# Head-Mounted Display in Work Assistance

## - An Origami Case Study -

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***Abstract*—Head-mounted display (HMD) has gained significant attention in recent years. The goal of this study was to verify whether using HMD in work assistance actually improves work efficiency via an evaluation test. We focused on the field of work assistance and reflected on whether people who use HMD become interested in using the technology to help them to work efficiently when they fold origami in their spare time, compared with other methods such as an origami book and cellphone applications. The results of our evaluation test show that HMD technology is effective in the field of work assistance.**

***Keywords-head-mounted display; HMD; work assistance; origami.***

## I. INTRODUCTION

In recent years, head-mounted displays (HMDs) have been sold by a variety of makers and are used in many industries.

For many years, HMDs have garnered attention as the device that realizes the visual aspect of virtual reality (VR), and there has been continued research and development into wearable computers. HMDs are display devices that use a head mount that can be either in the form of goggles or glasses. The HMD displays visuals in front of the eyes and is characterized by having a superior sense of immersion compared with typical displays. HMDs can be separated into four categories, but most of the products on the market today can be split into two main categories: one that shows an image in one eye, and one that shows an image in both. The other two categories are displays where you can see behind the images and see the surrounding landscape (see-through) and displays where you cannot (nonsee-through). HMDs for both eyes are the largest portion of consumer products. Products such as the SONY HMZ-T3 [11] (Fig. 1) represent nonsee-through displays for both eyes. This type of product is suited for the use of some types of audiovisual (AV) content such as when viewing movies or playing games because the user can be immersed into the images without seeing the surrounding background. In addition, see-through displays for both eyes such as the Wrap [13] series by Vuzix and Moverio [12] (Fig. 2) by Epson are also suited for use with AV content. In contrast, single-eye HMDs are unsuitable for the total immersion experience because they do not totally block the user's vision. Instead, they are suitable for use during work and thus these HMDs are designed for businesses.

Figure 1. HMZ-T3 [11].

Figure 2. Moverio [12].

There is also an unprecedented need for improvements in factory floor productivity. For example, it takes time to fix mechanical problems that occur in isolated locations. This then turns into a big problem for the production process. The engineers must be transferred to that location temporarily to address the work that cannot be done by the local staff. Technical succession is becoming difficult as the number of expert engineers declines.

What are the advantages of using HMDs to support daily operations? One is that an employee can work with their hands free. That means an employee can access a user manual or any other materials they need without breaking from their main duties. Therefore, in this paper, we will examine the effectiveness of using HMDs during work. We will consider whether superimposing movies or images onto a real-world view improves work accuracy and efficacy.

We note that fundamental research into HMDs and human anatomy has been explored previously [1] [2] [3] [4].

The aim of this experiment is to validate the work optimization of HMD and propose new usage methods for future HMDs by having students of the Tokyo University of Science, Suwa use and assess the technology.

In present-day origami, it is standard to fold the paper while looking at images in an origami book or on a cellphone application. In this experiment, we considered whether students could shorten the time to comprehend greater amounts of messages, seeking comments like "the directions are easy to understand" and "this is a smoother

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process than folding origami while looking at images" by having them fold origami while viewing movies on the HMD, whether they were able to enjoy origami thanks to this new method, and whether they would want to use this method again.

Section I discussed the background that led to this study, and the aim of this paper. Section II introduce the related works. Section III introduces the environment that was prepared for creating the contents used in the HMD, and the developed content for experiment. Section IV introduces the three methods in the experiment that were used for the materials in Section III. Section V discusses the results and observations of each experiment discussed in Section IV. Section VI proposes improvements for the methods in this paper based on the experimental results. Section VII discusses conclusions made based on the experimental results.

## II. RELATED WORKS

Currently, research is being conducted on applications for work support and other various applications [6] [7] [8][15], including the ones that we will introduce below.

*1) Logistics solutions:* In a four-company collaboration between Seiko Epson Corporation [12], Toyo Kanetsu Solutions K.K., Kokusai Kogyo Co., Ltd, and King Jim Co., Ltd, testing of logistics solutions using Epson's Moverio was conducted at Toyo Kanetsu Solutions K.K.'s plant in Chiba, Japan.

As shown in Fig. 3, these brand-new logistics solutions can aid workers in safely and efficiently completing their picking and sorting work while the navigation screen of the picking course is superimposed onto their real-world perception by having workers wear the Moverio in logistics facilities, such as a warehouse or logistics center with using Augmented Reality(AR).

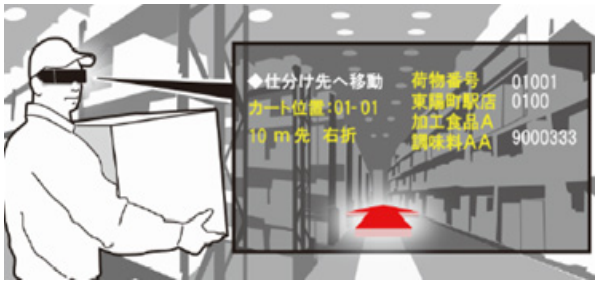



Figure 3. Logistics solutions using AR navigation.

*2) Sorting support for physical merchandise distribution:* Yamazaki et al. [5] focused on order picking for warehouse storage and proposed an order-picking system that assists workers through mixed reality (MR) technology. They identified problems that order-picking systems have faced in the past, and worked to improve work efficiency and reduce errors by solving those problems using MR technology. The system can intuitively present information to support the current task by superimposing computer-generated images onto the worker's field of vision through an HMD. This research confirmed the behavior of the developed system and carried out evaluative experiments that compared the impact of see-through video HMD and optical HMD on work efficiency.

*3) A Highly-portable Markerless User Interface Using Optical See-through HMD and AR Technology :* Irie et al. [15] proposed a system "AirTarget", which can point virtual and real object directly with user's finger is proposed for optic see-through HMD devices. The camera attached to the HMD device detects the position of user's fingertip, calibrates the gap between the sight of the camera and eye, and displays the cursor overlapped to the finger on the virtual plain. Finger detection is done in markerless image processing, so that it does not require specific input devices or external computer. This system enables to send control commands by simple gesture, working as a self-contained interface. The user is able to point a virtual object with their finger, and able to cut out an object of the real sight which can be used as a query of the image searching. And the simple gesture operation was achieved highlyaccuracy and recognition rate.

## III. CREATING THE HMD CONTENTS

In this section, environment that was prepared for creating the content, and the developed content for experiment are explained.

### A. How to Use an HMD

The controller has an Android system. The images and movies installed on the micro memory card are played by the Android system installed in the HMD controller (Fig. 4). The user views the images and movies through the headset.

The screen size changes according to the viewpoint. If the viewpoint is distant, the screen will also appear as if it is far away.

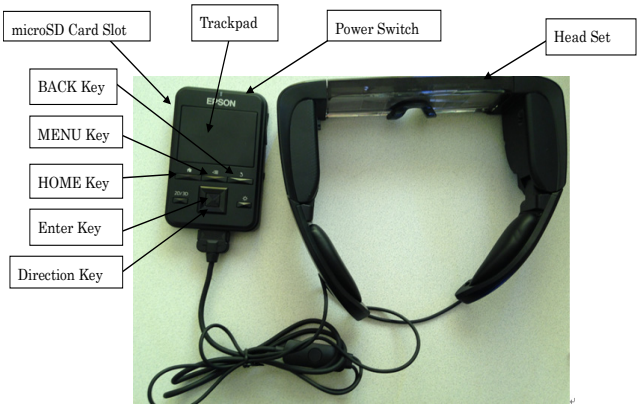



Figure 4. HMD controller and headset.

### B. Development/Testing Environment of HMD Images and Movies for this Study

As shown in Table I, As for HMD, MOVERIO was selected for this experiment considering the availability in Japan. A Smart Phone was used to capture the images and movies. And PC was used to edit the images and movies.

TABLE I. DEVELOPMENT/TESTING ENVIRONMENT OF HMD IMAGES AND MOVIES

| HMD | | Camera | | PC | |
|---|---|---|---|---|---|
| Product Name | MOVERIO (EPSON) | Product Name | iPhone5 | Product Name | Fujitsu FMV-E8290 |
| Movie | MP4(MPEG4+AAC)<br>MPEG2TS<br>(H.264+AAC)<br>SD-Video | Image | 8 Million Pxcels<br>(1280×960 dot) | CPU | Intel(R)Core™2Duo CPU P8700(2.53GHz) |
| Image | JPEG,PNG,BMP,GIF | | | Memory | 2GB |
| Memory | 1 GB<br>microSD(Max 2GB)<br>microSDHC(Max32GB) | | | OS | Windows7 Professional |

The GNU Image Manipulation Program (GIMP) was used to edit the images. A large number of images were prepared in this software using methods such as layering and by cutting the images into shapes.

### C. Content Used in the Experiment

*1) Origami book:* "Present, Decorate, and Enjoy Practical Origami" by Mitsunobu Sonobe was used in this experiment.

*2) HMD images:* For this experiment, six types of origami with the same estimated completion time were chosen from Sonobe's book. We took one picture per step for each of the six types of origami. The pictures were then transferred to the computer and then saved to the micro memory card. Figure 5 shows one example of an HMD image set of the origami contents used in this experiment on the HMD. This example is of a folding style for a dachshund.

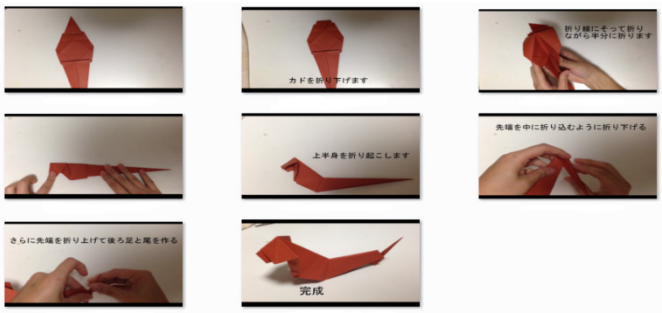
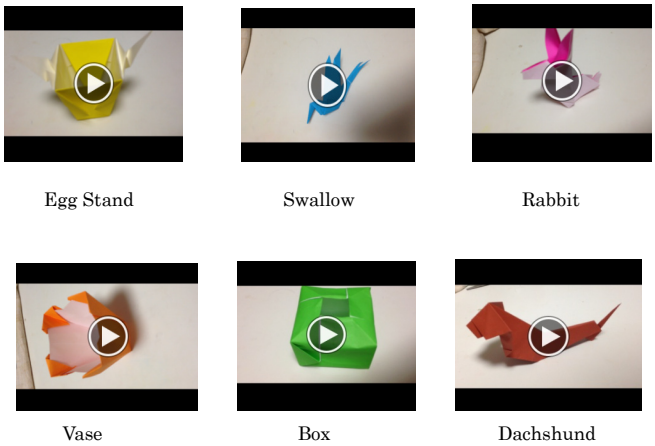



Figure 5. HMD image set.

*3) HMD movies:* We recorded movies showing the folding of the same six types of origami. Pace was considered while folding the origami so that all six types were completed in the same amount of time.



Egg Stand Swallow Rabbit

Vase Box Dachshund

Figure 6. HMD movies.

The movies were then saved to the micro memory card. Figure 6 shows the six types (movies) of the origami contents used in this experiment on the HMD.

## IV. EXPERIMENT

In this section, detailed process of our experiment is explained as follows.

### A. Experiment

*1) Purpose of this experiment:* The purpose of the experiment is to improve the efficiency of folding origami compared with the traditional method of using an origami book through an experiment where participants fold origami using an HMD. Another purpose of this experiment is to listen to the thoughts and opinions of the participants through the user surveys, and verify improvement plans for future materials.

*2) Participants:* Eighteen students from the Tokyo University of Science, Suwa.

*3) Details of the experiment:* We implemented three experiments: "origami book," "HMD images," and "HMD movies." Each of the participants performed each experiment in turns using HMD.

In each experiment, the participant created one of the six origami according to the instructions they received. They measured the time it took to complete each origami and answered a user survey after completing all experiments.

*4) Materials:* Origami book; movies and images created for this experiment; HMD; three sheets of origami paper per person; user survey sheet; timer; and writing tools.

*5) Experiment:* An origami book and HMDs were used in the experiment. Because most participants were using an

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HMD for the first time, we arranged for an explanation and some operational practice before the actual experiment began. For practice, the participants used movies and images that would not be used during the actual experiment. Additionally, to avoid bias in the data because of working order, the order for each participant was based on an order sheet created specifically for that practice. Each participant answered a user survey after completing the experiments with the origami book, HMD movies, and HMD images.

*6) The sequence:* First, prepare the origami book and turn on the HMD. Prepare the HMD so that it can be used immediately. Give the origami paper to participants so that they can begin folding the origami immediately. Each participant was called on individually and began their practice (see Fig. 7) based on the practice order listed below.

Figure 7. Test scene.

<For HMD images>

- Explanation of experiment
- Distribution of origami
- Prepare HMD images for practice
- Practice
- Prepare HMD images for actual experiment
- Fold origami
- Finish the origami and collect HMD

< For HMD movies>

- Explanation of experiment
- Distribution of origami
- Prepare HMD movies for practice
- Practice
- Prepare HMD movies for actual experiment
- Fold origami
- Finish the origami and collect HMD

<For the origami book>

- Explanation of experiment
- Distribution of origami and book
- Fold origami while viewing instructions in book
- Collect book

After a participant completed all three origami, we distributed a user survey and writing materials, and the participant was encouraged to express their opinions on the experiment freely. The experiment was considered complete when the participant had completed the survey and returned both the survey and writing materials.

There were 18 participants in total. We ensured that all 18 participants were equal and that there was no chance of Bias by having three different folding methods for six different types of origami.

## V. RESULTS AND OBSERVATIONS

Based on the experiment described in Section IV, Following result was observed.

### A. Survey Results

*1) Comparison of survey results:* The average of each survey category as shown in Fig. 8 is explained below.

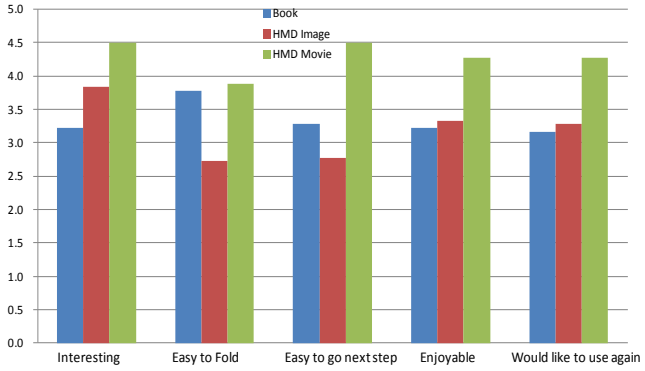


Figure 8. Average of each survey category.

a) The order of the results in the category, "Found it interesting" were HMD movies > HMD images > origami book. These results suggest that the participants developed an interest in HMD technology after the experiment.

b) The order of the results in the category, "Environment in which origami can easily be folded" were HMD movies > origami book > HMD images (there was a slim margin between HMD movies and origami book). These results suggest that folding origami using the HMD was not a hindrance for the participants.

c) The order of the results in the category, "Easy to understand next step" were HMD movie > origami book > HMD images. This shows that movies were easier to understand than images in the HMD environment and that images were inferior to the origami book.

a) The order of the results in the category, "Enjoyed folding the origami" were HMD movies > HMD images > origami book. These results suggest that the participants enjoyed folding origami better with HMD technology.

e) The order of the results in the category, "Would use again" were HMD movies > HMD images > origami book. These results suggest that participants would like to continue using HMD technology.

f) When we look at the average of the sum of all mean values, the average of both the origami book and HMD images are about the same, but the average for HMD movies is much higher than both categories, as shown in Fig. 9.

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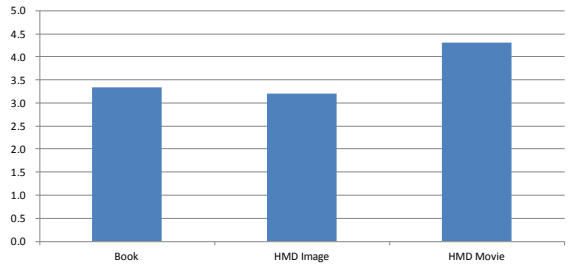


Figure 9. The average of each mean value by category.

*2) Analysis of survey results:* A one-way analysis of variance was conducted on each category using valuation points to verify whether there is a significant difference in the evaluation points in each category in the survey as shown in Fig. 8.

a) There is a significant difference between the origami book and HMD images in the category, "Found it interesting." There is also a significant difference in the traditional origami book and HMD movies as well as between HMD images and movies.

b) There is a significant difference between the origami book and HMD images in the category, "Environment in which origami can easily be folded." There is also a significant difference between HMD images and movies.

c) There is a significant difference between the origami book and HMD movies in the category, "Easy to understand next step." There is also a significant difference between HMD images and HMD movies.

d) There is a significant difference between the origami book and HMD movies in the category "Enjoyed folding the origami." There is also a significant difference between HMD images and movies.

c) There is a significant difference between the origami book and HMD movies in the category, "Would use again." There is also a significant difference between HMD images and movies.

## B. *Measurement of Completion Time*

As shown in Fig. 10, five of the six types of origami were faster to fold using HMD movies. Comparing Fig. 10 and Table II, it can be concluded that the more steps there are to complete the origami, the longer it takes when using the origami book compared with HMD movies and the smoother the process when using HMD movies. However, it is faster to use the traditional origami book rather than the HMD for origami with fewer steps to complete. These results show that the appropriateness of HMD or the original origami book depends on the number of steps needed. These results show that HMD is appropriate for difficult work and inappropriate for simple work.

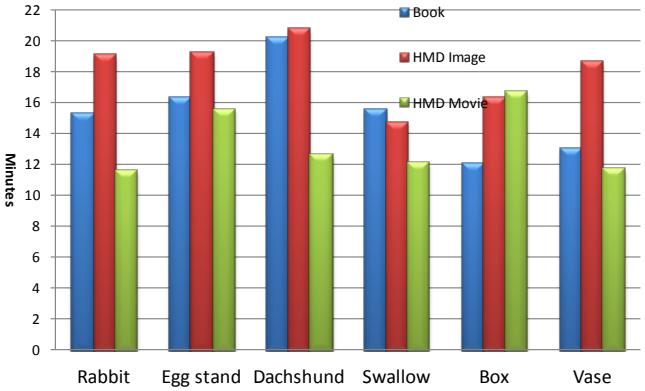


Figure 10. Measurement of completion time.

TABLE II. NUMBER OF STEPS

| | |
|---|---|
| Rabbit | 25 Steps |
| Egg Stand | 22 Steps |
| Dachshund | 25 Steps |
| Swallow | 28 Steps |
| Box | 18 Steps |
| Vase | 21Steps |

Figure 11 is the average value of completion time for the method used to complete the origami. This figure shows that the completion time was shorter when using the origami book compared with HMD images, and that the completion time was shortest when using HMD movies. The average work time was fastest with HMD movies.

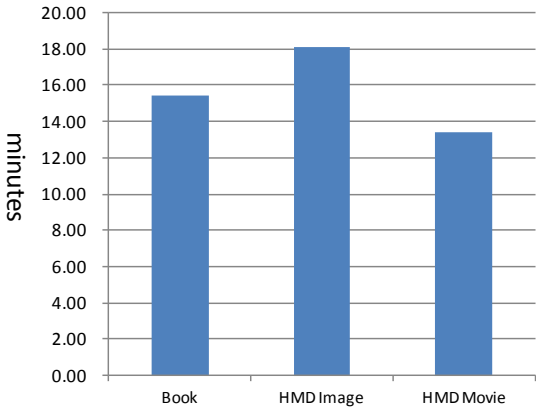


Figure 11 Average completion time by method.

## C. *Free Descriptions*

Participants' positive and negative opinions about this experiment are shown in Table III.

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TABLE III. OPINIONS

| | Good Point | Bad Point |
|---|---|---|
| Book | All Process can be seen at the same time. (6 people) | Hard to see complicated process. (7 people) |
| HMD Image | Can keep his own pace. Can compare his output. (10 people) | Hard to find the folding line. (7 people) |
| HMD Movie | Because This is see thorough HMD. It was very easy to do same things with movie. (14 people) | Once you get trouble, Operation is bit difficult. (6 people) |

The positive responses for HMD movies indicate that close to half of the participants held the opinion that HMD was "Easy to work with because I could copy the folding methods in the movie because the HMD was see-through." Everyone was used to the paper medium of the traditional origami book. As a result, participants felt that it was easy to understand how to fold the origami, easy to complete, and it was also easy to view the entire process.

Other relatively common opinions were that using HMD is "excitingly new" and that they "became interested in the technology." Another opinion that stood out was that the biggest difference from the traditional origami book was that "I was able to fold the origami while viewing the folding method in the see-through glasses, and it was better compared with using the traditional book." Negative opinions were "It's difficult to see and understand where to fold" and as a result, "It was a little confusing and the equipment was bothersome."

The aim was to verify whether the use of HMD improves efficiency over the traditional origami book, and to verify if we can increase interest in HMD. As a result, we can consider that the participants were able to increase their efficiency and work and becoming interested in HMD. It can be considered that there were no obstacles while they were working.

## VI. IMPROVEMENT PLAN

The improvement plan for creating future materials for work (this time for folding origami) with HMD was examined.

Many participants held the opinion that "it was difficult to locate the folding crease" with HMD images. Many participants held the opinion that "using the equipment was bothersome" regarding HMD movies.

An improvement plan for HMD images/movies was created based on these two points.

### A. Improvement Plan for HMD Images

The instructions for the HMD images used in this experiment were displayed together with the images. We thought that doing work using a different method to the traditional origami book was connected to the improvement of work efficiency; however, it was difficult for participants to locate the folding crease, increasing the completion time.

### B. Improvement Plan for HMD Movies

An HMD movie was created for this portion of the experiment. Many participants felt that it was tiresome to have to redo their work if they had trouble for some reason. The participants were able to complete the origami in a shorter amount of time compared with traditional methods. However, it was necessary to coordinate everyone because some people work quickly and some people work slowly.

To address this, we propose a subdivision of the movie into steps by creating an HMD movie that has a pause after each step. If the movies are subdivided by steps, then the participants will be better able to understand the actual situation and they can easily review a step when needed, thus further increasing work efficiency.

## VII. CONCLUSION

The aim of this study was to verify whether using HMD in the area of work assistance actually improves work efficiency using an evaluation test. Another aim is to review the improvement plan for future materials based on the experimental results, and to review conclusively the efficacy of HMD in the area of work assistance.

We focused on the field of HMD work assistance and reflected on whether people who use HMD become interested in using the technology to help them to work efficiently when they fold origami in their spare time, compared with other methods such as an origami book and cellphone applications.

In this experiment, 18 participants folded origami while using an origami book, HMD images, and HMD movies, and answered an accompanying user survey after completion of the experiment.

We observed the following three results:

1) To explore work efficiency improvement, participants folded origami using an origami book and HMD movie. Using the HMD movie was overall faster than using the traditional origami book. However, using HMD images is an inferior method to using an origami book. We also discovered that using HMD movies is an inferior method when there are few steps involved in completing the origami.

This may be because a user cannot see the whole picture when using HMD images and it takes time to operate the equipment. These results show that HMD movies increase work efficiency more than do HMD images. However, using HMD takes longer for simple tasks. The average completion time from these procedures show that the order of fastest completion time, in descending order, is HMD images > origami book > HMD movies. This order shows that HMD movies are more effective than an origami book or HMD images.

2) The interest in using HMD technology was examined using a paper user survey. When we examined the average values taken from the survey answers, HMD movies received a higher value than the origami book in three categories: "I became interested in the technology," "Enjoyed folding origami," and "I would like to use HMD again." The average data for each category tells us that

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participants preferred, in ascending order, HMD images < origami book < HMD movies. This result shows that using HMD is beneficial to improving participant interest in the technology.

3) In the "free description" section of the survey, six people held the positive opinion that "the origami is easy to understand because I could view the whole thing at once," regarding using the origami book. Seven people held the negative opinion that it was difficult to understand complicated origami instructions when using an origami book. Ten people held the positive opinion that folding origami while looking at HMD images "is comparable to when I fold origami on my own, at my own pace." Seven people held the negative opinion that "it was difficult to locate the folding crease" when using HMD images. Fourteen people held the positive opinion that "it was easy to copy the folding methods because the HMD movie is see through." Six people held the negative opinion that "It was a little confusing and difficult to use the equipment" regarding HMD movies.

From these three results, we can conclude that using HMD technology is effective in the field of work assistance.

In this study, we have not applied AR technology to Origami yet. However, in the next experiment, we are going to compare Origami with AR technology and Movie in HMD environment.

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