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Effects of slanted ergonomic mice on task performance and subjective responses

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ABSTRACT

The biomechanical benefits (e.g., muscular activity) of slanted ergonomic mice have been comprehensively identified; however, their effects on task performance and subjective responses have not been fully investigated. The present study examined the effects of two slanted mice (slant angle = 30° and 50°) in comparison with a conventional mouse (slant angle = 0°) in terms of task performance (task completion time and error rate) and subjective responses (perceived discomfort score and overall satisfaction score). Experimental results showed that all of the task and subjective measures worsened as the slant angle of the target mice increases. For example, the task completion time (unit: ms) and overall satisfaction score (unit: point) of the 30° slanted mouse (time = 0.71, satisfaction = −0.09) and 50° slanted mouse (time = 0.73, satisfaction = −0.79) significantly deteriorated than the conventional mouse (time = 0.65, satisfaction = 1.21). The slanted mice seem to compromise biomechanical benefits with task performance and subjective responses.

1. Introduction

The computer mouse is commonly used with graphic user interfaces. Using a computer mouse comprises one- to two-thirds of total computer usage time (Cook et al., 2000; Lee et al., 2008). In addition, the most frequently used input device among computer users is the computer mouse (Cook and Kothiyal, 1998; Jensen et al., 2002; Muller et al., 2010).

The conventional computer mouse has been identified as a risk factor for upper extremity musculoskeletal disorders (WMSDs) and localized pain. The conventional mouse requires a user to pronate the forearm and to extend the wrist during operation (Gustafsson and Hagberg, 2003). The pronation of the forearm may result in the development of WMSDs (Zipp et al., 1983; Hagberg, 1997; Liao and Drury, 2000). The extension of the wrist increases carpal tunnel pressure (CTP), which would be a potential risk factor for carpal tunnel syndrome (CTS) (Keir et al., 1999; Fogleman and Brogmus, 1995; Bower et al., 2006; Mogk and Keir, 2007). In addition, the conventional mouse may lead to micro lesions in the low-threshold motor units because they have been continuously activated while using a computer mouse (called Cinderella Hypothesis; Crenshaw et al., 2007). Therefore, prolonged awkward posture and monotone movements can induce localized pain and discomfort on upper extremities (Muller et al., 2010; Cook and Kothiyal, 1998; Hedge et al., 2010).

Slanted ergonomic mice have been introduced to reduce the negative effects of the conventional mouse in terms of arm posture, muscular activity, and CTP. The key feature of the ergonomic mice is the slanted angle of the top surface from the left side to the right side. The slant surface, contacted with the palmar side of the hand, can significantly reduce forearm pronation and wrist extension (Muller et al., 2010; Chen and Leung, 2007; Hedge et al., 2010) as well as reduce demands on muscle recruitments in the upper extremities and CTP at the wrist (Gustafsson and Hagberg, 2003).

The slant surface of an ergonomic mouse can restrict performance during mouse usage tasks and can affect the level of subjective preference. Gustafsson and Hagberg (2003) reported that use of a vertical mouse (slant angle = 90°) decreased productivity by 24% in comparison with a conventional mouse. Furthermore, their subjective preference results showed that most of the participants preferred the conventional mouse more than the vertical mouse. Similarly, Scarlett et al. (2005) has revealed that use of a vertical mouse showed worse completion time and error rate than a conventional mouse by 10% and 20%, respectively.

Although the slant angle of a computer mouse seems to negatively affect the task performance and subjective preference, its effects haven't been comprehensively studied yet. Chen and Leung (2007) studied the relationship between slant angle and upper

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extremity muscle use, and suggested that the optimal slant angle is between 20° and 30°. However, they did not consider performance or subjective measures in the determination of optimal slant angle, although the results on physiological measures (e.g., EMG) may be different from performance and subjective measures (Niesen and Levy, 1994; Gustafsson and Hagberg, 2003). Therefore, to understand the benefits of the slanted ergonomic mouse in comparison with the conventional mouse, the effects of slant angle on task performance and subjective responses should be examined.

The present study investigated the effects of two slanted ergonomic mice (slant angle: 30° and 50°) on task performance and subjective responses in comparison with a conventional mouse (slant angle: 0°). To compare the performance and subjective responses among the target mice, an experiment consisting of two mouse-intensive tasks (pointing and dragging) was conducted with 40 participants.

2. Experimental methods

2.1. Participants

Forty participants in their 20s were involved in this study. Twenty of them were male and 20 were female. The average ages for male and female were 23.2 (SD = 2.6) and 21.7 (SD = 1.8) years, respectively. The dominant hand of all participants was the right hand. No participant had any muscular symptom or discomfort on the experimental day. The average hand lengths of male and female were 18.1 (SD: 7.5) cm and 17.2 (SD: 7.7) cm, which are similar to those of Korean male (mean: 18.6, SD: 8.1) and female (mean: 17.5, SD: 7.8) in their 20s. None of them had experience using a slanted mouse before this experiment.

2.2. Experimental design

This study included two independent variables: mouse type (3 levels) and mouse task (2 levels). The mouse type consisted of three levels (Fig. 1): *CM* (slant angle = 0°), *SM30* (30°), and *SM50* (50°). The two slanted mice (SM) with different slant angle at the top surface were selected. As the conventional mouse (CM), a popular and common mouse was chosen. The target mice had slightly different specifications in overall size and weight as displayed in Table 1.

The mouse task was comprised two levels: pointing task (*PT*) and dragging task (*DT*). The PT as shown in Fig. 2a is to move a mouse arrow toward a target button (size: 1 cm × 1 cm) and then click it. The DT as displayed in Fig. 2b is to move a mouse arrow to a movable object (size: 1 cm × 1 cm), and to drag that object into the target region (size: 1 cm × 1 cm). The positions of all the objects in the PT and DT were randomly decided.

There were four dependent variables in the present study: task completion time (*Time*), error rate per 15-trials (*Error*), perceived discomfort score (*Discomfort*), and overall satisfaction score (*Satisfaction*). The Time was measured from the starting time to the ending time of a task. The Error was calculated by the number of errors made during 15 trials of a task. The Discomfort was obtained for each part of the arm (Fig. 3a) with Borg's CR-10 scale (Fig. 3b; Borg, 1998; Kwon et al., 2009). Lastly, the Satisfaction was obtained using a 7-point bipolar scale (Fig. 3c; Tuorila et al., 2008).

Table 1
Specifications of the target mice.

Mouse type	Slant angle (°)	Size (cm)			Weight (g)
		Width	Length	Height	
CM	0	5.5	11.0	3.5	80
SM30	30	7.3	10.6	5.2	120
SM50	50	8.2	10.0	8.0	130

Experimental software was developed using Visual Basic 6.0 (Microsoft, USA), which automatically randomizes the presentation order of experimental conditions and records the task performance (Time and Error). In order to confirm that the positions of the button and movable object, presented in the PT and DT, were randomly decided across the experimental conditions and participants, the software was designed to record their positions.

A desktop computer, operated by Window XP, was used in the experiment. A computer screen (19 inch) was located on about 60 cm from the eyes, and a standard keyboard was placed on about 40 cm from the participant. The experimental mouse was set on the right side of the keyboard. The table height was 70 cm from the floor and the seat height was adjusted by the participants to fit their body sizes.

The experimental procedure followed four steps. In the first step, informed consent was secured and the experimental purpose was well informed to the participant. In the second step, sufficient practice (180 trials: 3 (mouse) × 2 (task) × 30 (repetition)) was allowed to accustom each participant to the experimental tasks and the target mice. In the third step, two sessions of the main experiment (360 trials: 2 (session) × 3 (mouse) × 2 (task) × 30 (repetition)) were conducted. A 5-min break was allowed between sessions to minimize fatigue effect. The presentation order of all experimental conditions was randomized by the experimental software. During the second session, the Discomfort on each part of the arm was obtained. In the final step, the Satisfaction on the three mice was surveyed and an in-depth debriefing was completed.

2.3. Statistical analysis

All statistical tests were conducted by Minitab v16.0 (Minitab Inc., USA) with a 0.05 confidence level. Two-factor (mouse type and mouse task) within-subject ANOVA on the task and subjective measures were conducted to test the effects of mouse type and mouse task. Partial eta^2 ($\eta^2_{partial}$) on significant factor has

Fig. 1. Target mice used in the experiment.

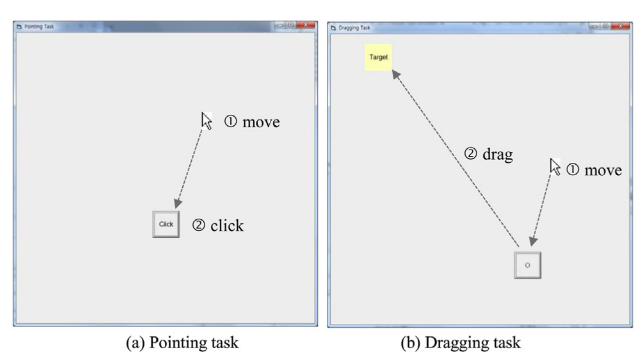


Fig. 2. Experimental tasks.

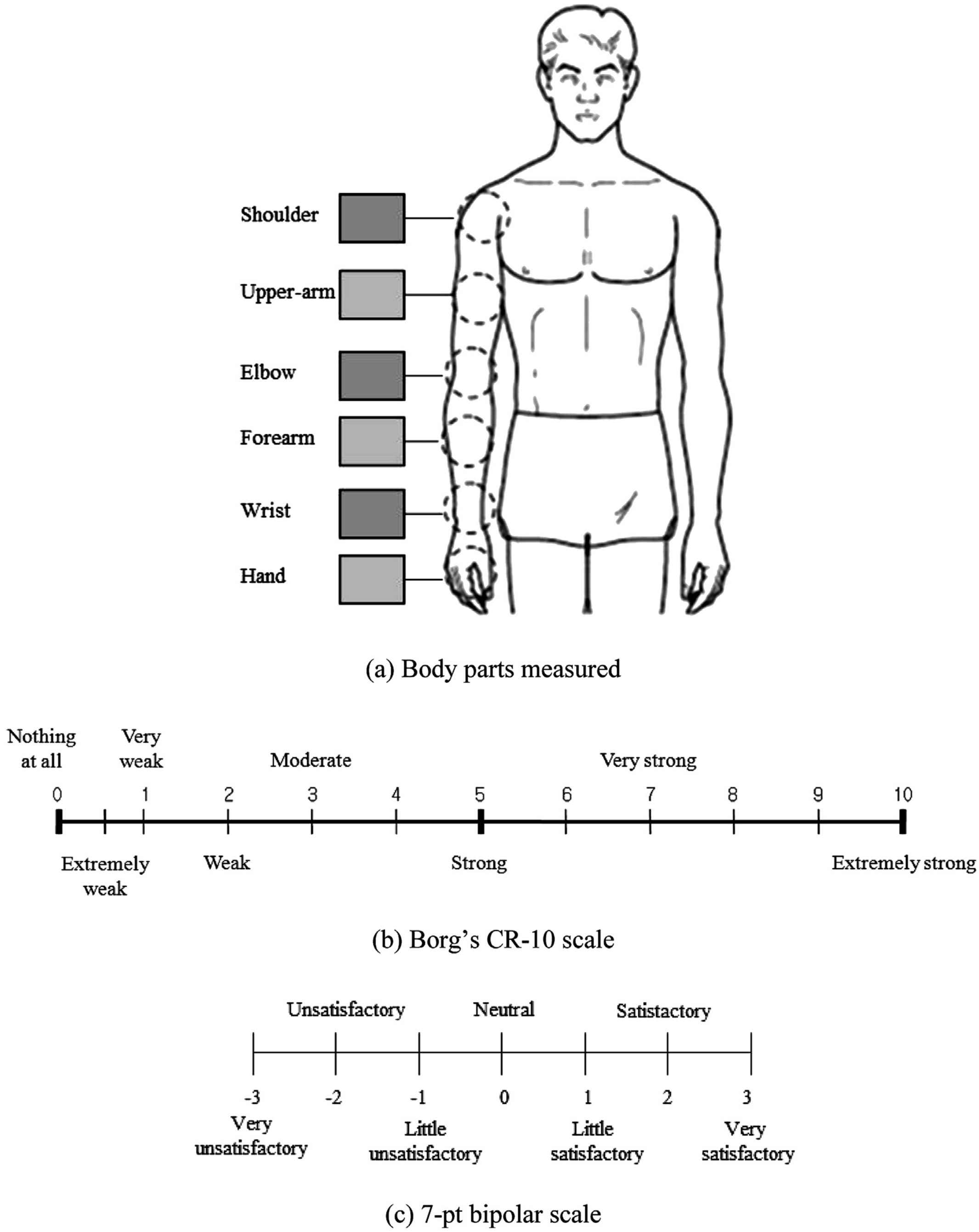


Fig. 3. Body parts and measurement scales for subjective responses.

been provided for the reference of effect size. In addition, *t*-test was completed on the pointing and dragging distance results, which were randomly determined by the experimental software. The *t*-test revealed no significant bias in the pointing and dragging distances across the experimental conditions or participants.

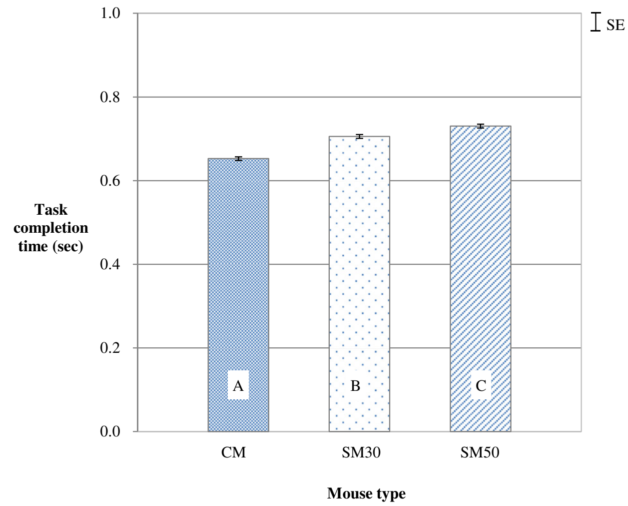
3. Results

3.1. Time and Error

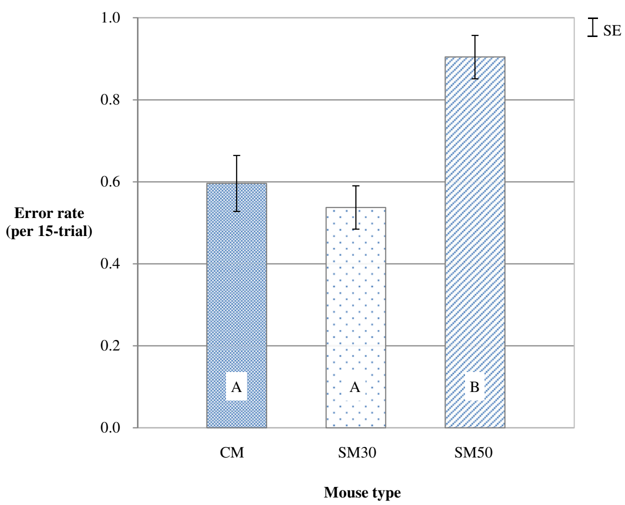
The Time (unit: s) of the CM ($\bar{x} \pm$ SE: 0.65 $\pm$ 0.005) was shorter than the Times of SM30 (0.71 $\pm$ 0.005) and SM50 (0.73 $\pm$ 0.005), respectively (Fig. 4a). Although the differences in Time among the three mice were small (max. difference = 0.07), they were significantly different from each other ($F(2, 78) = 64.0$, $p < 0.01$; $\eta^2_{\text{partial}} = 0.58$).

The Error (unit: number of errors per 15-trial) of the SM30 (0.54 $\pm$ 0.05) was smaller than the Error of the CM (0.60 $\pm$ 0.06) and SM50 (0.90 $\pm$ 0.07), respectively (Fig. 4b). The average difference (0.06) in Error between the SM30 and CM was small and not statistically significant, but the average difference (0.36) between SM30 and SM50 was relatively larger and significant ($F(2, 78) = 10.8$, $p < 0.01$; $\eta^2_{\text{partial}} = 0.19$).

The Time of the PT (0.59 $\pm$ 0.002) was significantly shorter than that of the DT (0.80 $\pm$ 0.005) ($F(1, 39) = 903.0$, $p < 0.01$;



(a) Task completion time



(b) Error rate per 15-trial

Fig. 4. Task performance with the target mice. (Alphabet letters indicate significant differences at $\alpha = 0.05$).

$\eta^2_{partial} = 0.95$). In addition, the Error of the PT (0.35 ± 0.06) was significantly smaller than that of the DT (0.68 ± 0.04) ($F(1, 39) = 142.2$, $p < 0.01$; $\eta^2_{partial} = 0.76$). Lastly, the interaction effect between task type and mouse type was not significant.

3.2. Discomfort and Satisfaction

The Discomfort across all parts of the arm increased as the slant angle of the mice increased (Fig. 5a). For example, in the wrist joint, the Discomfort of the CM (2.21 ± 0.27) was significantly smaller than those of the SM30 (3.00 ± 0.36) and SM50 (3.15 ± 0.37) ($F(2, 38) = 3.8$, $p = 0.03$; $\eta^2_{partial} = 0.09$). The Discomfort of the lower part of the arm (2.36 ± 0.10) was significantly higher than that of the upper part of the arm (1.39 ± 0.07) regardless of the mouse type. The most severe Discomfort was observed at the wrist joint (2.8 ± 0.20).

Similarly, the Satisfaction significantly decreased as the slant angle increased (Fig. 5b) ($F(2, 78) = 29.3$, $p < 0.01$; $\eta^2_{partial} = 0.39$). The Satisfaction with the CM (1.21 ± 0.17) was higher than that of the SM30 (-0.09 ± 0.23) or SM50 (-0.77 ± 0.22).

3.3. Relationships of Satisfaction with Discomfort, Time, and Error

The Satisfaction was negatively correlated with Discomfort, Time, and Error. The correlations between Satisfaction and Discomfort on all body parts showed negative relationships: hand ($r = -0.52$, $p < 0.01$), wrist ($r = -0.46$, $p < 0.01$), upper-arm ($r = -0.42$, $p < 0.01$), lower-arm ($r = -0.39$, $p < 0.01$), shoulder ($r = -0.31$, $p < 0.01$), and elbow ($r = -0.27$, $p < 0.01$). Similarly, negative correlations between Satisfaction and the task performance measures were observed: Time ($r = -0.19$, $p = 0.02$) and Error ($r = -0.17$, $p = 0.04$).

4. Discussion

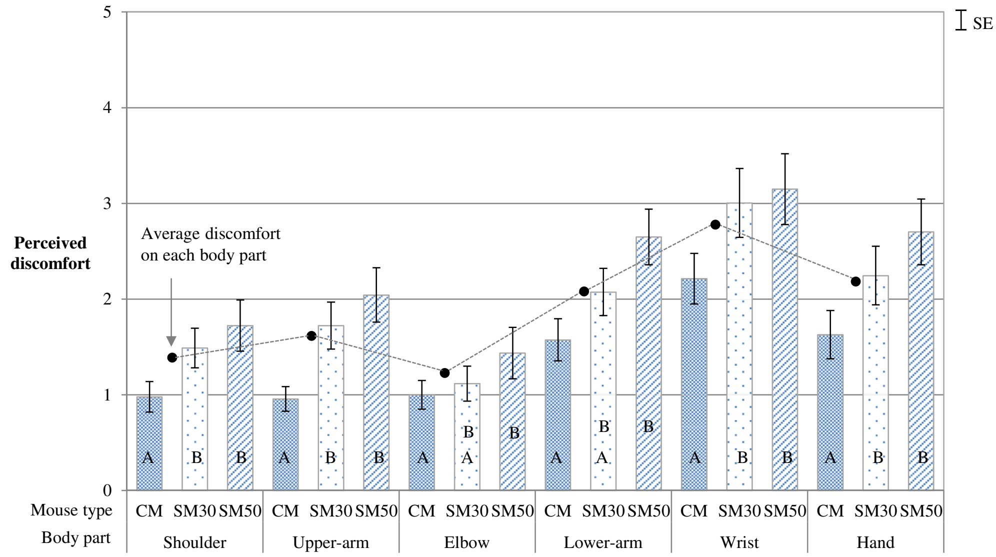
The actual differences among the task performances of the three mice were small, although they were statistically significant. The maximum difference in Time among the three mice was only 0.07 s (% difference = 11). The max difference of the Error was only 0.37 per 15 trials. This small performance decrement for the new type of mice was already reported in previous studies. Gustafsson and Hagberg (2003) found that a vertical mouse (slant angle = 90°) decreased a ~24% productivity in comparison with a conventional mouse during a document editing task. Muller et al. (2010) showed that a pen-type mouse had about 14% worse performance than a conventional mouse in pointing and dragging tasks.

The participants didn't prefer to the slanted mice in comparison with the CM. The Satisfactions on the two slanted mice (SM30 = −0.09; SM50 = −0.77) were all negative, indicating slight dissatisfaction. Contrary, the Satisfaction of the CM (1.21) was a positive value, which indicates slight satisfaction. This trend in user satisfaction for the new type of mice corresponded with previous studies' results for a vertical mouse (Gustafsson and Hagberg, 2003) and a pen-type mouse (Muller et al., 2010).

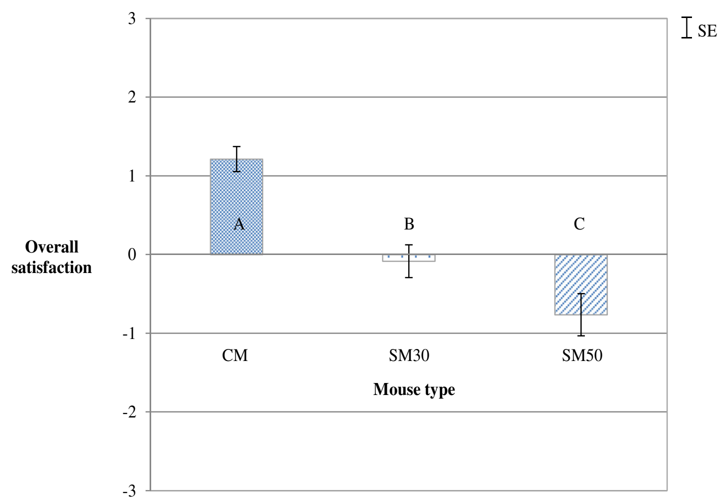
The in-depth debriefing of the present study provided a cogent reason for the decrease in Satisfaction with the slanted mice. Most of the participants emphasized that the slanted mice required excessive use of wrist deviation during operation in comparison with the CM. In addition, some of the participants claimed that wrist deviation motion in the neutral forearm position (0°) was harder than that in the pronated forearm position (90°). This subjective opinion may result from the reduction of the range of motion (ROM) at the wrist joint while forearm pronation (Chaffin et al., 1999).

The results of the present study were possibly contaminated by confounding design specification of the target mice. Since the present study used the three mice available in the market, the design specifications such as overall weight and size, which were not focused on this study, could not be perfectly controlled across the target mice. For example, the slanted mice were slightly heavier (SM30 = 120 g, SM50 = 130 g) and bigger (SM30 = 7.3 × 10.6 × 5.2, SM50 = 8.2 × 10.0 × 8.0; unit: cm) than the CM (80 g, 5.5 × 11.0 × 3.5). These differences might affect the experimental results.

Although the slanted mice were slightly heavier and bigger than the CM, they still have a biomechanical benefit in terms of muscular activity. As a follow-up study, the effect of the slanted mice on the muscular activity of extensor carpi radialis (ECR), which relates to wrist extension and deviation motions (Chen and Leung, 2007; Agarabi et al., 2004), had been investigated for a single participant. A root mean square (RMS) analysis for that participant showed that mean RMS values of the SM30 (24.1 mV) and SM50 (28.1 mV) were lower than that of the CM (36.6 mV) during the PT and DT. This indicated that the slanted mice required less muscular activities in comparison with the CM, although they were slightly heavier and bigger. The similar tendency was already found in Chen and Leung (2007) who investigates EMG signals on different slanted mice (slant angle = 0°, 10°, 20°, 25°, 30°) with different weights (range = 80.7 g–100.1 g).



(a) Perceived discomfort score for each body part



(b) Overall satisfaction score

Fig. 5. Subjective responses with the target mice. (Alphabet letters indicate significant differences at $\alpha = 0.05$).

Long-term use of the slanted mice may improve task performance due to learning effect (Kotani and Horii, 2003), but the slanted mice still have a weakness in comparison with the CM. As a follow-up experiment, the present study conducted the same experiment with a participant who had been using one of the slanted mice (SM50) for three months. The participant began to use the slanted mouse due to neck and shoulder pain caused by extensive use of a conventional mouse. She was totally satisfied with the slanted mouse and believed that it significantly relieved her pain as reported in Aaras et al. (2001). However, the experimental results of that participant showed that the task performance of the slanted mice (mean: 0.83) was still worse than that of the CM (mean: 0.56). This result agreed with what was found by Straker et al. (2000).

Acknowledgments

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