

Appendix

- A. Briefing**
- B. Sleeping questionnaire**
- C. Informed consent**
- D. Movements analysis**
- E. List of requirements**
- F. Ideation phase**
- G. Shape user test questionnaire**
- H. Code sensors**
- I. Concept validation questionnaire**

Comfort in a Vehicle Seat. Research and Redesign for Sleeping Purposes project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 31 - 08 - 2023 16 - 02 - 2024 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

This project focuses on the redesign of one of the vehicle seats of BMW, the ZeroG Lounger seat (see Figure 1), that is currently integrated in the BMW X7 model. The seat is integrated in the passenger side and designed for offering its occupants the best possible comfort on longer trips. Now, BMW is interested in developing this seat further. Their main goal is to make use of this seat for resting or taking a short nap when the vehicle is being charged in a charging station or, in the future, for sleeping in autonomous vehicles.

The project aims to redesign the ZeroG Lounger considering its negative aspects. First, I will research a few backrest angles and analyse which is the best and most comfortable for resting and taking a nap in the seat. Additionally, I will research, by asking the seat users, which areas of the seat are not comfortable enough and could be improved. For this, two considerations are taken into account: the space of the cabin of the vehicle, and the previous sleeping research, in which the conclusions were that the most comfortable angles for sleeping were 140 and 150° in standard seats. Therefore, now research is done to the main differences between 120° (angle commonly used) and 140° (preferred angle that fits in the space of the interior vehicle). Additionally, I will also research the most common postures and pressure points with the body to the seat while sleeping, and what aspects of the seat can be improved for those.

This project will focus mainly on the redesign of the seat from the insights obtained in the research. From the research experiment, the backrest angle will be analysed, posture, pressure, and its overall comfort. From the previous sleeping research done and the insights of 16 participants, four main focus points were extracted for analyzing with more detail in this research: improving the freedom of movement, uncomfortable leg support, lack of neck support, and discomfort in the arms. Taking into account these four points and the data from the new research, I will evaluate which part of the seat needs to be improved.

The main stakeholder in this project is the owner and driver of a BMW vehicle, who is interested in having a comfortable seat in their vehicle for resting and taking a nap. They want this for longer periods of driving, or for sleeping in the most comfortable way. According to BMW, the main owners of BMW are integrated in an age between 35 and 75(This will be taken into account for selecting participants). The second stakeholder is the BMW seat department, and their ultimate goal is to develop the most comfortable and adaptable seatfor BMW users. To reach this goal, research needs to be conducted first. This is where stakeholders from TU Delft, and therefore my chair and mentor, get involved. Peter has a more sitting comfort backgroung, and he is interested in comfort and seating position, as well as posture and pressure points on the seat. Gerbera has a design backgrnd (since she studied IDE), and is interested in comfort in transit and how this influences the passenger. BMW and TU Delft have been collaborating together since a long time ago offering research on the projects in which BMW is interested about.

space available for images / figures on next page

introduction (continued): space for images



image / figure 1: current ZeroG Lounger integrated in some BMW vehicles

Previous sleeping research: insights obtained

	110°	120°	130°	140°	150°	180°	Total
o Lack of neck support	19	15	8	2	4	1	49
o Uncomfortable position	9	10	7	6	7	2	41
o Pain in legs/feet	8	8	9	8	3	3	39
o Backrest angle	16	10	3	1	1	1	32
o Uncomfortable feet/leg support	10	3	5	3	4	4	29
o Neck pain	8	7	5	2	1		23
o Difficulty to sleep	4	3	4	4	6	1	22
o Chair size	2	2	1	1	1	13	20
o Angle does not allow liberty of movement	2	6		4	5	2	19
o Waking up during nap	1	4	4	2	5	2	18
o Arm rest	3	3	1	2	3	2	14
o Back pain	5	3	4		1		13
o Arm pain	1	1	2	1		2	7
o Lack of feet support		2				1	3
Total	88	77	53	36	41	34	329

image / figure 2: Some critical points from sleeping in different angles extracted from the previous sleeping research

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

This project focuses on the research that will be done for obtaining ergonomic data, from the participants that will be sleeping for ninety minutes in the vehicle seat mockup, and on how to translate that data into design opportunities for the seat. Additionally, it is a great opportunity to test a real seat vehicle with the possibility to further improve its main critical aspects. The research done regarding sleeping on vehicle seats, or sleeping positions on a seat is minimal so the answer can't be found in existing literature. Therefore, this project will focus on generating ergonomic data and relevant insights on how participants sleep in the Zero Lounge seat. From this, it will be evaluated which areas of the seat need further improvement, and what can be done for its redesign.

The main research topics for this project are:

What are the most critical points of the ZeroG Lounger seat that can be improved, regarding the preferred reclined angle for sleeping? (Taking into consideration the feedback provided by the participants of the sleeping experiment)

What are the most common sleeping postures while sleeping in the seat?

From the main problems extracted from the previous sleeping research, which one is more noticeable in the ZeroG Lounger, and which one is most important for the users? My design could be focused in one of this four areas:

- Lack of neck/head support
- Lack of liberty of movement
- Uncomfortable leg position/leg pain
- Uncomfortable armrest/Pain in the arms

The final solution is the redesign of the most uncomfortable area of the seat, according to the participants' insights. A variety of participants (different age, body size, anthropometric measurements) will try to sleep and their data will be collected and further analyzed. From this, a new design of the Lounge seat will be performed.

ASSIGNMENT **

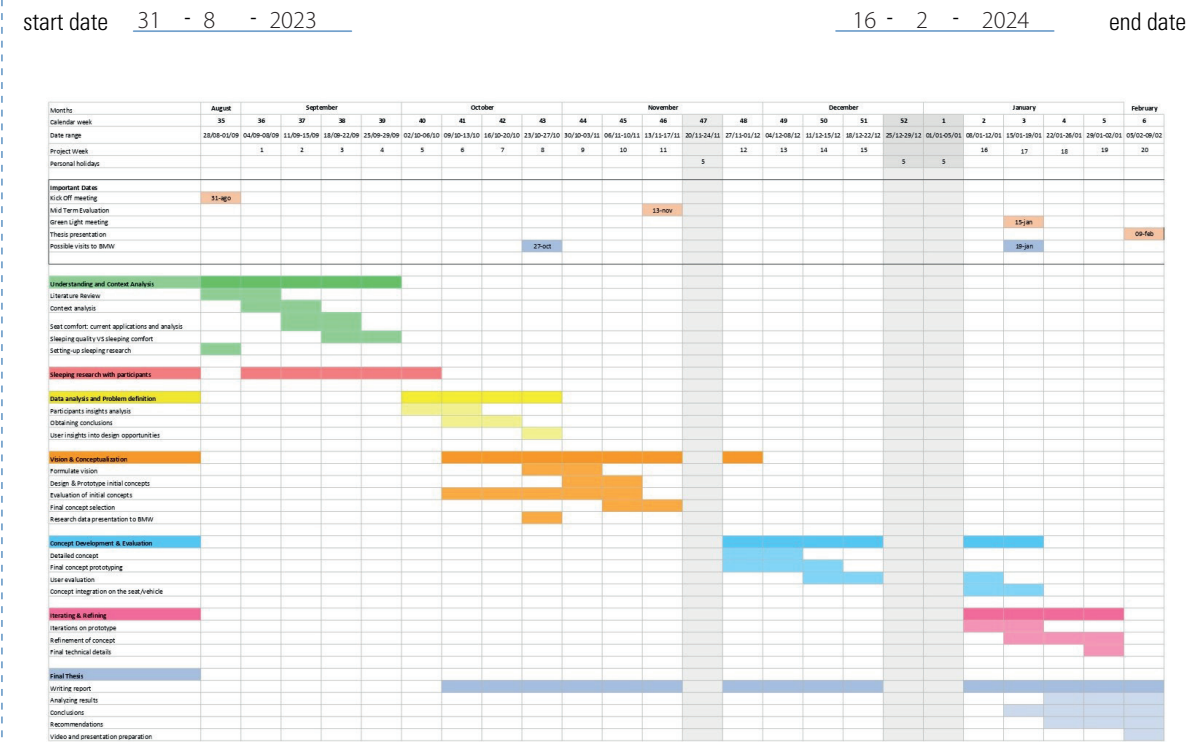
State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I will design the part of the seat that is mentioned as uncomfortable by the users who will test the seat. I will also (in an early stage), research the preferred backrest angle for sleeping in the Lounge seat, and at the same time which are the discomfort areas of this seat according to the insights. I will also keep in mind the most common sleeping postures in each angle. From this, I will redesign the Lounge seat by removing and improving the discomfort areas of the seat.

The project deliverables will consist of three parts. The first is the sleeping research with participants, in which I'll research the preferred backrest angle for sleeping and the discomfort areas of the seat. The second is analyzing the data and extracting the most problematic area of the seat, together with the most common postures for sleeping, and I will create a redesign of the specific area. The third is working on the design and prototype of the redesign and testing it with (ideally) the same participants or new ones.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.



The sleeping research with participants will be done during the first six weeks of the project. I will be attending most of the days the sleeping experiment. During the experiment, i will be working on the context analysis and literature review.

Once the experiment is completed, I will analyse part of the data from the experiment that I consider it is relevant for my graduation project.

When I went to talk to Peter regarding my interests for a future graduation project, he offered me the opportunity to work first as a research assistant for the previous sleeping experiment carried on for BMW. Every day I was more excited about collaborating and helping in the experiment, and later analysing the insights that the participants were providing. Working with the researchers everyday, attending the participants and at the end, analyzing the data extracted and obtaining conclusions gave me a lot of insights of possible and interesting graduation opportunities that I could develop. I learned a lot during those months, and while analysing different data, I came up with a series of improvements that could be integrated for better comfort while sleeping in a seat vehicle. When we went to Munich, while Peter and Gerbera showed the results to different BMW researchers, I proposed to continue with the research in a real seat vehicle for my future Graduation Project to BMW. From this, they were really interested in repeating the same experiment in the Lounge Seat. Now, I will be able to analyze the comfort in a real seat vehicle and propose improvements for enhancing the sleeping experience.

I am interested in developing my knowledge regarding comfort and ergonomics. How to read the sensor's data to see where the participant had comfort in their body or not, what factors of the seat affects to the comfort of the user and how it varies from one person to another (material, softness, size, texture...) and what aspects are more relevant.

* Obligatoria

1
Please give your participant number *

2
Is this your first time filling this questionnaire? *

☐ Yes

☐ No

3
What is your age? *

4
What is your sex? *

☐ Female

☐ Male

5
Is this questionnaire before or after your nap? *

☐ Before

☐ After

6
Before nap

7
During the past day, did you had difficulty staying awake while driving/cycling, eating meals, or engaging in social activity? *

No difficulty at all Very slight difficulty Somewhat difficult

☐ ☐ ☐

8
During the past day, how much of a problem has it been for you to keep up enough enthusiasm to get things done? *

No problem at all Only a very slight problem Somewhat of a pi

☐ ☐ ☐

9
How many hours of sleep do you usually aim for each night? *

☐ Less than 5 hours

☐ Between 6 to 7 hours

☐ Between 7 to 8 hours

☐ More than 8 hours

10
What was the duration of your sleep the past night? (please give your answer in hours) *

El valor debe ser un número.

11
During the past night, how would you rate your sleep quality overall? *

Very good Fairly good Fairly bad

☐ ☐ ☐

12

Did anything happen during the day that could influence your sleep? (e.g. physical activity, stress/worries, caffeine consumption) *

- ☐ Yes
- ☐ No

13

If your answer was 'yes' in the previous question can you please clarify?

16

How would you evaluate the **comfort of the seat** up until now? *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable Extreme comfortable

14

How alert/sleepy do you feel right now? *

- ☐ Extremely alert
- ☐ Very alert
- ☐ Alert
- ☐ Rather alert
- ☐ Neither alert nor Sleepy
- ☐ Some signs of sleepiness
- ☐ Sleepy, but no effort to keep awake
- ☐ Sleepy, but some effort to keep awake
- ☐ Very sleepy, great effort to keep wake, fighting sleep
- ☐ Extremely sleepy, can't keep awake

15

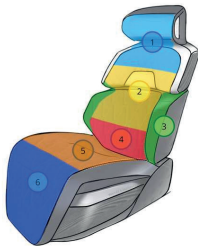
How fatigued do you feel right now? *

Fully alert, wide awake

Very lively, responsive, but not at peak

17

What areas of the seat are you expecting to be **uncomfortable**? *



- ☐ 1. Head/Neck support
- ☐ 2. Back support / reclination angle
- ☐ 3. Arm support
- ☐ 4. Lumbar support
- ☐ 5. Buttock support
- ☐ 6. Leg/Feet support
- ☐ 7. Material/Texture
- ☐ 8. Padding of the seat
- ☐ 9. None of them

18

Please indicate your **overall comfort** at this moment *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable Extreme comfortable

19

Please indicate your **overall discomfort** at this moment *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

22

3. Shoulders *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

23

4. Arms *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

24

5. Middle back *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

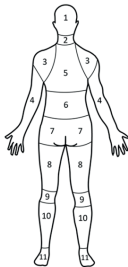
25

6. Lower back *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

Local Body Discomfort. Pre-nap



Using the image, please identify your discomfort for the body parts that you specifically feel **discomfort** for, this means you do not need do choose them all. (this image shows the backside of a human)

20

1. Head *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

21

2. Neck *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

26

7. Buttock *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

27

8. Thighs *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

28

9. Knees *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

29

10. Lower legs *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort Extreme discomfort

30

11. Feet *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

32

How fatigued do you feel right now? *

Fully alert, wide awake

Very lively, responsive, but not at peak

O

33

How much did the sleeping mask influence your sleep? *

34

During the nap, how would you rate your **sleep quality** overall? *

Very good

Fairly good

Fairly bad

35

Please rate your **sleep comfort** overall *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable

Extreme comfortable

Post nap

31

How alert/sleepy do you feel right now? *

- ☐ Extremely alert
- ☐ Very alert
- ☐ Alert
- ☐ Rather alert
- ☐ Neither alert nor Sleepy
- ☐ Some signs of sleepiness
- ☐ Sleepy, but no effort to keep awake
- ☐ Sleepy, but some effort to keep awake
- ☐ Very sleepy, great effort to keep wake, fighting sleep
- ☐ Extremely sleepy, can't keep awake

36

Please rate your **sleep discomfort** overall *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

37

Did you have a good nap or a bad nap? *

- ☐ Good
- ☐ Bad

38

Can you briefly explain why you had a good or a bad nap? *

39

During the nap, how long dit it take to fall asleep? You can make an estimation in minutes. *

El valor debe ser un número.

40

During the nap, Can you please estimate how many minutes of actual sleep you did get? (This may be different form the number of minutes you were laying down) *

El valor debe ser un número.

41

Please indicate your overall **comfort** at this moment *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable

Extreme comfortable

42

Please indicate your overall **discomfort** at this moment *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

43

Describe the nature of the **discomfort** *

45

What areas of the seat were **uncomfortable** while sleeping? *



- ☐ 1. Head/neck support
- ☐ 2. Back support / reclination angle
- ☐ 3. Arm support
- ☐ 4. Lumbar support
- ☐ 5. Buttock support
- ☐ 6. Leg/Feet support
- ☐ 7. Material/Texture
- ☐ 8. Padding of the seat
- ☐ 9. None of them

44

Please identify anything which caused you **comfort** during the nap *

46

Did you manage to sleep the last 30 minutes? *

- ☐ Yes
- ☐ No

47

If you didn't manage to sleep the last 30 minutes, why not? *

48

During the nap, did you have trouble sleeping because you... *

- ☐ Woke up during the nap?
- ☐ Had to use the bathroom?
- ☐ Coughed or snored loudly?
- ☐ Felt too cold?
- ☐ Felt too hot?
- ☐ Had bad dreams?
- ☐ Had pain/discomfort?
- ☐ had difficult placing the head/neck?
- ☐ had difficulty moving body and limbs? (small movements)
- ☐ Had difficulty changing posture/body orientation (major movements)
- ☐ Other reasons/ external disturbances?
- ☐ None of the above

49

If you chose 'Other reasons' in the previous question. Can you please explain?

Feet/leg support

54

Please rate the overall **comfort** of the leg/feet support *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable

Extreme comfortable

55

Please rate the overall **discomfort** of the leg/feet support *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

56

How did leg/feet support influence your sleep? (Think of influence on sleep quality, placing the legs in the seat, change of posture...) What would you change for making it more comfortable? *

50

How did the recline angle influence your sleep? (Think of influence on sleep quality, limb movement and posture change) *

51

Please rate the overall **comfort** of this backrest angle *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable

Extreme comfortable

52

Please rate the overall **discomfort** of this backrest angle *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

53

Is this your first session or your second session of the experiment? *

- ☐ First session
- ☐ Second and last session

Arm support

57

Please rate the overall **comfort** of the arm support *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable

Extreme comfortable

58

Please rate the overall **discomfort** of the arm support *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

59

How did the arm support influence your sleep? Would you change something from the arm support for a better comfort? *

Freedom of movement

60

How would you rate the liberty of movement during the nap (easiness to change posture, sit in different ways...) *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

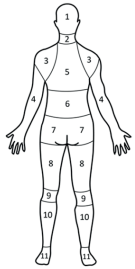
Not comfortable

Extreme comfortable

61

Were there any limitations or restrictions that prevented you from moving comfortably? *

Local Body Part Discomfort. Post-nap



Using the image, please identify your discomfort for the body parts that you specifically feel **discomfort** for, this means you do not need do choose them all. (this image shows the backside of a human)

65

1. Head *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

66

2. Neck *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

Neck support

62

Please rate the overall **comfort** of the neck support *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable

Extreme comfortable

63

Please rate the overall **discomfort** of the neck support *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

64

Was the head and neck support enough? If not, what would you change? *

67

3. Shoulders *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

68

4. Arms *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

69

5. Middle back *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

70

6. Lower back *

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

No discomfort

Extreme discomfort

9/2/24, 11:02

Sleeping Research questionnaire

71

7. Buttocks *

0

1

2

3

4

5

6

7

8

9

10

No discomfortExtreme discomfort

72

8. Thighs *

0

1

2

3

4

5

6

7

8

9

10

No discomfortExtreme discomfort

73

9. Knees *

0

1

2

3

4

5

6

7

8

9

10

No discomfortExtreme discomfort

74

10. Lower legs *

0

1

2

3

4

5

6

7

8

9

10

No discomfortExtreme discomfort

9/2/24, 11:02

Sleeping Research questionnaire

75

11. Feet *

0

1

2

3

4

5

6

7

8

9

10

No discomfortExtreme discomfort

76

Is this your first session or your second session of the experiment? *

☐

First session

☐

Second and last session

https://forms.office.com/Pages/DesignPageV2.aspx?origin=NeoPortalPage&subpage=design&id=TVJuCSlpMECM04q0LeCie3Cib6NORFMq...29/32

9/2/24, 11:02

Sleeping Research questionnaire

77

How was the overall **comfort experience** during the second session in comparison to the first session? *

☐

much better in the second session

☐

somewhat better in the second session

☐

stayed the same as in the first session

☐

somewhat worse in the second session

☐

much worse in the second session

78

Did you experience any **difference of discomfort** between the first and second session? *

https://forms.office.com/Pages/DesignPageV2.aspx?origin=NeoPortalPage&subpage=design&id=TVJuCSlpMECM04q0LeCie3Cib6NORFMq...30/32

9/2/24, 11:02

Sleeping Research questionnaire

79

Were there any noticeable differences in **sleep quality** between the two sessions? *

☐

much better in the second session

☐

somewhat better in the second session

☐

Similar in the first and in the second session

☐

somewhat worse in the second session

☐

much worse in the second session

80

If you had to choose, which reclined back angle would you prefer for sleeping in a car seat during 30 minutes? *

☐

Angle reclination of the first session

☐

Angle reclination of the second session

Este contenido no está creado ni respaldado por Microsoft. Los datos que envíe se enviarán al propietario del formulario.

 Microsoft Forms

C. Informed consent sleeping research

Informed consent

(01/09/2023)

Dear participant,

You are being invited to participate in a research study titled ‘Sleeping comfort in seat vehicle considering the backrest angle”. This study is being done by Gerbera Vledder from the TU Delft and is funded by an automotive company.

Research purpose

The purpose of this research study is to define the preferred seating angles for upright sleeping and will consist of two sessions of approximately 60 minutes each one. The data from this study will be used for scientific publication. During the research you will be asked to try and sleep for a duration of 30 minutes. After 30 minutes you will be woken up with fading in light and music. Before and after this period of sleeping we will ask you to fill in a questionnaire about sleeping comfort/quality and factors influencing sleeping comfort/quality. We will also measure some anthropometric measurements (e.g. stature, weight, hip width, elbow width, sitting depth and lower leg length). During the experiment, we will also record the pressure that your body stablish with the seat through some pressure sensors integrated in the seat, as well as your breathing rate and heart rate. You will sleep in a seat with a randomly assigned backrest angle.

Benefits and risks of participating

There are no heightened risks during this test. On the test day we will request you to consume no coffee or other drinks containing caffeine or taurine.

After completing both sessions, you will receive a 20€ voucher.

Due to the objective of this research participants with difficulty sleeping cannot participate in the research.

COVID-19 measures

The experiment will be performed individually each time, this means, one participant at a time sleeping. This distance cannot be guaranteed during the anthropometric measuring, between the researcher and the participant.

Regulation (and any updates) from the government and suggestions from RIVM will be strictly followed. To avoid the risk of COVID-19 infection, people with symptoms will be asked to take a self-test before coming to the test, and if the participant tests positive they will be excluded or asked to retry after a max period of 10 days (or if it’s at least 5 days ago that the symptoms started, you can retry 24 hours after your last symptoms). The same rule will be applied to the researchers.

Withdrawal from the study

Your participation in this study is entirely voluntary and you can withdraw from the study at any moment during the study, and you will still receive the agreed reimbursement. If requested, the (partially) collected data regarding you will be destroyed.

Anonymize & Store & Access of the data

The collected data will be anonymized in such a way that the name & the address of the participants can no longer be identified. In publication, only the following results will be published:

- Typical setups of the experiment (Photos without personal identify, e.g. any faces will be blurred);
- The statistical results of the average age and standard deviation of the group, weight and basic anthropometric measures, e.g. height;
- The statistical results of any subjective questions regarding the experience of comfort;
- The statistical results of any objective measurements regarding the movements of the body;
- The statistical results of any objective measurements regarding the local climate and the environment;
- The statistical results of any objective measurements regarding the reaction test;
- Observed seating/sleeping postures (video and photo material representing postures will be simplified to simple visualisations not containing personal identifiable information, e.g. no faces or other individual identifiable body features)
- Models generated based on the data
- The statistical results of the data collected through the sensors (pressure distribution, heart rate and breathing rate)

The data will be stored in a secure project folder on the TUDelft server, which only can be accessed by the involved researchers. The data is managed according to the data management plan (DMP) of this experiment.

The data will NOT be shared and re-used by default. But the participants can voluntarily donate the data to the research team in TU Delft for being anonymously used in future research.

For any questions regarding this research the following researcher can be contacted: Gerbera Vledder (g.vledder@tudelft.nl)

Consent form
Backrest seating angles and sleeping comfort

	<i>Please tick the appropriate boxes</i>	Yes	No
Taking part in the study	I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	<input type="checkbox"/>	<input type="checkbox"/>
	I have been able to ask questions about the study and my questions have been answered to my satisfaction.	<input type="checkbox"/>	<input type="checkbox"/>
Study purpose	I have read and understood the study information dated 01/09/2023, or it has been read to me.	<input type="checkbox"/>	<input type="checkbox"/>
	I understand that taking part in the study involves providing my basic anthropometric information including sex, age, body weight, stature, sitting depth, hip width, elbow width, lower leg length and my subjective scores of the test experience.	<input type="checkbox"/>	<input type="checkbox"/>
	I understand that taking part in the study involves the following risks: 1. I need to try and sleep for 30 minutes in a varying seat. 2. I need to participate two different days 3. I need to complete a reaction test (which involves looking at a smartphone and tab the screen when the screen says so). 4. I need to complete questionnaires following the protocols; 5. I cannot drink caffeine or Taurine containing drinks on the day of testing.	<input type="checkbox"/>	<input type="checkbox"/>
	I understand that I will be compensated for my participation with gift card for attending both sessions.	<input type="checkbox"/>	<input type="checkbox"/>
Study risk	I understand that taking part in this study involves the risk of COVID-19 inflection. I understand that these will be mitigated by excluding positively tested participants and researchers.	<input type="checkbox"/>	<input type="checkbox"/>
Use of data in the study	I understand that taking part in the study also involves collecting specific personally identifiable information (PII)[Anthropometric data, video material] and associated personally identifiable research data (PIRD) with the potential risk of my identity being revealed.	<input type="checkbox"/>	<input type="checkbox"/>
	I understand that the collected data will be anonymized in such a way that the name & the address can no longer be identified.	<input type="checkbox"/>	<input type="checkbox"/>

I understand that information I provide will be used for research, possible publications and communication about the publications. ☐ ☐

I understand that personal information collected about me that can identify me, such as name and pictures, will not be shared beyond the study team. ☐ ☐

Future use and reuse of the information by others

The data will NOT be shared and re-used by default. Yes ☒ No

The default choice of this question is NO

I voluntarily donate the collected anonymous data for future research in TU Delft. ☐ ☐

Signatures

Name of participant [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.



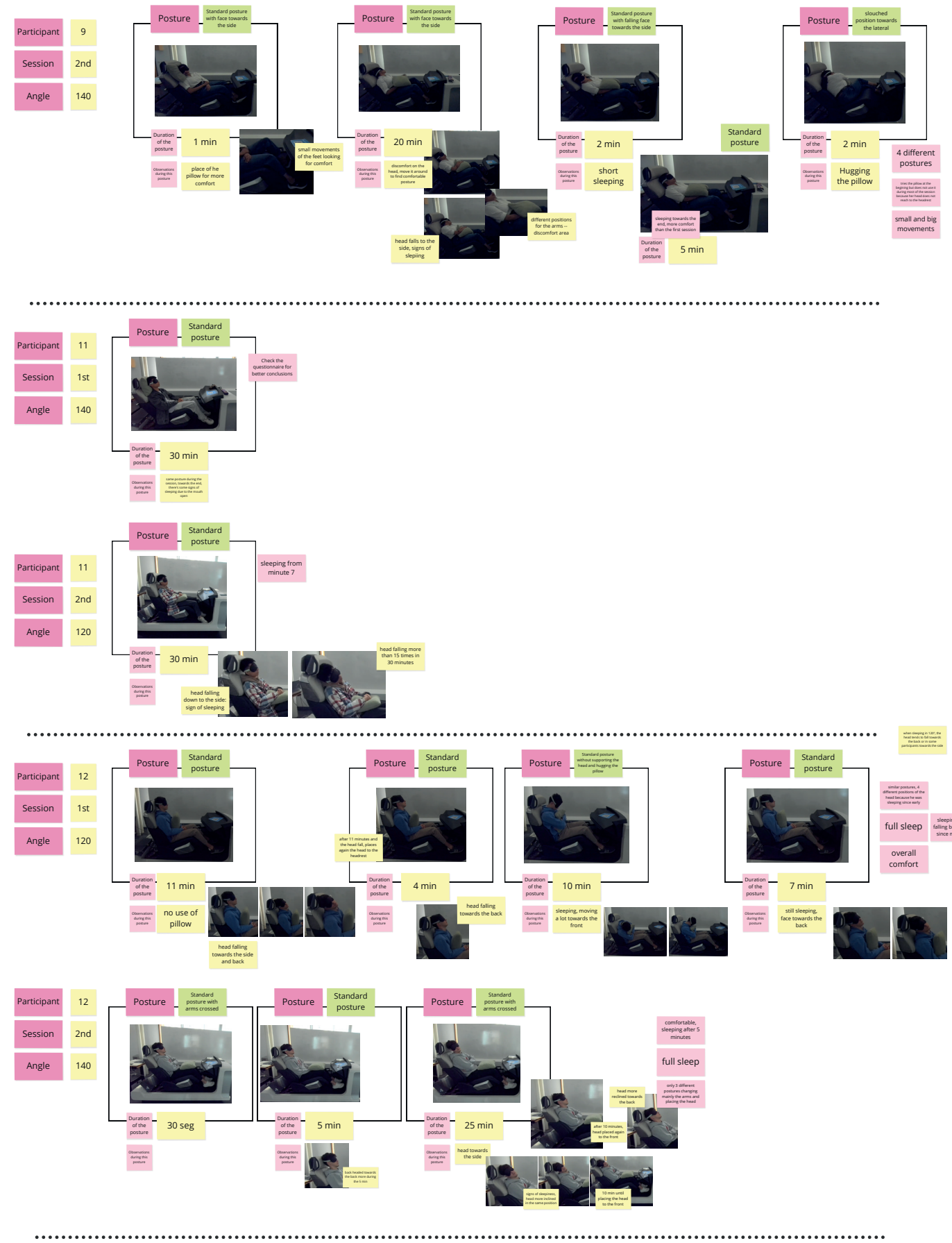
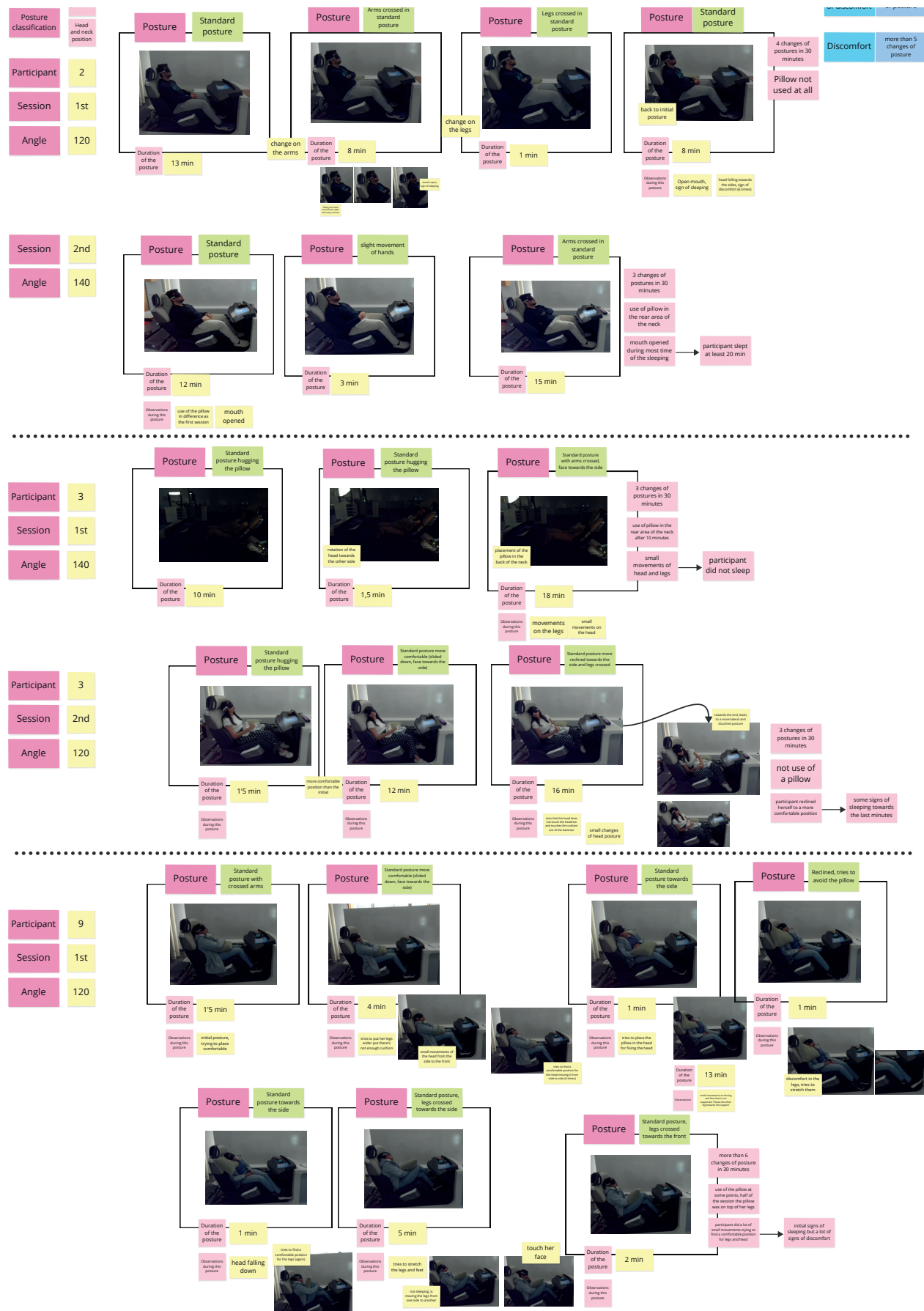
Gerbera Vledder 26/07/2023

Researcher name [printed] Signature Date

Study contact details for further information:

Gerbera Vledder
Faculty of Industrial Design Engineering
Landbergstraat 15, 2628 CE Delft
TU Delft

D. Movement analysis



Participant 13
Session 1st
Angle 140

Posture Standard posture

comfortable, sleeping after 5 minutes
full sleep
only one posture needed for sleeping
use of the pillow since the beginning

Duration of the posture 30 minutes

Observations during this posture

use of the pillow
signs of sleeping after 5 minutes
The face is not sleeping, it is awake

Participant 13
Session 2nd
Angle 120

Posture Standard posture

comfortable, sleeping after 5 minutes
full sleep
no use of pillow

Duration of the posture 30 minutes

Observations during this posture

signs of sleeping after 4 minutes

Participant 14
Session 1st
Angle 120

Posture Standard posture

comfortable in that position, but discomfort on arms and legs
no signs of sleeping
no use of pillow

Duration of the posture 30 minutes

Observations during this posture

movements of hands and legs, no sign of sleeping

After about 20 minutes, the chair finding a more comfortable position
movements of legs, back and forward, during a comfortable position
same position, small movements on the body, still not sleep

Participant 14
Session 2nd
Angle 140

Posture Standard posture

only one posture
signs of sleeping after 10 minutes, until the end
no use of pillow

Duration of the posture 30 minutes

Observations during this posture

signs of sleeping after 10 minutes

head kept on the same position, no use of pillow

Participant 6
Session 1st
Angle 140

Posture Standard posture

only one posture
signs of sleeping after 10 minutes, until the end
no use of pillow

Duration of the posture 30 minutes

Observations during this posture

signs of sleeping after 10 minutes

sliding after 10 minutes

face inclined backwards through the time

small movements of feet the first minutes

Participant 6
Session 2nd
Angle 120

Posture Standard posture

only one posture
signs of sleeping after 10 minutes, until the end
no use of pillow

Duration of the posture 29 minutes

Observations during this posture

no use of pillow on the head
pillow supporting the arms
sleeping the feet for 11 minutes, not sleeping
signs of sleeping after 11 minutes

head falling towards the back
head falling towards the side
different movements on the hands

slept for 15 minutes

Posture Standard posture with head towards the side

Duration of the posture 1 minute

Observations during this posture

wake up after 15 minutes sleeping and read another posture

Participant 8
Session 1st
Angle 140

Posture Standard posture

Duration of the posture 26 minutes

Observations during this posture

place the arms vertical position than the rest of the body

head changed the arms position, no sign of sleeping

Participant 8
Session 1st
Angle 140

Posture Standard posture with legs crossed

same posture with small variations of legs and arms
heavy signs of sleeping, constant movements of arms or legs during the 30 minutes
use of the pillow

Duration of the posture 4 minutes

Observations during this posture

stretch the legs at the end of the session

face more relaxed after putting the pillow - no sign of falling asleep

Participant 8
Session 2nd
Angle 120

Posture Standard posture with legs crossed (reclined posture)

Duration of the posture 5 minutes

Observations during this posture

the face is relaxed, the arms are not sleeping, the head is not sleeping

reclined in the seat

change the posture to a more comfortable position and change the arms

Participant 8
Session 2nd
Angle 120

Posture Standard posture with legs crossed (upright posture)

Duration of the posture 1 minute

Observations during this posture

after a few, places the pillow in the lumbar area

Participant 8
Session 2nd
Angle 120

Posture Standard posture reclined

Duration of the posture

Observations during this posture

places the pillow in the lumbar area

face towards the side

head falling towards the side at least 8 times

position after 22 minutes of sleep

uncomfortable as the original position of the pillow is different position
sleep after 7-8 minutes for a duration of 22 minutes
use of the pillow in the lumbar area, not head

Participant 10
Session 1st
Angle 140

Posture Standard posture with face reclined towards the side

Duration of the posture 12 minutes

Observations during this posture

small movements on the legs, no sign of sleeping

face falling towards the side through the time

Posture Standard posture with face reclined towards the side with the pillow

Duration of the posture 18 minutes

Observations during this posture

face falling less to the side thanks to the pillow

signs of sleeping after 2 minutes, face fell towards the front the whole session

Participant 10
Session 2nd
Angle 120

Posture Standard posture

same posture
use of the pillow

Duration of the posture 30 minutes

Observations during this posture

use of the pillow

no change of posture

on head of discomfort with the face through the time
face falling towards the front

Participant 15
Session 1st
Angle 120

Posture Standard posture with crossed legs

Duration of the posture 8 minutes

Observations during this posture

place the arms hugging the pillow

face closing towards the side after falling asleep

change on the arms, still hugging the pillow

signs of sleeping, face more relaxed after 8 minutes, no sign of falling asleep

pillow is not a comfortable position for the head

Posture Standard posture with face reclined towards the side

Duration of the posture 3 minutes

Observations during this posture

change of the head towards the front

Posture Standard posture with face reclined towards the side

Duration of the posture 7 minutes

Observations during this posture

mouth open, some signs of sleeping

Participant 15
Session 1st
Angle 120

Posture Standard posture with face reclined towards the side

Duration of the posture 4 minutes

Observations during this posture

sleeping

head falling more through the time in this posture

Posture Standard posture with arms crossed

Duration of the posture 8 minutes

Observations during this posture

small movements of the head but fully asleep

4 to 5 different postures but similar among them
sign of discomfort on the head at the beginning, but it disappears after 4 minutes, face more relaxed after 8 minutes, no sign of falling asleep

not use of the pillow for the head, just for placing the arms

Participant 4

Session 1st

Angle 120°

Posture Standard posture

only one posture

sleeping after 5 minutes

use of pillow on the headneck



Duration of the posture 30 minutes

Observations during the posture

no change of posture or movement

signs of sleeping after 5 minutes

The diagram illustrates the experimental setup. A participant is lying in a reclining chair, watching a screen. The setup is labeled 'Posture' and 'Standard posture with crossed arms'. The participant is wearing a 'Pillow' and 'Headrest'. The screen displays 'only one posture'. The participant is also wearing a 'Pillow' and 'Headrest'. The participant is also wearing a 'Pillow' and 'Headrest'.

Participant	7		Posture	Standard posture with crossed arms	<p>only one posture</p> <p>sleeping almost no movement during 24 minutes</p> <p>no use of pillow</p>
Session	1st		Duration of the posture	30 minutes	
Angle	140		Observations during this posture	no use of pillow	<p>mouth open and head falling to the side</p>
				signs of sleeping after 6 minutes	

The diagram illustrates the experimental setup for the study. It shows a participant seated in a chair, holding a tablet. The setup is labeled with various conditions:

- Participant:** 7
- Session:** 2nd
- Angle:** 120
- Posture:** Standard posture with crossed arms
- Duration of the posture:** 30 minutes
- Observation during the posture:** signs of sleeping after 5 minutes; mouth open
- only one posture:** sleeping: almost no movements, during 27 minutes
- no use of pillow:** head falling towards the side

Participant	5
Session	1st
Angle	120

Posture

Reclined to the side placing feet on the cup support

Duration of the posture

30 minutes

Observations during the posture

head falling

only one posture

sleping almost no movements, during 25 minutes

use of pillow in the side, didn't reach the head-restraint

Sleep for at least 25 minutes

Small movements at the starting of the session

Participant	5
Session	2nd
Angle	140

Posture

Reclined to the side placing feet on the cup support

Duration of the posture

1minutes

Observations during the posture

Posture

Reclined to the side placing feet on the cup support

Duration of the posture

28 minutes

Observations during the posture

some signs of sleeping, around 20 minutes

New table

	Backrest angle	Amount of sleep	Use of pillow	Change of postures	Head posture
P.2	120°	signs of sleeping around 15 minutes	no use of pillow	4 changes of postures (arms and legs)	head falling backwards when sleeping
	140°	around 20 minutes	use of pillow from minute 0'	3 changes of postures (arms and legs)	no movement on the head because of the pillow
P.3	120°	participant slept the last 15 minutes	no use of pillow	3 changes of posture	head falling towards the side when sleeping
	140°	participant did not sleep	use of pillow from minute 20'	3 changes of posture	no movement of the head: participant put the pillow and didn't sleep
P.4	120°	25 minutes	use of pillow from minute 0'	no change of posture	no movement
	140°	sleeping, not clear how much (20 min)	use of pillow from minute 0'	no change of posture	no movement
P.5	120°	25 minutes	use of pillow from minute 0'	no change of posture	head falling towards the front
	140°	sleep for 20 minutes	use of pillow from minute 0'	no change of posture	head covered by the body, no visual movements
P.6	120°	sleep for 15 minutes	no use of pillow	2 changes of posture (head)	no change on the head
	140°	sleep for 20 minutes	no use of pillow	no change of posture	face falling towards the side and back
P.7	120°	sleep for 25 minutes	no use of pillow	no change of posture	head falling towards the side
	140°	sleep for 23 minutes	no use of pillow	no change of posture	head falling towards the side
P.8	120°	sleep for 20 minutes	no use of pillow	3 changes of posture	head falling towards the side
	140°	no signs of sleeping	use of pillow	2 changes of posture	no movements
P.9	120°	initial signs of sleeping for aprox. 8 minutes but lot of discomfort	use of pillow for only 2 minutes	more than 6 different postures	lots of movements trying to place the head comfortable, mainly towards the side
	140°	sleeps the last 10 minutes	pillow not used, participant did not reach the headrest	4 changes of posture	head falls towards the sides when participant is sleeping/trying it
P.10	120°	sleeping for 25 minutes	use of pillow since 0'	no movements	head falling towards the front
	140°		use of pillow after		head falling

P.10	120°	sleeping for 25 minutes	use of pillow since 0'	no movements	head falling towards the front
	140°	no signs of sleeping	use of pillow after 12 min	2 change of posture	head falling towards the side
P.11	120°	sleeps during 23 minutes	no use of pillow	no change of posture	head falls towards the side during 15 minutes
	140°	unclear, sleeping towards the end	use of pillow since minute 0'	no change of posture	head keeps in same positions due to the pillow
P.12	120°	sleep since minute 3	no use of pillow	4 changes of posture	head falling towards the back, both sides and front
	140°	slept at least 25 minutes	no use of pillow	3 changes of posture	head falling towards the back and side in several occasions
P.13	120°	sleeping at least 27 minutes	no use of pillow	no change of posture	head falling backwards
	140°	slept at least 25 minutes	use of pillow	no change of posture	head placed bu the pillow
P.14	120°	no initial signs of sleeping	no use of pillow	no change of posture. Small movements on head and legs	head kept without movement
	140°	sleeping during 20 minutes	no use of pillow	no change of posture	head falls slightly towards the back but not notorious
P.15	120°	sleeping for 15 minutes	no use of pillow	5 change of posture	head falling to the side
	140°	sleeping 10 minutes, unclear	no use of pillow	5 change of posture	no movement
P.16	120°	no clear signs of sleeping	no use of pillow	5 changes of posture	no movements
	140°	20 minutes of sleep	use of pillow in neck area	2 changes of posture	no movements
P.17	120°	25 minutes of sleep	use of pillow	2 changes of posture	face falling towards the front
	140°	22 minutes of sleep	use of pillow	3 changes of posture	face falling towards the back and side

E. List of Requirements

Category		Explanation	Requirement (R) or Wish (W)
1	Functionality	The design must be adjustable and enable the passengers to place it in their preferred position	R
2	Functionality - Ergonomics	The design must be adjustable in height and accommodate users of different sizes to provide adequate support (P05 to P95)	R
3	Functionality	The headrest must be adaptable and comfortable to different backrest positions	R
4	Functionality	The headrest must be able to use while performing other activities apart from sleeping, such as watching in-vehicle infotainment or having a conversation in active seating with the driver.	R
5	Functionality	The interaction with the headrest should be as easy as possible (intuitive mechanisms and how to adjust it)	W
6	Functionality	The headrest should be personalizable to their preferences and likings when sleeping or performing other activities	R
7	Functionality	The design should be easy to use: passengers can easily adjust and customize the head restraint and neck support to their preference	W
8	Functionality	The head restraint must have an adjustable angle for different preferences and backrest angles	R

Category		Explanation	Requirement (R) or Wish (W)
1	Design shape	The design must offer an adjustable neck support to different neck widths to ensure firmness on the head while sleeping	R
2	Design shape	The neck support should offer a "360° support" covering the are of the head and neck, to avoid the "falling head effect" while sleeping	W
3	Design shape	The design should offer a chin support that prevents the head to fall forwards	W
4	Design shape	The design must not obstruct the movements of the passenger while sleeping, but help the passenger to place in their ideal posture	R
5	Design shape	The design should help the passenger to change postures while sleeping and relaxing, avoiding long term discomfort	W
6	Design shape - Functionality	The design should support the head and neck of the passenger in all activities when reclining to the back	W
7	Design shape - Ergonomics	The design must align with the natural curvature of the head and neck, promoting comfort and reducing strain	R
8	Design shape	The neck support should be symmetrical and offer the same amount of head support when reclining the head towards left or right	W
9	Design shape	The neck support should not provide a sensation of	W

		claustrophobia or oppression	
10	Design shape	The head restraint redesign and neck support should be easy to integrate in the current seat of BMW	W
11	Design shape	The design must cover the current gap without support in the seat: area between the shoulders and top of the head	W
12	Design shape	The perception of comfort should be integrated in the design before testing the product	W
13	Design shape	The design should avoid the users from prefer using a pillow	W
14	Design shape	The neck rest of the headrest should be easy to remove	W

Category		Explanation	Requirement (R) or Wish (W)
1	Sleeping	The design must improve the comfort while sleeping in different backrest angles, 140° and 120°, with preference for the first one.	R
2	Sleeping	The design should improve sleeping comfort in different backrest angles (120° and 140°)	W
3	Sleeping	The design should improve the time to fall asleep, considering a 30 minute power nap	W
4	Sleeping	The design allows freedom of movement while sleeping	R
5	Sleeping	The design is adaptable to different types of trips: duration of the trip and time of sleep	W

Category		Explanation	Requirement (R) or Wish (W)
1	Dimensions	The neck support must fit within the dimensions and current characteristics of hte current BMW seat	R
2	Dimensions	The redesign should not interfere with the back area of the current seat	R
3	Dimensions	The dimensions of the head restraint will be provided by current regulations in head restraint and by ergonomic demographics in P05 to P95	R
4	Dimensions	Weight should be in range of current head restraints and travel pillows	R

Category		Explanation	Requirement (R) or Wish (W)
1	Safety	The headrest should provide a safety feeling while sleeping and doing other activities	W
2	Safety	The design must be able to hold the force of the passenger when placing the head towards the back.	R
3	Safety	If integrating wings in the neck support, the design must be able to hold the force of the passenger when falling their head towards the sides when sleeping	R
4	Safety	The mechanisms and parts of the headrest should operate reliably and handle miss-use	R

5	Safety	The design should have the less amount of components as possible, reducing discomfort and easiness to break	W
6	Safety	The design must not contain any sharp edges or visible mechanisms that can be dangerous to the passengers	R
7	Safety	the design must prevent access to moving parts and getting fingers stuck	R
8	Safety	The design cannot create visibility obstruction to the driver	R

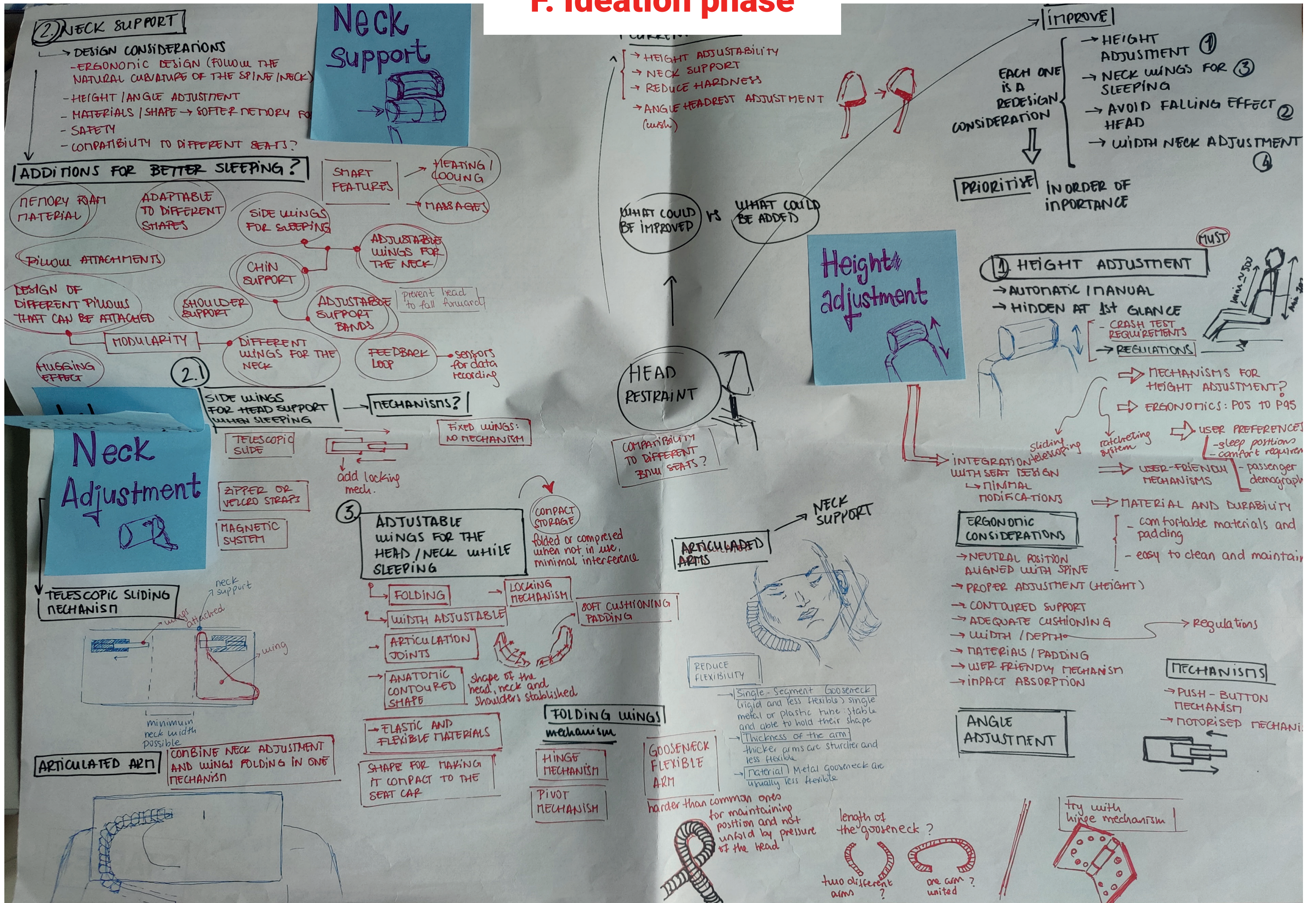
Category		Explanation	Requirement (R) or Wish (W)
1	Materials	The design should consider the different needs of firmness of the foam depending on the area of contact with the boy: firm in the head and jaw support, and softer in neck and cheek	W
2	Materials	The design should consider cool and breathable materials	W
3	Materials	The material used for the design must be easy to clean, such as removable covers or cleanable materials	R
4	Materials	The external cover material of the headrest should vary depending on the area of contact with the body: softer for the neck support	W

Category		Explanation	Requirement (R) or Wish (W)
1	Maintainance	The headrest lifespan should have at least 10 years without maintenance, or according to recommendations of BMW seats	R

Category		Explanation	Requirement (R) or Wish (W)
1	Regulations	The design must follow the different car regulations and seat standards	R
2	Regulations	The headrest restraint should effectively reduce the risk of whiplash injuries in the event of a rear-end collision	R
3	Regulations	The material and design should absorb impact forces to minimize head and neck injuries in accidents	R
4	Regulations	The head restraint must be at least 700mm above the seating reference point in their highest position and not deflect more than 100mm moment. The lateral width must not be less than 171 for individual seats	R

Category		Explanation	Requirement (R) or Wish (W)
1	Aesthetics	The different functions of the design should be clear for the passenger and intuitive to use	W
2	Aesthetics	The design should provide an aesthetic feeling of comfort on the passenger	W
3	Aesthetics	The design must be integrable in the current seat and therefore continue with similar aesthetics	R

F. Ideation phase



SHAPE WINGS

TUBULAR

FOLLOWING THE SHAPE OF THE HEAD/NECK

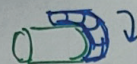
N° OF FLEXIBLE ARMS?

inclination

CHAIR INTEGRATION

- MINIMAL MODIFICATIONS
- NON-DISTURBING WHEN NOT USING IT
- EASY TO EXTRACT AND USE

BENDED UP



1. HEAD SUPPORT

ANGLE ADJUSTMENT

HEIGHT ADJUSTMENT

WHEN NOT USED, PLACE THEM AS SHOULDER SUPPORT ?

SHAPE OF THE WINGS

- SUPPORTING THE NECK
- SUPPORTING THE CHIN
- EMBRACING THE CHEEK FOR A MORE COMFORTABLE EXPERIENCE

ANATOMICAL CONTOURING

natural curves of head, neck and shoulders

ADJUSTABLE WIDTH

expand and contract easily

HEIGHT CONSIDERATIONS

suitable height for avoiding strain and discomfort

HIDDEN MECHANISM

mechanism inside the lateral wings

PADDED SURFACE

soft, cushioning padding (comfortable & pressure relieving)

USER FRIENDLY

SECURE LOCKING

DURABILITY

SAFETY COMPLIANCE

INTEGRATED IN NECK SUPPORT, NOT IN HEAD SUPPORT

RECLINING POSITION FOR RECLINED HEAD



360° SUPPORT

CHIN SUPPORT

- AVOIDING HEAD FALLING FORWARD
- COMFORTABLE, AVOID "CLAUSTROPHOBIA" FEELING

OTHER SEAT DESIGN RECOMM.

IMPROVEMENT OF SHOULDER SUPPORT

ARM SUPPORT

HAVING THE OPTION OF USE A PROPER ARM SUPPORT IF DESIRED

LEG SUPPORT

DEVELOPMENT OF FOOTREST FOR MORE RECLINED ANGLES

ADJUSTABILITY OF SEAT PAN FOR SHORTER / TALLER PEOPLE

REDUCE THE SHARP ANGLE BETWEEN THE SEAT PAN & LEG SUPPORT

G. Shape user test questionnaire

Concept shaping

Concept 1

1. What do you like about concept 1?

2. What you do not like about concept 1?

3. Concept 1. How intuitive it is to adjust the headrest and bend it?

4. Indicate your overall comfort with concept 1

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortableExtreme comfortable

Concept 2

5. What do you like about concept 2?

6. What you do not like about concept 2?

7. Concept 2. How intuitive it is to adjust the headrest and bend it?

8. Indicate your overall comfort with concept 2

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortableExtreme comfortable

Preference

9. Would you prefer to sleep without support or with any of both supports? Why?

10. Which headrest would you prefer for sleeping

- ☐ Concept 1
- ☐ Concept 2
- ☐ I would prefer to sleep without headrest

H. Sensors code

```
1 import time
2 import Adafruit_ADS1x15
3 from datetime import datetime
4
5 # Allow to write the new result in a new line on the txt
6 def append_new_line(file_name, text_to_append):
7     """Append given text as a new line at the end of file"""
8     with open(file_name, "a+") as file_object:
9         file_object.seek(0)
10        data = file_object.read(100)
11        if len(data) > 0:
12            file_object.write("\n")
13        current_time = datetime.now().strftime("%Y-%m-%d %H:%M:%S")
14        file_object.write(f"{current_time}, {text_to_append}")
15
16 # Create an ADS1015 ADC (16-bit) instance. Note you can change the I2C address from its default (0x48) and/or bus number
17 adc = Adafruit_ADS1x15.ADS1115(address=0x48, busnum=1)
18
19 adc.data_rate = 250
20
21 # Choose a gain of 1 for reading voltages from 0 to 4.09V.
22 GAIN = 2/3
23
24 # Create a Loop
25 while True:
26
27     #Convert Count to Pa
28     #Sensor dimensions
29     side_sensor_mm = 36
30
31     #Are sensor in mm²
32     area_sensor_mm2 = side_sensor_mm ** 2
33
34     # Conversion area to m²
35     area_sensor_m2= area_sensor_mm2 * 1e-6
36
37     #Pression Range Pa
38     range_pression_kpa = (10 - 0.02) * 9.8 / area_sensor_m2
39
40     #Range ADS counts
41     range_adc_counts = 2 ** 16 - 1
42
43     #Sensitivity in counts to Pa
44     Sensitivity_counts_to_Kpa = range_adc_counts / range_pression_kpa
45
46     # Read the value coming from Analogue In Pin 0, set gain to the above value
47     values1 = adc.read_adc(0, gain=GAIN)
48     values2 = adc.read_adc(1, gain=GAIN)
49     values3 = adc.read_adc(2, gain=GAIN)
50     values4 = adc.read_adc(3, gain=GAIN)
51
52
53     #Conversion to Pa
54     Pression_kpa1 = values1 / Sensitivity_counts_to_Kpa
55     Pression_kpa2 = values2 / Sensitivity_counts_to_Kpa
56     Pression_kpa3 = values3 / Sensitivity_counts_to_Kpa
57     Pression_kpa4 = values4 / Sensitivity_counts_to_Kpa
58
59
60
61
62     # Print the values to the shell, right click shell to enable the plotter
63     print("Channel 1:", Pression_kpa1)
64     append_new_line('test1.txt', str(Pression_kpa1))
65     print("Channel 2:", Pression_kpa2)
66     append_new_line('test2.txt', str(Pression_kpa2))
67     print("Channel 3:", Pression_kpa3)
68     append_new_line('test3.txt', str(Pression_kpa3))
69     print("Channel 4:", Pression_kpa4)
70     append_new_line('test4.txt', str(Pression_kpa4))
```



```
61
62 # Print the values to the shell, right click shell to enable the plotter
63 print("Channel 1:", Pression_kpa1)
64 append_new_line('test1.txt', str(Pression_kpa1))
65 print("Channel 2:", Pression_kpa2)
66 append_new_line('test2.txt', str(Pression_kpa2))
67 print("Channel 3:", Pression_kpa3)
68 append_new_line('test3.txt', str(Pression_kpa3))
69 print("Channel 4:", Pression_kpa4)
70 append_new_line('test4.txt', str(Pression_kpa4))
71
72 # Pause for two second (so as not to be overwhelmed by data)
73 time.sleep([2])
```

I. Concept validation questionnaire

User test - Head support concept

General information

1
Name

2
What is your age?

- ☐ Female
- ☐ Male
- ☐ Prefer not to say

4
Provide your approximate height in cm

5
Provide your approximate weight in kg

Head support questionnaire

6
Did you manage to sleep? If yes, how many minutes of sleep did you get?

7
Indicate your overall comfort at this moment

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable Extreme comfortable

8
How would you evaluate the comfort of the head/neck support at the beginning of the test?

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable Extreme comfortable

9
How would you evaluate the comfort of the head/neck support after the nap?

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not comfortable Extreme comfortable

10
How easy was to adjust the head/neck support to your preferences?

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not easy at all Very easy

11
How intuitive was the head/neck support for adjusting it to your preferences?

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not intuitive at all Very intuitive

12
How easy was it for you to adjust the height of the head support?

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Not easy at all Very easy

13
Did the head/neck support adjust to your preferences? (Height, neck width, head width...)

14

How did the head/neck support influence your sleep?

15

Do you think the head support enhanced your ability to sleep in the seat?

16

Were there any specific aspects of the head/neck support that positively or negatively influenced your sleep quality?

17

Was this head/neck support enough for a comfortable nap? If not, what would you change about it?

19

Neck

- ☐ Very severe discomfort
- ☐ Severe discomfort
- ☐ Medium discomfort
- ☐ Slight discomfort
- ☐ Very slight discomfort
- ☐ No discomfort

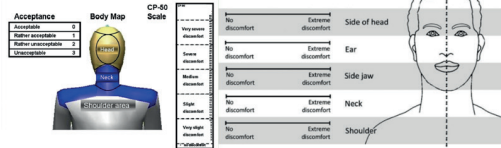
20

Shoulder area

- ☐ Very severe discomfort
- ☐ Severe discomfort
- ☐ Medium discomfort
- ☐ Slight discomfort
- ☐ Very slight discomfort
- ☐ No discomfort

Local discomfort

Using the images, please identify your discomfort for the body parts that you specifically feel **discomfort**



18

Head

- ☐ Very severe discomfort
- ☐ Severe discomfort
- ☐ Medium discomfort
- ☐ Slight discomfort
- ☐ Very slight discomfort
- ☐ No discomfort

21

Side of head

- ☐ Very severe discomfort
- ☐ Severe discomfort
- ☐ Medium discomfort
- ☐ Slight discomfort
- ☐ Very slight discomfort
- ☐ No discomfort

22

Ear

- ☐ Very severe discomfort
- ☐ Severe discomfort
- ☐ Medium discomfort
- ☐ Slight discomfort
- ☐ Very slight discomfort
- ☐ No discomfort

23

Side jaw

- ☐ Very severe discomfort
- ☐ Severe discomfort
- ☐ Medium discomfort
- ☐ Slight discomfort
- ☐ Very slight discomfort
- ☐ No discomfort

24

Thanks for your help! Is there anything else you would like to add?