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Special Topic
Ergonomics in Seating

Ergonomic Evaluation of Console Chairs for a Weapon Locating Radar

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Objective: The present study is intended to evaluate the usability of a console chair for a weapon locating radar by comparing with different kinds of chair design.

Background: Console chairs need to be ergonomically designed to reduce physical workload of operators and improve mission capability; few studies have been reported which systematically evaluate usability of military console chairs.

Method: Ergonomic design of a console chair, a bus seat, and an office chair was evaluated in terms of headrest, seatback, seatpan, armrest, and controller on a 7-point scale. Ten males in their 20s and 30s were recruited considering the demographic characteristics of console operators.

Results: The satisfaction scores of the console chair for headrest, seatback, and seatpan were significantly higher than those of the bus seat (mean difference [MD] = 0.9) and office chair (MD = 1.3). Meanwhile, the satisfaction scores of the console chair for armrest and controller were significantly lower than those of the office chair (MD = -1.4) and bus seat (MD = -2.2).

Conclusion: The armrest and controller of the console chair needs ergonomic improvements for better comfort.

Application: The evaluation results of the console chair would be of use for ergonomic console chair design.

Keywords: Ergonomic console chair, Weapon locating radar, Ergonomic evaluation

1. Introduction

A weapon locating radar (WLR) have been developed for an accurate and expedite detection of the provocation by the enemy. The well-developed WLR can contribute to improving fire detection capabilities and real-time counter-fire operation capabilities against the enemy. The WLR is consisted of three parts (shelter, antenna, and vehicle), and the shelter is an operation room where operators sit on the console chair to monitor displays and control buttons of a console. An ergonomic console chair can contribute to enhancing operational efficiency by minimizing human error and improving usability (Sanders and McCormick, 1993). The existing studies regarding ergonomic console layout design have applied different optimization methods to

arrange design element (e.g., button) in the console (Hani et al., 2007; Holman et al., 2003; Jung et al., 1995; Pham and Onder, 1992; Sargent and Kay, 1997; Udosen, 2006; Wang et al., 1991; Xu et al., 2010a, 2010b, 2011).

Console chairs need to be ergonomically designed for console operators who conduct a long-term monitoring mission. A primary mission of console operators is to monitor radar imagery of the console display, while sitting on the console chair. Console chairs not considering operator's body characteristics can induce inconvenience, pain, or fatigue to console operators (ANSI/HFES 100, 2007; Grandjean, 1980; Kirk, 1969). Therefore, it is recommended that operator's body characteristics be considered in designing the console chair.

Although studies regarding the usability of different chair types have been conducted, those of military console chairs are insufficient. For example, bus seats have been improved through many research: Kim et al. (2012) developed a questionnaire for ergonomic evaluation of a bus seat; Lee et al. (2013) proposed a design approach of a bus seat based on 3D bus seat shape and passenger's satisfaction; Park et al. (2013) developed an ergonomic evaluation protocol of a bus seat. Meanwhile, Kim et al. (2013) proposed an ergonomic chair applying the Kansei engineering to considering user's emotion and usability. However, the present study found a lack of usability studies for military console chairs; thus the study on ergonomic console chairs have been requested.

The present study developed ergonomic improvement strategies of a console chair of the WLR in comparison with other chair types. The console chair was evaluated against a bus seat and an office chair for each part (e.g., seatback) using an evaluation questionnaire developed for the study. Finally, enhancement strategies of the console chair were presented based on satisfaction scores of evaluation criteria for chair part.

2. Method

2.1. Selection of evaluation chairs

In order to compare the satisfaction levels of a console chair (Figure 1a) with those of different types of chairs, a bus seat (Figure 1b) and an office chair (Figure 1c) were analyzed in the study. As shown in Figure 1a, the console chair (Woochang Co., South Korea) has a suspension (height = 100~150mm) on its lower part for shock mitigation, and the front and rear heights of the console chair are adjustable, respectively. As shown in Figure 1b, the seat height of the bus seat (Hyundai Motor Co., South

(a) Console chair (b) Bus seat (c) Office chair

Figure 1. Evaluation chairs

Korea) is fixed, and the headrest and seatback are not separated. As shown in Figure 1c, the heights of the headrest and armrest of the office chair (Patra Inc., South Korea), and their angles are adjustable. Also, the seatback of the office chair is bendable backwards with high flexibility for the user's posture, and five wheels are attached to the lower part of the office chair for movement. Each of three evaluated chairs has different design characteristics; however the present study found that the headrest, armrest, seatback, seatpan, and controllers of three chairs shared some common characteristics.

2.2. Development of an evaluation questionnaire

Referring to the existing studies, an evaluation questionnaire was developed applying a three-step: (1) selection of evaluation criteria, (2) selection of evaluation parts, and (3) analysis of relationship between criteria and parts. First, in the evaluation criteria selection step, a total of 12 evaluation criteria in overall satisfaction, biomechanical quality, and affective quality were selected referring to the existing studies on the usability of chairs (Kim et al., 2010; Kolich, 2003; Smith et al., 2006) as presented in Table 1. The biomechanical quality was classified into eight evaluation criteria (reach, adjustment, force, shape, pressure distribution, body support, bolster, and size). The affective quality was subdivided into three evaluation criteria (touch, cushion, and grip).

Table 1. Ergonomic Evaluation criteria

Criteria		Description
Overall satisfaction		Overall satisfaction with seat
Biomechanical quality	Reach	Ease of reaching a controller
	Adjustment	Ease of adjusting a controller
	Force	Appropriateness of force requirement for operation of a controller
	Shape	Appropriateness of the shape of seat to the shape of the body
	Pressure distribution	Appropriateness of sitting pressure distribution
	Body support	Appropriateness of the support of seat to the body
	Bolster	Fit of seat bolster to the body
	Size	Satisfaction with the size of seat
Affective quality	Touch	Satisfaction with the material of seat cover
	Cushion	Satisfaction with the hardness or softness of seat cushion
	Grip	Fit of controller to the hand

Second, in the evaluation parts selection step, 14 evaluation parts consisting of one headrest part, one armrest part, four seatback parts, four seatpan parts, and four controllers were selected as shown in Figure 2. The seatback (thoracic, lumbar, side, and overall parts), seatpan (hip, thigh, side, and overall parts), and controller (cushion tilting, seatback angle, suspension hardness, and seat fore/aft location parts) were evaluated in each of four detailed parts, respectively.

Finally, in the relationship analysis step, a total of 79 evaluation items were selected through analysis of relationship between 12 evaluation criteria and 14 evaluation parts as presented in Table 2. For example, the adjustment criterion was evaluated in terms of six different chair parts possible to operate with operator's hands (headrest, armrest, cushion tilting, seatback angle, suspension hardness, and seat fore/aft location). The pressure distribution criterion was assessed in terms of seatback and seatpan which are chair parts pressed by the operator's weight; whereas headrest was excluded since the operator has an option to use it. The body

support and bolster criteria were evaluated in terms of seatback supporting the operator's upper body and seatpan wrapping around the operator's lower body.

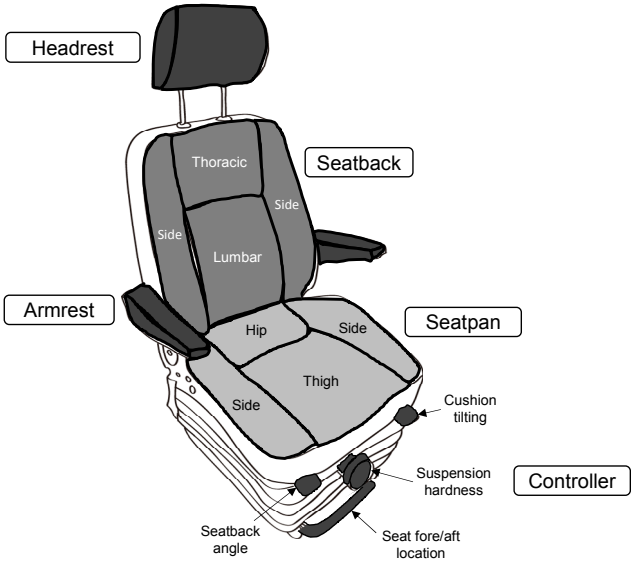


Figure 2. Classification of chair parts

Table 2. Relationship analysis between evaluation parts and criteria

Chair part		Ergonomic criteria											
		Overall satisfaction	Biomechanical quality								Affective quality		
			Reach	Adjustment	Force	Shape	Pressure distribution	Body support	Bolster	Size	Touch	Cushion	Grip
Headrest		○		○				○	○	○			
Armrest		○	○	○	○					○*	○	○	
Seatback	Thoracic	○				○	○	○		○			
	Lumbar	○				○	○	○		○			
	Side	○				○	○	○		○			
	Overall	○				○	○	○		○	○	○	
Seatpan	Hip	○					○		○	○			
	Thigh	○					○		○	○			
	Side	○					○		○	○			
	Overall	○					○		○	○	○	○	
Controller	Cushion tilting	○	○	○	○					○			○
	Seatback angle	○	○	○	○					○			○

Table 2. Relationship analysis between evaluation parts and criteria (Continued)

Chair part		Ergonomic criteria											
		Overall satisfaction	Biomechanical quality								Affective quality		
			Reach	Adjustment	Force	Shape	Pressure distribution	Body support	Bolster	Size	Touch	Cushion	Grip
Controller	Suspension hardness	○	○	○	○					○			○
	Seat fore/aft location	○	○	○	○					○			○

*Size of armrest was evaluated in terms of length, width, height, and location.

In the experiment, subjective satisfaction was assessed with the participant sitting on the target chair. Ten male participants in their 20s or 30s (age = 30.5 ± 3.7yr; stature = 172.8 ± 6.6cm; weight = 70.7 ± 10.8kg) were recruited consistent with the real operator's age, gender, and body size. The participant was instructed to monitor the console display, while sitting on the chair. A 7-point scale (1-point: extremely dissatisfaction, 4-point: neither, 7-point: extremely satisfaction) was applied to determine the satisfaction level, and Figure 3 shows an example of evaluation questionnaire for satisfaction level of the seatpan.

Chair part	Criteria	Console chair						
		Extremly dissatisfaction	Very dissatisfaction	Somewhat dissatisfaction	Neither	Somwhat satisfaction	Very satisfaction	Extremly satisfaction
Seatpan overall satisfaction	Size	①	②	③	④	⑤	⑥	⑦
	Bolster	①	②	③	④	⑤	⑥	⑦
	Pressure distribution	①	②	③	④	⑤	⑥	⑦
	Touch	①	②	③	④	⑤	⑥	⑦
	Cushion	①	②	③	④	⑤	⑥	⑦
	Overall satisfaction	①	②	③	④	⑤	⑥	⑦

Figure 3. An example of evaluation questionnaire

3. Results

The console chair was most preferred in terms of headrest, seatback, and seatpan (Figure 4). As shown in Figure 5, the mean satisfaction score was significantly higher for the headrest of the console chair (4.3 ± 1.4pt) by 0.8 pt and 0.7pt than the bus seat (3.5 ± 1.4pt) and the office chair (3.6 ± 1.8pt), respectively (t[98] = 2.97, p = 0.004; t[93] = 2.37, p = 0.020). As shown in Figure 6, the same was true for the seatback of the console chair (5.3 ± 1.5pt) by 0.8pt than the bus seat (4.5 ± 1.2pt) and the office chair (4.6 ± 1.6pt), respectively (t[437] = 6.34, p < 0.001; t[442] = 5.82, p < 0.001). As shown in Figure 7, the same was also true for the seatpan of the console chair (5.4 ± 1.4pt) by 1.2pt and 0.8pt than the bus seat (4.2 ± 1.1pt) and the

office chair (4.6 ± 1.3pt, respectively (t[357] = 8.87, p < 0.001; t[372] = 5.92, p < 0.001). Meanwhile, the largest mean differences between the console chair and the bus seat among all evaluation criteria were revealed in the body support (MD = 1.3pt) of headrest, the size (1.4pt) of seatback, and the cushion (2.4pt) of seatpan. The largest mean differences between the console chair and the office chair were shown in the body support appropriateness (1.3pt) of headrest, the body support appropriateness (2.0pt) of seatback, and the bolster appropriateness (2.1pt) of seatpan.

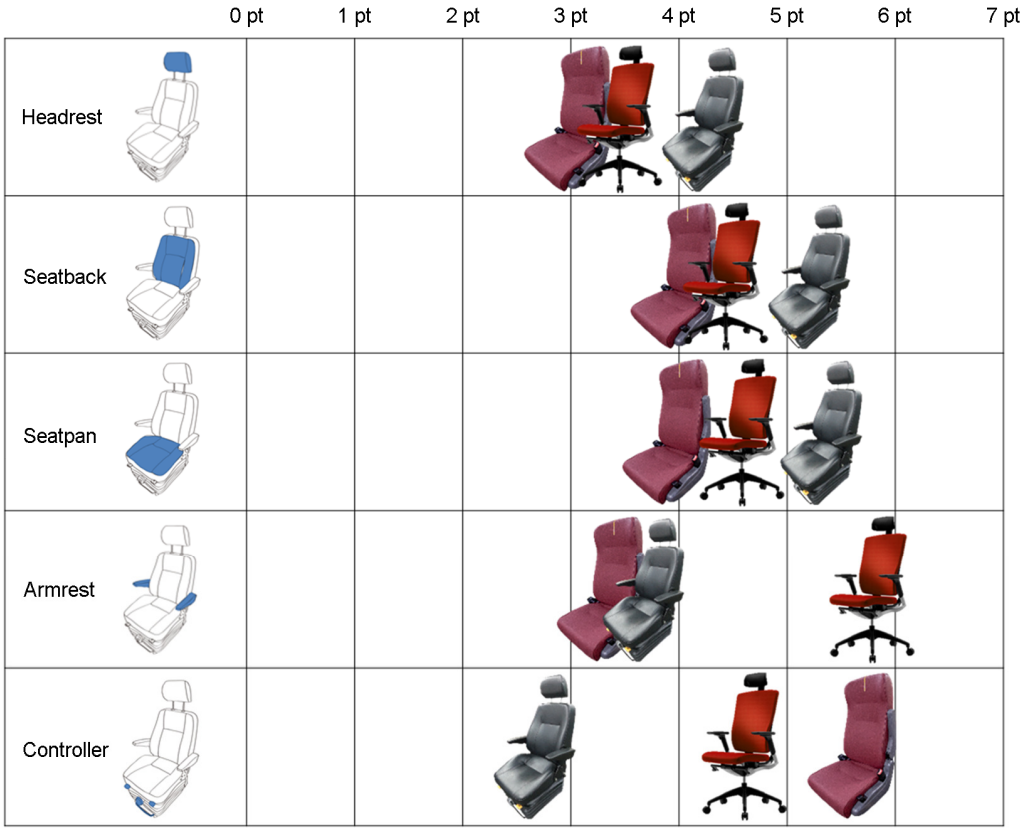


Figure 4. Summary of evaluation results

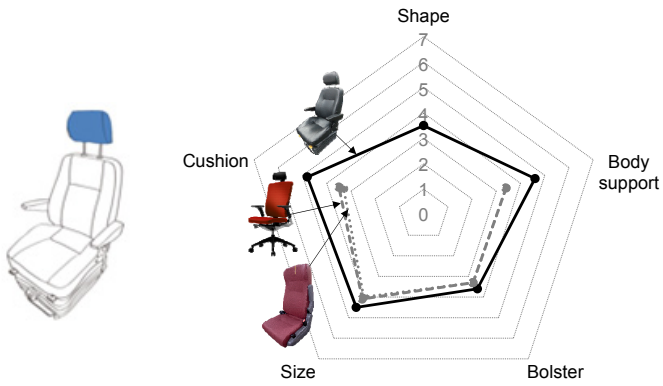
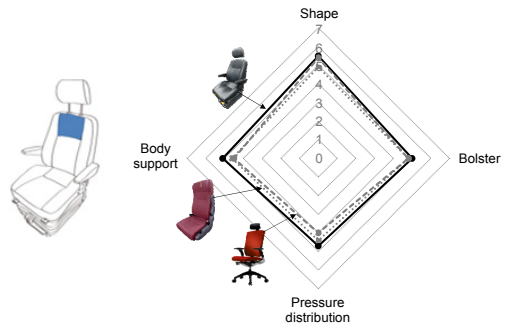
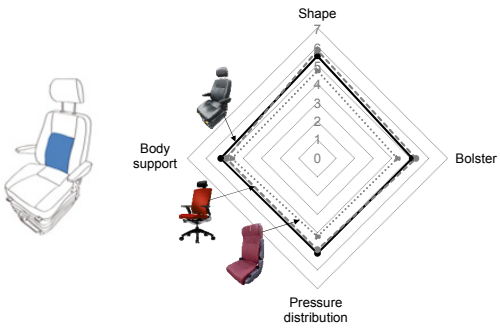


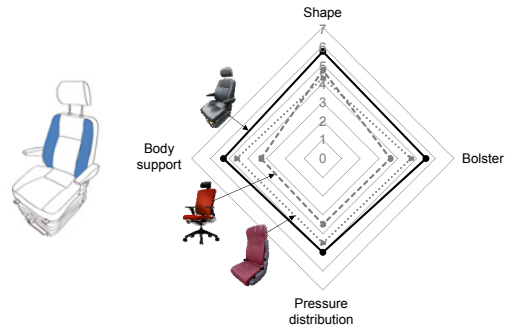
Figure 5. Satisfaction comparison of headrest



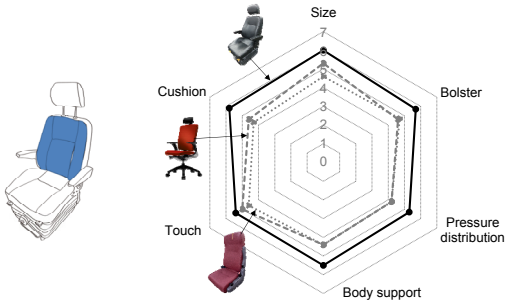
(a) Thoracic support



(b) Lumbar support

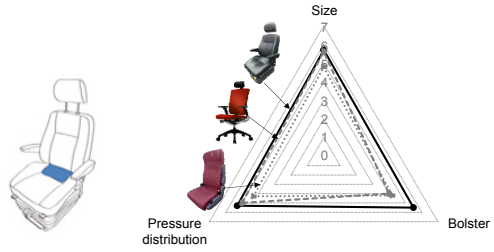


(c) Side support

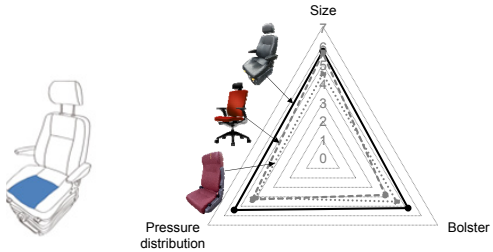


(d) Overall

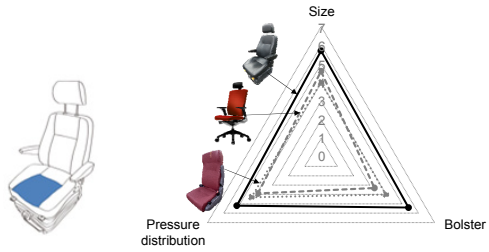
Figure 6. Satisfaction comparison of seatback



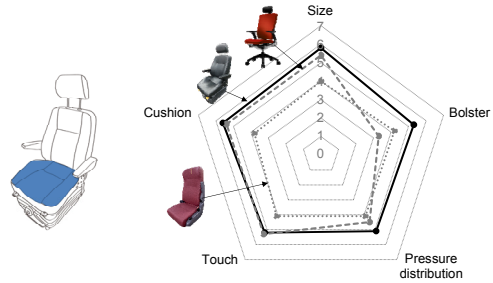
(a) Hip support



(b) Thigh support



(c) Side support



(d) Overall

Figure 7. Satisfaction comparison of seatpan

The satisfaction level of armrest was highest in the office chair, followed by the console chair and the bus seat (Figure 4). As shown in Figure 8, the mean satisfaction score of armrest of the console chair (3.8 ± 1.6pt) was 0.3pt higher than the bus seat (3.5 ± 1.3pt); meanwhile, it was significantly 3/5 times lower than the office chair (5.9 ± 1.3pt) (t[192] = -10.13, p < 0.001). The width appropriateness evaluation criterion (MD = 2.2pt) of armrest of the console chair was most preferred to the bus seat; while the ease of cushion tilting of armrest of the console chair was least preferred to the office chair (-4.6pt).

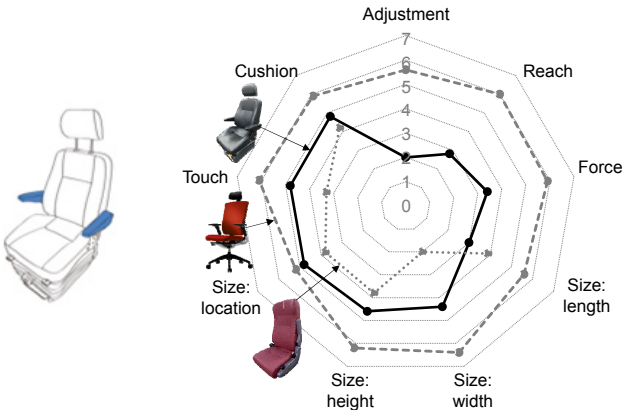
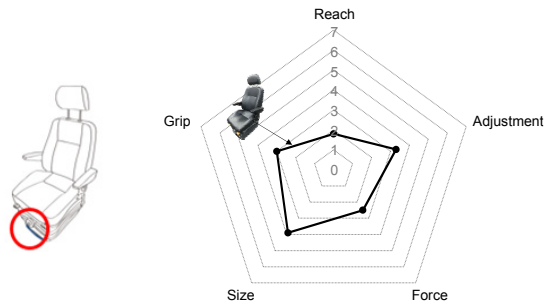
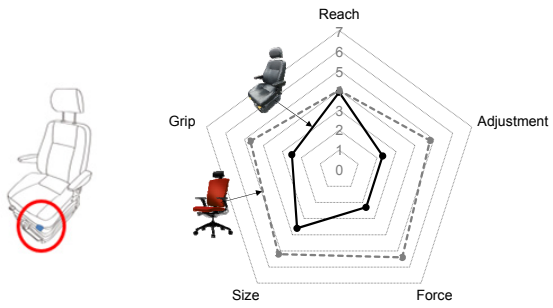


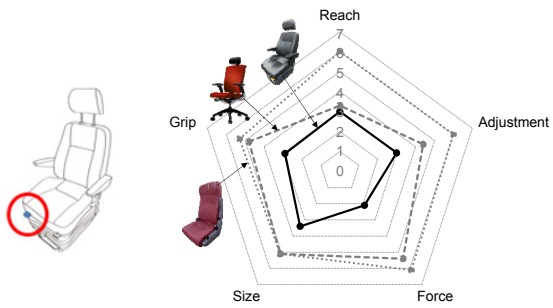
Figure 8. Satisfaction comparison of armrest



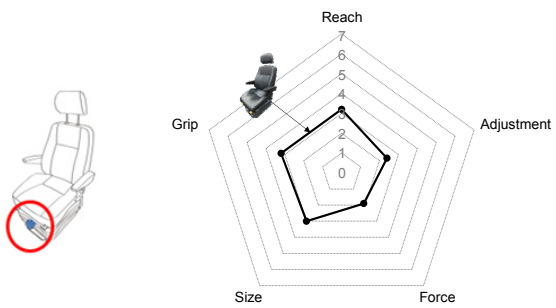
(a) Seat fore/aft location



(b) Cushion tilting



(c) Seatback angle



(d) Suspension hardness

Figure 9. Satisfaction comparison of adjustment lever

The controller of the console chair was least preferred to the other chairs (Figure 4). As shown in Figure 9, the mean satisfaction score of cushion tilting and seatback angle of the console chair (2.8 ± 1.4pt) was significantly lower than the bus seat (5.7 ± 1.3pt) and the office chair (4.7 ± 1.3pt), by 2.9pt and 1.9pt, respectively (t[132] = -13.97, p < 0.001; t[236] = -10.74, p < 0.001). On the other hand, the force appropriateness (MD = -4.0pt, -3.3pt) of the console chair was lower than other two chairs.

4. Discussion

In the study, the console chair of the WLR was compared with the different types of chair (bus seat and office chair) for ergonomic improvements of the console chair in terms of biomechanical and affective qualities. We have found no studies on the usability of military console chairs in our literature review; the lack can be attributed to the importance of sturdiness of console chair to fulfil military missions. Meanwhile, if the console chair on which the operator conducts a long-term monitoring mission seated is not comfortable, it can cause negative effects on the monitoring due to pain or fatigue. Thus, an ergonomic console chair design considering both biomechanical and affective qualities would contribute to improving operation efficiencies of the WLR by providing better comfort to console operators.

The design strategies for ergonomic console chair presented in the study could provide better seat comfort to console operators during long-term monitoring, because the headrest, seatback, and seatpan of the console chair were preferred to the bus seat and the office chair; therefore improvements would not be required. The headrest of the console chair, made of comfortable cushion material, is adjustable to the operator's head position. Also, the seatback and seatpan of the console chair received superior satisfaction in terms of appropriateness of size, body support, cushion, and bolster. This superiority could be attributed to an ergonomic contour which can wrap around and support the operator's body, providing better seat comfort.

However, we found that the armrest and controllers of the console chair would need improvement because of lower satisfaction than the other chairs. Nine satisfaction criteria (adjustment, reach, force, length, width, height, location, touch, and cushion) in armrest of the console chair were evaluated lower than the office chair, with the highest mean difference in adjustment criterion (MD = -4.6pt). It is difficult to adjust the height (S1. loosening rotation lever, S2. adjusting armrest height, and S3. tightening rotation lever), and furthermore the controller is located on the lower part of the armrest invisible to the seat occupier. However, frequency of adjusting the armrest height of the console chair would be low because operators adjust the height only once in beginning of his duty.

The present study has limitations because the number of participants was small and the experiment was conducted while the participant was seated for a short time. Only ten males representing the typical operator's age, gender, and body sizes were recruited; however, to have optimal result it is needed to evaluate a large number of people including real operators of the WLR. In addition, the subjective satisfaction was evaluated while the participant was seated on the chair only for a few minutes; thus, an evaluation of monitoring would be needed for a long seating.

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