Conference Supplement of CSCW 2004, in Chicago, IL, USA, (2004)

The Advantages and Limitations of a Wearable Active Camera/Laser in Remote Collaboration

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ABSTRACT
The Wearable Active Camera/Laser (WACL) is a new collaboration tool that allows a remote expert to not only independently set his or her viewpoint into the workplace of a fieldworker wearing the WACL but also to point to real objects directly with a laser spot. In this paper, we examine how communication patterns differ between the WACL interface and a typical headset interface. Results show that experts talked more to workers wearing the WACL when detailed instructions were needed and talked more to workers wearing the headset when view changes were required. These results along with task performance and user preferences analyzed in a previous study have implications for improving the WACL so as to redress the communication asymmetries by enhancing the visual assistance.

Categories and Subject Descriptors
H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces—*CSCW*

General Terms
Design, Human Factors

Keywords
wearable active camera/laser, HMD, gesture, AR

1. INTRODUCTION
Unlike most video-conferencing systems, the focus with wearable collaborative systems is on the real world task space. They are suitable for situations where the user wants to move around the task space rather than stay fixed in one place. We are interested in collaboration between a mobile fieldworker and a remote expert such as a network engineer who has to move around while getting directions from a remote supervisor. We have recently developed a Wearable Active Camera/Laser (WACL) [5] that involves wearing a steerable camera/laser head. The WACL is worn on the shoulder and so is an unencumbered Input/Output device for remote collaboration.

In a previous user study [3], we compared remote collaboration with the WACL interface to that with a typical head mounted display (HMD) interface in terms of task performance, ease of use, and user preference (Figure 1). We examined task completion time and questionnaire results obtained from a series of Lego block selection and assembly

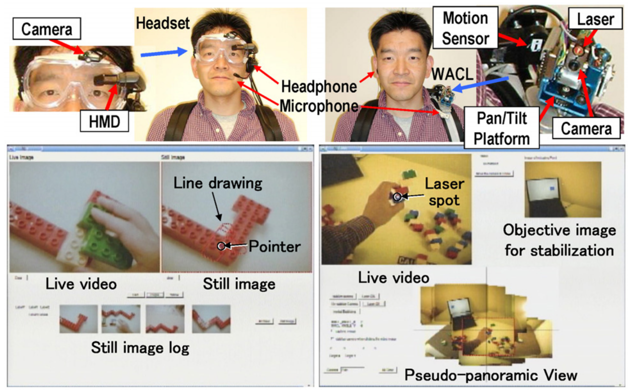

Figure 1: The headset worn by a fieldworker (upper left), the GUI used by an expert to interact with the headset wearer (lower left), the WACL (upper right), and the GUI used by an expert to interact with the WACL wearer (lower right).

tasks. There was no significant difference in the total completion time between the headset and the WACL, but we found that the WACL was more comfortable to wear, was more eye-friendly, and caused less fatigue to the wearer.

In this paper, we clarify the advantages and limitations of the WACL interface by examining how communication patterns differ between the WACL and the headset from transcripts of video log data collected in the previous study. Task phases during collaboration on real world tasks primarily consist of object/location identification, procedural instruction, and comprehension monitoring [2]. Visual assistance by pointing with a mouse cursor in the HMD case or a laser spot with the WACL is valuable for the identification phase. More advanced visual assistance such as line drawing on the HMD view is suitable for the procedural instruction phase. Meanwhile, the view-controllability of the WACL gives the remote expert better situational awareness and allows him or her to point at a target regardless whether it is inside the field of view or not. Thus we hypothesized that experts would talk more to fieldworkers wearing the WACL during procedural instruction phase and would talk more to ones wearing the headset when view changes are required.

2. METHOD
2.1 Equipment and Task
The headset interface provides users with visual assistance not only by pointing, but also by line drawing on live or still images. The headset interface has similar functions to

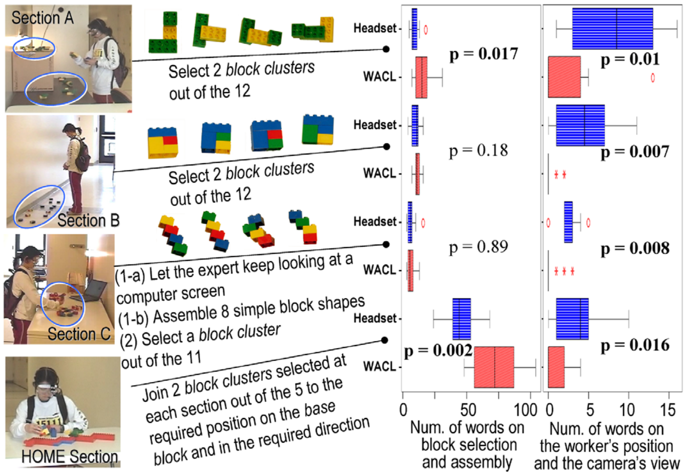

Figure 2: Tasks at each section (left) and the number of experts' words (right).

DOVE [4]. In the context of wearable interface, line drawing on a still images is a simple but effective way to prevent a registration problem between images and the line drawing. An experimental workplace contained four sections (Figure 2-left). Dozens of assembled Lego *block clusters* were distributed in sections **A**, **B**, and **C**. In each trial, under guidance from the remote expert, the worker first had to pick up one or two *block clusters* in each of those three sections, and then complete the trial by assembling the block clusters at the **HOME** section.

2.2 Subjects and Procedure

Sixteen subjects (7 female, 9 male) served as fieldworkers, and two male experts were paired with eight subjects each. Each pair had a training trial and then an actual trial with each of two media conditions (HMD and WACL). Transcripts of the actual trials were made manually from video log data, and we counted the number of *morae* (*mora*: phonetic unit in Japanese), words on block selection/assembly, and words on the worker's position and the camera's view by participant role (expert/worker) and section.

3. RESULTS

The number of *morae* that experts uttered accounted for about 90% of all in both media conditions. There were significantly fewer *morae* uttered by experts in the headset condition than in the WACL condition (Wilcoxon signed rank test, $p = 0.03$), but there was no difference between the two conditions with the worker's speech. Accordingly, we focus here on the expert side. Figure 2-right shows the number of words on block selection/assembly and that on position/view by section and media condition. Experts used significantly fewer words on block selection/assembly in sections **A** and **HOME** with the headset condition than with the WACL condition, but there was no difference between two conditions in sections **B** and **C**. As for words relating to position/view; the number was significantly fewer in every section with the WACL condition than with the headset condition.

4. DISCUSSION AND FUTURE WORK

Although conversational analysis from two experts might not be statistically meaningful, these results agree with our hypotheses. In sections **A**, **B**, and **C**, the dominant task for workers was only to pick up the *block clusters* that experts needed. Visual assistance by pointing was valuable for the identification phase, but not that much for the procedural instruction given to workers in **HOME** section. Since experts were able to use line drawing on still images in the headset condition, they did not need to describe the details about the place and the direction of the *block clusters* to join. Both the experts commented that block assembly imposed more burdens on them in the WACL condition.

The tasks themselves at sections **A** and **B** were similar. However the visual cues used to find the *block clusters* was different (**A**: shape, **B**: color). The resolution of targets in images needs to be higher for identifying the object shape rather than the color. Since workers with the WACL had no means of confirming how the *block clusters* appeared in images unlike with the HMD, the experts sometimes sent misdirection to the workers due to the unclear appearance. This increased the number of words spoken for block selection in section **A**. A zoom mechanism or higher-resolution imaging sensors might help solve this problem.

Meanwhile, the experts had difficulty in observing everything at a glance in every section. In the headset condition, they often needed cooperation from the workers so that they were able to look at the workplace as they wished, and this increased the number of words spoken about position/view in each section.

It was found that the WACL interface induced communication asymmetries [1] which provided a better impression to the workers [3], and imposed more burdens on the experts when they needed to send detailed instructions. One practical means of redressing the asymmetries is to equip the WACL user with an additional display device for providing advanced visual assistance. A Shoulder-Worn Display (SWD) [5] may be suitable for this purpose since the SWD has the same advantages of the WACL, namely a hands-, eye-, and head-free interface. Another possibility is to use a MEMS mirror for scanning light beams to project detailed visual assistance directly on the real workplace.

ACKNOWLEDGEMENTS: This work is supported in part by Special Coordination Funds for Promoting Science and Technology from MEXT and by JSPS Postdoctoral Fellowships for Research Abroad (H15).

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