Influence of Shape Characteristics on Disassembly Efficiency of Joint Cube Puzzles Depends on Different Situations

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CHAPTER 1　INTRODUCTION

This research is a basic study to apply the structural elements that join parts together without using nails or screws in the fields of architecture and furniture to the design of furniture that users themselves assemble, which is called DIY. The research is based on a three-dimensional puzzle, and reports the results of discussions, experiments, and analyses through experiments on the efficiency of disassembling assembled objects and the way of recognizing the space necessary for users to imagine the disassembly procedure in the process.

At present, in order to reduce the burden of assembly on users as much as possible, furniture that can be easily assembled with joints without using nails or screws is on the increase. However, the wood processing technique of jointing is often inherited from craftsmen, and when it is applied to the field of furniture, its shape is often composed of a relatively simple face shape that is easy for users to assemble intuitively. However, as the number of parts increases, users often make mistakes in the order of assembly, which causes stress. On the other hand, disassembling furniture with a large number of parts is a more difficult process than assembly, and in some cases, users may damage the furniture by pulling or twisting the parts in the wrong direction. In this paper, we discussed the characteristics of the shape design of component joints that stimulate cognitive abilities and allow users to disassemble components intuitively just by looking at the shape of the joint, without reading the instruction manual or assembly drawing. There have been many studies on how to easily join parts together. However, there has been no academic research on the disassembly of a joint that utilizes the formative elements of the joint and verifies its efficiency from a cognitive approach from the user side.

CHAPTER 2　LITERATURE REVIEW

The purpose of this study is to determine whether the shape characteristics of a joint affect the difficulty for users during disassembly, that is, whether shape characteristics have an effect on disassembly efficiency. It aims to find a method that under limited conditions can improve disassembly efficiency by reducing difficulty in disassembly and the time spent on errors as much as possible.

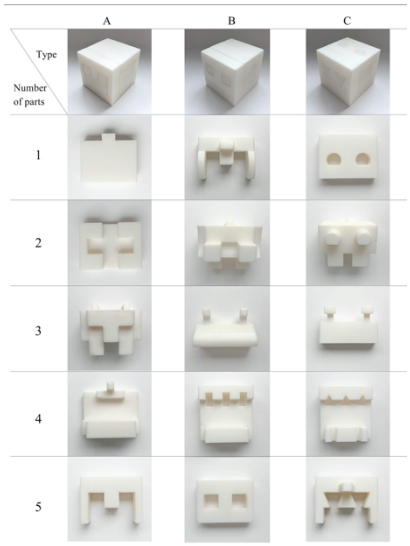

Fig1.Conceptual models in prior research.

Previously, J. Peng used three different shape variations of joint cube puzzles for the assembly process experiment in his study (as shown in fig.1; Type A: Edges, burrs, and notches are all rectilinear. Type B: Notches and burrs were similar in shape to Type A. The rectilinear shape was transformed into a curve in two close spaces. Type C: Basically similar to Type B, but shapes such as triangles and semicircles appeared. These shapes were different from the rectilinear shape in Type A. Each cube comprised five parts and had the same dimensions: 80mm*80mm*80mm). It was found that the assembly efficiency of the cube puzzles with a shape characteristic added at the joint (Types B and C) was higher: it took less time with fewer errors to complete assembly of the cube puzzles. In this study, the same set of cube puzzles were first used for an observation experiment of disassembly. Less time and fewer errors during

the process of cube puzzle disassembly were considered indicators of higher efficiency. Here, two hypotheses were put forward. First, shape characteristics have a positive impact on disassembly and improve the disassembly efficiency of joint cube puzzles. In this case, the result was that the existence of shape characteristics in the same cube puzzle has a positive impact on its assembly and disassembly. Second, shape characteristics have no positive effect on the disassembly of joint cube puzzles. In this case, it was quite necessary to develop a new set of cube puzzles and discuss the relationship between shape characteristics and disassembly.

CHAPTER 3 RESEARCH METHOD&EXPERIMENTS AND RESULTS

The experimental method and the results of this study were described. The purpose of the experiment was to understand the difficulty level of the shape of the joints when users disassemble the modeling objects with joints, and also to understand the characteristics of the design of the joints to improve the disassembly efficiency. Three experiments were conducted on 56 subjects between the ages of 25 and 34, using seven types of 80 mm cube puzzles with joints. In the experiment, we disassembled the above seven types of Cube Puzzles and recorded the number of errors in the disassembly procedure and the average time required for disassembly by video recording.

Fig2. Seven cube puzzles with joints in the experiments.

In the experiment 1, Types A, B, and C were compared. The results in Table 1 showed that when participants disassembled a cube puzzle that could be opened via multiple parts, the average number of errors was not different, even though these cube puzzles took more time to disassemble. Thus, puzzle shape had no positive effect on disassembly efficiency.

Table1 One-way ANOVA Analysis for Types A, B, and C

TypeA-B-C		N	M(s)	SD	df	F	P-value
Time	A	8	10.250	2.964	2,21	4.174	**0.030**
	B	8	13.880	5.915			
	C	8	19.500	9.008			
Errors	A	8	0.130	0.354	2,21	0.700	**0.508**
	B	8	0.380	0.744			
	C	8	0.500	0.756			

N: Number of participants; M: Mean, s=second(s); SD: Standard Deviation; df: degree of freedom; P-value: Significance

In the experiment 2, new cube puzzles Types A1 and A2 were developed based on Type A. There were two comparisons in the experiment 2: Types A and A1, Types A1 and A2. The results are shown in Table 2 and Table 3. A statistically significant difference was found between Types A and A1 in terms of Average Time (t(14)=-2.278, p=.039). Type A1(M=4.250, SD=2.252) had a significantly higher mean average number of errors than Type A(M=0.130, SD=0.354), (t(14)=-5.118,p=0.000).These findings provide evidence that the disassembly efficiency of Type A1 is lower than that of Type A. Type A1 (M=4.250, SD=2.252) had a significantly higher mean average number of errors than Type A2 (M=2.000, SD=1.690),(t(14)=2.260, p=.040). These findings provide evidence that the disassembly efficiency of Type A2 is higher than that of Type A1.

Table2 Independent Samples t-test for Types A and A1

Type A -A1		N	M(s)	SD	t	df	P-value
Time	A	8	10.250	2.964	**-2.278**	14	**0.039**
	A1	8	15.000	5.099			
Errors	A	8	0.130	0.354	**-5.118**	14	**0.000**
	A1	8	4.250	2.252			

N: Number of participants; M: Mean, s=second(s); SD: Standard Deviation; df: degree of freedom; P-value: Significance

In the experiment 3, to further verify whether the shape characteristic has a positive impact on disassembly efficiency when there is only one key clue part in a cube puzzle, it was necessary to

Table3 Independent Samples t-test for Types A1 and A2

Type A1 -A2		N	M(s)	SD	t	df	P-value
Time	A1	8	15.000	5.099	**2.810**	14	**0.014**
	A2	8	9.130	2.997			
Errors	A1	8	4.250	2.252	**2.260**	14	**0.040**
	A2	8	2.000	1.690			

N: Number of participants; M: Mean, s=second(s); SD: Standard Deviation; df: degree of freedom; P-value: Significance

use cube puzzles with different numbers of parts to perform the experiment again. Two new Types D and D1 were developed consisting of three parts each. The results in Table 4 showed that a statistically significant difference existed between Types D and D1 in terms of average time (t(14)=2.434, p=.029), indicating that the average time of Type D1 was significantly higher than that of Type D. Moreover, Type D (M=7.630, SD=3.420) had a significantly higher mean average number of errors than Type D1 (M=2.130, SD=0.991), (t(14)=4.369, p=.001).

Table4 Independent Samples t-test for Types D and D1

Type D -D1		N	M(s)	SD	t	df	P-value
Time	D	8	16.130	11.457	2.434	14	0.029
	D1	8	6.000	2.673			
Errors	D	8	7.630	3.420	4.369	14	0.001
	D1	8	2.130	0.991			

N: Number of participants; M: Mean, s=second(s); SD: Standard Deviation; df: degree of freedom; P-value: Significance

CHAPTER 4 ANALYSIS AND CONCLUSIONS

The results showed that when participants disassembled a cube puzzle that could be opened via multiple parts, the average number of errors was not different, even though these cube puzzles took more time to disassemble. Thus, puzzle shape had no positive effect on disassembly efficiency. However, when participants disassembled a cube puzzle with only one key clue part that was labeled, it had a positive effect on disassembly efficiency, that is, labeling the first shape to be moved made the disassembly process more efficient. As a result of the analysis, there was a difference in the degree of difficulty depending on the shape of the joint during assembly, but there was no significant difference in the process of disassembly. However, it is argued that if some of the joints have obviously different shapes, such as a semicircular shape in a part of the shape that consists of a face, the user will take the shape as the first hint and it will affect the disassembly efficiency.

CHAPTER 5 FUTURE WORKS

The purpose of this paper is to design a joint for users to disassemble furniture assembled by themselves, such as DIY, which is an important factor in efficient design for users to disassemble furniture with ease. In order to solve this problem, the proposed method was experimented using cube puzzles. We analyzed the cognitive behavior and efficiency changes of disassembling by the modeling elements of the joint. These studies have revealed the effective factors that add value to products, and will contribute greatly to the development of the design field, especially the furniture design field.

In order to apply this research theory to practical design in the future, it is necessary to conduct a profound study. At the preliminary stage of design, not only the convenience of assembly and disassembly should be taken into consideration, but also the users should be considered. Though people aged 25-34 preferred buying RTA Furniture, the survey did not take into consideration whether or not they had design experience. Based on the theory of the left and right hemispheres of the brain, people treat the same object with different perspectives. Therefore, grouping participants according to whether they have design experience or not, is a method that can be further studied. Furthermore, the size of the shape characteristics needs to be discussed. In this study, sizes of all the shape characteristics and key clues were same. Different sizes may have different effects on cube puzzle disassembly. These issues and details will continue to be studied in the future.

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