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Chapter 8

Evaluation for smart air travel support system

CheeFai Tan[1], Wei Chen[2], and Matthias Rauterberg[3]

Long haul air travel passengers will experience different level of physiological and psychological discomfort. It is because the long haul air travel is not a natural activity for human being. The literature review showed that seating comfort and discomfort is subjective and interchangeable. Comfort is an attribute that is highly demanded by most of the aircraft passengers. An aircraft passenger's comfort depends on different features and the environment during air travel. Seat discomfort is a subjective issue because it is the customer who makes the adjustment based on their seating experience. The aircraft passenger seat has an important role to play in fulfilling the passenger comfort expectations. The seat is one of the important features of the aircraft where the aircraft passenger spends most of the time during air travel. A smart support system for long haul air travel has been developed at the Eindhoven University of Technology, the Netherlands. The purpose of the system is to reduce travel discomfort and improve the comfort experience during long haul air travel.

In this chapter, four experiments were reported. The first study is to identify factors of seating comfort. Next, the survey of relationship between seat location and sitting posture is reported. It is followed by the validation of aircraft cabin simulator. Lastly, the validation experiment of Smart Neck Support System is described. The validation experiment is to validate the developed smart systems for neck support in a simulated "real life" setting. The aim of a developed smart system is to support the passenger's head and reduce passenger neck muscle stress during air travel adaptively. An aircraft cabin simulator was utilized to conduct the validation experiment. The calibration experiment was conducted to gain information to be used for the validation experiment. The validation is an important process of Smart Neck Support System (SNes).

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8.1 Introduction

Air travel is becoming increasingly accessible to people both through the availability of cheap flights and because the airlines now are able to cater for individuals of all ages and disabilities. However, long haul air travel is not a natural activity for humans. Many aircraft passengers experience different degrees of physiological and psychological discomfort and even stress during flying. The aircraft passenger's health may endanger by excessive stress that may cause passenger to become aggressive and over-react [1]. A number of health problems can affect aircraft passengers. During the departure process, an aircraft passenger may experience anxiety caused by overcrowded airport and complicated airport departure procedures. After boarding into the aircraft cabin, the aircraft passenger may experience discomfort caused by environmental factors such as humidity, pressure, and noise. Besides, some aircraft passengers also feel discomfort during sitting where the passenger may be affected by the seat location, seat position, and sitting duration. A long haul air travel across different time zones and irregular meal timings may continuously affect the health of an aircraft passenger [2].

Comfort is an attribute that today's passenger demand more and more. An aircraft passenger's comfort depends on different features and the environment during air travel. Seat discomfort is a subjective issue because it is the customer who makes the final determination and customer evaluations are based on their opinions having experienced the seat [3]. The aircraft passenger seat has an important role to play in fulfilling the passenger comfort expectations. The seat is one of the important features of the vehicle and is the place where the passenger spends most of time during air travel. The aviation industry is highly competitive and therefore airlines try to maximize the number of seats [4]. Often this results in a very limited amount of seating space for passengers, especially in economy class [5].

8.2 Seat comfort and discomfort

The Cambridge Advanced Learner's dictionary (2008) defined comfort as "a pleasant feeling of being relaxed and free from pain." Seat comfort is determined subjectively because the user justifies the seat comfort based on his/her subjective experience in using the seat [3]. Helander [6] stressed that a good ergonomic design of the seat is a precondition for seat comfort. De Looze *et al*. [7] described comfort as affected by different factors such as physical, physiological and psychological factors. Helander and Zhang [8] noted that there is a difference between seating comfort and discomfort in office chairs. They described how comfort is related to emotional aspects such as feeling safe and luxury. Their findings described that the physical aspects such as feeling pressure and muscle pain are related to body discomfort.

Table 8.1 Causes of seating discomfort [10]

Human experience mode	**Biomechanical**		**Seat/environment**
	Physiology causes	**Engineering causes**	**Source**
Pain	Circulation occlusion	Pressure	Cushion stiffness
Pain	Ischemia	Pressure	Cushion stiffness
Pain	Nerve occlusion	Pressure	Seat contour
Discomfort	-	Vibration	Vehicle ride
Perspiration	Heat	Material	Vinyl upholstery
Perception	Visual/auditory/tactile	Breathability Design/vibration	Vehicle cost

The concepts of comfort and discomfort in sitting are under debate. There is no widely accepted definition, although it is beyond dispute that comfort and discomfort are feelings or emotions that are subjective in nature [7]. Seating discomfort has been examined from a number of different perspectives. The problem with evaluating comfort with regard to pressure or any other factor is that comfort is subjective and not easy to quantify. Seating discomfort varies from subject to subject and depends on the task at hand. Comfort, however, is a vague concept and subjective in nature. It is generally defined as lack of discomfort [9]. Discomfort feelings, as described by Helander and Zhang [8], is affected by biomechanical factors and fatigue. The sources of such discomfort are listed in Table 8.1.

8.2.1 Identifying factors of seating comfort

In this subsection, a questionnaire is developed to determine the relationship between the selected factors and comfort in economy class aircraft passenger seat. Zhang *et al*. [11] identified the comfort and discomfort factors of office chair. The research defined 23 comfort factors and 20 discomfort factors in using office chair.

8.2.1.1 Selection of comfort factors

First, all possible comfort factors related to sitting were collected from various journal articles and online journal database. The journal articles were studied to select the possible comfort and discomfort factors. For example, the factors selected from Kolich [12] paper were "breathability" and "styling."

From the literature review, potential factors were selected based on their relationship with seating comfort and discomfort. Next, 28 studies were used to select 41 factors.

8.2.1.2 Methods

There were 55 students ($N = 55$) recruited from Department of Industrial Design, Eindhoven University of Technology, the Netherlands, to volunteer in the main study. The online questionnaire with 41 factors was developed by using QuestionPro systems and send to respondents via electronic mail. The respondents rated the factors in terms of comfort on a 4-point scale (1 = not related to comfort, 2 = slightly related to comfort, 3 = closely related to comfort, 4 = very closely related to comfort). Fifty-five respondents filled in the questionnaire online.

8.2.1.3 Data analysis

In the study, 41 comfort factors were ranked on mean ranks (MR) of their rating score with the Friedman test. The factor that was not rated by the subject was coded as "99" and regarded as a missing value. Next, 41 factors were classified into factors with Principal Components Analysis (PCA) with Varimax Rotation method.

8.2.1.4 Results

The 41 comfort factors were ranked from 1 to 41. The Friedman test, which evaluated differences in medians among the 41 comfort factors, is significant χ^2 (40, $N = 41) = 274$, $p < 0.001$. From the result as shown in Table 8.2, "spacious" (MR = 29.68) exhibited the highest comfort factor level. It was followed by "adjustable" (MR = 28.83), "ergonomic" (MR = 28.62), "head rest" (MR = 28.04), "seat contour" (MR = 26.90), and "neck support" (MR = 26.37). The comfort factors were ranked based on MRs.

A factor analysis was conducted to identify the underlying dimensions of the comfort factors. Scores on the 41 factors were submitted to PCA with Varimax Rotation. The comfort factors were classified into 12 factors with eigenvalues greater than 1. Thus, the six factors solution yielded the best solution (Table 8.3). Factors 1–6 explained 58.69% of the variance in the data. The other six factors explained 19.37%, which showed less variance than the first six factors and will not be further discussed.

The first factor included eight factors that described the "no irritation in sitting," i.e., "no shock," "no strained," "no fatigue," "no pressure," "not tired," "no sore muscles," "not bouncy," and "no heavy leg." The first factor explained 22.92% of the variance in the data. The second factor included eight factors, i.e., "leg support," "side support," "arm rest," "spacious," "neck support," "adjustable," "head rest," and "ergonomic." This factor appeared to reflect the support of economy class aircraft passenger seat and it was labeled as "body support." The third factor included four factors, i.e., "safety," "reliable," "intelligent," and "functionality," and was labeled as "seat function." The fourth factor was labeled as "feeling in sitting" and included five factors, i.e., "no hardness," "no vibration," "firmness of back rest," "warm," and "no stiffness." The fifth factor was labeled as "long hour sitting" and included three factors, i.e., "long duration," "seat cushion firmness," and "fit." The sixth factor included three factors, i.e., "relax," "adaptable," and "restful." Therefore, it was labeled as "relaxing."

Table 8.2 The mean ranks for comfort factors

No.	Factor	Mean rank
1	Spacious	29.68
2	Adjustable	28.83
3	Ergonomic	28.62
4	Head rest	28.04
5	Seat contour	26.9
6	Neck support	26.37
7	Relax	25.59
8	Firmness of backer seat	25.38
9	Seat cushion firmness	25.27
10	Restful	24.67
11	Safety	24
12	Adaptable	23.38
13	Arm rest	22.91
14	Lumbar support	22.9
15	No stiffness	22.6
16	Breathability	22.41
17	No sore muscles	22.4
18	No fatigue	22.37
19	Fit	21.77
20	Side support	21.37
21	Leg support	20.49
22	No hardness	19.78
23	No pressure	19.56
24	Not tired	19.26
25	No shock	19.15
26	No vibration	18.93
27	Reliable	18.79
28	Well being	18.70
29	Warm	18.41
30	No uneven pressure	18.29
31	Functionality	18.24
32	No uneasy	18.01
33	Massage	18.00
34	No heavy leg	17.66
35	No strained	17.41
36	Automatic adjustment	16.28
37	Long duration	16.17
38	Pleasurable	16.07
39	Intelligent	12.72
40	Not bouncy	12.07
41	Short duration	11.55

8.2.1.5 Summary

The comfort factor, namely "spacious," was most related to comfort in experiencing economy class aircraft passenger seat, followed by "adjustable," "ergonomic," "head rest," "seat contour," and "neck support." Next, the Factor Analysis with Varimax Rotation is used to classify the selected comfort factors into

Table 8.3 Factor loading of the comfort factors

		Factor					
No.	**Factors**	**1 No irritation in sitting**	**2 Body support**	**3 Seat function**	**4 Feeling in sitting**	**5 Long hour sitting**	**6 Relaxing**
1	No shock	0.828					
2	No strained	0.798					
3	No fatigue	0.736				0.470	
4	No pressure	0.689					
5	No tired	0.673					
6	No sore muscles	0.658					
7	No bouncy	0.649					
8	No heavy leg	0.462					
9	Leg support		0.844				
10	Side support		0.786				
11	Armrest		0.774				
12	Spacious		0.682				
13	Neck support		0.647				
14	Adjustable		0.541				
15	Head rest		0.470				
16	Ergonomic		0.463				
17	Safety			0.798			
18	Reliable			0.771			
19	Intelligent			0.638		0.452	
20	Functionality			0.509			
21	No hardness				0.755		
22	No vibration				0.676		
23	Firmness of backrest			0.459	0.596		
24	Warm	0.477			0.575		
25	No stiffness				0.554		
26	Long duration					0.743	
27	Seat cushion firmness					0.635	
28	Fit					0.561	
29	Relax						0.853
30	Adaptable						0.630
31	Restful						0.523
32	Lumbar support						
33	Well being						
34	No uneven pressure						
35	Automatic adjustment						
36	No uneasy	0.551					
37	Seat contour						
38	Short duration						
39	Pleasurable						
40	Massage						
41	Breathability						
	Explained variance	22.92%	12.06%	7.27%	6.38%	5.63%	4.43%
	Cronbach's alpha	0.860	0.840	0.730	0.790	0.660	0.730

Note: Only factor loadings > 0.450 are displayed

factors. The first six factors, which explained 58.69%, were selected. The first six factors were "no irritation in sitting," "body support," "seat function," "feeling in sitting," "long hour sitting," and "adaptability." The main study showed that the factors of the factor "no irritation in sitting" are most related to comfort and the factors of the factor "relaxing" are least related to comfort. From the factor analysis result, it can be assumed that the main perception of respondents about the economy class aircraft passenger seat comfort is "no irritation in sitting." It is followed by "body support," where the respondents felt that the body support of the aircraft passenger seat will improve the seating comfort.

8.2.2 Survey of relationship between seat location and sitting posture

During air travel, passengers can book the preferred seat location or receive an assigned specific seat location during check-in. The seat location in the economy class cabin can be classified to aisle, center, and window seat [4]. The observation method was used in economy class aircraft cabin to investigate (a) the relationship between different economy class aircraft passenger seat location and sitting posture and (b) the relationship between gender and sitting posture. The observation was conducted in the economy class cabin of Malaysia Airlines (Boeing 747-400). The flight was from Kuala Lumpur International Airport, Malaysia, to Schiphol International Airport, the Netherlands. The departure time was 11:55 p.m. on May 27, 2009 and the arrival time was 6:35 a.m. on May 28, 2009. The flight duration was 12 h 40 min. The sitting postures of 12 passengers within observer eye view were observed and recorded.

8.2.2.1 Methods

Observation administration and recording

The observer and observed subjects sat at the location as shown in Figure 8.1. The sitting location of the observer was seat number "35C." The seat numbers of observed subjects were "34B," "34C," "34D," "35A," "35B," "35D," "35E," "35F," "35G," "36D," and "36E." The observed subjects were within the observation range of the observer. The other seats were occupied by passengers as well but they were out of the observation range of the observer. The observer recorded the sitting postures of the subjects in every 15 minutes.

	A	B	C		D	E	F	G
33					SUBJECT 5 (Female)			
34		SUBJECT 1 (Male)	SUBJECT 2 (Male)		SUBJECT 6 (Male)			
35	SUBJECT 3 (Female)	SUBJECT 4 (Male)	OBSERVER	Aisle	SUBJECT 7 (Male)	SUBJECT 8 (Female)	SUBJECT 9 (Female)	SUBJECT 10 (Male)
36					SUBJECT 11 (Male)	SUBJECT 12 (Female)		

Figure 8.1 The sitting location of observer and observed subjects

The sitting posture was pre-defined and coded in seven postures as referred to Table 8.4. The explanation of seven postures are as follows:

1. Sitting posture “A”: the passenger’s head faces forward.
2. Sitting posture “B”: the passenger’s head tilts to right.
3. Sitting posture “C”: the passenger’s head tilts to left.
4. Sitting posture “D”: the passenger’s head rotates to right.
5. Sitting posture “E”: the passenger’s head rotates to left.
6. Sitting posture “F”: the passenger’s head and body rotate to right.
7. Sitting posture “G”: the passenger’s head and body rotate to left.

If a subject leaves the seat, we code this condition as “others.”

8.2.2.2 Results

A Crosstab and Chi-square method was used to analyze the recorded data. The first analysis investigates the relationship between seat location and sitting posture. Next, the relationship between the gender and sitting posture was examined.

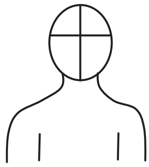
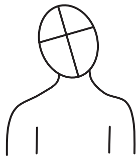
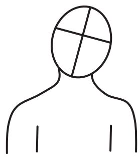
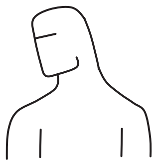
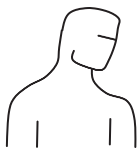
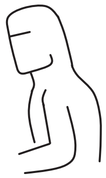
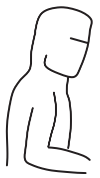
For Crosstab analysis on the relationship between seat location and sitting posture, out of 330 postures that are recorded in the aisle seat, 185 postures are position “A” (56%) and 64 postures are position “D” (19%). The results showed that the preferred sitting positions in aisle seat are positions “A” and “D.” For the center seat, positions C (10%), D (19%), and E (14%) were preferred by the subjects. For the window seat, out of 110 recorded postures, positions “B” (22%) and “E” (13%) were preferred by the subjects. On average, the seat location of passengers will affect their sitting posture during air travel. A Chi-square test showed that this difference was significant (χ^2 (10) = 43.332, $p < 0.001$). Position A was preferred by 51% of the observed passengers because it is the most comfort position.

For the relationship between gender and seat location, Crosstab and Chi-square methods were used. The observed subjects were seven males and five females. Out of 262 postures that were recorded from female passengers, females preferred positions “B” (12%), “C” (10%), “D” (20%), and “E” (13%). In contrast, males preferred position “A” (58%) as referred to the 374 recorded positions. On average, there was a significant difference between the gender of passengers and their sitting posture during air travel. A Chi-square test showed that this difference was significant (χ^2 (5) = 21.687, $p < 0.05$).

8.2.3 Validation of aircraft cabin simulator

The validation experiment of the aircraft cabin simulator was carried out using the presence questionnaire [13]. The presence questionnaire is used to measure the presence between real and simulated flight experiences in aircraft cabin simulator. The validation experiment was designed by Hao Liu and the author. The validation experiment was conducted as a part of the experiment to validate the developed in-flight entertainment system by Hao Liu *et al*. [14] for SEAT project. The participants were required to sit inside the cabin simulator to simulate a flight from Schiphol International Airport, the Netherlands, to Shanghai Pudong International Airport, China.

Table 8.4 *The coding of sitting posture for observation purpose*

No.	Sitting posture
A	
B	
C	
D	
E	
F	
G	
Others	Subject leaves the seat

Leong-6990392 1 February 2019; 17:12:28

8.2.3.1 Methods

Participants

Twelve participants (six females and six males) were invited to participate in our validation experiments. The age of the participants ranged from 21 to 33 years. The professions in the first experimental group included one reporter, two workers, and three engineers. The professions in the second experimental group included one student, two workers, and three engineers. The participants were recruited through advertisement in regional news (newspaper, radio, and television) and were given €50 upon completion.

Supporting personnel

A former professional flight attendant from Swiss Air was invited to provide cabin service during user experiments. Hao Liu acted as the simulated flight captain. The author provided technical supports. Matthias Rauterberg coordinated and directed the experiments.

Experimental setup

We conducted the validation experiment for the aircraft cabin simulator inside the simulation laboratory in the Main Building of Eindhoven University of Technology. Twelve participants were allocated to two experiments. Each experiment consisted of six participants. The participants were tested at the economy class section in the aircraft cabin simulator. The in-flight entertainment system was installed and used by the participants as well. Both experiments simulated the KLM KL0895 flight from Schiphol International Airport to Shanghai Pudong International Airport. Both experiments were conducted with the same environment and procedure following the real flight schedule.

Questionnaire

Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another [15]. In this chapter's context, presence means the "passenger's" subjective experience of being in a long haul flight, even when the "passenger" is physically sitting in the aircraft cabin simulator. The presence questionnaire by Usoh *et al*. [13] is used to measure the perceived presence of participants. It is customized resulting in the following five questions:

1. Please rate your sense of being in the long haul flight on the following scale from 1 to 7.
   I had a sense of "being there" in the long haul flight:

Not at all	○	○	○	○	○	○	○	**Very much**
	1	2	3	4	5	6	7	

2. To what extent were there times during the experience when the laboratory became the "real long haul flight" for you, and you almost forgot about the "real world" of the laboratory in which the whole experience was really taking place?

There were times during the experience when the virtual "long haul flight" became more real for me compared to the "real flight"...

At no time	○	○	○	○	○	○	○	**Almost all the time**
	1	2	3	4	5	6	7	

3. When you think back about your experience, do you think of the laboratory more as the laboratory that you saw, or more as somewhere that you visited? Please answer on the following 1–7 scale:
   The laboratory seems to me to be more like...

Laboratory that I saw	○	○	○	○	○	○	○	**Somewhere that I visited**
	1	2	3	4	5	6	7	

4. During the time of the experience, which was the strongest on the whole, your sense of being in the long haul flight or of being in the real world of the laboratory?
   I had a stronger sense of being in...

The real world of the laboratory	○	○	○	○	○	○	○	**The virtual reality of the Longhaul flight**
	1	2	3	4	5	6	7	

5. The questionnaire was distributed to participants at the end of the simulated flight.

Apparatus and data recording

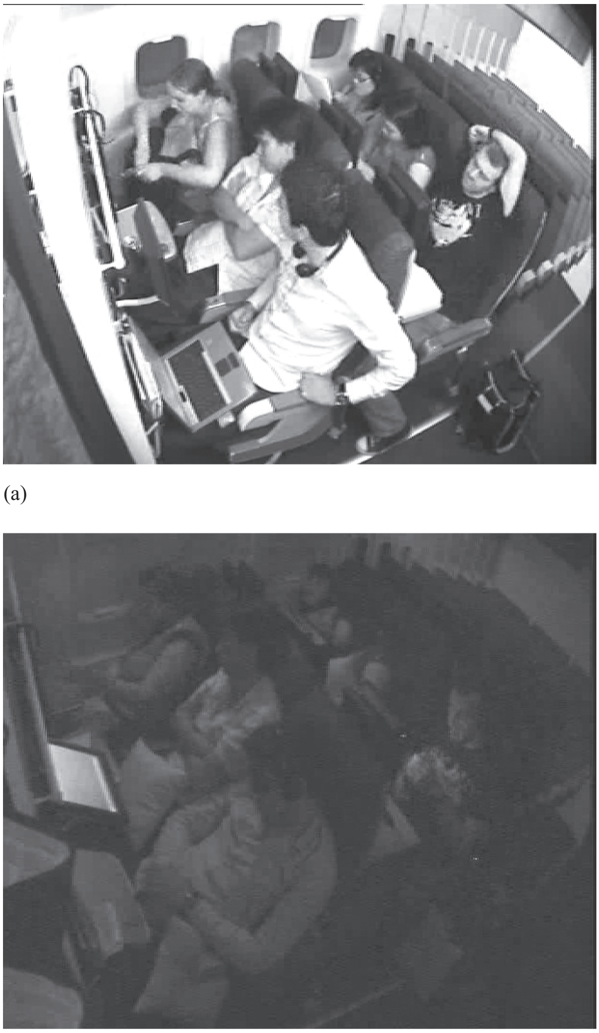
The following hardware were used for both experiments:

- Observation camera
- Computer
- Aircraft cabin simulator

A CCTV observation camera was used to record the situations inside the simulator throughout the experiment. Two CCTVs were installed in the economy class section of the simulator. The activity of the participants was observed and monitored. The recorded data were saved in the computer. Two snapshots of the video recordings in the aircraft cabin simulator are shown in Figure 8.2.

Experimental procedure

In order to simulate a real flight experience, the participants were requested to bring along their hand luggage and the mockup air tickets, which were issued beforehand. Before the experiment started, 15 min of briefing was conducted. Next, the participants were positioned to the seat according to the mockup air ticket. The participants were given a drink and snack before the departure. The general simulated procedure in the KLM economy class as well as flight procedure was used. The flight simulation procedure is shown in Figure 8.3. The departure time of the flight is Amsterdam local time 6:18 p.m. The arrival time of the flight is Amsterdam local time 4:55 a.m. + 1 day (Shanghai local time 10:55 a.m.). The flight duration is



(a)

(b)

Figure 8.2 The video recording inside the aircraft cabin simulator: (a) Time: 22:16:49; (b) Time: 03:15:31 (+1 day)

10 h 35 min. The first experiment was conducted on July 31, 2009 (Friday); the second experiment was conducted on August 7, 2009 (Friday).

Safety precaution

The safety precaution provides information intended to prevent personal injury to the participants, the experiment operators and property damage. During the experiment, the participants seated inside the aircraft cabin simulator for more than 10 h. The aircraft cabin simulator setup is equipped with electrical and electronic equipment such as a computer and a beamer. Subsequently, smoke detectors were

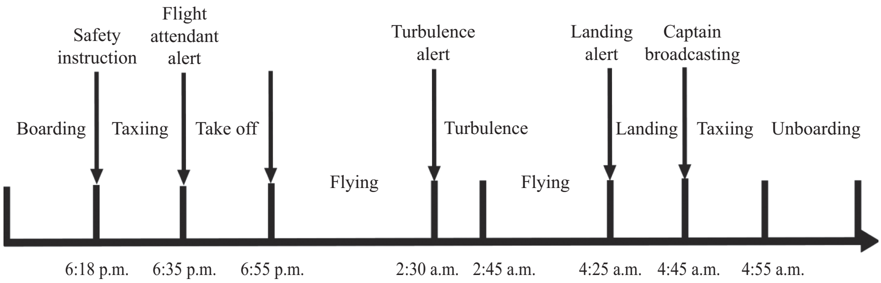


Figure 8.3 Procedure of the flight simulation

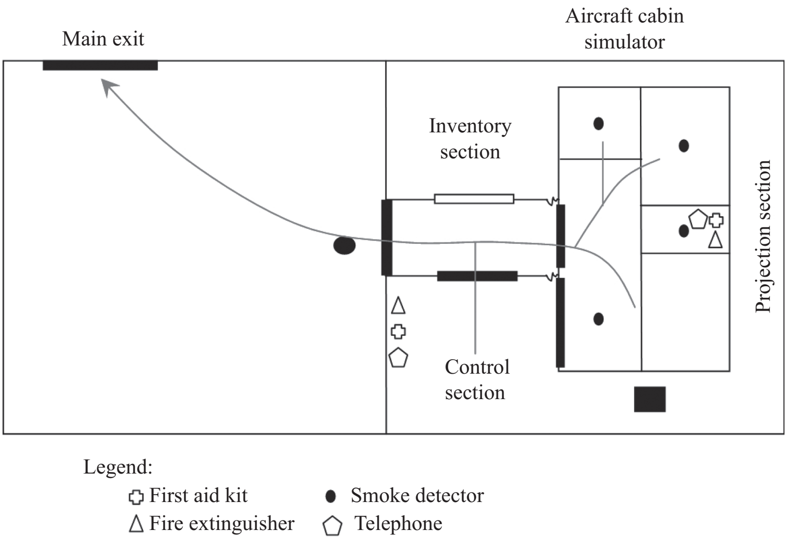


Figure 8.4 The floor plan for emergency evacuation and the location of safety equipment

installed inside the simulator as well as the ceiling of the Simulation Lab. Fire extinguishers and fire blankets were equipped at the control section and inside the simulator. An evacuation plan was also designed for an emergency evacuation. Figure 8.4 shows the evacuation route during emergency as well as the location of the smoke detectors. The university security was informed about the experiment and permission to stay overnight was granted before the experiment started.

Statistical analysis

Applied statistics was used to analyze the questionnaire data. The statistical analysis was carried out with SPSS® version 17.0 for Windows®.

8.2.3.2 Results

The results of the presence questionnaire for 12 participants are described in this section. The raw data analysis of the questionnaire is described in Liu *et al*. [14]. The means and standard deviations of the questionnaire scores are shown in Table 8.5.

Table 8.5 Means (M) and standard deviations (SD) of presence questionnaire

No.	Question	M	SD	N
1	*I had a sense of "being there" in the long haul flight*	4.00	0.74	12
2	*There were times during the experience when the virtual "long haul flight" became more real for me compared to the "real flight"...*	3.75	1.22	12
3	*The laboratory seems to me to be more like...*	3.58	0.79	12
4	*I had a stronger sense of being in...*	3.92	0.79	12
5	*During the experience I often thought that I was really sitting in the laboratory....*	3.50	1.09	12

As referring to Table 8.5, the first question about "*I had a sense of "being there" in the long haul flight*" showed the neutral result ($M = 4.000$, $SD = 0.739$). Question 2 is about "*There were times during the experience when the virtual "long haul flight" became more real for me compared to the "real flight"*. The statistical result ($M = 3.750$, $SD = 1.215$) showed that the participants tend to experience the real world of the laboratory. Next, the result at Question 3 ($M = 3.583$, $SD = 0.793$) showed that the participants think that they felt the simulator is more like the laboratory that they saw than somewhere that they visited. The result of Question 4 ($M = 3.917$, $SD = 0.793$) showed that the participants have a stronger sense of being in the real world of the laboratory than in the virtual reality of the long haul flight. Lastly, the result of Question 5 ($M = 3.500$, $SD = 1.087$) showed that the participants realized that they were in the laboratory most of the time rather than "never because the long haul flight overwhelmed me".

8.2.3.3 Summary

Based on the results of our presence questionnaire by 12 participants inside the aircraft cabin simulator, they felt that they were experiencing the laboratory environment more than real long haul flight situation. Subsequently, the overall mean ratings ($M = 3.750$, $SD = 0.925$) are 0.25 lower than mean rating of neutral (4). The overall result showed that the developed aircraft cabin simulator is able to simulate the average aircraft cabin for research purpose.

8.2.4 Validation experiment for smart neck support system (SNes)

8.2.4.1 Research questions

There are two research questions related to the validation experiment. The first question is to examine subjectively about the comfort experience of the participants with or without the smart neck support system based on the questionnaire. The second question is to examine objectively whether the SNes is able to reduce the SCM muscle stress when supported by our SNes. Both questions are applicable to our treatment group in the validation experiment.

The first question is to examine subjectively about the comfort experiences of the participant with or without the smart neck support system by answering the questionnaire after each experiment (control experiment and treatment experiment).

The second question is to examine whether the SCM EMG values of the participant supported by SNes are lower than without support condition. The result from this hypothesis is important information used to validate the developed smart neck support system subjectively and objectively.

8.2.4.2 Methods

The architecture of the can be roughly sketched as consisting of a bottom sensor layer, a middle network layer and a top application layer. As one of the primary information-acquiring means at the bottom layer of the tags have found increasingly widespread applications in various business areas, with the expectation that the use of RFID tags will eventually replace the existing bar codes in all business areas.

Participant

Three participants ($N = 3$) with no neck pain over the last 3 months were recruited in this experiment. The group consisted of one female and two males aged between 27 and 32 years (mean 29.67 years). They were informed regarding the experiment, which involved questionnaires, sat inside the aircraft cabin simulator for 1 h with SCM electromyography measurement and video recording. The participants were invited for the experiment and were given €20 after completion. The demographic details of the participant are shown in Table 8.6.

Experimental setup

We conducted two experiments inside the aircraft cabin simulator. The location of the experiment is in the simulation laboratory in the main building of the Eindhoven University of Technology. The first experiment was done with the control group where there is no installation of the SNes and the participants had attached EMG electrodes. The first experiment was conducted from 7:00 p.m. to 8:00 p.m. on Friday (first day). The second experiment was done with the treatment group where there is installation of the SNes to the economy class aircraft passenger seat and the participants had attached EMG electrodes. The second experiment was conducted from 7:00 p.m. to 8:00 p.m. after 1 week (second day). Both experiments recruited the same participants and tested under the same experimental conditions. The duration of both experiments is about 1 h. The experimental setup for the treatment group in the aircraft cabin simulator is shown in Figure 8.5.

For observational purposes, CCTVs were installed inside the aircraft cabin simulator. There were two CCTVs used to monitor each participant's activities separately. One CCTV is located in front of the participant and another CCTV is

Table 8.6 Table demographic details of participants

Variable	**M**	**SD**	***N***
Age (years)	29.67	2.52	3
Weight (kg)	64.67	4.51	3
Height (m)	1.72	0.07	3
BMI (kg/m^2)	21.77	0.55	3

Figure 8.5 The installation of three SNes prototypes in the aircraft cabin simulator for validation experiment with the treatment group

located directly above the head of the participant. There is a CCTV that monitored the overall activities in the cabin.

Questionnaire

A questionnaire was distributed after the experiment with the control group and the experiment with the treatment group. The questionnaire consisted of two sections: (1) questions regarding the comfort factors of the neck support (without SNes in control group, with SNes in treatment group) during the experiment and (2) questions about demographic background. The primary goal of our investigation is to understand the smart neck support effects to the participant after the experiment. The questionnaire had two main parts:

1. The first part examined the comfort factor of the neck support of the economy class aircraft passenger seat during the experiment. It contained 10 questions that evaluated the comfort feeling of the participants during the experiment. Participants could indicate their degree of comfort based on a 9-point Likert scale (1 = "not at all"; 5 = "moderately"; 9 = "extremely").
2. The second part assessed demographic variables of the participants, such as gender, age, height and weight.

Apparatus and data recording

For the first experiment with the control group, the following hardware were used:

- MP150 Biopac system with EMG module (MP150WSW with EMG100C)
- Aircraft cabin simulator
- Personal computer (Intel Pentium Dual Core)
- CCTV (VZOR VMP311)

The specification of the second-hand aircraft passenger seats used in both experiment were as follows:

Product name: Recaro Air Comfort
Model no.: 3010-3
Weight: 29.349 kg
Date of manufacture: July 14, 1981

Next, in order to gather EMG value of the SCM muscle and observe the activity of the participants during the second experiment with the treatment group, different hardware were used. The hardware used during the second experiment were as follows:

- MP150 Biopac system with EMG module (MP150WSW with EMG100C)
- Smart neck support system (SNes)
- Aircraft cabin simulator
- Personal computer (Intel Pentium Dual Core)
- CCTV (VZOR VMP311)

Three smart neck support systems were installed on each aircraft passenger seat inside the aircraft cabin simulator. The computer was used for data logging and video recording. The CCTVs were installed at the front as well as above each participant.

Experimental procedure

Before the experiment with the control group, 15 min of briefing was conducted. Next, the participants were positioned inside the aircraft cabin simulator. After that, the light in the aircraft cabin was dimmed and the participants were advised to rest during the 1-h experiment. The EMG measurement and video recording were conducted on a real-time basis. After 1 h of experiment, the participants were given a questionnaire.

For the experiment with the treatment group, we started the experiment with 45 min of briefing to the participants and the attachment of electrodes on the SCM muscles. After that, we positioned the participants on the economy class aircraft passenger seats. The aircraft passenger seat sitting positions were classified as aisle seat, center seat, and window seat. Next, the light in the aircraft cabin was dimmed and the participants were advised to rest during the 1-h experiment. The EMG signals of the participants were monitored and recorded in parallel with system logging and video recording. The validation experiment setup in the aircraft cabin simulator is shown in Figure 8.6. After the experiment, the EMG electrodes were detached from the participants and a questionnaire was given to each participant. Lastly, debriefing was conducted and each participant was paid with a token of appreciation.

Signal acquisition and processing

The normalized EMG activity was analyzed. Normalization of EMG activity was performed for each participant individually. To measure the MVC of SCM muscle, the participant's head was turned to the maximum head rotation angle.

Data analysis

For the recorded normalized EMG data, the data with the complete cycle were selected for further analysis. The complete cycle is the cycle from (1) SNes detects the participant's head, (2) the support of the participant's head, and (3) the deactivation of SNes when the participant's head is away. The selection of the normalized EMG data is based on the data log information. The data log is recording

Figure 8.6 The experimental setup of participants for the treatment group in the aircraft cabin simulator

the time when the system is activated and the time when the system is deactivated. The data log with complete cycles of airbag activity will be selected for further analysis. The complete cycle was described as (1) the participant's head is in touch with the airbag; (2) after time *t* the airbag is inflated and supports the participant's neck; and (3) the participant is not in touch with the airbag, the airbag will be deflated. The data with incomplete cycles will be ignored. The selected average normalized EMG value was used for statistical analysis. For the statistical analysis, the time domain was divided into 10 time intervals where 1 time interval represents 1 min. The normalized EMG values were then averaged over 5 sec blocks in each time interval. Hence, each 1 min time interval has twelve 5 sec blocks. The average normalized EMG value was further analyzed with statistical method. A descriptive statistical method was used to analyze the questionnaire about comfort factors as well as to examine differences before support by SNes and after support by SNes.

Limitation

The validation experiment was conducted on SNes inside the aircraft cabin simulator. The experiment was conducted in the static aircraft cabin like environment. Thus, some important factors such as accelerations and air pressure like the real aircraft environment could not be addressed. In addition, the aircraft passenger seat used was a second-hand aircraft seat, which has been used for almost 29 years. Besides, there was no sleeping activity among the participants. For control group, only questionnaire data were available.

8.2.4.3 Results

The results from the questionnaire distinguished between the experiment with the control group and the experiment with the treatment group. The means and standard deviations of the questionnaire scores are shown in Table 8.7. Both groups use

Table 8.7 The questionnaire scores for the two groups (control and treatment)

Group	***N***	**M**	**SD**
Control	30	5.10	1.37
Treatment	30	5.60	1.63

Table 8.8 The comfort factor scores related to the control group and treatment group

			Control group		**Treatment group**	
No.	**Comfort factors**	***N***	**M**	**SD**	**M**	**SD**
1	Good neck support	3	3.67	2.31	5.67	3.22
2	Relax	3	5.00	0.00	4.67	1.53
3	Seat cushion firmness	3	5.33	1.16	5.00	2.65
4	Restful	3	4.67	1.16	5.00	1.73
5	No stiffness	3	4.67	0.58	5.33	0.58
6	No sore muscles	3	4.67	1.16	5.33	1.16
7	No fatigue	3	5.67	2.31	7.00	1.00
8	No neck strained	3	5.00	1.73	6.00	2.00
9	Fit	3	6.33	0.58	5.67	0.58
10	Comfortable	3	6.00	1.00	6.33	1.53
		Total	5.10	1.37	5.60	1.63

the mean score across the 10 questions. The mean scores from the statistical results showed that the mean scores for the treatment group (M = 5.60, SD = 1.63) is higher than for the control group (M = 5.10, SD = 1.37).

The means and standard deviations of the comfort factor scores are shown in Table 8.8. We found that the comfort factors, such as "good neck support" (control group: M = 3.67, SD = 2.31; treatment group: M = 5.67, SD = 3.22), "restful" (control group: M = 4.67, SD = 1.16; treatment group: M = 5.00, SD = 1.73), "no stiffness" (control group: M = 4.67, SD = 0.58; treatment group: M = 5.33, SD = 0.58), "no sore muscles" (control group: M = 4.67, SD = 1.16; treatment group: M = 5.3, SD = 1.16), "no fatigue" (control group: M = 5.67, SD = 2.31; treatment group: M = 7.00, SD = 1.00), "no strained" (control group: M = 5.00, SD = 1.73; treatment group: M = 6.00, SD = 2.00) and "comfortable" (control group: M = 6.00, SD = 1.00; treatment group: M = 6.33, SD = 1.53) show the increase of mean ratings for comfort in the treatment group. Subsequently, there are three comfort factors that show the decrease of mean ratings, these are "relax" (control group: M = 5.00, SD = 0.00; treatment group: M = 4.67, SD = 1.53), "seat cushion firmness" (control group: M = 5.33, SD = 1.16; treatment group: M = 5.00, SD = 2.65), and "fit" (control group: M = 6.00, SD = 1.00; treatment group: M = 5.67,

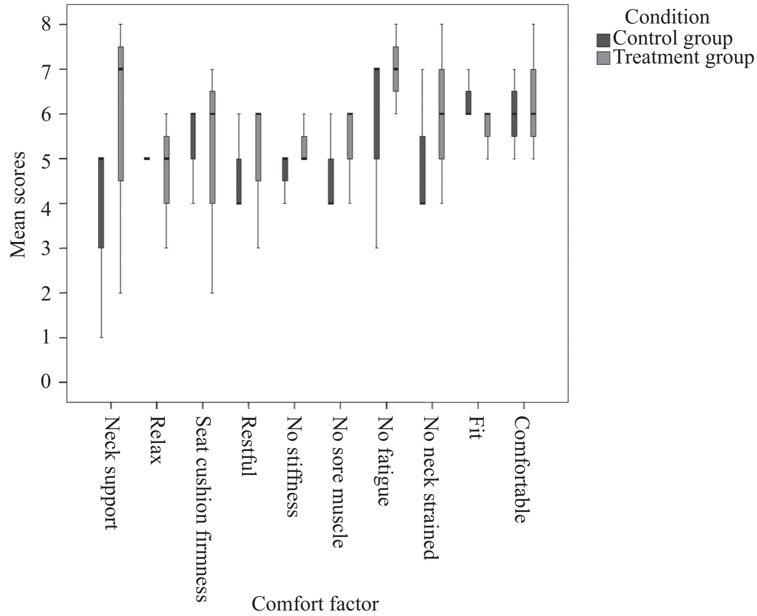


Figure 8.7 The box plot of comfort factors for the control group and the treatment group

Table 8.9 The normalized EMG values for the two test conditions

Test condition	***N***	**M**	**SD**
Before supported by SNes	30	3.03	2.31
After supported by SNes	30	2.82	2.13

SD = 0.58). The mean ratings on the comfort experiences for the experiment with control group and experiment with treatment group are shown in Figure 8.7.

After the experiment with the treatment group, the results from EMG measurements were selected and analyzed. The mean scores of the normalized EMG value after supported by SNes (M = 2.82, SD = 2.13) are lower than the mean scores of the normalized EMG value for before supported by SNes (M = 3.03, SD = 2.31). The means and standard deviations of the normalized EMG value for the two test conditions are shown in Table 8.9. The mean scores of the normalized EMG value after supported by SNes are also lower than the mean scores of the normalized EMG value before supported by SNes. The mean scores for each participant are shown in Table 8.10. The mean scores of the normalized EMG value for the participants in relation with neck support activity are shown in Figure 8.8.

Therefore, H_0 can be rejected and H_1 is selected for hypothesis 2.

Table 8.10 The normalized EMG values for each participant separately

		P1		P2		P3	
Test condition	***N***	**M**	**SD**	**M**	**SD**	**M**	**SD**
Before supported by SNes	30	4.93	1.39	3.56	2.81	1.41	0.35
After supported by SNes	30	4.38	1.21	3.37	2.68	1.37	0.35

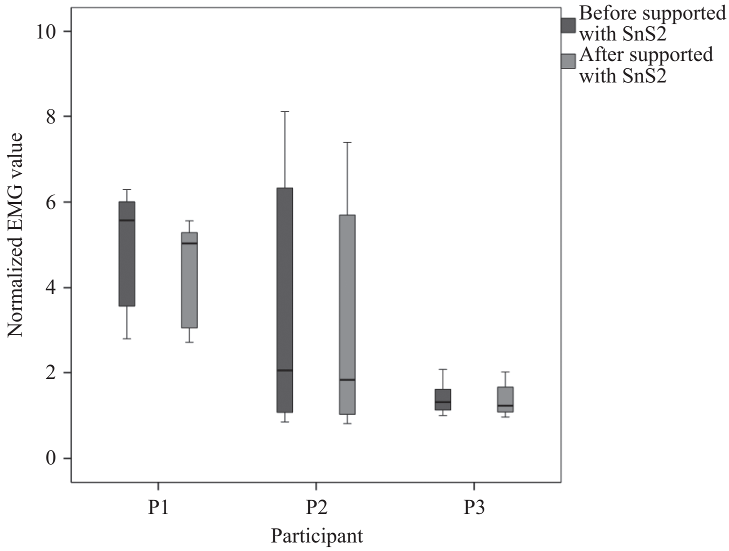


Figure 8.8 The box plot of normalized EMG value for the participants in relation to both neck conditions (before supported by SnS2 and after supported by SnS2)

8.3 Discussion and conclusion

This experiment validated the developed SNes. The major findings from the validation experiment were:

- The mean ratings of a sitting participant in experience on the seat with SNes demonstrate more comfort than without SNes.
- The mean ratings of a sitting participant SCM EMG value supported by SNes are lower than without support condition.

The questionnaire was used for the experiment with the control group as well as the treatment group. The participants evaluated the SNes based on their experience during the experiment. The mean scores of comfort factors for the treatment group are higher than for the control group. The result shows that the seat enhanced with

SNes is able to improve the subjective comfort experience while sitting. Out of ten comfort factors, there were seven comfort factors that showed the increased of mean ratings such as “good neck support,” “restful,” “no stiffness,” “no sore muscles,” “no fatigue,” “no neck strained,” and “comfortable.” Three comfort factors presented lower mean ratings, i.e., “relax,” “seat cushion firmness,” and “fit.” The developed SNes prototype demonstrated comfort improvement in seven comfort factors and decrease of comfort experience in three comfort factors.

For the second result, we tested the SCM participants with EMG measurement to validate the SNes objectively. The result from the experiment showed that the SNes is able to reduce the SCM muscle stress. The developed SNes is able to adapt to the participant’s neck posture automatically and provides the necessary neck support to reduce the SCM muscle stress.

The EMG measurements of the SCM muscle demonstrated that the developed SNes provides support to the participant’s neck as well as reduces the SCM muscle stress. The experiment was conducted in the aircraft cabin simulator and tested in the same environment for both experiments. The result from the questionnaire proved that the participants feel subjectively more comfortable with a seat equipped with SNes. For the experiment with the treatment group, the SCM EMG measurement showed that the SCM EMG value was reduced objectively when it is supported by SNes. The EMG value is lower when both SCM muscles are supported by SNes. The result from the validation experiment is in parallel with the findings in the calibration experiment. It can be proved that the developed SNes is able to improve the comfort experience and to reduce the SCM muscle stress.

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