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学位論文 題目	Influence of Shape Characteristics on Disassembly Efficiency of Joint Cube Puzzles Depends on Different Situations（異なる状況下での継手を用いた組木の分解効率における形状特性の影響）
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論文内容の要旨

Ready-to-assemble (RTA) furniture is favored by consumers because of its convenient transportation and lower price. Its box packaging can reduce transportation costs, reduces the risk of damage in the process of transportation, and has greater flexibility in sales. At the same time, it provides conditions for customers to assemble furniture by themselves, making the assembly work easier. In recent years, the demand for RTA furniture has grown worldwide. Due to the COVID-19 pandemic, the number of people working from home has skyrocketed, which has increased the demand for space-saving home office furniture in modular form. With the rapid development of the economy and rhythm of life, people's demand for products has become much clearer. Most people do not want to spend much time thinking about how to use a complex product. For people who move frequently and have busy schedules, time savings and affordability are important factors in choosing a product. Therefore, RTA furniture is a good choice for them.

Compared to traditional furniture, RTA furniture has a simpler structure and fewer parts. Because of the seemingly straightforward construct and components, assembly and disassembly errors often occur. During the assembly process, people can refer to instructional guides or use virtual reality (VR) systems to avoid errors. Alternatively, the instruction manual can be used to learn how to assemble the furniture.

However, the disassembly process typically happens without any instructions, requiring users to rely on their own spatial abilities and understanding. Unlike assembly, disassembly is often overlooked. Especially when moving, people are often faced with a large number of items that need

to be disassembled. As users' spatial abilities and understanding vary, the time required for disassembly and the number of errors differ between people. Therefore, it is necessary to consider how to improve the efficiency of disassembly. Both cube puzzles and RTA furniture have similar shape characteristics. Precisely because of these characteristics, people get easily confused when an error occurs in the disassembly process. For this reason, cube puzzles are the target of this study.

Prior research has shown that the existence of shape characteristics affects the efficiency of assembly. However, no discussions have been conducted on the disassembly of cube puzzles.

The purpose of this study is to determine whether shape characteristics affect difficulty for users during disassembly, that is, whether shape characteristics have an effect on disassembly efficiency. It aims to find a method that can improve disassembly efficiency under limited conditions.

In order to verify whether the presence of shape characteristics affect disassembly efficiency, the author conducted a disassembly process experiment with seven different types of joint cube puzzles (marked Types A, B, C, A1, A2, D, and D1). The experiment was divided into three groups with a total of 56 participants from different countries. The author used video recordings to observe the time spent by the participants in disassembling the joint cube puzzles and the number of errors and then analyzed the data.

The three joint cube puzzles (marked Types A, B, and C) for Experiment 1 were taken from previous studies. Type A had only vertical straight-line form characteristics. In Type B, curves appeared. Type C had axial symmetrical triangles and semicircles added to its joints. All three joint cube puzzles could be opened via multiple components at the same time. These three joint cube puzzles have been validated in previous experiments on assembly; the presence of these shape characteristics were shown to improve the assembly efficiency. The reason for using this set of cube puzzles in Experiment 1 was to determine if the presence of the shape characteristics would improve the efficiency of disassembly when using the same set of cube puzzles for disassembly experiments. A one-way analysis of variance (ANOVA) was used to analyze the data of experiment 1. The results show that the shape characteristics did not improve the efficiency of the disassembly.

For this reason, a new hypothesis was proposed. If a cube puzzle can only be opened using one part, that is to say, if there is a limit to the starting step of the disassembly task of one key clue, do the shape characteristics of the joints have an impact on the disassembly efficiency? New cube puzzles, Types A1 and A2, were developed based on Type A. Type A1 had only vertical straight-line-form characteristics. Type A2 was the same as Type A1 except that a semicircle was added at the joint of the key clue. In Experiment 2, two sets of cubes were compared (Types A and A1, Types A1 and A2). When the cube puzzles were limited to having no shape characteristics added to the joints, the disassembly efficiency was compared between the cube puzzle with multiple openings (Type A) and the cube puzzle with only one key clue (Type A1). When the cube puzzles were limited to having only one key clue, the disassembly efficiency was compared between the cube puzzle without shape characteristics on the joints (Type A1) and the cube puzzle with shape

characteristics added at the joint (Type A2).

Experiment 2 aimed to determine whether the shape characteristics had a positive effect on the disassembly under limited conditions. An independent samples t-test was used to analyze the data of Experiment 2. The results show that when a cube puzzle could be opened via multiple parts, shape characteristics had no positive effect on disassembly efficiency. However, when a cube puzzle with only one key clue part was labeled, shape characteristics had a positive effect on disassembly efficiency.

In order to verify whether this conclusion can be applied to other cube puzzles, a new set of cube puzzles (Types D and D1) was developed. The same results were obtained as for Types A1 and A2 in Experiment 2. This reinforces the findings of Experiment 2.

Through three groups of experiments, it was found that when the cube puzzles were limited to only one key clue, the shape characteristics at the joint of the key clue were more easily noticed. The disassembly interference was thus reduced owing to the shape characteristic.

This study is basic research; its discovery elements will support the disassembly processes of DIY furniture.

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論文審査結果の要旨

本研究は、建築や家具の分野で部品同士を釘やネジ等を使用せずに互いに接合させる構造の造形要素を DIY と呼ばれる、ユーザ自身が組み立てる家具へのデザインに応用するための基礎研究である。研究では立体的なパズルを基軸に、組み立てられた造形物を分解する際の効率性やその過程でユーザが分解の手順をイメージするために必要な空間の認識のあり方について実験を通して考察・実験・分析した結果を報告したものである。

現在、ユーザに可能な限り組立の負担を軽減させるために、釘やネジ等を使用せずに継手等で容易に組み立てる家具が増加傾向にある。しかし、継手という木材加工技術は職人から受け継いだものが多く、家具の分野に応用される場合、その形状はユーザが直感的に組み立て易い比較的単純な直面状で多くは構成されている。しかし、部品数が増加するとユーザは組み立て順序を間違えストレスが発生することが多々ある。一方で、部品数が多い家具は、分解する際に組み立て以上に難解なプロセスがあり、場合によってはユーザが間違った方向に部品を引いたり、ねじったりすることで、破損させてしまうことも考えられる。本論文では、ユーザが取扱説明書や組立図を読まずとも、接合部分の形状を見ただけで、認知的な能力を刺激し、直感的に分解が出来る部品の接合部分の形状デザインに関する特徴を基軸に論じている。これまで部品同士を容易に接合するための研究は多々ある。しかし、継手の造形要素を生かした分解に関して、ユーザサイドからの認知的なアプローチでその効率性や検証を行った学術的な研究はない。

本論文の構成は以下のものである。

本論文の第1章は序論であり、本研究の背景と目的、及び本論文で用いる用語の定義について述べている。

第2章では、本研究と関連の深い先行研究を整理して述べている。

第3章では、本研究における実験方法とその結果について述べている。実験の目的は、継手を有した造形物をユーザが分解をする際の継手の形状の難易度を把握し、さらに、分解効率を上げるための継手のデザインの特性を事解するためである。実験は25才から34才まで56名の被験者に対して、継手で構成された80mm四方の3種類の組木を用いて行っている。3種類の組木は、1つは直面だけで構成された組木であり、もう1つは、前述の直面で構成された造形の一部に曲面が施された継手が含まれる組木である。さらに、もう1つは継手に三角形や半円等の造形が施された組木である。実験では上述の3種類の組木を分解し、被験者が分解をする手順を間違えたエラーの数と分解に要した平均時間の比較をビデオによる撮影を行い記録している。

第4章では、本研究の実験結果について分散分析を用いて示している。分析の結果、組み立ての際は継手の形状によって難易度の差が生じたが、分解を行う行程では、大きな差が生じなかった。しかし、継手の一部に明らかに異なる形状、例えば、直面で構成されている形状の一部に半円形の形状が含まれることで、ユーザはその形状を最初のヒントとし、分解効率に影響を与えると論述している。

第5章では、結論であり、本論文をまとめるとともに、本研究がDIY家具の分解プロセスにおいて重要な基礎研究である意義を述べており、また、今後の展開に残された課題について述べている。

以上、本論文は、DIY等のユーザ自身が組み立てた家具を分解する際の効率的なデザインを行う上で重要な要素である、ユーザが手際よく分解するための接合部分のデザインを行うことを目標としている。本提案手法では、その課題を解決するために、組木を使って実験を行った。そして、継手の造形要素による分解する際の認知的な行動や効率性変化について分析した。これらの研究は製品に付加価値をもたらす有効な要因を明らかにしたものであり、デザイン分野、特に家具デザイン分野の発展に寄与するところが大きい。

よって、本論文は博士（芸術工学）の学位論文として合格と認める。

原著論文（1編）

Yimin Wang, Peng Jiang, Takamitsu Tanaka : Influence of Shape

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