Investigation of the Optimal Interactive Methods for Natural User Interfaces

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ABSTRACT

The present study investigated the issues of performance and usability caused by joint-based interactive methods and CD gains with a Fitts task. Ten healthy participants performed multi-directional tapping tests with three joint-based interactive methods and three CD gains. The experimental results indicated that the joint-based interactive method and CD gain affected the performance indices and subjective usability ratings during a distal pointing task. The wrist-based interactive method is a better interactive method for tasks where pointing speed is the highest priority. The shoulder-based interactive method should be avoided in distal pointing tasks. The 1.7 CD gain, which was found to cause significantly higher MT and ER and lower TP and subjective usability rating scores than other two CD gains, should be avoided in distal pointing tasks. The elbow-based interactive method and 1.0 CD gain should be avoided when ID is higher than 5.79 bits; the shoulder-based interactive method is only suggested for use when ID is less than 3.56 bits; and 1.7 CD gain is not suggested for use when ID is between 3.56 and 5.79 bits. Furthermore, the best suggested CD gain range for the wrist-based interactive method is a range of more than 1.0. The optimal CD gain setting of the elbow-based interactive method is 0.6, and the 1.0 CD gain is feasible for the shoulder-based interactive method.

Keywords: Distal pointing, Joint-based interactive method, CD gain, Performance, Usability

1. Introduction

Natural User Interfaces (NUIs) are becoming common in both work and domestic environments. The most intuitive gesture for interaction with NUIs in extrapersonal space is distal pointing (Bateman et al., 2013). Using novel direct-pointing devices, users aim at a specific position, and visual feedback is provided by a cursor to indicate the focus point. This kind of interactive method is easy for novices to learn and understand, but it can cause physiological fatigue (Lin et al., 2016; Oh and Stuerzlinger, 2002) and may have poor accuracy (Kopper et al., 2010). These problems can make distal pointing a tiresome and inefficient selection method, particularly with smaller targets. Manipulating control-display gain (CD gain) has been reported to be an effective approach to improving performance of the distal pointing technique. However, no definitive picture of the impact of CD gain on performance and usability has been confirmed.

2. Method

PARTICIPANTS: Ten right-handed graduate students (eight males and two females, mean age = 25.8 years, SD = 2.9 years).

EXPERIMENTAL DESIGN:

The present study used a 3×3×3 repeated-measures design. The independent variables were joint-based interactive method (three levels: wrist-, elbow-, and shoulder-based interactive methods), CD gain (three levels: 0.6, 1.0, and 1.7), and index of difficulty (low, medium, and high). The dependent variables were movement time (MT), error rate (ER), throughput (TP), and subjective usability rating score.

3. Results

MT: There were significant differences in movement time among the interactive methods, CD gains, and IDs. Significant interactions of method-by-CD gain, method-by-ID, and CD gain-by-ID were found.

ER: There were significant differences in error rate among the CD gains, and IDs. A significant CD gain-by-ID interaction was found.

TP: There were significant differences in throughput
among the interactive methods, CD gains, and IDs. Significant interactions were found for interactive method-by-ID and CD gain-by-ID.

**USABILITY SCORES:** There were significant differences in usability scores among the interactive methods and CD gains. No significant interactions in the subjective usability ratings were found.

To further provide concrete guidelines for designers of systems that use distal pointing, the interactive methods, CD gains, and IDs were assessed in the following way. All methods, CD gains, and IDs were compared based on the post hoc comparisons of the one-way ANOVA procedure for the interactions, and comparisons were performed for MT, ER, and TP. Judged by statistical significance, one point was awarded for each better, and a negative point for each worse, method and CD gain. Table 1-3 summarizes the analytical results.

| CD Gain |
|---------|
| 0.6 |
| 1.0 |
| 1.7 |

**Table 1. Summarized scores for interaction of Interactive Method and ID.**

| Interactive Method | ID |
|--------------------|----|
| Wrist | 0.6 | 0.0 | 1.0 | 1.7 |
| Elbow | 2 | 3 | 4 |
| Shoulder | 2 | 3 | 4 |
| Low | 2 | 3 | 4 |
| Medium | 2 | 3 | 4 |
| High | 2 | 3 | 4 |

**Table 2. Summarized scores for interaction of CD gain and ID.**

| ID |
|----|
| Low | 0.6 | 1.0 | 1.7 |
| Medium | 0.6 | 1.0 | 1.7 |
| High | 0.6 | 1.0 | 1.7 |

**Table 3. Summarized scores for interaction of Interactive Method and CD gain.**

| Interactive Method | CD Gain |
|--------------------|---------|
| Wrist | 0.6 | 1.0 | 1.7 |
| Elbow | 2 | 3 | 4 |
| Shoulder | 2 | 3 | 4 |
| 0.6 | 1 | 2 | -1 |
| 1.0 | 2 | 0 | 0 |
| 1.7 | 2 | -2 | -4 |

**4. Conclusion**

Based on the results of the study, the following conclusions can be drawn. The wrist-based interactive method, which can substantially shorten movement time (MT), is a better interactive method for tasks where pointing speed is the highest priority. The shoulder-based interactive method caused the greatest MT, highest error rate (ER), and lowest throughput (TP), so it should be avoided in distal pointing tasks. From a usability perspective, participants mostly preferred the elbow-based interactive method, as indicated by the results on willingness to use, ease of use, and recovery from mistakes. The 1.7 CD gain, which was found to cause significantly higher MT and ER and lower TP and subjective usability rating scores than other two CD gains, should be avoided in distal pointing tasks. Based on the summarized subjective usability rating scores, participants preferred the 0.6 and 1.0 gains over the 1.7 CD gain due to better performance. Finally, our findings revealed several design issues and principles for the use of distal pointing techniques. The elbow-based interactive method and 1.0 CD gain should be avoided when the index of difficulty (ID) is higher than 5.79 bits; the shoulder-based interactive method is only suggested for use when ID is less than 3.56 bits; and 1.7 CD gain is not suggested for use when ID is between 3.56 and 5.79 bits. Furthermore, the best suggested CD gain range for the wrist-based interactive method is a range of more than 1.0. The optimal CD gain setting of the elbow-based interactive method is 0.6, and 1.0 CD gain is feasible for the shoulder-based interactive method.

**Acknowledgements**

This study was subsidized and supported by a Grant from the Ministry of Science and Technology, Taiwan, R.O.C. (Project No. MOST 105-2218-E-011 -009 -MY2), for which the authors are grateful.

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