The Impact of Different Visual Feedback Presentation Methods in a Wearable Computing Scenario

Hendrik Iben[1], Hendrik Witt[1], and Ernesto Morales Kluge[2]

[1] Center for Computing Technologies, University of Bremen, Germany
{hiben,hwitt}@tzi.de
[2] BIBA - Bremen Institute for Industrial Technology and Applied Work Science, Bremen, Germany
mer@biba.uni-bremen.de

Abstract. Interfaces for wearable computing applications have to be tailored to task and usability demands. Critical information has to be presented in a way allowing for fast absorption by the user while not distraction from the primary task. In this work we evaluated the impact of different information presentation methods on the performance of users in a wearable computing scenario. The presented information was critical to fulfill the given task and was displayed on two different types of head mounted displays (HMD). Further the representations were divided into two groups. The first group consisted of qualitative representations while the second group focused on quantitative information. Only a weak significance could be determined for effect the different methods used have on the performance but there is evidence that familiarity has an effect. A significant effect was found for the type of HMD.

1 Introduction

We choose a simple task applicable to wearable computing scenarios were the information can be presented in different ways. This task serves as an abstraction for a real task in a similar way Witt and Drugge showed in [2006] by simulating a primary task. Participants were asked to calibrate a rectangular table by adjusting the height of the four table legs using an open-jaw wrench. The status of the calibration was represented by the angle formed between the floor and two orthogonal axes on the tables' surface. The deviation from the calibrated state on each axis was presented to the participants via a HMD while performing the adjustments. This task was chosen as an example for a typical maintenance scenario.

The goal of the study was to determine how the method of information representation and the use of either a monocular or binocular HMD affect the performance at the calibration task.

J.A. Jacko (Ed.): Human-Computer Interaction, Part III, HCII 2009, LNCS 5612, pp. 752–759, 2009.

1.1 Experiment Setup

The apparatus used in the study consists of a wearable computer (OQO), a MicroOptical SV-6 non-transparent HMD, a Zeiss ProVi 2D non-transparent HMD and a special textile vest designed and tailored to unobtrusively carry all equipment as well as all needed cabling for the HMD (figure 2). The task given to the participants consists of aligning a rectangular table with the floor. To accomplish this task, the height of the table legs has to be changed by turning

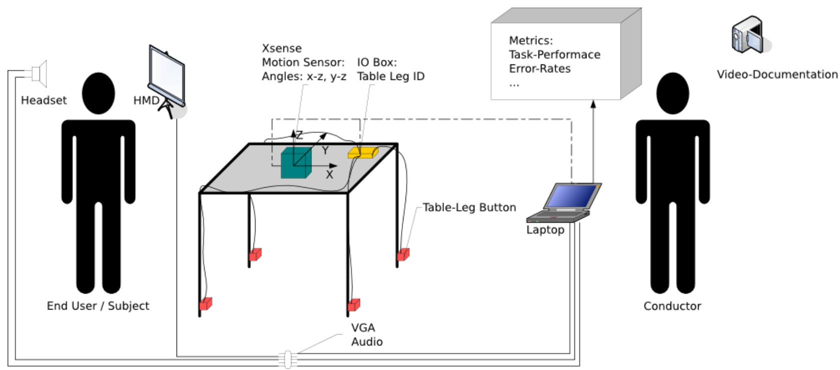


Fig. 1. Experiment setup

Fig. 2. Vest with wearable computing equipment

an adjustment screw with the open-jaw wrench. Ideally, this task can be solved in three steps by adjusting the height of three table legs to match the height of the remaining one. To measure the alignment of the table an XSense MT9 inertial sensor is used to acquire needed pitch and roll values. For the purpose of subject post-hoc motion analysis and to determine problem-solving strategies dependent on the feedback methods presented, a button is mounted to each leg of the table. Subjects have to press first the button mounted on the leg of the table to indicate their proceeding adjustment of the height adjustment screw of that particular leg. Button pressed events are logged in the central log file of each user. Figure 1 provides a schematic overview on the setup.

1.2 Representation Methods

Three different groups of representation methods were tested where in each group a qualitative and a quantitative method exists. The groups are *shape-based*, *bargraph*-based and *textual* representations.

Shapes
Qualitative shape feedback (figure 3) is based on the form or size of a shape that implies whether a certain threshold value has been reached. The calibration result is adjusted correctly when a (green) circle is displayed. Increasing deviation from the calibrated state is indicated by the representation morphing into a (red) triangle. The shape morphing is performed by removing vertices from the polygon approximating the circle until only three vertices remain. In the subjects' display this output modality is represented for each angle.

The quantitative shape based feedback (figure 4) used here consists of two needles that are correlated to the measured angle in the physical set-up. The area defined by the space between the two needles indicates the state of the measured object and the setup is adjusted correctly when a rectangular area can be seen. In addition to the graphical representation, the measured values are also displayed in text.

Bargraph-Area
The qualitative bargraph (figure 5a) has two axes which represent the two measured angles without any quantitative data and only with the modulus of the

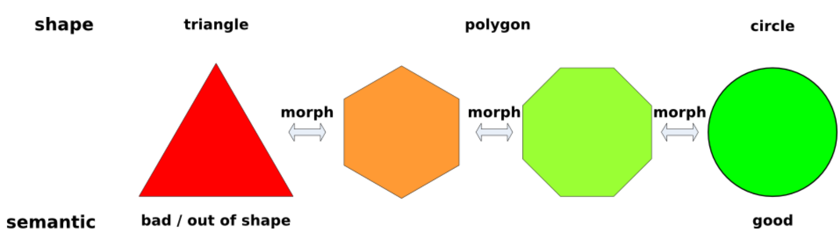


Fig. 3. Qualitative shape based feedback

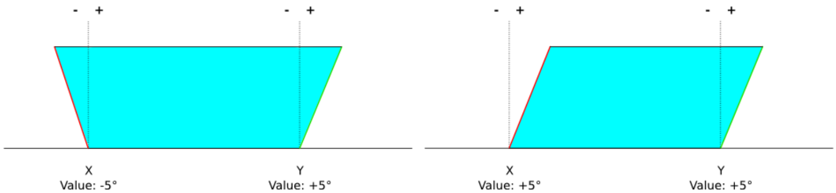
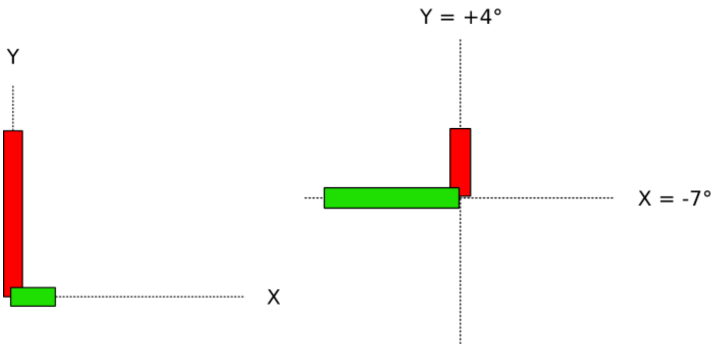


Fig. 4. Quantitative shape based feedback



(a) qualitative **(b)** quantitative

Fig. 5. Bargraph-area representations

measured value. The set-up is adjusted correctly when the graphs disappear in the origin.

The quantitative bargraph (figure 5b) covers a scale from negative to positive values for both axes. Furthermore the values are displayed at the axes, so that an explicit value can be read.

Textual-Feedback
The qualitative textual feedback is a message indicating whether the angles have to be increased or decreased. The screen will display 'increase' in case the value of the angle is lower than the desired value and 'decrease' in case the value is higher.

The quantitative textual feedback is realized by displaying explicit values on the display. For a measured value of e.g. -4 the system will display '-4'. When the system displays '0', the table has been calibrated on that axis.

2 Methods

A total of 20 subjects were selected for participation in the experiment. The study used a within subject design with the feedback method as the single independent variable, meaning that all subjects tested every method where the type of HMD was evenly distributed among the subjects. To avoid learning effects, the subjects were divided into counterbalanced groups where the order of methods differs. A single test session consisted of one practice round where the subject got to understand each feedback method, followed by one experimental round during which data was collected for analysis. The time to complete the primary task naturally varies depending on how quick the subject is. When comparing task completion times, the values were normalized. In the end of the experiment subjects were provided with questionnaires to record qualitative data used for later evaluation, e.g. to gain user acceptance measures. User acceptance was measured by asking the participants to rank all six methods according to their preference. This results in a rank of one to six for each method where one is used for the best method.

3 Results

The average task completion times (see table 1) for each presentation method have been computed for the two types of HMDs used and for the average of both groups.

Table 1. Task completion times

output device	TCT (s)			
	Shape qual.	Shape quan.	Bargrap qual.	Bargraph quan.
Monocular	131,21±71,20	132,08±67,37	135,66±44,82	129,57±103,64
Binocular	105,97±48,04	134,79±84,07	175,34±113,47	119,78±90,98
average	118,59±60,51	133,43±74,16	155,50±86,40	124,67±95,05

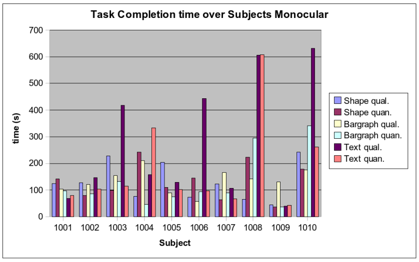
output device	TCT (s)	
	Text qual.	Text quan.
Monocular	274,77±226,66	180,92±175,36
Binocular	162,98±85,49	131,63±44,85
average	218,88±176,31	156,27±127,11

The results show large differences in the task completion time over all subjects regardless of the information presentation method (see figures 6a and 6b). There is also no clear difference between the percentage of time needed for each presentation method when using a monocular or binocular HMD (see figure 6c).

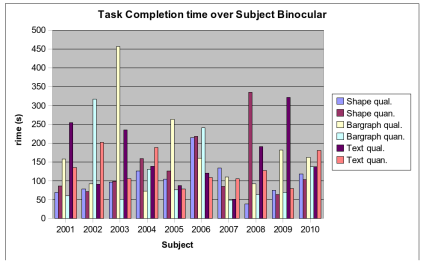
To verify whether the method or the type of HMD had a significant effect on the task completion times, a two-way ANOVA was performed.

For the type of HMD, a p-value of 0.203412 was calculated suggesting no significant effect on the times. A p-value of 0.056378 was calculated for the presentation method suggesting only a weak significance.

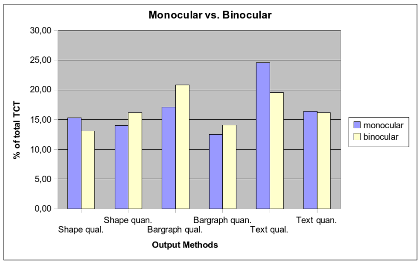
The combined effect of HMD and presentation type resulted in a p-value of 0.361591.



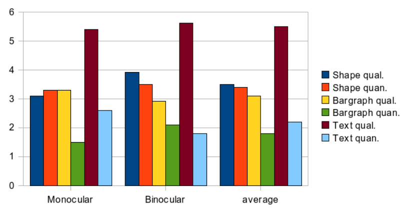
(a). task completion times, monocular



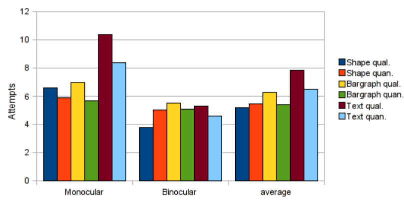
(b). task completion times, binocular



(c). comparison of task completion time



(d). subject preferences (lower is better)



(e). needed attempts

Fig. 6. Evaluations

Despite the statistical weakness when analysing the measurements the evaluation of the questionnaires draws in interesting picture (see figure 6d). When asked for their preference, the non-shape quantitative methods are ranked far better. Also the subjects have ranked the qualitative text representation to be the worst.

Participants ranked the presentation methods in this order (best to worst, average over both groups): Bargraph quantitative, Text quantitative, Bargraph qualitative, Shape quantitative, Shape qualitative, Text qualitative.

In addition to the task completion time the number of attempts to complete the task were also recorded (see figure 6e). An analysis of the average number of attempts needed shows a difference between the groups using monocular and binocular HMDs. A two-way ANOVA was performed on the average number of attempts needed resulting in a p-value of 0.0098 suggesting a significant effect. Users of binocular HMDs needed less attempts in all modalities where the modality with the least average attempts (3.8 attempts) needed was the qualitative shape based feedback method. Most attempts (5.3 attempts) were needed with the qualitative text based feedback method. For monocular HMDs the modality with less attempts (5.7 attempts) was the quantitative bargraph method. Most attempts (10.4 attempts) were needed with the qualitative text based method. On average, least attempts (5.2 attempts) were needed with the qualitative shape based method, while most attempts (7.85 attempts) were needed with the qualitative text based method.

The quantitative bargraph method was ranked as the best method on average by the participants and also the task completion time is lowest (on average) for this method. The number of needed attempts, while not lowest, is also very small compared to the other methods.

4 Discussion and Future Work

From a statistical point of view, no significant effect could be found for the type of the presentation method. Still the analysis suggest a higher relevance of the presentation to the task completion time. Evaluating questionnaires asking for a ranking of methods a clear preference for quantitative methods could be found while the text based qualitative method was ranked worst by far.

The participants best ranked method was the quantitative bargraph representation. While the quantitative shape based representation is very similar to this method (in terms of visual feedback) it was not ranked very good. A possible explanation can be given by taking into account that bargraphs are a very common and understood concept while the quantitative shape based method makes use of geometric properties to provide visual feedback. The method could have been rejected by the participants because it is an unfamiliar concept.

The use of binocular HMDs shows a significant decrease in the number of attempts needed to complete a task. It is still unknown what aspect causes this advantage. One possible explanation could be the expected effect of binocular rivalry associated with the use of monocular displays. A simpler possible explanation could also be that the used binocular HMD was easier to wear by the majority of the participants leading to a better performance. However, both argumentations do not explain the significant increase of needed attempts while no significant increase in completion time was observed.

Further studies should concentrate more on different aspects of information display in wearable computing scenarios and the differences of monocular and binocular HMDs with respect to the attention payed to the information. It is reasonable to assume that some presentation techniques are more efficient for certain types of information than others. An in-depth evaluation of presentation methods is necessary to find suitable methods for common types of information. It is unclear if it is possible compensate the negative effect of binocular rivalry when using monocular HMDs by presentation techniques. More studies have to be performed to find reliable presentation techniques for monocular and binocular HMDs in wearable computing scenarios. When designing information representation methods, the differences between the two types of displays and the conceptual approach to encoding the information have to be considered carefully.

Acknowledgements

This study was conducted in part of the WearIT@Work project which is funded in part by the Commission of the European Union under contract 004216 - WearIT@Work.

Reference

[2006] Witt, H., Drugge, M.: Hotwire: An apparatus for simulating primary tasks in wearable computing. In: Proc. CHI 2006: Extended Abstracts on Human Factors in Computing Systems (April 2006)