".
8. Please state your age and gender.

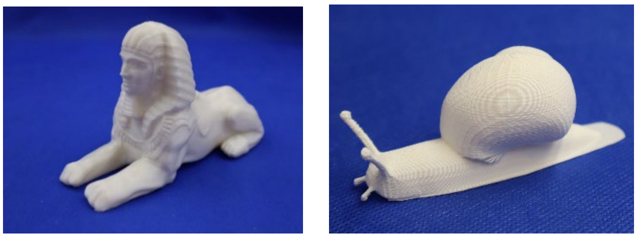

Fig. 1. Two of the models that were sent to the attendee (left: sphinx, right: snail).

3 Results

3.1 Respondents

We received responses to the questionnaire from 32 people (67% recovery rate). One of these respondents was a sighted person, whose answers were excluded from the analysis. The respondents consisted of 22 males and 9 females in age groups ranging from 10–19 up to 80–89. Most of the respondents were in their 50s, 20s and 60s.

16 respondents received the snail model, and 16 respondents received a sphinx model (large or small). One person received both models, so the total number of models is higher than the number of respondents because this person was counted twice.

3.2 Correct Answer Rate

Figure 2 shows the numbers of people who correctly identified the snails and sphinxes. The correct answer rate for snails was 75% (12 people), and the correct answer rate for sphinxes was 50% (8 people). It is possible that differences in the size of the sphinxes affected the percentage of correct answers. Of the eight respondents who correctly identified the sphinx, seven had received the larger model and only one had received the smaller model. But on the other hand, of the seven respondents who failed to identify the sphinx, four had received the larger model and three had received the smaller model, so it cannot be said that people responded incorrectly because they were given smaller models. Wrong answers for the snail model included insect (2 people) and ammonite (1 person). Wrong answers for the sphinx included lion (3 people), animal (2 people), and dog (1 person).

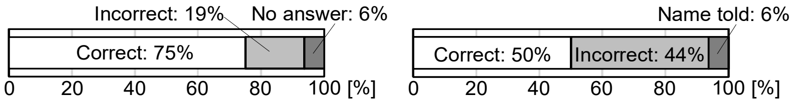

Fig. 2. Correct answer rates for model recognition (left: sphinx, right: snail).

3.3 Grounds for Recognition

We asked the respondents to describe which characteristics of the model provided the basis upon which they recognized it as a snail or sphinx. Of the twelve people who had correctly identified the snail, six attributed their success to the combination of the shape of the rounded or coiled shell and the two protuberances, two mentioned that they had also recognized the body in addition to these two features, and another three only mentioned the shell. On the other hand, two of the people who incorrectly identified the snail as an ammonite mentioned only the round shell part. The two who identified it as an insect only mentioned the protuberances.

Six of the eight people who identified the sphinx correctly said they recognized that it had an animal's body and a human face. Some of them even mentioned the hair behind the face, the beard at the bottom of the head, its ornaments, and its rolled-up tail.

3.4 Effect of Visual, Tactile, and Hearing Experience

People who had previously seen a real snail or a photograph of it achieved a better correct response rate (100%) than people who had not (25%) (Fig. 3, left). However, the ratio of correct and incorrect answers in the recognition of the sphinx was the same regardless of visual experience (Fig. 3, right).

In the recognition of snails, the correct answer rate was higher for respondents who had previously touched a real snail or its model (88%), but even respondents with no such experience achieved a high correct answer rate (71%) (Fig. 4, left). In the recognition of the sphinx, the numbers of correct and incorrect answers were almost the same regardless of experience (50% and 53% respectively, Fig. 4, right).

In the recognition of snails, respondents who had previously read or heard about their shape achieved a high recognition rate (80%), but so did respondents with no such experience (80%) (Fig. 5, left). In the recognition of the sphinx, respondents who had previously heard or read a description of it achieved a higher recognition rate than those who had not (60% and 40% respectively) (Fig. 5, right).

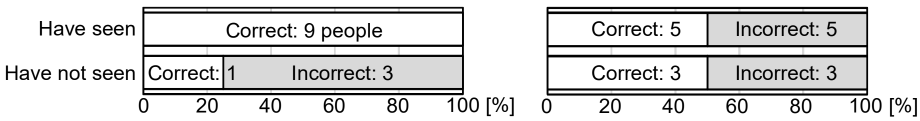

Fig. 311. Effect of visual experience on model recognition (left: sphinx, right: snail).

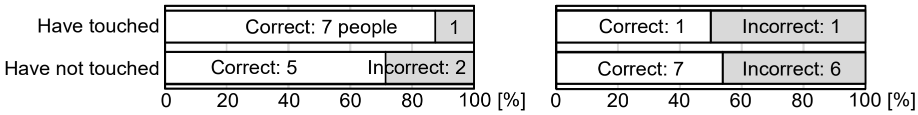

Fig. 4. Effect of tactile experience on model recognition (left: sphinx, right: snail).

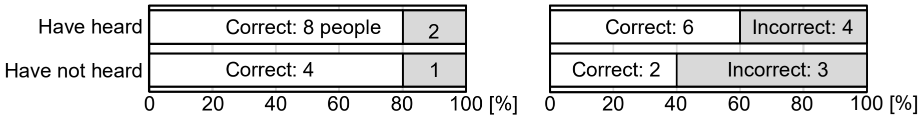

Fig. 5. Effect of hearing experience on model recognition (left: sphinx, right: snail).

3.5 The Effects of Age

For both the snail and the sphinx, the average age of correct respondents (46.2 years and 67.4 years respectively) was higher than the average age of incorrect respondents (20.0 years and 37.6 years respectively) (Fig. 6).

The question "When did you start getting information from the outside through your sense of hearing or touch (rather than sight)?" substantially asked the age of onset of blindness. The chronological age minus the age of onset of blindness makes the main usage history of auditory and/or tactile senses. Respondents who correctly identified the snail had a longer usage history of auditory and/or tactile senses than those who did not (correct: 26.4 years, incorrect: 18.7 years). However, this is reversed in the recognition of the sphinx (correct: 25.0 years, incorrect: 27.3 years) (Fig. 7, right).

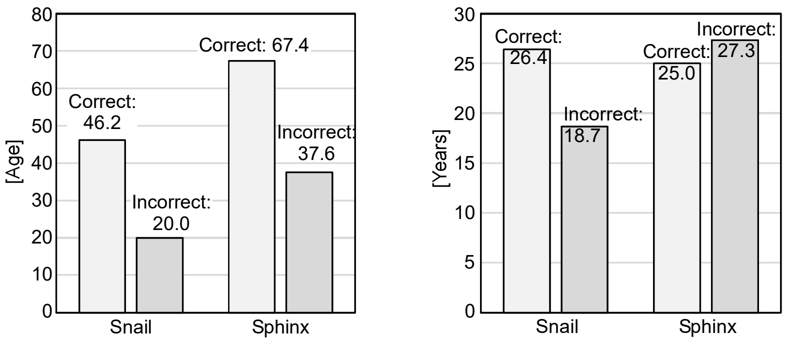

Fig. 6. Average age (left) and average use history of auditory and/or tactile senses (right) of the respondents divided by the correctness of their answers.

4 Discussion

We will first consider the limitations of this survey. This questionnaire was aimed at symposium participants, which made it impossible to impose controls on parameters such as their age or their history of visual impairment. It is not possible to consider interactions between visual, tactile, and hearing experience, age, and history of information acquisition. There were also two types of model sent to the questionnaire respondents. Thus, the effects of the visual and/or tactile experience were not explicitly shown by the numbers.

Within these limitations, we will describe the impressions we gained through compiling the questionnaire results. In order to recognize an object by touch without being told what it is, it seems that it is essential to have had prior experience of seeing or touching the object, or having it described in some way. From a comparison of the characteristics of respondents providing correct and incorrect answers, it seems that the correct respondents arrive at their responses by grasping a number of characteristics that lead towards a logical result, while the incorrect respondents only had a partial grasp of these characteristics. It seems that the inability of incorrect respondents to identify other characteristics was not caused by a lack of tactile ability, but by a lack of top-down information telling them that something should be there. Whether the face of the sphinx was recognized as a human face or as a strange animal face seems to have depended on whether or not the respondents were expecting to find a human face there.

The average age of correct respondents was higher than that of incorrect respondents. The average ages may have been influenced by data from the extreme ends of the age range (with one respondent aged from 10–19 and one aged from 80–89), but if the age difference is meaningful, then perhaps older people have had more opportunities to access various kinds of information, and this knowledge may have assisted in their recognition of the items. Two of the respondents who failed to identify the sphinx correctly were in their 20s and 30s, and had no prior experience of seeing, touching or learning about the sphinx.

Acknowledgments. This research and the model delivery service are supported by the Research Institute of Science and Technology for Society (RISTEX, JST) (Grant No.: JPMJRX19I7 and JPMJRX21I5). The provision of models to schools for the blind was supported by a grant-in-aid for scientific research (Kiban-B, 20H01705).

References

1. Introduction of the 3D model provision service, https://3d4sdgs.net/service-en.html, last accessed 2022/4/28.
2. Heller, M. A., Ballesteros, S. (Ed.): Touch and Blindness—Psychology and Neuroscience. Lawrence Erlbaum Associates, New Jersey, USA (2006).
3. Theurel, A., Frileux, S., Hatwell, Y., Gentaz, E.: The haptic recognition of geometrical shapes in congenitally blind and blindfolded adolescents: Is there a haptic prototype effect?. PLoS ONE 7(6), e40251 (2012).
4. Occelli, V., Lacey, S., Stephens, C., John, T., Sathian, K.: Haptic object recognition is view-independent in early blind but not sighted people: Perception 45(3), 337-345 (2016).