Usability of Assembly Instructions: A Case Study of Portable Toilet Cardboard

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ABSTRACT

This is an investigative study on how effective are the existing assembly instructions and new design instructions in terms of usability. The effective assembly instructions assist novice users to assemble the products at home. The portable toilet cardboard is used as a case study with four types of instructions. Four groups composed of twenty-four subjects are assigned to assemble the cardboard with usability testing method. The result shows that the step-by-step procedure with the guiding part on the product is the most effective in terms of time to complete each task and number of errors.

KEYWORDS

Usability; Instruction; Assembly; Portable toilet.

INTRODUCTION

Sixty-five of Thailand's 77 provinces were declared flood disaster zones, and over 20,000 square kilometres of farmland was damaged (Wikipedia, 2011). Thousands of people in Thailand have been living in filthy flood water for some three months. The simple thing like disposal of human waste became complicated; hence, several designs of DIY portable toilets for flood victims were invented. The portable toilet is made up of corrugated paper which is the most effective material than plastic since it is economical, easily produced, light, durable, and recyclable. Corrugated paper has been purposely designed for toilet users, for example, the Brown Corporation patented the combined toilet and seat apparatus (Wharton, 2007). The product is easy to use since it is made from one piece of paper with adhesive binding tape on one side. Because the product is irreplaceable when it becomes dirty, the corrugated toilet paper is designed with several knockdown pieces. The knockdown design is also convenient for logistics and manufacturing. Therefore, the assembly instructions need to be clear and simple for users. In this study, the portable toilet which was designed into three pieces requires users to figure out how to put them together without using glue. Most of the patents related to techniques of folding cardboard, utilizing tenon and ensuring interlock can be seen from the U.S. patents, for example, knockdown corrugated paper board table (Slate, 1971). Many of them are complicated in terms of folding and assemblage.

Literature Review

According to Agrawala et al., (2003), it is difficult and costly to design assembly instructions which are easy to understand and to follow. If the assembly instructions are complex to use, the users must have a good problem solving skill. Cognitive psychologists have developed a variety of techniques to investigate how subjects mentally represent ideas and concepts. Heiser and Tversky (2002) experimented on the technique to determine mental representations of assembling parts. They showed that people preferred instructions presenting the assembly operations across a sequence of diagrams rather than a single diagram showing all the operations. This is called 'step-by-step instructions' (Novick et al, 2000). Instructions become complicated if they are split in numerous diagrams. Another type of instructions is called the 'structural and action diagrams'. This type presents all parts of the assembly operation in their final assembled positions. Users must compare two consecutive diagrams to infer which parts are attached. Novick et al (2000) recommend that action diagram is more superior to structural diagram for TV stand assembly while toys such as LEGO often use structural diagram. In this study, the combination of action and structure diagram is an interesting investigation. Specifically, the exploded view illustration in the technical documents similar to mechanical engineering can either be used or not for novice users. Driskill et al., (1995) mentioned that this type of illustration is easy to understand even by people without area of expertise. Although a lot of assembly instructions have been investigated, the assembly instructions for novice users have not been studied yet.

Objectives

The study involves four designs of assembly instructions. Two of them use the existing design principle while the two other designs are redesigned. The objective of this study is to identify the most effective assembly instructions.

METHOD

All subjects were assigned to read the instructions before assembling the product. Four types of assembly instructions were designed for portable toilet as follows:

1) Guiding sticker on product by pairing the same two numbers on the joint and interlock parts. The guiding sticker represents the sequence of assembly from the first pair to eleven pairs (figure 1a). The aim of this new design is to embed the instructions on the product;

2) Structural and action diagrams show final assembly positions and three parts with assembly lines (Figure 1b). The drawing is similar to the exploded view illustration in mechanical engineering drawing. Both structural and action diagram are combined together because users cannot imagine the final outcome of assembled product. Therefore, the structural diagram can be a representation of products.

3) Step-by-step instructions show how to assemble the toilet with four sequential steps (Figure 1c);

4) Step-by-step with guiding parts on a product (figure 1d) consists of instructions combining first and third types. As distinction, there are three alphabets representing three components of toilet cardboard rather than the joint assembly and sequence.

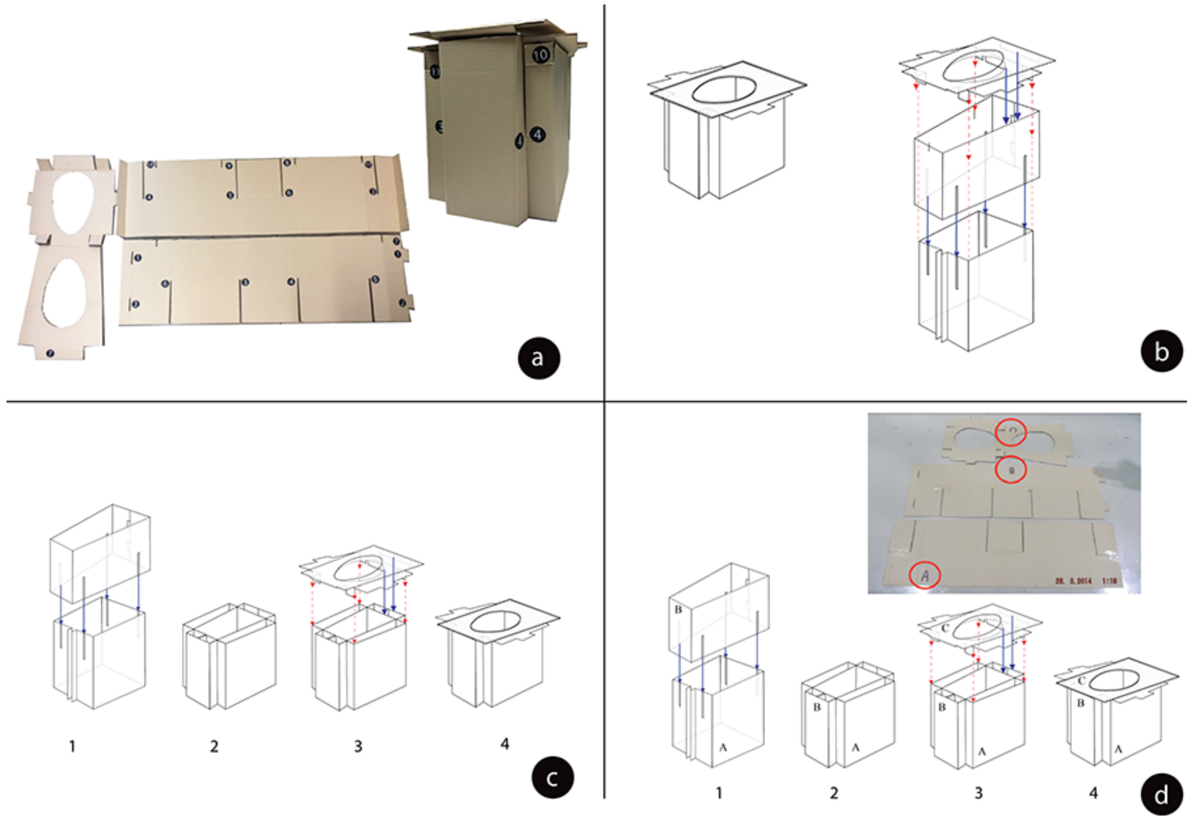

Figure 1. Four types of instructions

Participants

By using a convenient sampling, the usability testing was conducted with 24 subjects comprising high school students, office workers, security guard, and janitor. The age range is between sixteen to fifty four years old (M = 36.5, SD = 12). Six groups were assigned to use each instruction. Each group had an equal the number of males and females. There was no repetitive testing on the same subject for different types of instructions. All participants had no experience in the assembling portable toilet cardboards.

Procedure

Before assembling the toilet cardboards, all subjects were tasked to read the instructions carefully, and they were allowed to see the instructions any time during the assembling tasks. The subjects assembled the paper parts to form a toilet, undergoing four tasks of assembly process as follows:

1) reading an instruction,
2) folding the papers,
3) assembling the body structure by putting two boxes together, and
4) attaching a seat pad on top of the body.

The video data were loaded into video analysis software Observer® XT (Noldus, 1991) and all of the tasks performed were coded during observation. This allowed the timing and assessment of the tasks performed and the counting of human errors. The timing and errors were taken from the videotaped data with statistical output of subjects' performance. For the analysis of error, it was classified into five types: 1) Skip: The user did not perform the task or the user forgot what to do. 2) Incomplete: The user performed a correct action but did not complete the task in details. 3) Too much: The user performed an incorrect action and inserted extra action. 4) Too long: The user spent time longer than the expected maximum time. 5) Wrong direction: The user performed action in wrong sequence.

Figure 2. Experiment with assembly instructions

RESULTS

The effectiveness of the instructions on the ability to assemble the paper toilet is focused on spending time and number of errors.

Time to complete each task

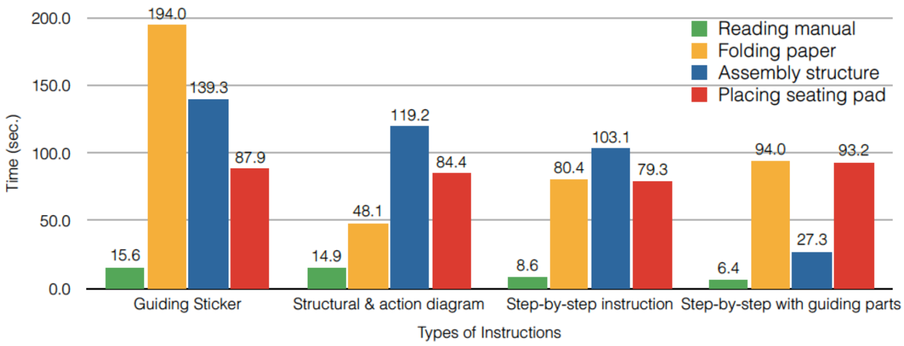

Figure 3. Mean time of each task

Figure 3 shows the mean time on each task. Subjects spent most of their time on guiding sticker, and the time utilized on folding paper (*M*=194 sec., *SD*=6.3) was the highest because the guiding sticker did not show how to fold the paper. They folded the paper back and forth for several times. Subjects did not have a clear goal of the final assembly or formulate their mental models. In terms of sequence of task, the subjects did not follow the numbers on the stickers showing the sequence of assembly. Many subjects made a lot of errors on assembling the interlock joints, which had basically two possibilities to lock them. Moreover, the simultaneously actions did not work for the guiding stickers; hence, many subjects did not know that they needed to assemble two interlocks at the same time.

The structure and action diagram instructions showed the problem when many subjects without a background in mechanical drawing could not understand the assembly line. They mentioned that it was difficult for them to figure out how the parts would fit together despite of a clear illustration of dash lines.

The mean time utilized in assembling structure through step-by-step with guiding parts (*M*=27.3 sec., *SD*=6.5) was faster than the step-by-step instruction (*M*=103.1 sec., *SD*=66.5). The reason was that the assembly structure was clearly shown on the sticker placed on the corrugated paper. Subjects were able to map the alphabets of the instructions on the product.

Number of and type of errors

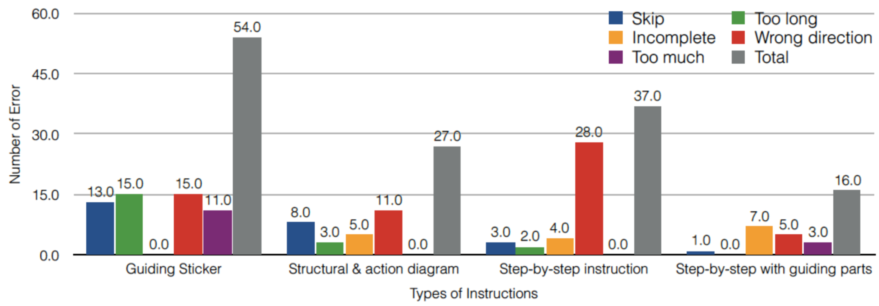

Figure 4. Number of errors in each task

The maximum number of errors was acquired mostly on the guiding sticker followed by the step-by-step instructions, the structural & action diagram, and the step-by-step with guiding parts respectively. Subjects who tested with the guiding stickers made a high number of errors for all types including the error in incompletion. The total number of errors of the guiding sticker is 54 times. Many subjects who made an error did not recognize the pairing numbers of guiding stickers. Aslo. the structure & action diagram lacked a complete picture in each step. The step-by-step instructions had an advantage over the action diagram, since it showed smaller goals when finishing each step.

Time-event analysis

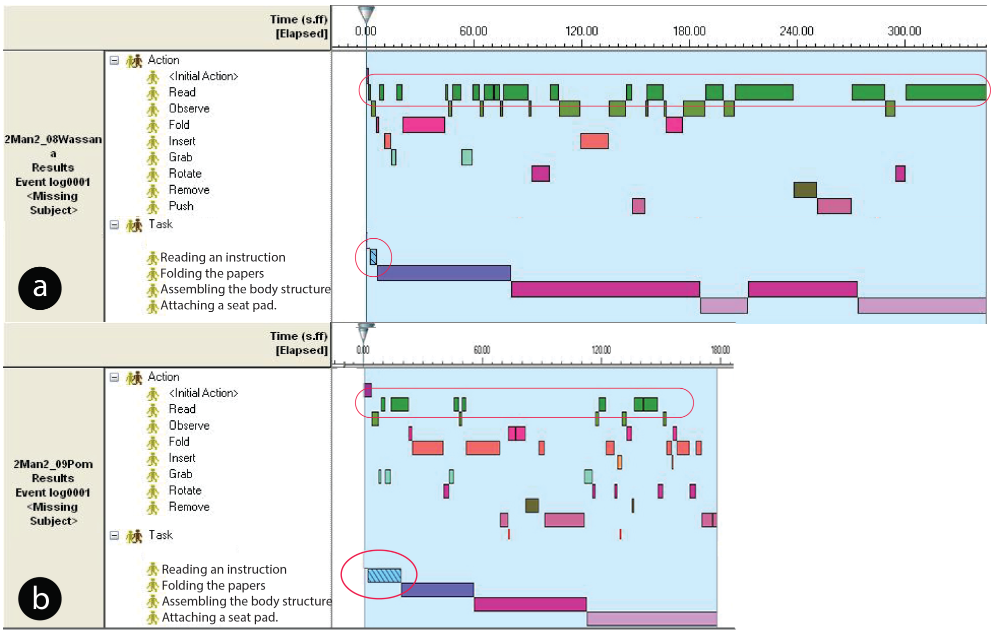

Figure 5. Comparing two behaviors of understanding manual

The time-event analysis indicates the sequence of each action as shown in Figure 5. The diagram shows the time duration of each action such as “read”, “observe”, “fold” and others. It includes four main tasks. Figure 5a shows that the subjects did not spend time in reading an instruction at the beginning. As a result, the subjects repeatedly read the assembly instructions many times (See the marker on Figure 5). If subjects spent time to understand the manual at the beginning (Figure 5b), they would use less time in other tasks.

Independent variables

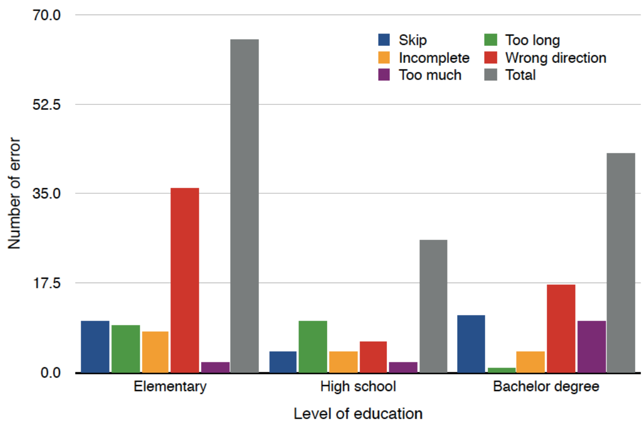

Figure 6. Level of education and errors

There are several independent variables on this study, for example, experience of assembling products, gender, age and education. The resulting errors are correlated between low education and older age. Nine out of 24 subjects with elementary education and older age made more mistakes in action than other subjects with other education levels (Figure 6). For subjects with high school level, the error is less due to their education and younger age correlating together. High school students seemed to have less errors and time duration in performing the task. This group of subjects performed the cognitive task faster than the other groups. Some subjects with educational background as university design students who had an experience in mechanical drawing before performed faster than other careers.

CONCLUSIONS

This study reveals the result of usability testing showing human performance in relation to time utilized complete the task and number of errors. Using cognitive psychology allowed examination of users' perceptions and understanding of assembly instructions. The summary of design principles has indicated the following: 1) Subjects percieved the goal or final assembled position more than the action diagram only, 2) The guiding sticker on the product without instructions was difficult to use. On the other hand, using the assembly instructions with the guiding sticker could help subjects to achieve the goal, 3) Subjects understood the step-by-step assembly better than seeing only the final assembled position, 4) Subjects who spent time in understanding the instructions at the beginning could achieve the goal faster than the ones who read the manual and working on the task simultaneously, 5) When using exploded view of product as an action diagram, the background knowledge of users should be considered. Many of them had a difficulty to imagine the final assembled position.

For futher development, it is interesting to find out how to link the assembly instructions and the product. Users tend to perform well when there are assembly instructions on the product. The computing media could be a linkage for the novice users to bridge the gap in mental model. The new media such as augmented reality could be used in conjuction with real products since the augmented image could map the product guide in accordance with assembly instructions.

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