Development of Tabletop Models of Internal Organs for Anatomy Learning of the Visually Impaired

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Abstract. In this study, we developed two types of tabletop models of internal organs as tactile teaching materials that can be used by the visually impaired when learning anatomy. The first one is a model in which parts of the internal organs that do not have connectional relationships are placed in a concave area of a pedestal. The second one is a model in which parts of the internal organs have a connectional relationship. Parts of the organs were connected using connecting pins, holes, and rubber tubes. A connected respiratory system, a connected digestive system, and a connected urinary system are also placed in the concave areas of the pedestal. Evaluation experiments conducted on the two types of tactile teaching materials revealed that the second model is a better teaching material in terms of placement stability and an understanding of the connectional relationship of internal organs.

1 Introduction

For the visually impaired to properly understand different shapes, an appropriate three-dimensional model applied as a tactile teaching material is required. For example, a service allowing the creation and use of tactile maps has been offered to the visually impaired and their caregivers [1–3]. Moreover, studies have been conducted on the use of 3D printers to help the visually impaired [4–6].

To date, many 3D teaching materials have been developed for the visually impaired [7], including models of mathematical curved surfaces [8], enlarged models of plankton skeletons [9], heart models [10], and tactile globes [11]. Thus, various targets have been developed for this purpose.

In the physical therapy department of a school for the blind, students with visual impairments aiming to become licensed masseurs, or acupuncture or moxibustion therapists, learn anatomy to understand the structure and function of the human body. However, commercially available organ models, which are almost at the real scale, are unsuitable for beginners learning anatomy. The authors developed prototypes of enlarged skull

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model, myofibril model, stretch reflex model, hepatic lobule model, crystalline lens model, ear model, and cardiac valve membrane models. The developed prototypes were utilized by visually impaired students at Hiroshima Central Special Support School.

In this paper, we report the development of a tabletop model of internal organs that enables visually impaired students to learn the position and shape of internal organs by touch, as well as the results of an evaluation experiment conducted on the models.

2 Method

In the development of a tabletop internal-organ model, it is important to make the model of an appropriate size and adequately simplify the shapes of the organs. In terms of size, commercially available organ models are almost at the actual scale and are thus too large to be provided to each student. The model was therefore reduced to a size that could be used on a desk. Commercially available models have complicated shapes that reflect those of the actual organs and, when downscaled, provide too much information for beginners. They should therefore be appropriately simplified. The degree of such simplification was not determined automatically, but was chosen through interactions between model developers and teachers in the educational field.

Through this development process, two tabletop internal-organ models (Models A and B) were developed in this study. Model A consists of 12 organs (i.e., lungs, trachea, heart, esophagus, stomach, spleen, liver, duodenum, pancreas, small intestine, large intestine, and kidneys). These organs have no connectional relationships and are simply placed in the concave portions of the pedestal. Figures 1(a) and 1(b) show photographs of the pedestal and placed organ parts of Model A. Model B consists of 13 organs (i.e., lungs, trachea, heart, esophagus, stomach, spleen, liver, duodenum, pancreas, small intestine, large intestine, kidneys, ureter, and bladder), which were placed in several connected forms in the concave portions of the pedestal. Figures 1(c) and 1(d) show photographs of the pedestal and placed organ parts of Model B. The details of the model development are as follows (note, however, that we mainly describe Model B owing to space limitations).

2.1 Model Development Policy

The authors improved the initial model based on feedback from the visually impaired who tried out the initial model, and the shape of each organ was modified using 3D CAD (Autodesk Fusion 360). Model B was designed such that the organ parts could be connected to each other with pins or rubber tubes to help understand the connectional relationships among the organs.

2.2 Model Creation Using Additive Manufacturing

To create the models, 3D printers (Microboard Technology, Afinia H800+, and Afinia H +1) were used. Model A was made of a PLA filament, and Model B was made of an ABS filament. Because the connecting pins of Model B were fine and easily damaged, their strength was retained by increasing the modeling density. After modeling all organ parts, both Models A and B were placed on the pedestals to check for any problems, such as interference between organs, and then adjusted overall.

The organ models of Model B are shown in Figs. 2, 3, 4, 5 and 6 and Fig. 7. Parts of the respiratory (trachea and two lungs) and circulatory (heart and spleen) systems are colored red, parts of the digestive system (esophagus, stomach, liver, duodenum, pancreas, small intestine, and large intestine) are colored yellow, and parts of the urinary system (kidneys, ureter, and bladder) are colored blue. Figure 7 show the connectional relationships for each organ system. Coloring the organ parts is helpful for both partially and fully sighted individuals in distinguishing the different organ systems and understanding each system as a unit.

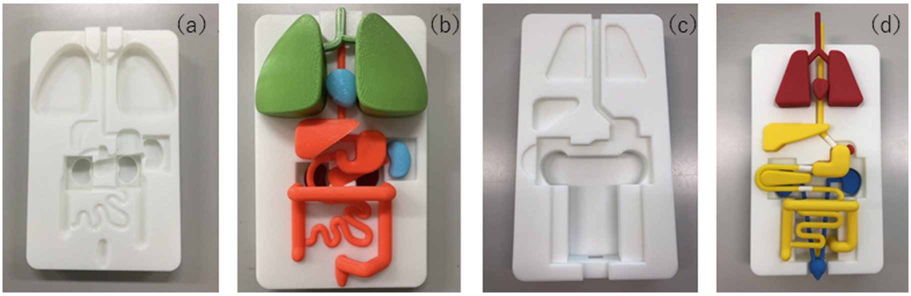

Fig. 1. (a) A pedestal of Model-A. The models of the internal organs are not placed in the pedestal. The size of the pedestal is 190 mm (length) × 120 mm (width) × 25 mm (height). (b) A pedestal of Model-A and all parts placed inside. (c) A pedestal of Model-B. The models of the internal organs are not placed in the pedestal. The size of the pedestal is 210 mm (length) × 120 mm (width) × 28 mm (height). (d) A pedestal of Model-B and all parts placed inside.

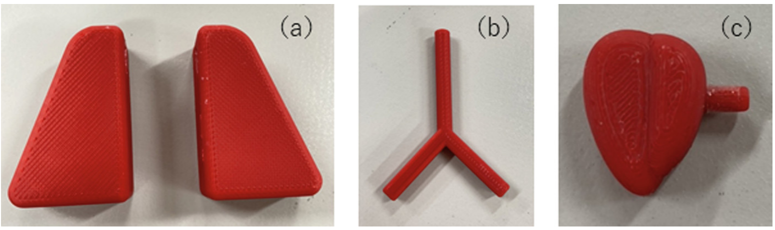

Fig. 2. (a) Two lungs (model): The right lung has a hole on the inner surface for connecting to the trachea. The left lung has two holes on the inner surface, one of which connects to the trachea and the other connects to the heart. (b) Trachea (model): The two prisms below the bifurcation are connected into the holes on the sides of both lungs. (c) Heart (model): A fixing pin for insertion into the left lung protrudes toward the right.

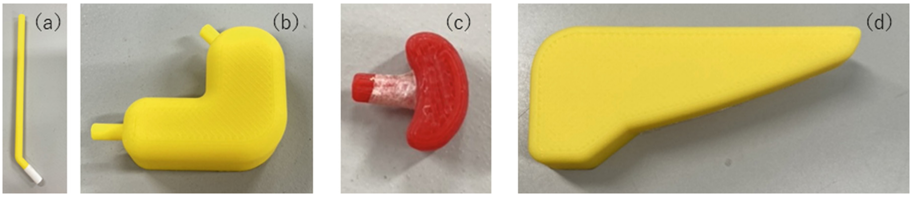

Fig. 3. (a) Esophagus (model): A rubber tube is installed at the bottom end to connect the entrance pin of the stomach. (b) Stomach (model): An entrance pin (upper) connects to the esophagus and an exit pin (lower) connects to the duodenum. (c) Spleen (model): A fixing pin for insertion into the stomach protrudes toward the left. (d) Liver (model): The left lobe (right side of the figure) is thin. The right lobe is thick and fits into the concave portion of the pedestal.

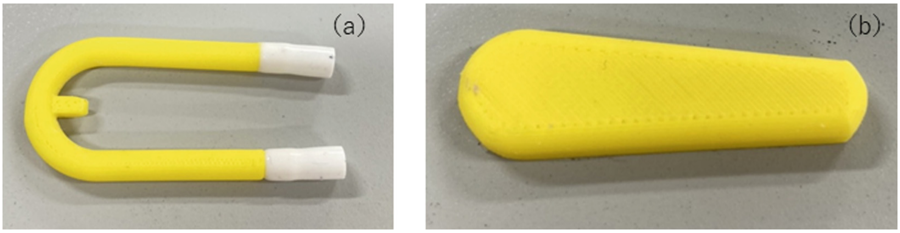

Fig. 4. (a) Duodenum (model): The rubber tube at the upper right end connects to the exit pin of the stomach, and the rubber tube at the lower right end connects to the entrance pin of the small intestine. There is a fixing pin inside the curve to insert into a hole of the pancreas. (b) Pancreas (model): There is a hole on the left side to insert a fixing pin of the duodenum.

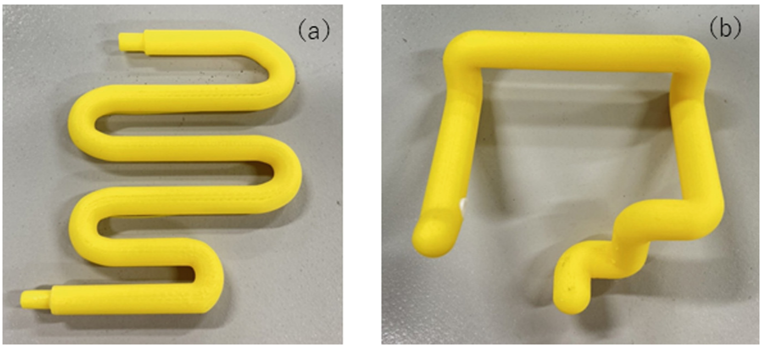

Fig. 5. (a) Small intestine (model): An entrance pin (upper end) connects to the duodenum and an exit pin (lower end) connects to the large intestine. (b). Large intestine (model): A hole for connecting an exit pin of the small intestine is installed in front of the left side (rubber tube embedded).

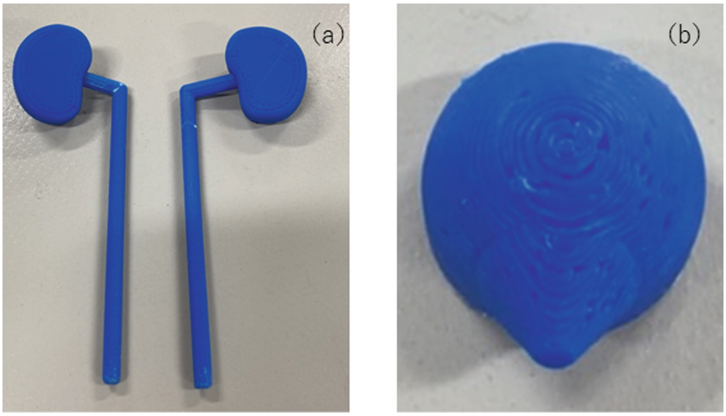

Fig. 6. (a) Kidney and ureter (model): The model of the kidney and ureter is pre-combined. (b) Bladder (model): There are two holes on the upper side of the bladder model for connecting the two ureters. The narrowed part on the lower side represents the urine outlet. (Color figure online)

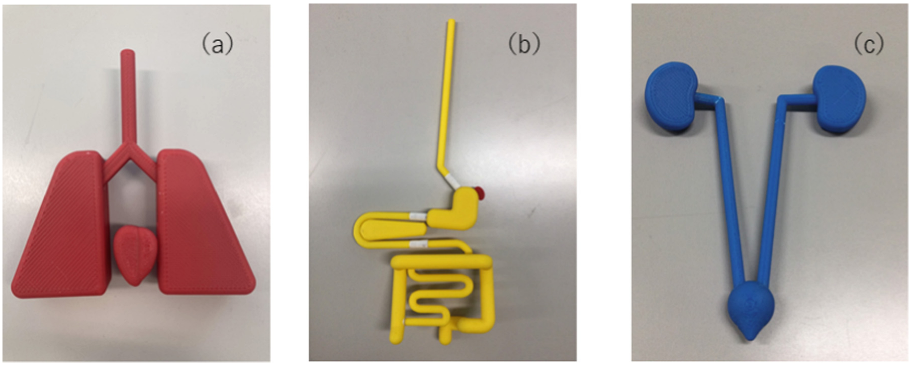

Fig. 7. (a) A unit in which the respiratory system and the heart are fixed. (b) A unit in which the digestive system and the spleen are fixed. (c) A unit of the urinary system. (Color figure online)

3 Evaluation Experiments

An evaluation was conducted on 12 subjects using Models A and B developed in this study. Six sighted adults wearing eye masks participated in the evaluation. The tester described the models and asked the subjects questions. It took approximately 75 min per subject to describe and conduct a listening-based investigation of the models. A similar survey was also conducted with six visually impaired people who were blind or amblyopic. In the survey of the visually impaired, the questionees read the description about the two anatomy models before the survey and touched the models for a few minutes just before the survey. The tester only asked questions in the survey, and each survey lasted 10–30 min. The results when comparing Models A and B are presented below.

Q1 Which model has a stable connection between organs?

Choices/Questionee	A	B	Both A and B	Neither A nor B
Sighted	0%	66%	34%	0%
Visually impaired	0%	100%	0%	0%
Total	0%	83%	17%	0%

Q2 Which model has a stable position after placing each organ on the pedestal?

Choices/Questionee	A	B	Both A and B	Neither A nor B
Sighted	34%	66%	0%	0%
Visually impaired	0%	100%	0%	0%
Total	17%	83%	0%	0%

Q3 Which model makes it easier to understand the connection of the organs?

Choices/Questionee	A	B	Both A and B	Neither A nor B
Sighted	0%	100%	0%	0%
Visually impaired	0%	100%	0%	0%
Total	0%	100%	0%	0%

Q4 Which model makes it easier to understand the location of the organs?

Choices/Questionee	A	B	Both A and B	Neither A nor B
Sighted	34%	66%	0%	0%
Visually impaired	0%	83%	0%	17%
Total	17%	74.5%	0%	8.5%

Q5 Which model is more suitable for self-operation?

Choices/Questionee	A	B	Both A and B	Neither A nor B
Sighted	33%	17%	33%	17%
Visually impaired	0%	83%	0%	17%
Total	16.5%	50%	16.5%	17%

Several observations were made during the evaluation experiment. For Model A, there were two subjects who could not accurately distinguish between the top and bottom of the heart. The kidneys and spleen were difficult to distinguish because their shapes and sizes were similar. The small intestine, pancreas, stomach, and spleen were also difficult to locate because there was no gap between them and the concave area of the pedestal. After placing the liver and large intestine in the concave area of the pedestal, the subjects frequently shifted them from the correct position. For Model B, the connections were mostly successful. However, for the connection between the small and large intestines, the interference between them hindered the connection task. When the end of the ureter was connected to the hole in the bladder, the connection was unstable because the current holes in the bladder were shallow. Because the large intestine and ureter switch positions dorsabdominally, it is necessary to temporarily lift the bladder and place the anus on the dorsal side when placing the large intestine and anus in the pedestal. Only half of the subjects conducted this task independently.

4 Discussion

From the results of Q1 and Q2, Model B was found to be superior to Model A in terms of the stability of the connection and arrangement of each organ part. We considered that connecting multiple organs into a unit would result in the stability of the arrangement. As a natural result, all subjects chose Model B for Q3 because the organ parts of Model A were not connected to each other; that is, they were independent, whereas the organ parts of Model B were able to connect with each other with rubber tubes or pins. For Q4, most subjects chose Model B. The organ parts were connected to each other before being placed on the pedestal in Model B, and thus it was considered that the connectional relationship between the organs could be more clearly imagined by the subjects. According to Q5, 67% of the subjects responded that Model A could be used without assistance, whereas 33% of the subjects answered that Model B could be used without assistance. The percentage of respondents who preferred Model A was the highest in Q5. This might be because most of the subjects were unable to connect the small intestine and the large intestine by themselves for Model B.

In a future study, modification of the shapes of the small intestine and large intestine can solve this problem and eliminate the interference of the parts during the connection task. Based on indications from the teachers of a school for the blind, we plan to make further improvements to Model B. In particular, the following three aspects will be applied: First, we will modify the shapes of the small and large intestines and improve the connectional holes of the bladder. In addition, we will place the duodenum and pancreas deeper than the current positions such that the duodenum will contact the right kidney and the pancreas will contact the left kidney. As a result, the stomach will be located in the correct position, that is, the front of the pancreas. Third, we will assign different colors to the heart and respiratory system. In Model B, both the circulatory system (the heart and spleen) and the respiratory system (the lungs and trachea) are colored in red. In a future study, we plan to change the color of the respiratory system from red to green, incorporating the opinions of the subjects.

5 Conclusion

In this study, we developed two types of models with the aim of providing tabletop models of internal organs that can be used by visually impaired students when learning anatomy. One is a model in which the parts of the internal organs do not have connectional relationships, and the other is a model in which the parts of the internal organs have such relationships. Evaluation experiments conducted on the two types of tactile teaching materials clarified that the model with a connectional relationship was a better teaching material in terms of placement stability and understanding the connectional relationship of the internal organs.

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References

1. Minatani, K., et al.: Tactile map automated creation system to enhance the mobility of blind persons - its design concept and evaluation through experiment. ICCHP 2010, LNCS, vol. 6180, pp. 534–540. Springer, Heidelberg (2010)
2. Watanabe, T., Yamaguchi, T., Koda, S., Minatani, K.: Tactile Map Automated Creation System Using OpenStreetMap. In: Miesenberger, K., Fels, D., Archambault, D., Peňáz, P., Zagler, W. (eds.) ICCHP 2014. LNCS, vol. 8548, pp. 42–49. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-08599-9_7
3. Watanabe, T., Yamaguchi, T.: Six-and-a-half-year practice of tactile map creation service. Stud Health Technol Inform. **242**, 687–694 (2017)
4. Minatani, K.: An Analysis and Proposal of 3D Printing Applications for the Visually Impaired. Stud Health Technol Inform. **242**, 918–921 (2017)
5. Minatani, K.: A Proposed Method for Producing Embossed Dots Graphics with a 3D Printer. In: Miesenberger, K., Kouroupetroglou, G. (eds.) ICCHP 2018. LNCS, vol. 10897, pp. 143–148. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-94274-2_20
6. Minatani, K.: Examining visually impaired people's embossed dots graphics with a 3D printer: physical measurements and tactile observation assessments. AHFE 2018, AISC, vol. 794, pp. 960–969. Springer, Cham (2018)
7. Teshima, Y.: Three-dimensional tactile models for blind people and recognition of 3D objects by touch. ICCHP 2010, LNCS, vol. 6180, pp. 513–514. Springer, Heidelberg (2010)
8. Teshima, Y., et al.: Models of Mathematically Defined Curved Surfaces for Tactile Learning. In: Miesenberger, K., Klaus, J., Zagler, W., Karshmer, A. (eds.) ICCHP 2010. LNCS, vol. 6180, pp. 515–522. Springer, Heidelberg (2010). https://doi.org/10.1007/978-3-642-14100-3_77
9. Teshima, et al.: Enlarged skelton models of plankton for tactile teaching. ICCHP 2010, LNCS, vol. 6180, pp. 523–526. Springer, Heidelberg (2010)
10. Yamazawa, K., et al.: Three-Dimensional Model Fabricated by Layered Manufacturing for Visually Handicapped Persons to Trace Heart Shape. In: Miesenberger, K., Karshmer, A., Penaz, P., Zagler, W. (eds.) ICCHP 2012. LNCS, vol. 7383, pp. 505–508. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-31534-3_74
11. Teshima, Y., et al.: Development of Tactile Globe by Additive Manufacturing. In: Miesenberger, K., Manduchi, R., Covarrubias Rodriguez, M., Peňáz, P. (eds.) ICCHP 2020. LNCS, vol. 12376, pp. 419–426. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58796-3_49