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Effect of Shape of Pen on Usability

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Abstract— **Using electromyography (EMG) analysis and psychological rating, the usability of pen was evaluated. The experimental factors were the pen diameter (three levels:8mm, 11mm, and 13.8mm). The length of pen tip was fixed to 14mm. Surface EMG was recorded from extensor digitorum and flexor digitorum superficialis. The EMG before and after a long-hour writing task was measured to evaluate the fatigue of forearm using %MVC (Mean Voluntary Contraction), mean power frequency (MPF) and psychological rating on usability. Concerning %MVC and MPF, the difference before and the experimental task were used for the evaluation. The evaluation value corresponded to subtraction of value after the experimental task from that before the experimental task. As a result of a one-way (pen diameter) ANOVA, no significant main effects of pen diameter were for both EMG evaluation measures. As for the psychological rating on usability, Kruscal-Wallis non-parametric test was carried out. The psychological rating on ease of grip revealed a significant main effect of pen diameter. A pen with a diameter of 11mm was found to have a significant higher rating score. Keywords: universal design, usability, EMG, pen diameter, length of pen tip, psychological rating.**

I. INTRODUCTIONS

There are many studies that made an attempt to evaluate physical workload or fatigue on the basis of surface EMG [1]-[6]. In these studies, integrated EMG, root mean square of EMG, or spectral analysis of EMG is used to evaluate physical fatigue or workload. Harvey et al.[7] investigated how the rate of rise in integrated EMG (iEMG) activity changed with time during cycling, and provided a measure to evaluate fatigue.

With the integration of personal computers into many workplaces, the reports of computer related upper extremity musculoskeletal pain has increased [7]. In spite of relatively low and light workload as compared with predominantly physical work such as lifting or repetitive muscular activity, computerized work includes both mental and physical workload, and induces computer related pains and injuries such as computer related disorder (CRD), cumulative trauma disorder (CTD), repetitive strain injury (RSI), and upper extremity musculoskeletal disorder (UEMSD). These disorders account for 50% of all work related injuries in office settings. There are many studies that tried to evaluate physical workload or fatigue and protect computer related pains and injuries [7]-[15]. These studies can be mainly classified into two categories: reduction of workload or fatigue when using a keyboard and reduction of workload or fatigue when using a mouse. Harvey at al.[7] examined, using surface EMG from right upper trapezius, right posterior deltoid, right lower tarapezius/rhomboids, and left sternocleidomastoid/scalene, muscle tension and subjective muscle tension awareness while using a computer mouse. They predicted that upper extremity musculoskeletal disorder (UEMSD) and computer related disorder (CRD) will increase when we abduct our arms to reach a mouse positioned to the side of standard width. Lee et al.[8] designed and tested alternative computer mouse designs and attempted to reduce extensor muscle loading of the index and middle fingers by altering the orientation of the button switch direction and the force of switch. Using %MVC, they showed that the alternative mouse design reduced sustained extensor muscle loading; however higher flexor muscle loading was induced and performance decreased. Simoneau et al. [9] examined the systematic effect of varying the slope angle of a computer keyboard along with varying keyboard height on wrist extension angle while typing. They showed that as keyboard slope angle moved downward from 15 to -15 deg, mean extension decreased approximately 13 deg. Keyboard height had a similar effect with mean wrist extension decreasing from 21.8 deg (when the keyboard was lower than elbow height) to 7.3 deg (when the keyboard was higher than elbow height). They concluded that the downward sloping of computer keyboards could possibly be beneficial in the prevention of musculoskeletal disorders.

A large shift in personal computer operations has reduced the opportunity to write with a pen, and thus we are apt to easily feel fatigued during a long-term writing with a pen. Many ergonomic approaches are tried to develop a usable and comfortably writable pen. However, it has not been systematically explored how the pen diameter or the length of pen tip which is related to the support of thumb, index finger and middle finger. Scientific (ergonomic) approach to identify parameters that affects the usability of pen would be helpful to the good design of a pen.

The aim of this study was to identify a pen diameter that is evaluated to be usable from the viewpoints of both EMG analysis and psychological rating on usability. Evaluation measures were %MVC and MPF obtained from EMG measurements and psychological rating on ease of grasp, comfort in writing and extent of fatigue. The experimental task was to write a pre-specified Japanese character for 10 min. On the basis of the experimental results, what characteristics a usable pen should be equipped with.

II. METHODS

Participants

Five male undergraduates from Okayama University participated in the experiment. The mean age of the participants was 23.2 years. Four of them were right-handed. The mean height and weight of the participants were 169.0cm and 62.4kg, respectively. The mean grip force by a dominant hand of the participants was 43.9kg.

Task

The photo of pens used in the experiment is shown in Photo.1. The length of a pen tip was fixed to 14mm. Three pen diameters were used: 8mm, 11mm, and 13.8mm. The outline of pen characteristics (pen diameter and length of pen tip) is illustrated in Figure 1.

The task was to write a single Japanese character on a paper for ten minutes with each pen.

Design and Procedure

Electromyographical (EMG) activity was acquired with measurement equipment shown in Figure 2. An A/D.

Photo 1. Pens used in the experiment.

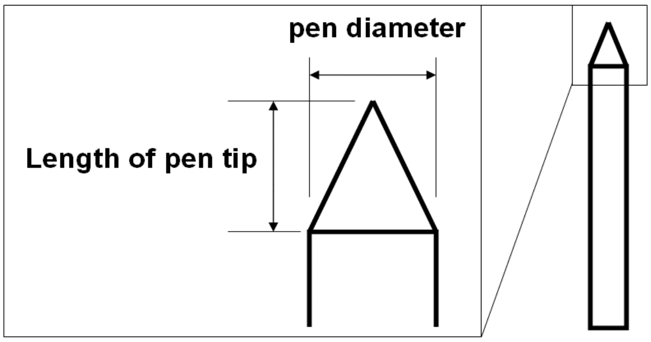

Figure 1.Outline of pen characteristics (pen diameter and length of pen tip).

instrument PowerLab8/30 and bio-amplifier ML132 were used.

Surface EMG was recorded using A/D instrument silver/silver chloride surface electrodes (MLAWBT9), and sampled with a sampling frequency of 1kHz. The frequencies of low pass and high pass filters were set to 100Hz and 1Hz, respectively.

A completely within-subject design was used. An experimental factor was a pen diameter with three levels (8, 11, and 13.8mm). Before starting a writing task, maximum voluntary contraction (MVC) was measured by griping a hand dynamometer with maximum possible force or exerting maximum possible power under pressing the back of the dominant hand. Immediately after the writing task, a similar procedure was repeated. During the writing task, EMG was not recorded. Only before and after the writing task, EMG was measured. The two active electrodes were placed 3cm apart for extensor digitorum communis and flexor digitorum superficials.

The order of performance of three diameter conditions was randomized across the participants. The writing task for each pen diameter was continued for 10 min. After each writing task was completed, the psychological rating on ease of grip, ease and comfort in writing and extent of less fatigue was evaluated using a five-point scale (1:very poor, 5:very good).

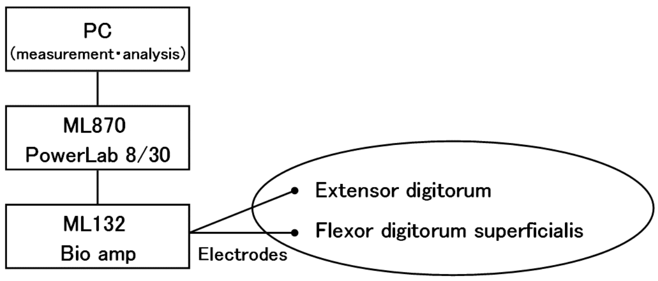

Figure 2. Outline of measurement apparatus.

III. RESULTS

EMG analysis

The evaluation value was obtained as follows. FFT was carried out on EMG data consisting of 1024 measurements. MPF can be calculated as follows.

$$MPF = \frac{f_i pow_i}{\sum pow_i} \qquad (1)$$

where f_i and pow_i are frequency and corresponding power, respectively. As for MPF, it is well known that it decreases with the accumulation of fatigue [16]. The evaluation measure on MPF corresponds to subtraction of value after the experimental task from that before the experimental task. If MPF after the experimental task decreases relative to that before the experimental task, it means that fatigue was induced by task loading. The percentage of EMG measurement before or after the experimental task relative to EMG at the maximum voluntary contraction was calculated as %MVC. If fatigue is induced by a writing task, %MVC after the experimental task is expected to be lower than that before the experimental task. As for %MVC, therefore, the evaluation index was obtained by subtraction %MVC after the experimental task from that before the experimental task. For both MPF and %MVC indices, the larger the index is, the heavier the induced fatigue is.

In Figure 3, the evaluation index (MPF) is shown as a function of pen diameter for both extensor digitorum communis and flexor digitorum superficials. In Figure 4, the evaluation index (%MVC) is shown as a function of pen diameter for both extensor digitorum communis and flexor digitorum superficials. As a result of a one-way (pen diameter) ANOVA (Analysis of Variance) carried out on both evaluation indices, no significant main effects of pen diameter were detected.

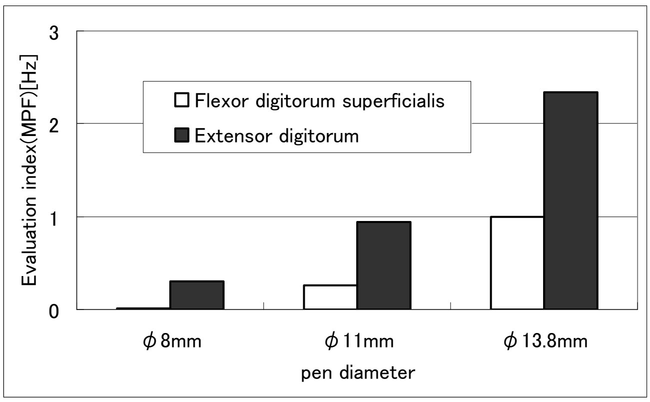

Figure 3. Evaluation index (MPF) shown as a function of pen diameter for both extensor digitorum communis and flexor digitorum superficials.

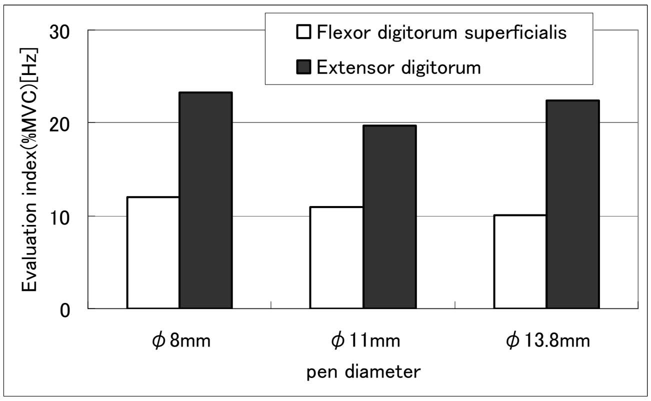

Figure 4. Evaluation index (%MVC) shown as a function of pen diameter for both extensor digitorum communis and flexor digitorum superficials.

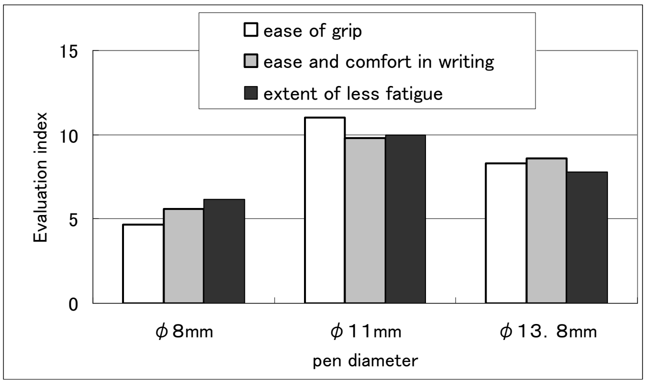

Figure 5. Mean rating scores for ease of grip, ease and comfort in writing and extent of less fatigue as a function of pen diameter.

Psychological rating on usability

As for the psychological rating on usability, Kruscal-Wallis non-parametric test was carried out. The psychological rating on ease of grip revealed a significant main effect of pen diameter. A pen with a diameter of 11mm was found to have a significant higher rating score. In Figure 5, the mean rating scores for ease of grip, ease and comfort in writing and extent of less fatigue are plotted as a function of pen diameter.

IV. DISCUSSION

As shown in Figure 3, it tended that the evaluation index (MPF) for both extensor digitorum communis and flexor digitorum superficials was larger when the pen diameter was 13.8mm, although no significant main effect of pen diameter was detected. Now in Japan, it is believed and commercially advertised that the pen with larger diameter is easy to write. We must be cautious to conclude that a pen with a diameter of 13.8mm is easy and comfortable to write and to induce less fatigue. As far as the results in this study is concerned, a pen diameter of 13.8mm which are believed to assure high usability and comfort no longer led to higher evaluation, rather led to lower evaluation.

The diameter did not affect the evaluation index(%MVC). This measure %MVC reflects the physical workload, because gripping a hand dynamometer with maximum possible power is clearly different from that with about 50% maximum possible power. Writing for 10 min by a pen is not so high in its workload. This index might be proper not for the evaluation of fatigue but also for the evaluation of physical workload. Therefore, it can be inferred that the clear differences were not detected.

As shown in Figure 5, a pen with a diameter of 11mm was found to be more highly evaluated than other pens with different diameters. In particular, a significant main effect of pen diameter was detected for the ease of grip. Combining the results in Figure 3 and Figure 5, it might be concluded that a pen diameter assures high comfort and less fatigue.

aFuture research should also measure pen pressure and classify participants according to pen pressure level in order to investigate the effect of pen diameter on usability in more detail and systematically. More longer writing task was imposed on participants, and the effects of pen shape on usability should also be explored.

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