SL·ËËG

CDP Report

Advanced Concept Design for Noise-free ICU

2016-2017

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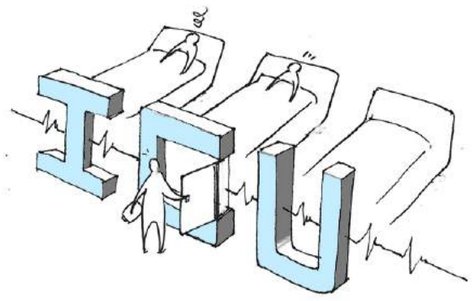

PREFACE

This project report is the final summary and reflection of the course Advanced Concept Design (2016-2017) at TU Delft, regarding the topic “Noise-free ICU”. The concept design was finished individually and guided by the concept design project coach, Erik van Kuijk. I would like to thank his constructive advice during every fruitful meeting.

During the first quarter, several ergonomic (AEE) and social-cultural (DCS) studies were initiated within a five-people group. The outcomes may not be directly relevant to this project, but the process of the collaborative research was rewarding. So I am also grateful for my 5A teammates, Marijn van Bekkum, Ward Hendrix, Stijn Krabbenborg, and Malcolm Royen, who were patient and helpful even after the assigned collaborating period.

The course along with the project has been a great educational journey. I hereby present my first design, SLEEG, as a proper industrial design student. Hope you enjoy reading it.

Project 5:	Noise free Intensive Care Units
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*Glossary

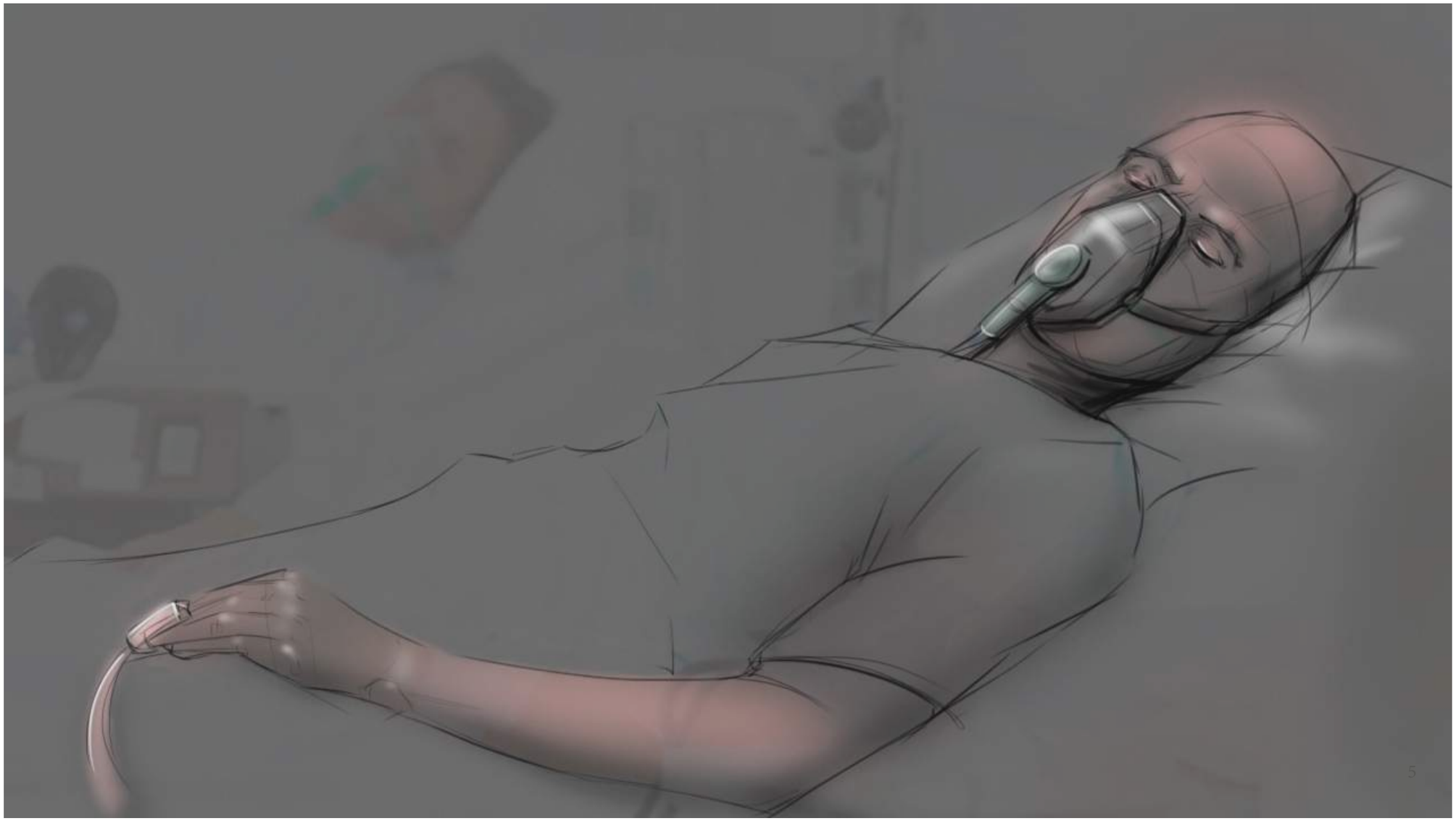
AASM classification, (American Academy of Sleep Medicine) sleep stages S1 to S4 are referred to as N1, N2, and N3, with N3 reflecting slow wave sleep (SWS, stage REM is referred to as stage R. According to the AASM manual, a minimum of 3 EEG derivations, sampling activity from the frontal (Fp2), central(C4), and occipital(O2) regions, has to be recorded.

EEG- electroencephalogram- a test that is used to track electrical activity of the brain and detect abnormalities. It envolves placing electrodes seperately and measure the voltage difference.

Hypnogram- a conventional way to represent a night's sleep. Such diagram is oftenly used in many commercial sleeping application in smart devices, providing sleep status with progression of time.

IDOS index, ICU Depth of Sleep - the method using single channel EEG: a proof of concept of a simple electroencephalography index in the non-sedated. A proof of using EEG to monitor sleep.

PSG, polysomnography; is a test to diagnose sleep disorders. It records brain waves, blood oxgen level, heart rate and breathing, eye movement (EOG), muscle tension (EMG), etc.



1. INTRODUCTION

Thirty-eight new Intensive Care Units (ICU) are under constructions in the west-wing of the Erasmus University Medical Center (EMC), Rotterdam. The aim of this project is to design products or systems to push the progress of achieving “Noise-free ICU”. The proposed product set, SLEEG, was considered mainly from patients’ perspective, aiming to realize the “noise-free”/disturb-free healing environment, so that they can recover faster with improved sleep quality.

Figure 1.1 Current EMC- ICU

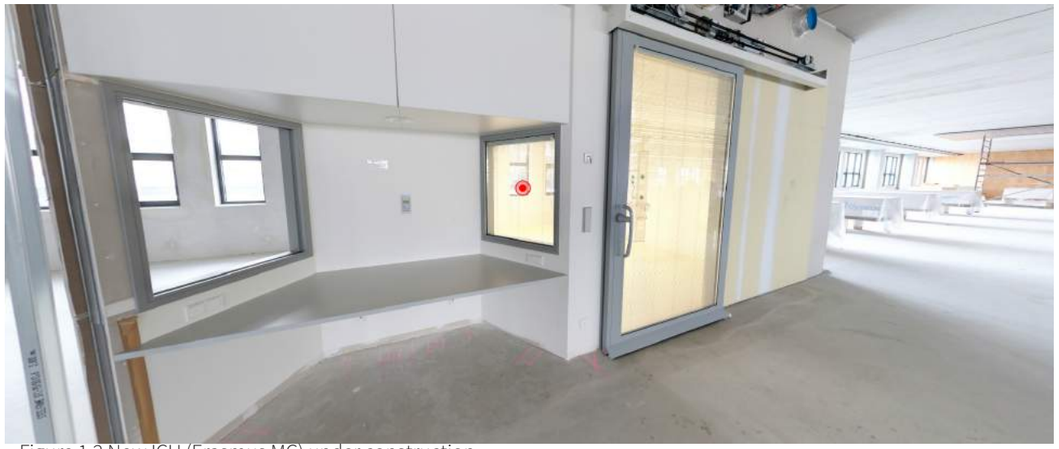


Figure 1.2 New ICU (Erasmus MC) under construction

1.1 Problems

Countless research have addressed the importance of sleep for the recovery of the body and mind. ICU patients are known to experience severely disturbed sleep, with possible detrimental short-term and long-term effects (Reinke ***et al***, 2014). Surveys of ICU survivors have shown that sleep deprivation was ranked among the top 3 major sources of anxiety and stress along with pain and intubation (Kamdar, ***et al***, 2012).

One of the factor to poor and fragmented sleep is the disturbances from patient-care activity. A recent study (Ritmala-Castren, et. al, 2015) indicates that nursing care is well planned and performed while the patients are awake, but more careful planning would allow them to sleep full 90-minute sleep cycles. In another word, it is crucial to know when they are awake since sedation is prevalent in ICU. In addition, nurses determine the patient’s wakefulness by observation, which can be troublesome since they have to enter the room and stand next to the patient. The readings from the facial response are not always accurate, and this process may accidentally arouse the patient.

1.2 Vision

For the actual well-being of ICU patients, the concept shall eventually improve their sleep by resolving environmental causes of poor sleep, such as unnecessary disturbances.

Unique Selling Point -

Current ICU have numerous environmental factors causing sleep deprivation among the patients. Noise and lights are the main concerns, but these two elements are initially intended to notify or assist the caregivers. From a more unusual but direct angle, patient-care activity was mainly considered to reduce sleep loss.

What SLEEG does is to show patients’ sleep status (awake, light sleep and deep sleep)to people outside the room, so that they know when to enter the room without disturbances. In addition, for future scenario, as ICUs are equipped with higher level of automation, sound cues or visual cues are no longer clustered for caregivers to perceive. But Human-interactions are more valued for providing emotional reassurance. Therefore a good timing is the prerequisite for a high quality communication, and SLEEG is able to provide such information (Fig.1.3).

Figure 1.3 Simple color-coded sleep status

2. CONCEPT SUMMARY

What is SLEEG?

People sleep poorly in hospital, especially in ICU due to many reasons, noise, light, discomfort, stress, patient-care activity, etc. While it is unpractical to invent a magical tool that resolve all problems, the proposed concept, ***SLEEG*** is a sleep monitoring system that targets on reducing unnecessary disturbances from patient-caregiver interactions via showing the patient's' sleeping or resting status.

The objectives of this concept design are

(1) Design a comfortable and accurate sleep measurement system.

(2) Provide detected information to caregivers in an efficient and a clear way.

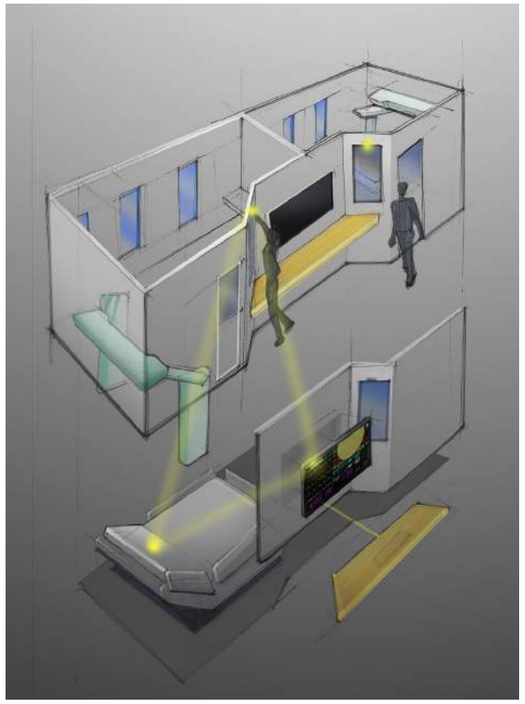


Figure 2.1 Using SLEEG in the new EMC- ICU layout

2.1 EEG detector

Corresponding to objective(1), the sleep measurement device is a light and non-invasive wearable. With three separate sensors, this battery-powered device enables the recording of electrical brain wave detection (electroencephalography, EEG) and the wireless transmission of data for further analysis. It is tailored for ICU patients for its adaption on different types of ventilation masks (Fig.2.2, Fig. 5.3).

2.2 Sleep status indicator

For objective(2), a simplified head-up "display" with minimal but understandable icons is used for indicating the sleep status. It showcases three status, awake, asleep, deep sleep, also with possibility of customization for including more content. The information is preferably projected onto a observing window (Fig.2.3) which ensures the message is clear at a glance in a non-obstructive way.

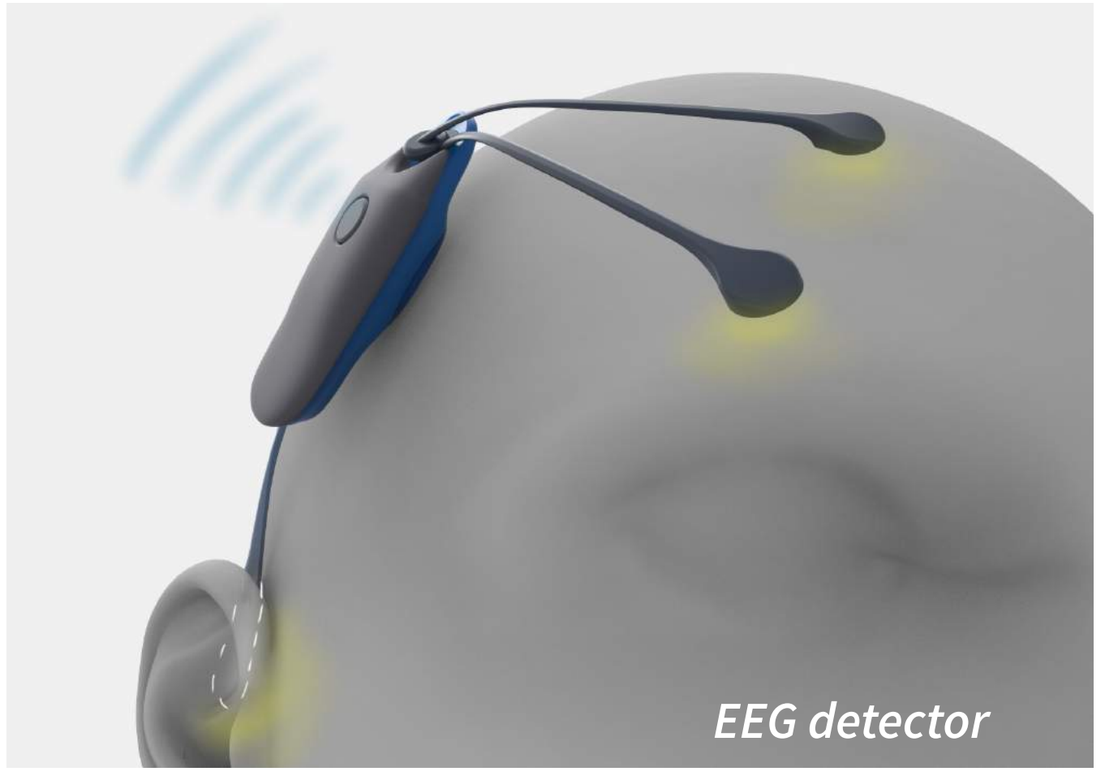


Figure 2.2 The sleep measuring device of *SLEEG*

Figure 2.3 The sleep status indicating device of *SLEEG*

3. RESEARCH FINDINGS

Based on the nature of this proposed design, the major portion of relevant research relates to neurological studies about the target group, following by societal and ergonomic concerns.

3.1 Target group sleep architecture

Comparing to normal adult hypnogram, ICU patients are known to suffer from fragmented sleep lead by light sleep and rapid eye movement (REM) sleep (Parthasarathy & Tobin, 2002). For the past two decades, the effects of sleep loss among ICU patients remain largely unknown and unexplored whereas sleep loss and fatigue among medical personnels received much more attentions these years (Freedman et.al, 1999; Weinhouse et.al, 2006). In addition, there is also an urge to find the correlation between sleep deprivation and other common phenomenon, such as delirium (Fig.3.1) (Trompeo et al., 2011).

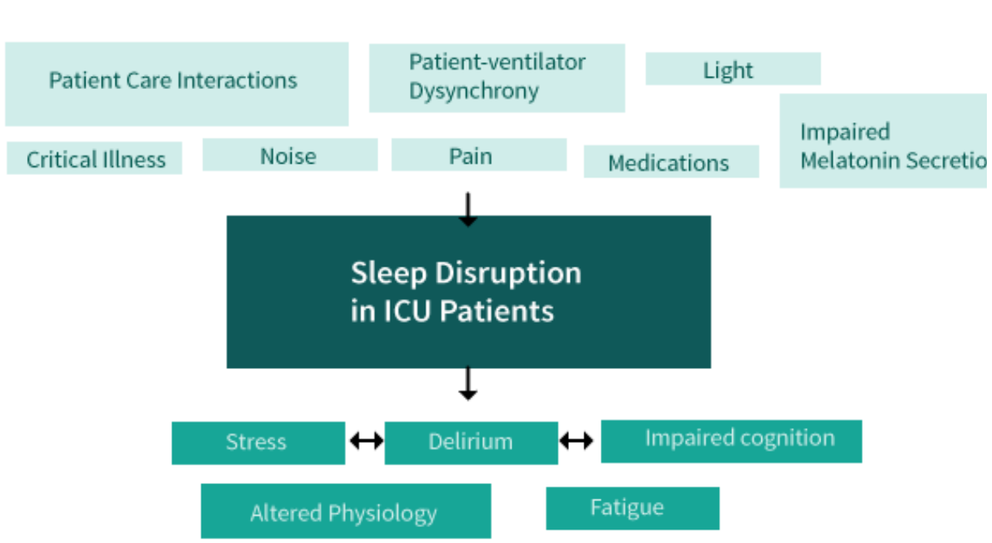


Figure 3.1 Correlations with sleep disruption in ICU patients (Kamdar et.al, 2012)

3.1.1- Sleep and recovery

Many reports have addressed that understanding the potential contribution of ICU-related sleep disruption on patient recovery is an important area of investigation (Fig.3.1). Sleep of normal people has already proven to incubate a constellation of physiologic changes which further indicates people with critical illness may suffer severe outcomes from these alterations (Kamdar, 2012). Hence, sleep quality improvement can potentially speed up patient's physical and consequently psychological healing. The accelerations in recoveries may presumably shorten their stays and therefore reduce the medical cost.

3.1.2 - Sleep cycles

Characteristics of sleep among critically ill patients are demonstrated via PSG and summerized below (Weinhouse et.al, 2006).

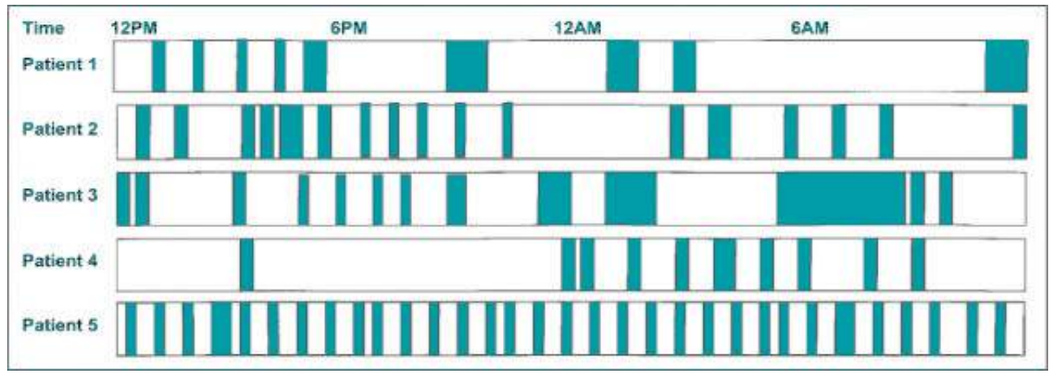


Figure 3.2. Sleep fragmentation in 5 ICU patients.dark=sleep and white = wakefulness. © American Thoracic Society. Freedman NS, Gazendam J, Levan L, et al.

- Severely fragmented (Fig.3.2)
- Total sleep time (TST) over 24 hours may be normal
- Sleep may be evenly distributed between day and night
- Increased time in stage N1, N2 sleep (N=Non-REM, rapid-eye-movement)
- Decreased time or zero in stages N3, N4, and REM
- Increased arousals and awakenings

3.1.3 - Sleep and sedation

Sleep among ICU patients is much more complicated than normal sleep tracking and monitoring it can be challenging, due to the factors such as sedation, medicine affected conditions, and effect of sepsis, etc. Take sedation for instance, sleep is associated with cyclic progression of EEG stages, but sedation variably alters normal sleep architecture (Weinhouse, et.al, 2006). Therefore the presence of sedating agents can be the artefacts while intepreting sleep EEG.

As more data contributing to the interpretation of detected neurological signals, a more comprehensive system of detecting consciousness level can be developed in future scenario. The system may very likely to elucidate more prognostic value, and can be a complementary tool to current assessment methods (e.g. Glasgow Coma scale, GCS) which are subjective and non-continuous.

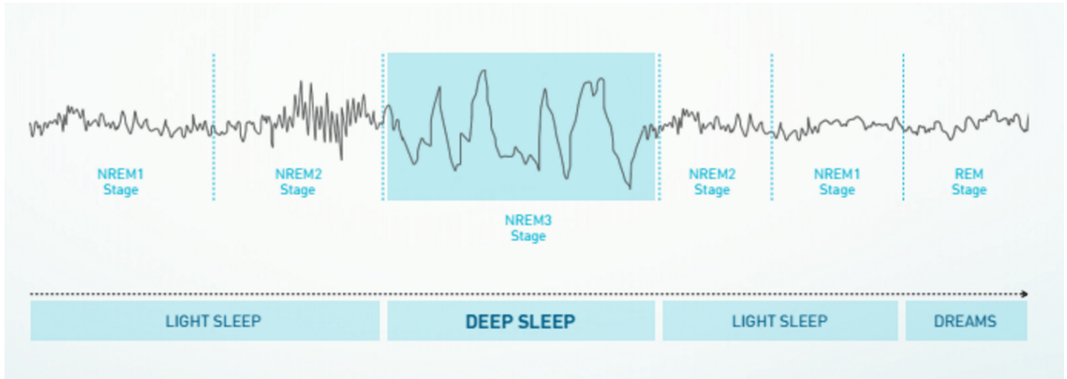


Figure 3.3 Real-time acquisition and analysis of sleep EEG (Prasuethsut, 2016)

3.2 Sleep & patient-care activity

3.2.1 - Sleep factors

In order to resolve sleep disturbances, several factors are summarized and listed:

Factors	Explanations
Noise	Unwanted sounds from environment
Light	No cues for day and nights
Pain/illness	Physiological pains and consequent stress
Patient-care activity	Vital connections, medication administration, diagnostic testing, etc.
Dyssynchrony	Discomfort with mechanical ventilation
Medications used in ICU	With adverse effects on sleeping

Table 1. Factors in intensive care Unit that have adverse affects on sleep.

3.2.2 - What are THESE activities?

A investigation by Ritmala-Castren (2015) recorded that nursing activities at night were performed with a median of 0.6 per hour for each ICU patient*. These activities include but not limited to caring for patients' physical needs (blood sample, assessment, medication, fluid therapy, breathing exercise, enteral nutrition, hygiene, suction, oxygen delivery), observing, responding to patients' requests, relieving pain, and providing comfort and information to the patient (Larrabee et al., 2001).

Indeed, frequent patient interactions are necessary for physiologically unstable patients. Yet nurses have reported that modifiable factors, such as visitation times, bathing, patient turning, and linen changes, often prevent patients from consolidating adequate sleep (Olson et al., 2001).

(*patients profile : median APACHE II = 16, *acute physiology and chronic health evaluation* (min0-max 71)

3.2.3 - Automation and human interactions

In the future, as the healing environment becomes smarter and automation is gradually playing a more important role in medical world, the alarm of notifying human-being will be very likely reduced to a comfortable level. But it does not mean that caregivers will be replaceable.

As a finding from our cultural-societal study, in highly automated room, such as eICU or remote ICU (Fig. 3.3) where intensivists are communicating via internet, actual patient-nurse interactions will be certainly more valued.

Figure 3.3 A futuristic wireless and remote ICU (Dishman, 2011)

4. WORKING PRINCIPLES

4.1 Measuring sleep

Recent studies on sleep quality on patients mostly based on observations from staff (not continuous) and questionnaires from survived patients (not prompt). Another sleep measurement is through polysomnography (PSG) which provides much more accountable data. It is considered the "gold standard" of sleep studies due to its technical complexity (a.k.a.cumbersome and time-consuming) and professional interpretation (a.k.a. expensive) (Watson, 2007). Therefore there is a need for accurate but relatively simple detection of sleep quality among average ICU patients via special brainwave patterns (NREM), sporadic eye movement, loss of muscle tone (REM).

	+ PROS	- CONS
Neurological feedback (brainwave measurement)	Relatively reliable Non-invasive	Hard to interpret Close to head
Breath tracking	Easy, cheap	Mechanical ventilator interfered
Vitals	Data already available	Not precise, disrupted (artifacts)
Micro facial expression	May... be accurate Non-contact	High-resolution camera Lack of studies (accuracy pending)
Muscle contraction	Cheap Acute	Cramps (artifacts) Accuracy pending

Table 2. A comparison of multiple sleep monitoring mechanism

Neuro-signal EEG was selected to be the solution for sleep detection. Similar non-invasive options (magnetoencephalography, MEG, functional magnetic resonance imaging, fMRI) may be available in operating room for knowing patient's consciousness. EEG devices are relatively cheap, small and with possibility to be simplified. However, current medical EEG needs complicated implementation, that explains they are only used when they truly needed. For sleep detection, the number of the electrodes can be significantly reduced. Many commercial sleep products are utilizing this technology to track and regulate sleep cycles, such as Rhythm Dreem headband (Fig.4.1). According to the scientific white paper (Rhythm, 2016), its science team claims that using EEG is the optimal solution for the product due to vast amount research in the field. They also believe that the combination of neurophysiology, cognitive science and data science is revolutionizing neuroscience from a biology-dominated discipline. Their vision in developments of "data-mining and machine learning will bring a significant progression in sleep study and the deeper functioning of the brain" can also be applied to sleep during critical care, of course with more challenges and constraints.

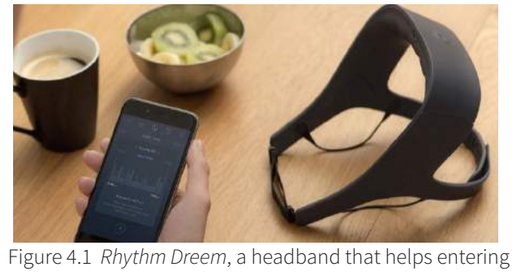


Figure 4.1 *Rhythm Dreem*, a headband that helps entering deep sleep stage

4.2 Indicating sleep status

As mentioned in the objective(2), sleep status or any relevant information shall be shown without clustering the existed work flow. Based on the architectural layout of the new ICU -Erasmus MC (Fig. 1.2), nurses and people on the corridor can see the patients from windows next to the work desk.

Head-up displays (HUD) are becoming more prevalent in automobiles (Fig.4.2) and is believed to have a promising future (CNET, 2014). It uses optics to reflect projected important information on the “display” (windscreen) without major distractions. So similar principles can be adapted into sleep indicator. The transparency of it allows the projection of information without blocking the view through window.Therefore a projected image on the window is non-obstructive and also effective. While adapting this technology to ICU windows, the major task is simplification, for the projected image shall be clear and minimal.

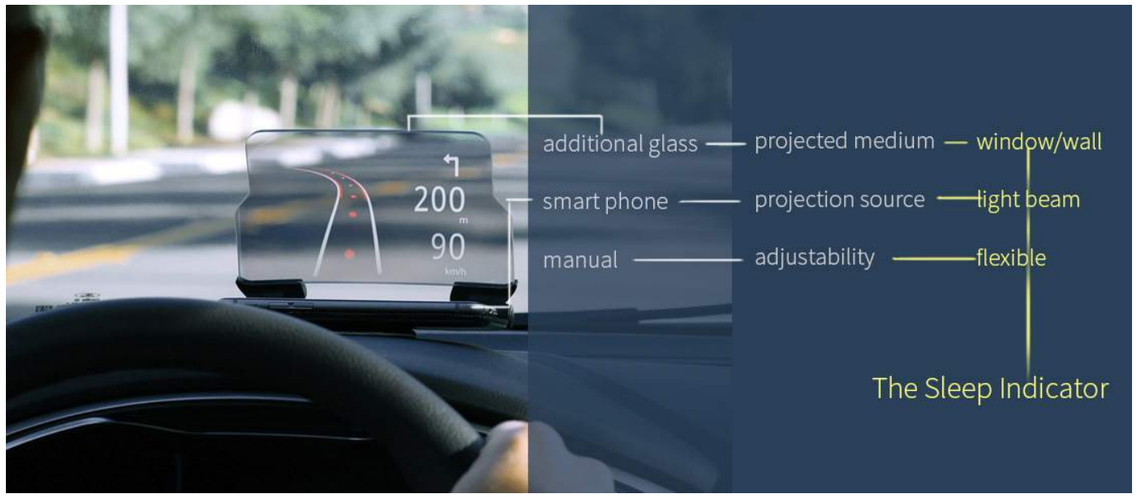


Figure 4.2 How to adopt HUD from automobiles to ICU sleep indication

5. CONCEPT PRESENTATION

5.1 How to set up SLEEG?

1. Install *SLEEG software** to a monitoring computer, and pair *detector* and *the indicator.*
2. Attach the *EEG-detector* onto the strap of ventilation mask (1 side).
3. Adjust the electrodes to designated locations for accurate measurement.
4. Install the *indicator* near a preferred location (observing window, door, etc.)
5. Customize the size/position and the content of the projected signals via installed software.

* The *SLEEG software* is crucial of the product, yet not presented in details in this report

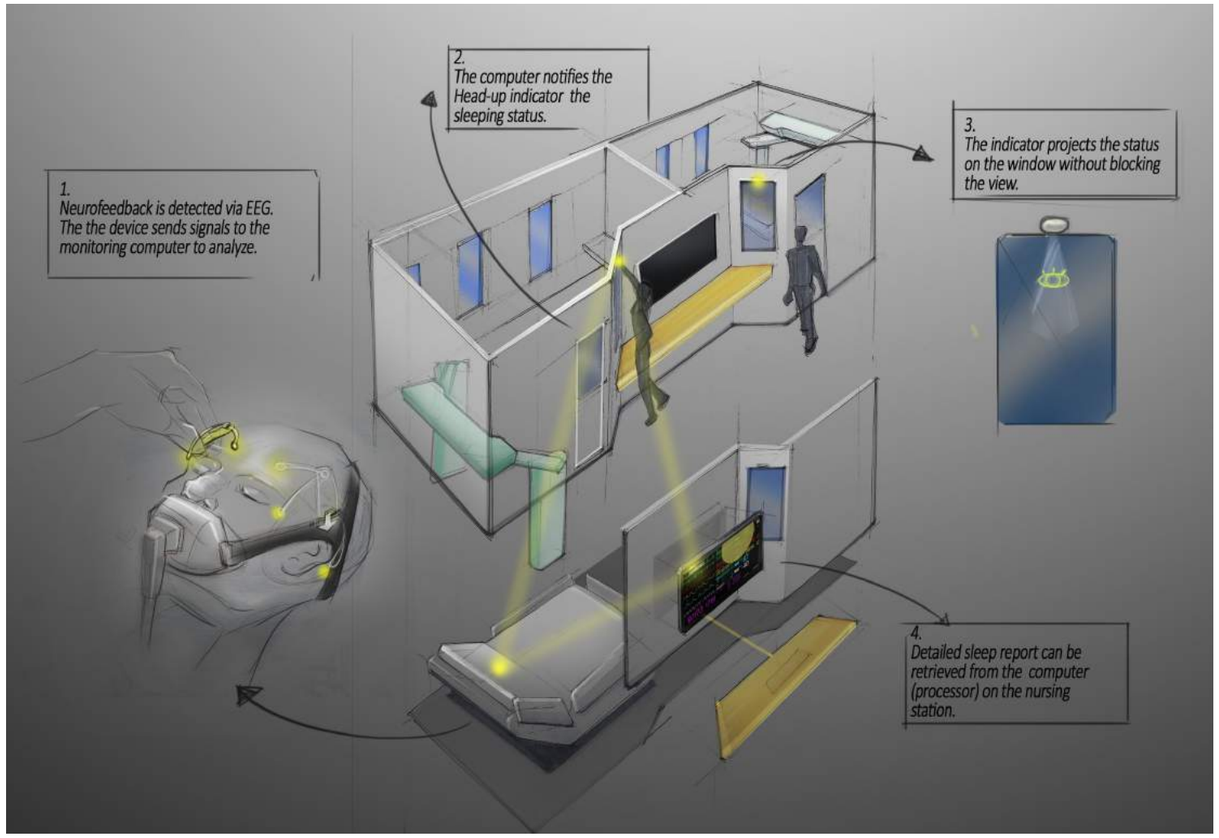


Figure 5.1 How to use *SLEEG*

5.2 EEG- Detector

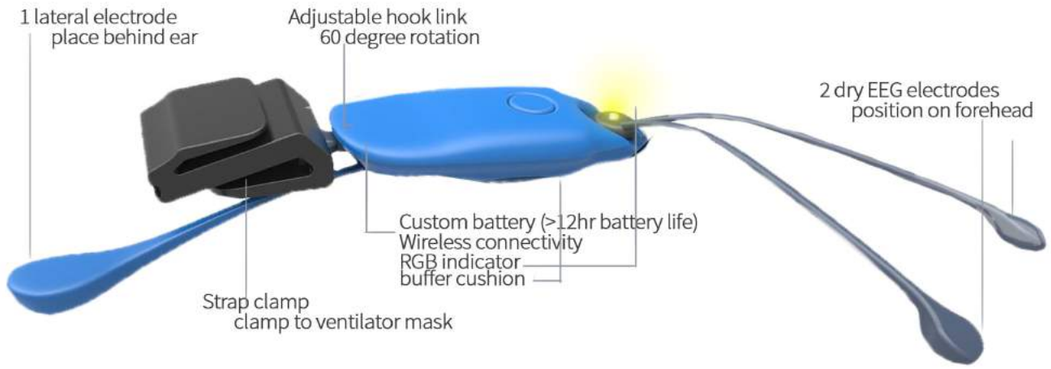


Figure 5.2 EEG Detector specifications

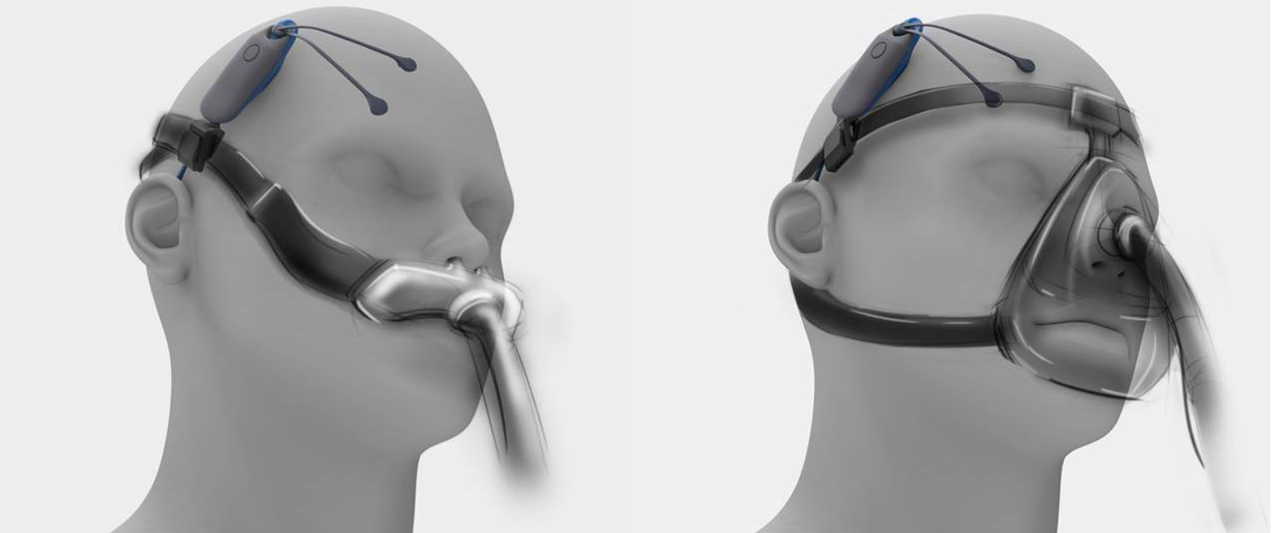
M = manufacture
P = purchase
S = software under development

• EEG detector	M	15
Custom battery	P+M	15
Wireless connection	P+S	20
RGB indicator	P	3
2 dry EEG electrodes	M+P+S	2X30
1 lateral electrode	M+P+S	30
*Adjustable link	M	1.5
*Mask clamp	M	5
• Adjustable headband	M	12
• Inductive charger	P+S	25

Estimated cost = $186.5 /detector

The main detection body is made from high-quality plastic (injection-moulded) embedded with a fabric cushion underneath. This also applies to the *adjustable link and *mask clamp which demand relatively high strength to hold the whole device. 3 sensors need metal core to achieve certain stiffness so that the sensing heads can be placed and stay still. The cores are wrapped with (in this order) insulating material, wires, insulating material, and finally silicone encasement for water/liquid proofing purpose.

Figure 5.3 EEG Detector clamps on different masks



5.3 Head- up indicator

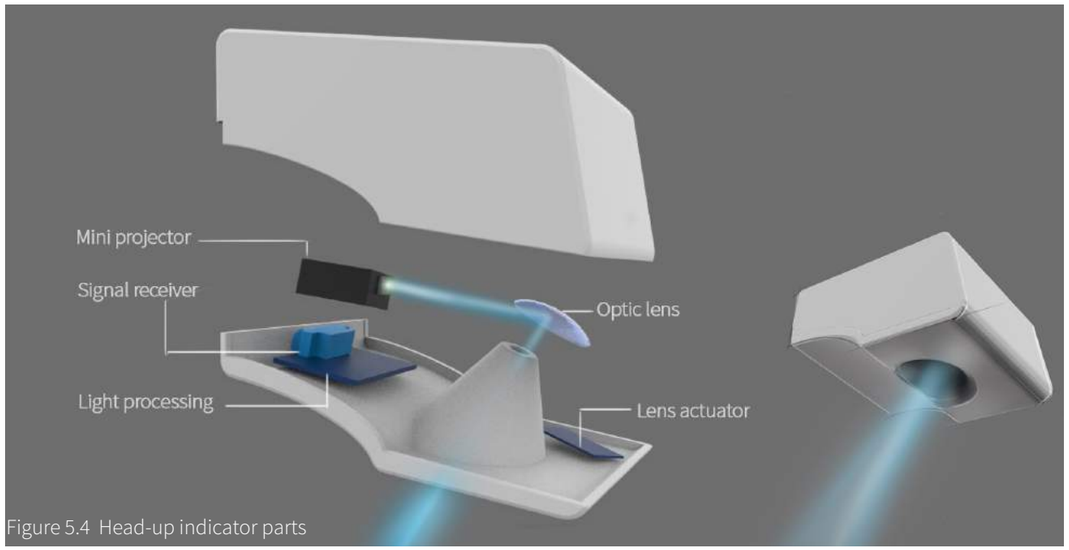


Figure 5.4 Head-up indicator parts

• Head-up body	M	3
Mini projector	P	8
Signal sensor	P	10
Lighting processing	P+S	15
Lens optic	P	5
Lens actuator	P+S	10
• Mounting Bracket	M	2
AC input	P	3

Estimated cost = $56/device

The encasement uses white plastic with matt finish to accomodate ICU general tone, and also gives a light feeling. It uses injection moulding for this simplistic yet dynamic appearance. Many parts inside can be purchased but the device demands software syncing feature, which makes it more expensive than a lighting device and similar to a projector.

The customizable lighting feature, and separate mounting method allow the device to aim larger market, which can boost the manufacturing batch size and hence lower the cost per part.

Figure 5.5 Using SLEEG in the new ICU

5.4 FAQ

[Q]What if the patient does not have a ventilating mask?
[A] It comes with an adjustable headband to accommodate the condition (Fig. 5.6). However, it is not yet the optimal solution.

[Q]What about the quality of the head-up indicator?
[A] The observing window is laminated, so the projected image may be double-shadowed. However, it is not a major concern as differentiating colors and the icons are the main purpose.

[Q] What are the placement of the electrodes for EEG readings?
[A} AASM standardized the PSG electrode position to be on C4, Fp2, O2, M1. The proposed positions are simplified to C4 , Fp2, T3 (Fig. 5.7).

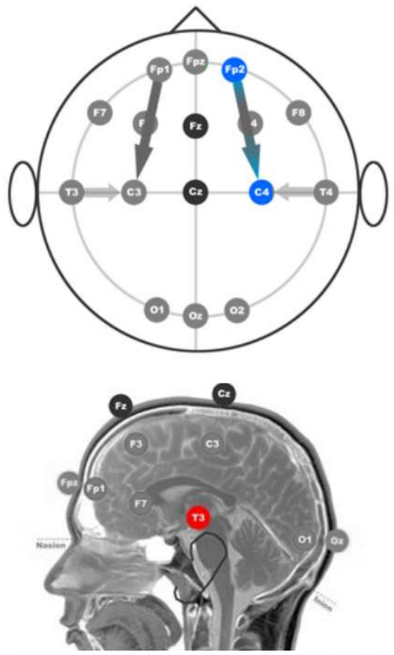


Figure 5.7 Simplified electrode ositioning (image modified from Trans-Cranial-Technologies, 10/20 System Positioning Manual)

6. EVALUATION

6.1 Procedures

Interviews were conducted with 6 people (M = 3, F = 3) regarding their opinions on sleep in general and their preference on wearable appearance when sleeping. The interviewees are relatively young comparing to the target group, but everyone is a potentiall user of ICU. For this evaluation test, given the time and regional limitations, they may not be the ideal group but still valid.

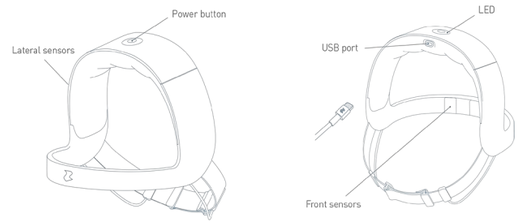


Figure 6.1 Schematic view of *Rhythm Dreem*

Interviewing content reads:

Age…….. Gender……

1. Have you used sleep monitoring applications (on your phone)?

2. Do you notice or even wake up if someone opens your door?

3.Have you fallen asleep with an eye patch or a hat, etc.? On what occasion?

4.1. Do you think you can fall asleep with this additional headset (Fig 6.1?

4.2 This device is intended to help you enter deep sleep stage. Are you willing to use it?

5. What do you think of the appearance (Fig 6.2)? Do you think you can sleep with this small, light and non-invasive device with an additional strap?

6. Imagine you are an ICU patient with a ventilator (Fig. 6.3, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?

1//Understand their values on sleep quality.

2//To know their abilities of understanding their own sleeping without devices.

3//To know on what occasions normal people use additional wearables while sleeping.

4// To know their justifications on using sleep device that may seem uncomfortable.

5// Present the design (*EEG headband*), ask them about the appearance and what they can associate it with?

6// Introduce the function and ask them about their preference of using it, along with reasonings.

Figure 6.2 Side view of *EEG detector from SLEEG*

Figure 6.3 Detecor position example

6.2 Findings

- Most interviewee have used smartphone apps relating to sleep (Fig. 6.4). Although many apps are free, some stopped using the app because the tracking mechanisms are inaccurate.
- Participants with trouble sleeping are more willing to try or purchase sleeping device that can scientifically improve sleep quality. (One suggest his preference on a device than sleeping pill which can be more effective)
- During hospitalization, all participants suggest they do not worry about their appearance as long as they are recovering well. "*I trust the doctors that they will put the right thing on my head*".
- Participants are welcoming about using this monitor not just for their own benefits, but also reassuring for their family.

6.3 Recommendations

Based on the findings, the product, ***EEG detector,*** can be improved from two aspects.

(1) Focus on improving detection accuracy and user physiological benefits. This can be achieved by collaborating with clinical medical field, neuroscience, and commercial sleep product (see Section 4.1).

(2) Develop two versions of sleep report, including one with more neurological precision for caregivers, and one version with extrapolated data targeting family or patients themselves. The latter composes part of the patient's diary, which can be an objective reference after discharging from ICU. We can see younger generation (future ICU users) do pay attention to their sleep, as they obtain such information from smart applications or internet, the interpretation of hypnogram will not be an issue.

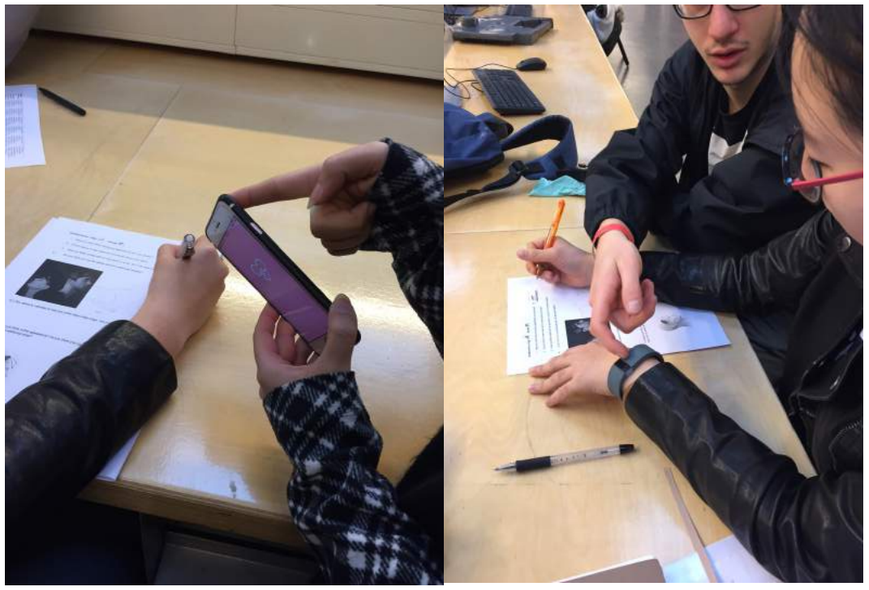


Figure 6.4 During the interviews, participants are sharing their experiences of sleep tracking

7. CONCLUSION & OUTLOOKS

Sleeping status indeed (unfortunately) is the additional input to the information cluster that the caregivers already have. This report wants to convey the importance of sleeping quality, and the way of indicating it is minimal, non-obstructive and customizable. The ultimate goal of ICU medical practice is the wellbeing of the patients, therefore their recoveries are the priorities. Faster recovery will shorten their stays, and eventually lower the medical cost significantly.

The potential benefits are apparent,

1. Patients sleep better with less disturbances, so they may physically recover faster.
2. In the future, ICU will be equipped with higher level of automation, but patient-nurse interactions will be more valued so that they can heal faster emotionally.
3. Sleep report may help prognosis or at least be a recovering reference after discharging.
4. Due to the close connections between sleep, sedation and delirium, the reservoir of brain activity data may further contribute to neurological studies on ICU medicine practices.

8. REFERENCE

Burry, L., (2013) Improving Sleep & Sedation in Your ICU. Retrieved from https://www.eiseverywhere.com/file_uploads/31f4dbff290d2c088ba2a8bfba19c552_SleepandSedation-Burry.pdf

Caddy, B. (2016). How mind reading wearables let us delve inside our brains. Wareable. Retrieved from https://www.wareable.com/wearable-tech/looking-inside-the-brain-2219

CNET, (2014) Is it finally time for head-up displays in cars?. Road|Show. Retrieved from. https://www.cnet.com/roadshow/videos/is-it-finally-time-for-head-up-displays-in-cars/

Freedman N.S., Kotzer, N., Schwab., R.J (1999) Patient perception of sleep quality and etiology of sleep disruption in the intensive care unit. Am J Respir Crit Care Med.;Vol.159: 1155-62.

Kamdar, B. B., Needham, D. M., & Collop, N. A. (2012). Sleep Deprivation in Critical Illness: Its Role in Physical and Psychological Recovery. Journal of Intensive Care Medicine, 27(2), 97–111. Retrieved from http://doi.org/10.1177/0885066610394322

Larrabee, J., Bolden, L., (2001) Defining patient-perceived quality of nursing care. Journal of Nursing Care Quality, 2001;Vol.16:34-60

Olson, D., Borel, C., Laskowitz, D., Moore, D/, McConnell, E., (2001) Quiet time: a nursing intervention to promote sleep in neurocritical care units. Am J Crit Care. 2001;10(2):74–78
Rhythm science team, (2016) A scientific overview of Rhythm's technology: the Dreem headband.

Parthasarathy, S., Tobin, M.. (2002) Effect of ventilator mode on sleep quality in critically ill patients. Am. J. Respir. Crit. Care Med. 2002; Vol.166: 1423–1429

Prasuethsut, L. (2016,March). Rythm Dreem headband promises you'll sleep better wearing it. Wareable. Retrieved from https://www.wareable.com/meet-the-boss/rythm-dreem-headband

Ritmala-Castren, M., Virtanen,I., Leivo, S., Kaukonen, K., Leino-Kilpi., H., (2015) Sleep and nursing care activities in an intensive care unite, Nursing and Health Sciences, Vol.17:354-361

Trompeo AC, Vidi Yl Locane MD.Sleep disturbances in the critically ill patients: role of delirium and sedative agents. (2011) Minerva Anestesiol. Vol.77:604-612.

Watson, L.,Measuring sleep in critically ill patients: beware the pitfalls. (2007) Critical Care; 11(4):159

Weinhouse, G.L., Schwab., R.J.(2006) Sleep in the Critically ill Patient, SLEEP, Vol. 29, No. 5
Dishman, L. (2011, June 2). The Hospital Room of the Future: Flexible, Media Rich, Very Shiny [blog post].

APPENDIX

Figure 1.1 Current EMC- ICU
http://www.erasmusmc.nl/intensivecare/patientenzorg/locaties/ICV_3/

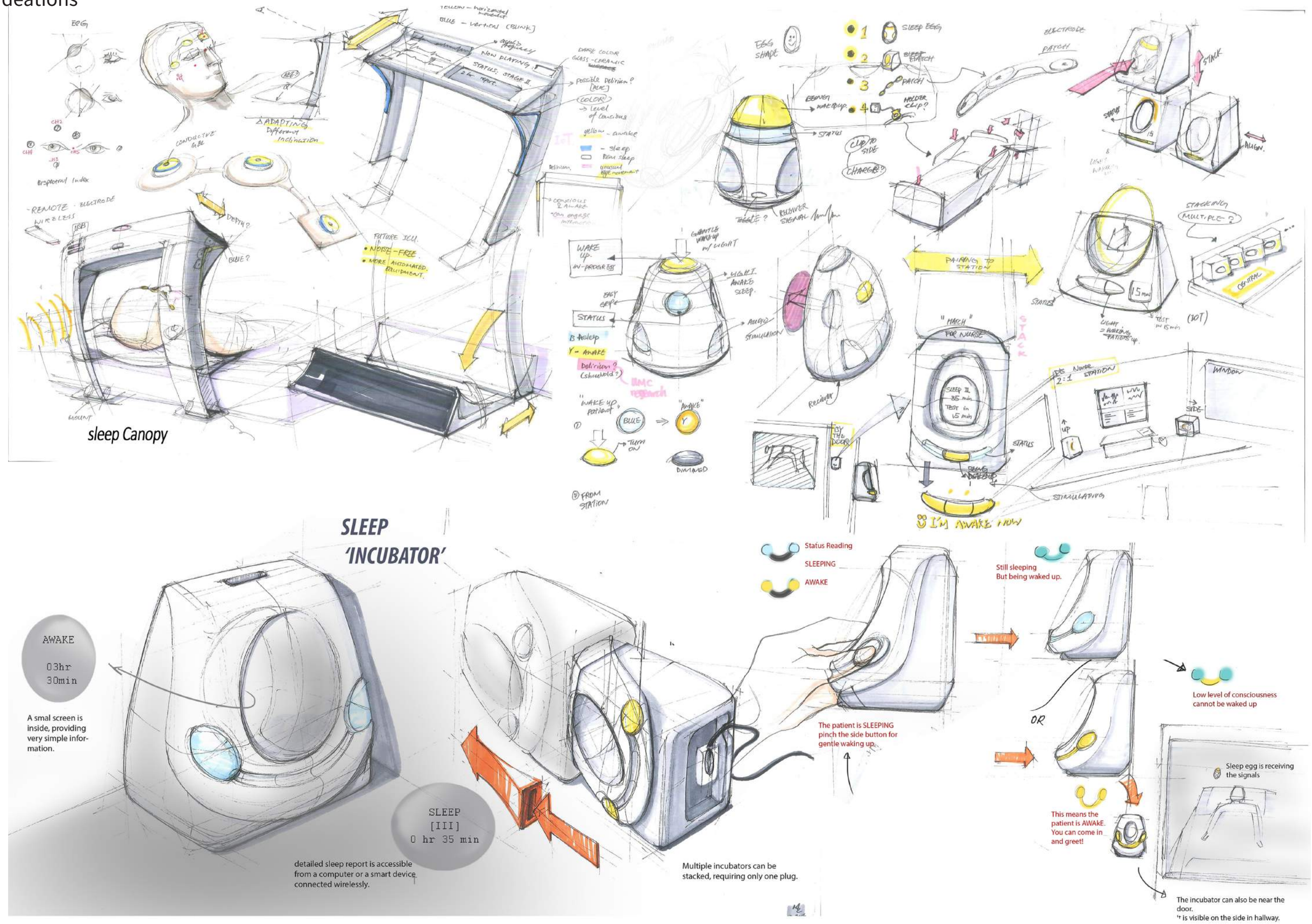
Figure 1.2 New ICU under construction
http://www.erasmusmc.nl/nieuwbouw/nieuwbouwinbeeldj1/360gradenfotos/?lang=en

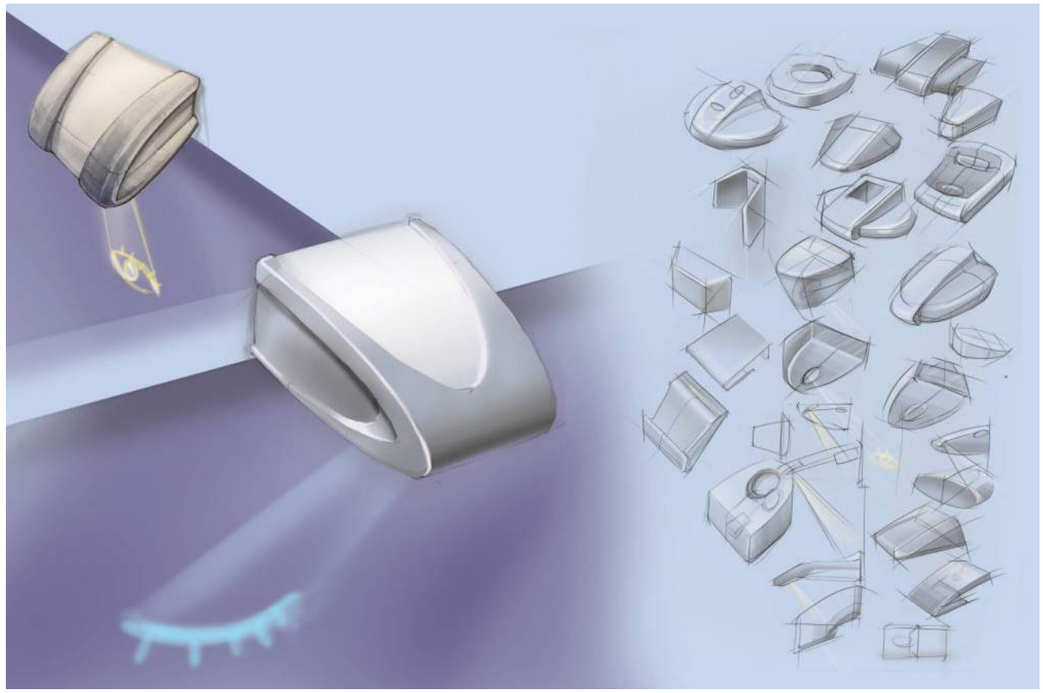
Figure 4.1 Rhythm Dreem, a headband that helps entering deep sleep stage
https://rythm.co/product.html

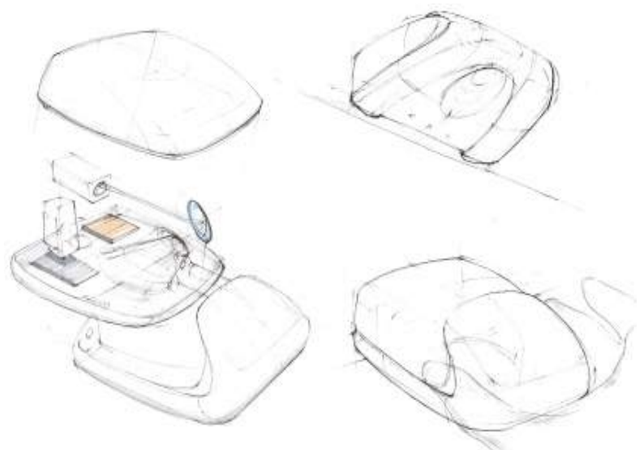
Figure 4.2 How to adapt HUD technology
https://www.igeeksblog.com/hudway-glass-head-up-display-for-car/

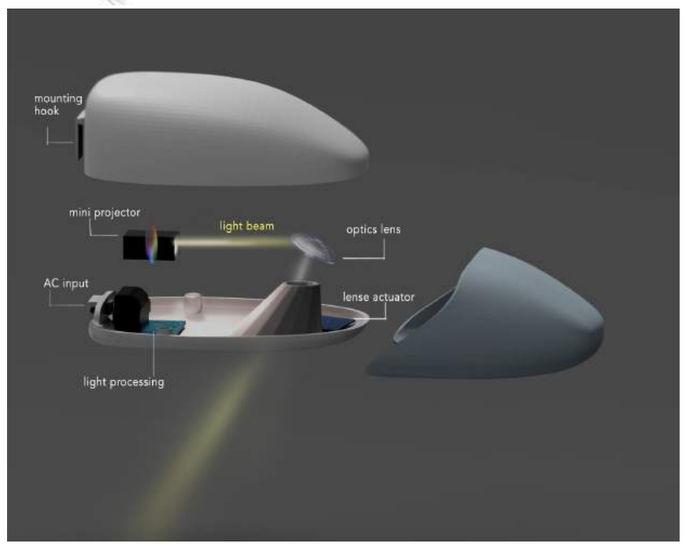
Figure 5.7 Simplified electrode positioning.
https://www.trans-cranial.com/local/manuals/10_20_pos_man_v1_0_pdf.pdf

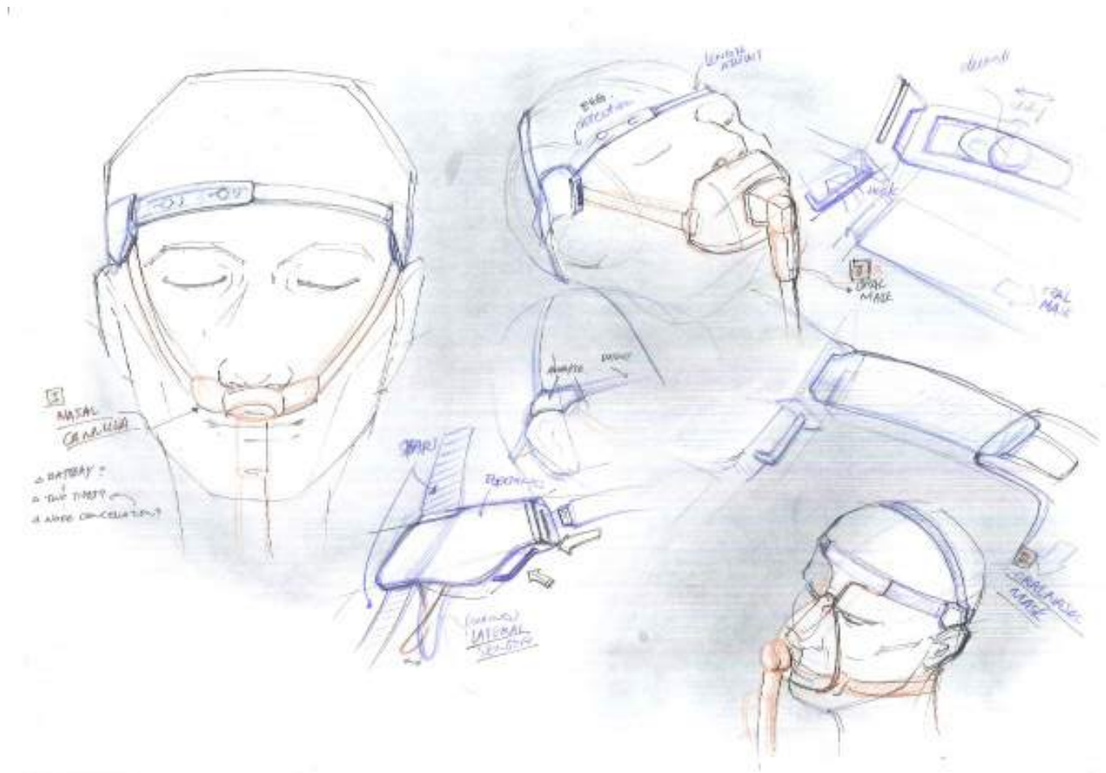
Ideations


sleep Canopy
SLEEP
'INCUBATOR'
AWAKE
03hr
30min
A smal screen is inside, providing very simple information.
SLEEP
[III]
0 hr 35 min
detailed sleep report is accessible from a computer or a smart device connected wirelessly.
Multiple incubators can be stacked, requiring only one plug.
Status Reading
SLEEPING
AWAKE
The patient is SLEEPING pinch the side button for gentle waking up.
Still sleeping
But being waked up.
OR
Low level of consciousness cannot be waked up
This means the patient is AWAkE. You can come in and greet!
Sleep egg is receiving the signals
The incubator can also be near the door.
* is visible on the side in hallway.









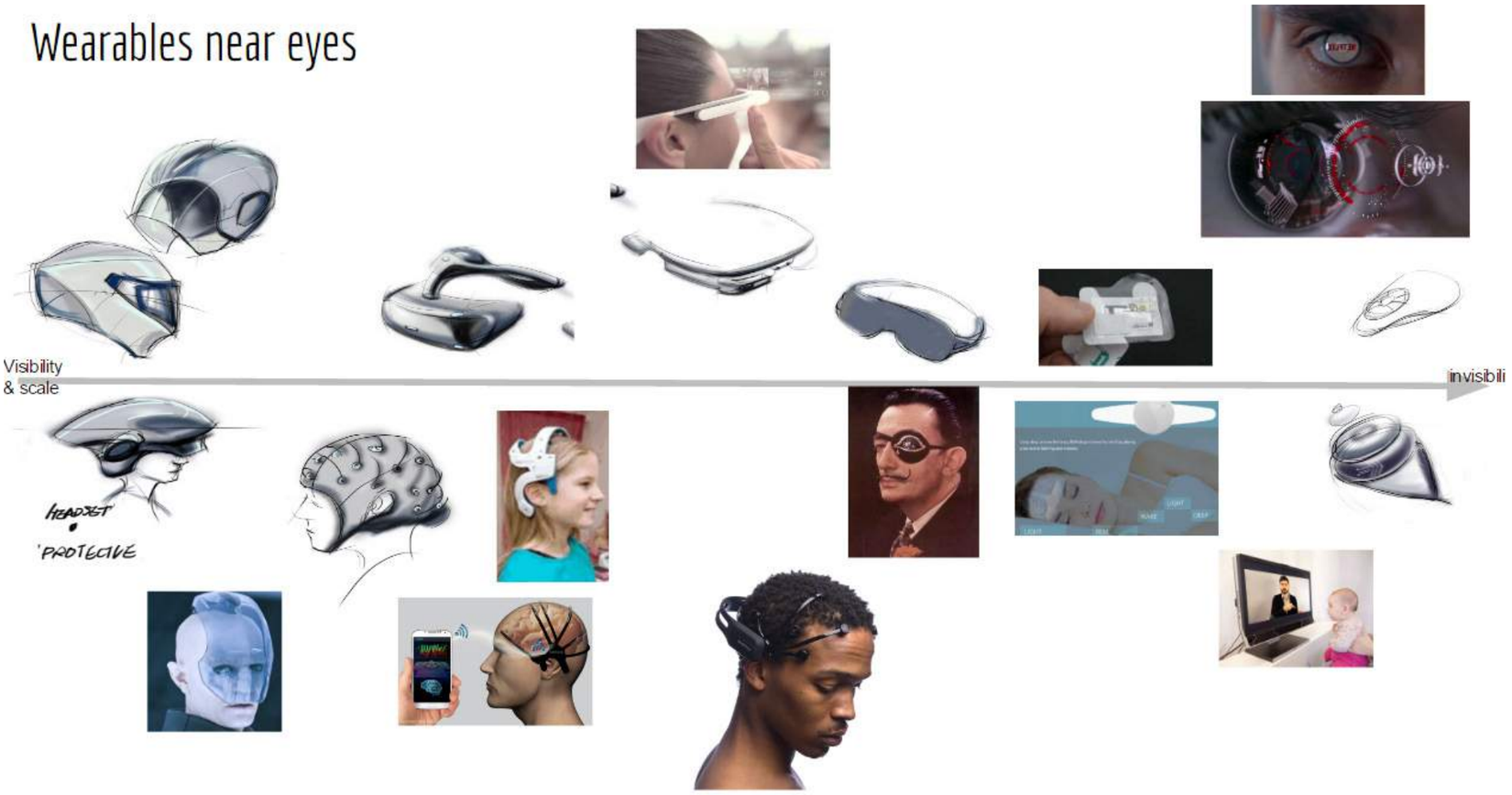
I. Nasal pillow, nasal cannula

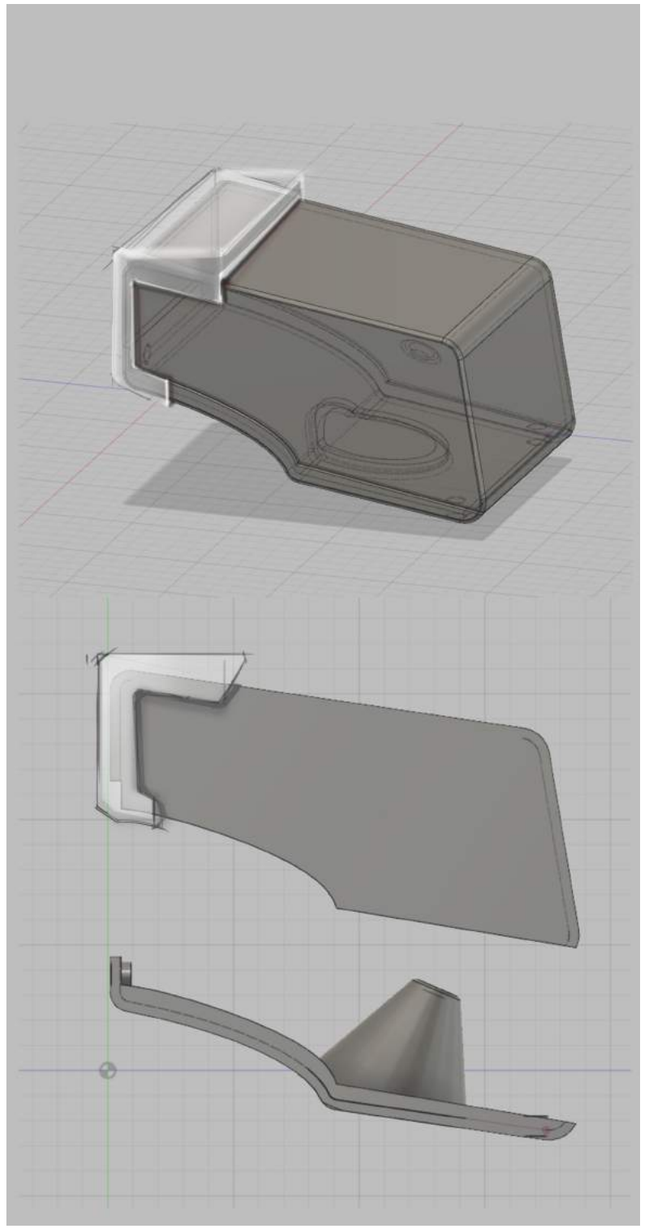
II. oral-nasal mask
1 strap

III. Facial mask (oral-nasal)
+ Nose mask, 2 straps

IV. Full face mask (eyes covered)

Wearables near eyes





Mounting suggestion

Evaluation Details

#1 (Age…22.. Gender…F…)
1.Have you used sleep monitoring applications (on your phone)?
Yes. Sleep Cycle. Pillow (But did not use it for a while, mainly because it is not accurate enough)
Another application I use is Muji to Sleep (great user experience, but it's not apted to track sleep)

2.Do you notice or even wake up if someone opens your door?
Yes if I sleep lightly.
3.Have you fallen asleep with an eye patch or a hat, etc.? On what occasion?
Yes. I put an ice pack while sleeping when I have a fever.

4.1 Do you think you can fall asleep with this additional headset?
I can but I worry about those people who have sleeping problem already.
4.2 This commercial product is intended to help you entering deep sleep stage. Are you willing to use it?
Yes. I will. More likely than not knowing the functions.

5. What do you think of the appearance? Do you think you can sleep with this small, light and non-invasive device with an additional strap?
It looks like a device with tentacle. Other than that, it looks fragile which is susceptible to deformation.

6. Imagine you are an ICU patient with a ventilator, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?

I don't mind wearing it. I don't think there is discomfort as long as it stays where it is designed to be. After knowing its function, I am more willing to wear it.

#2 (Age…23.. Gender…M…)

1.Have you used sleep monitoring applications (on your phone)?
Yes. Misfit activity tracker.

2.Do you notice or even wake up if someone opens your door?
No. I usually sleep quite deeply.
3.Have you fallen asleep with an eye patch or a mask, etc.? On what occasion?
No. Never used it since I can fall asleep with light on.

4.1 Do you think you can fall asleep with this additional headset?

4.2 This commercial product is intended to help you enter deep sleep stage. Are you willing to use it?

After knowing the use, yes I can give it a try.

5. What do you think of the appearance? Do you think you can sleep with this small, light and non-invasive device with an additional strap?

It reminds me of a spying gadget.

6. Imagine you are an ICU patient with a ventilator, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?
I don't mind because I often sleep with my earbuds on. Plus, if I am a patient, I won't care about the appearance.

#3 (Age…29.. Gender…M…)

1.Have you used sleep monitoring applications (on your phone)?
Yes. Sleep Cycle.

2.Do you notice or even wake up if someone opens your door?
Sometimes, like 20% of the chance.
3.Have you fallen asleep with an eye patch or a hat, etc.? On what occasion?
Yes, maybe only on the plane. But they cause sweat, which I don't like.

4.1 Do you think you can fall asleep with this additional headset?
4.2 This commercial product is intended to help you enter deep sleep stage. Are you willing to use it?
Before Knowing its use, unlikely. But after knowing its function, I can give it a try just out of curiosity.

5. What do you think of the appearance? Do you think you can sleep with this small, light and non-invasive device with an additional strap?
I do have a feeling that it is a bluetooth device, like a fancy earphone. I am willing to wear it while sleeping but I will feel constrained due to the movement towards the sides.

6. Imagine you are an ICU patient with a ventilator, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?
I don't mind. After knowing its use, it doesn't increase the chance of me wearing it, because I trust doctors and nurses. If they want me to wear it, I will wear it.

#4 (Age…23.. Gender…M…)

1.Have you used sleep monitoring applications (on your phone)?
Yes. Sleep as Android. Good app, but does not solve all problem so occasionally, I have to take sleep-aid pill.

2.Do you notice or even wake up if someone opens your door?
Yes for light sleep
3.Have you fallen asleep with an eye patch or a mask, etc.? On what occasion?
No, but i would imagine I can only have light sleep with those.

4.1 Do you think you can fall asleep with this additional headset?
Yes, if the weight is light enough.
4.2 This commercial product is intended to help you enter deep sleep stage. Are you willing to use it?
Yes (after knowing its function)! Very willingly actually because I have trouble sleeping for a long time.

5. What do you think of the appearance? Do you think you can sleep with this small, light and non-invasive device with an additional strap?
I already have seen something like this, so I would imagine is measuring brain activity with electrodes. But I am worrying about turning sideways.

6. Imagine you are an ICU patient with a ventilator, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?
Yes but I am afraid I won't feel too much discomfort because I may be sedated. (The interviewee already had knowledge about brain waves and EEG) And if I feel discomfort, it will be mainly from the ventilator. Also, it is nice if my family knows my sleep conditions, or how I rest in hospital.

#5 (Age…37.. Gender…F…)

1.Have you used sleep monitoring applications (on your phone)?
No. Because I don't know there is such thing like sleep tracker on a phone.

2.Do you notice or even wake up if someone opens your door?
Yes I do notice the door opening but I would like to continue sleeping.

3.Have you fallen asleep with an eye patch or a hat, etc.? On what occasion?
Only a mask when taking a nap during day time. Not often though.

4.1 Do you think you can fall asleep with this additional headset?
Yes, I don't think the headset is too bulky.

4.2 This commercial product is intended to help you enter deep sleep stage. Are you willing to use it?
Yes. I will for sure after knowing the function. Sleep is important, and have a good sleep can be such a luxurious thing these days.

5. What do you think of the appearance? Do you think you can sleep with this small, light and non-invasive device with an additional strap?
The shape reminds me of a toy, and yes, I can sleep with this size "toy".

6. Imagine you are an ICU patient with a ventilator, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?

I will wear it because I believe everything put on me in ICU will be helping my recovery.
After knowing its function, I am very willing to put it on, because I know how hard it is to have a good sleep in hospital (I stayed in general ward, and private room several time for the past 12 years), I do prefer people don't disturb me once I fall asleep. But it is nice to come in when I am awake, because private room can be quite boring.

#6 (Age…22.. Gender…M…)

1.Have you used sleep monitoring applications (on your phone)?
No. But my mom use it.

2.Do you notice or even wake up if someone opens your door?
Maybe notice the door but not wake up entirely.

3.Have you fallen asleep with an eye patch or a mask, etc.? On what occasion?
I often use mask for the eyes, to block the light.

4.1 Do you think you can fall asleep with this additional headset?

4.2 This commercial product is intended to help you enter deep sleep stage. Are you willing to use it?
Sure I will try it on, but I am skeptical about the function.

5. What do you think of the appearance? Do you think you can sleep with this small, light and non-invasive device with an additional strap?
Why not, as long as I don't have to wear it outside.

6. Imagine you are an ICU patient with a ventilator, and this EEG detecting device will tell the sleep status so that people outside the room will know when to enter the room. Will you wear it?
I can wear it. Appearance does not matter since the use of it is the priority. I trust the doctors that they will put the right thing on my head. Plus I don't get to see myself with it and I don't think my family will find it scary-looking, either. Overall, it sounds like an interesting device.