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ERGONOMIC PLACEMENT OF LARGE SHARED VISUAL DISPLAY BY ELECTROMYOGRAPHY

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Abstract. *This study evaluates the activity of the sternocleidomastoid (SCM) muscle when monitoring information displayed on large shared visual display (LSVD) and recommends proper position for LSVD. Many studies have conducted ergonomic evaluation for single and regular sized monitors by analyzing electromyography (EMG). Ergonomic assessment for LSVD was performed in the study. Eighteen participants gazed static information presented on the wall and EMG activities were recorded from the SCM muscle. Both fixed and swivel chairs were provided for the experiment. EMG was normalized to peak maximum contractile for the muscle (%MVC) and analyzed. Totally twelve positions were selected and examined for LSVD. Borg rating of perceived exertion (RPE) was also measured to assess the subjective psychophysical exertion due to the placement of LSVD. EMG was proportional to the lateral rotation of head regardless of the type of chairs. Swivel chair was somewhat effective to reduce EMG activity of SCM muscle. The intensity of SCM muscle activity would be substantial if LSVD is placed 60° + left and 45° + high with a fixed chair. We recommend frequently monitored LSVD should be located within 45° to the both left and right directions. 30° would be preferred and 45° could be acceptable in the vertical direction for the position of LSVD.*
Keywords: Electromyography, Sternocleidomastoid, Large shared visual display

1. **Introduction.** Ergonomic design is very significant for control room because safe and efficient operation is potentially dependent on human factors [1]. ISO 11064 is widely used to design ergonomic control room [2,3].

Large shared visual display (LSVD) is commonly used in control room to support group interactions, group process, and team work [4]. ISO 11428 recommends placing LSVD at directly front of operators and operators can easily monitor LSVD without rotating their heads. ISO11064-3 also recommends the information presented on LSVD can be seen from normal working position for both vertical and horizontal planes. However, each LSVD cannot be placed directly front of the operator because multiple LSVDs are normally installed and utilized in a control room.

LSVD is also widely used to deliver information in public places. Although public information is monitored relatively short time and intermittently, the position of LSVD is very important. We have experience to bend our head back to see LSVD to check information such as airplane and train arrival and departure time, and public advertisement, because LSVDs are usually built in high place.

Sternocleidomastoid (SCM) muscle is directly related to lateral and medial rotation, flexion and extension of the head [5-9] and work-related musculoskeletal disorder (WMSD) [10,11]. It is reported WMSD is experienced by approximately 33% of visual display terminal (VDT) operators [12]. The activity of SCM muscle was measured to evaluate work by surface EMG in this study [9,13]. Head extension and rotation is required to monitor LSVD when positioned not direct front of operators or observers. Long-lasting and static head rotation and extension can cause WMSD [9].

LSVD might be a significant cause of WMSD but regular PC and laptop monitors have been mainly studied [14-16]. We investigated the activity of SCM muscle due to the positions of LSVD and recommended proper installation spots for LSVD.

2. Method.

2.1. Apparatus. The electrical activity produced by right and left SCM muscle was measured using a four channel surface EMG (QEMG-4, LXM 3204; LAXTHA Korea). Bipolar self-adhesive Ag/AgCl surface electrodes were attached on the SCM muscles (Figure 1) after cleaning the skin with 80% alcohol.

Figure 1. SCM muscles with EMG electrodes attached

EMG of SCM muscles were sampled at 1000 Hz and band-pass filtered with a bandwidth of 20$\sim$1000Hz and high pass.

2.2. Participants. Twenty university students (13 men and 7 women) participated in the experiment and their ages ranged from 22 to 27 (M = 24.44, SD = 1.46). Approximately 30 US dollars were paid to the participants for the experiment. All participants reported having normal or corrected normal eye sight. We excluded students having a history of neck, shoulder, or back pain or a trauma from the experiment. We informed the subjects about the experiment and informed consent was obtained before the experiment.

2.3. Experimental design. The experiment was designed as a $2 \times 2 \times 3$ completely randomized factorial design to examine the effects of gaze direction and height. Independent variables were vertical deviation (30° and 45°), rotational direction (left and right), and horizontal deviation (30°, 45° and 60°). Dependent variables were activity of SCM muscle and perceived exertion.

Maximal isometric axial rotation strength of SCM muscle was measured for normalizing the EEG data. Twelve positions were selected for the eye gaze fixation by combining left and right side directions (30°, 45° and 60°) and vertical upward directions (30° and 45°) as shown in Figure 2. Numerical information was presented on the 12 positions on the stage wall in an auditorium. Both fixed and swivel chairs were examined in the experiment.

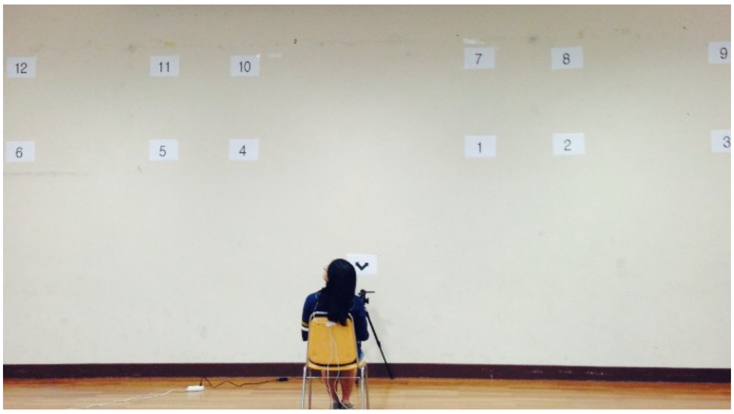

Figure 2. Snapshot of experiment

2.4. **Procedure.** Subjects were explained about the experiment. The participants first conducted their maximal isometric voluntary contraction (MVC) of SCM muscle.

The participants were then requested to stare on the target located just direct of them at sitting eye height. They were then asked to stare at the randomly selected position in random order. The participants gazed at the selected position at least for 5 seconds and their SCM muscle activity was measured.

Perceived exertion was measured by using a questionnaire after measuring the activity of SCM muscle.

3. **Results.** Muscle activity was measured, rectified, normalized, and analyzed in order. $EMG\%_{MVC}$ was calculated by normalizing EMG amplitude to the peak EMG value found during maximal voluntary contraction for SCM muscle [17].

The intensity of muscle activity was arbitrarily ranked as light ($< 3\%_{MVC}$), moderate ($3\%_{MVC} \leq EMG \leq 8\%_{MVC}$), and substantial ($> 8\%_{MVC}$) [18]. The assumption of normality for EMG data were satisfied using Kolmogorov-Smirnov test.

3.1. **Fixed chair.** A repeated-measures ANOVA was conducted to evaluate the effects of horizontal and vertical locations of gaze. Main effects of factors and interactions were assessed using the multivariate criterion of Wilks's lamda (Λ).

The multivariate test indicated significant main effect for rotational direction, $\Lambda = .58$, $F(1, 9) = 6.50$, $p<.04$, horizontal deviation, $\Lambda = .16$, $F(2, 8) = 21.46$, $p<.01$, and interaction between horizontal and vertical deviation, $\Lambda = .51$, $F(1, 9) = 8.56$, $p<.02$. Gazing at left side by rotating the head increased SCM muscle activity more significantly than right side. Table 1 shows $EMG\%_{MVC}$ for the various locations of monitoring.

Table 1. $EMG\%_{MVC}$ due to the placement of gaze with fixed chair

Vertical deviation	Left			Right			Vertical deviation
	6°	45°	30°	30°	45°	60°	
45°	8.93 (1.82)	6.12 (2.29)	5.24 (3.03)	3.10 (.92)	3.87 (.97)	5.98 (1.93)	45°
30°	6.99 (2.39)	4.50 (1.31)	3.58 (1.32)	3.03 (.92)	4.30 (1.12)	6.54 (1.94)	30°

Pairwise comparisons were conducted to follow up the significant main effect of horizontal deviation. All comparisons among the means of 30°, 45° and 60° were significant controlling for pairwise error rate across the three tests at .01 level by using the Holm's sequential Bonferroni procedure. Differences in mean $EMG\%_{MVC}$ were significant between 30° and 45°, $t(17) = 4.87$, $p<.001$, between 45° and 60°, $t(17) = 8.41$, $p<.001$, and between 30° and 60°, t(17) = 10.16, p<.001. The intensity of SCM muscle activity was proportional to the degree of lateral head rotation [9].

Four paired-samples t-tests were performed to follow up the significant interaction. We controlled for pairwise error by Holm's sequential Bonferroni approach. Mean differences of leftdown and leftup positions were significant, t(17) = 3.10, p<.006, and left and right up locations were also significant, t(17) = 2.69, p<.015. Left-up spot needs significantly more SCM contraction than leftdown position. Participants exerted significantly more SCM contraction for leftup position than rightup spot.

Borg CR10 scale was employed to evaluate perceived exertion. There was no significant difference between 30° and 45°. The participants felt 30° and 45° lateral head rotation is very light exertion. Significant differences were detected between 45° and 60°, t(17) = 7.62, p<.001, and between 30° and 60°, t(17) = 5.18, p<.001.

3.2. **Swivel chair.** A repeated-measures ANOVA was performed to examine the effect due to the locations of the LSVD. The main effects and interactions were tested by the multivariate criterion of Wilks's lamda. The main effect of head rotation degree was significant, $\Lambda = .16$, $F(2,6)=15.97$, p<.004 (Table 2).

TABLE 2. $EMG\%_{MVC}$ due to the placement of gaze with swivel chair

Vertical deviation	Left			Right			Vertical deviation
	60°	45°	30°	30°	45°	60°	
45°	6.16 (1.56)	4.22 (1.36)	3.02 (.98)	3.23 (1.13)	4.30 (1.35)	5.70 (1.38)	45°
30°	6.16 (1.52)	3.72 (1.05)	3.17 (1.17)	3.36 (.93)	3.91 (.85)	6.10 (1.82)	30°

Follow-up comparisons were conducted and all comparisons among horizontal deviations (30°, 45° and 60°) were significant with pairwise error rate maintained at .01 level by using the Holm's sequential Bonferroni procedure. Differences in mean $EMG\%_{MVC}$ were significant between 30° and 45°, t(17) = 5.73, p<.001, between 45° and 60°, t(17) = 8.81, p<.001, and between 30° and 60°, t(17) = 9.40, p<.001. The intensity of SCM muscle activity was proportional to the degree of lateral head rotation.

4. **Conclusions.** LSVD is commonly used in the public places and control room. We measured activity of SCM muscle to ergonomically evaluate and recommend the positions of LSVD.

The level of muscle activity may constitute an important risk factor for development of musculoskeletal disorders. Control room operators having complaints related to the neck would have significantly higher EMG level [19].

It is believed lateral head rotation is much less required when swivel chairs are provided. We found, however, operators would rotate their heads to monitor LSVDs located not front of them even sitting on the swivel chairs. Swivel chair does not eliminate operators' head rotation and does not reduce SCM muscle activity significantly.

EMG activity of SCM muscle was proportional to lateral head rotation degree regardless of the type of chairs. The placement of LSVD directly affects the activity of SCM muscle. The severity of SCM muscle activity is considerable if LSVD is located 60° + left and 40° + high and fixed chair used.

Proper positions for LSVD would be within 45° to the both left and right directions. In the vertical direction, 30° would be preferred and 45° could be acceptable for LSVD placement.

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