Assistive Sleeping Aid for People with Ataxia

Submitted in partial fulfillment of the requirement of the degree of

Master of Design
by

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22m2237

Project Guide
Prof. Purba Joshi

IDC School of Design

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
(2024)

Approval Form

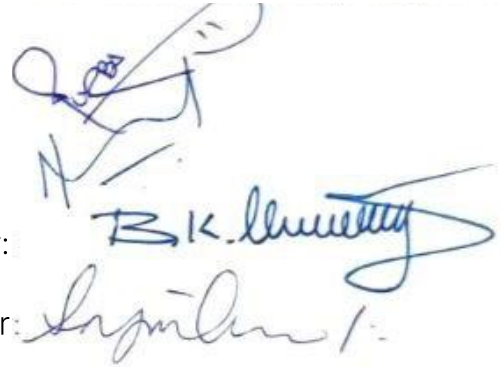
This is to certify that the Industrial Design Project entitled "**Assistive Sleeping Aid for People with Ataxia**" by Sukhadev Kumavat is approved for partial fulfillment for the Master of Design degree in Industrial Design.

Prof. Purba Joshi (Project Guide):

Signature of the Chair Person:

Signature of the Internal Examiner:

Signature of the External Examiner:



Dare: 27-05-2024
Place: IDC School of Design, IIT Bombay

Declaration Form

I, declare that this written report represents my ideas in my own words, and where others' ideas or words have been included I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea, data, facts or source in my submission.

I understand that any violation of the above will be caused for disciplinary action by the Institute and can also evoke penal action from the source, from which proper permission has not been taken or improperly been cited.

Signature: 
Name of the student: Sukhadev Mohanlal Kumavat
Roll No.: 22m2237
Date: 15-05-2024

Abstract

This is a College course project in an effort to understand the Design Process that is followed to design any product for general consumers.

The topic selected for the project was an Assistive Sleeping Aid for People with Ataxia. The Concise brief can be Quoted as “To design a wearable assistive product for people living with ataxia which provides a support on the neck which eventually helps them in having a better sleep.. Also keeping in mind usability, ergonomics, aesthetics, visual semantics as features." The issues targeted were selected based on research study that were conducted during the project.

Ataxia is considered a rare disorder, but its prevalence varies depending on the type and geographic location. Certain forms, such as spinocerebellar ataxias (SCAs), have been reported worldwide, while others may be more common in specific populations or regions. There is currently no cure for most types of ataxia, but treatment focuses on managing symptoms, improving quality of life, and slowing disease progression where possible. Therapeutic interventions may include physical therapy, speech therapy, assistive devices, and medications to alleviate symptoms such as tremors or muscle stiffness.

Acknowledgement

I would like to use this opportunity to give thanks to those who helped me going through this Course project. I would like to extend my respect to all the people who helped me in accomplishing this task.

First, I would like to thank my Course Guide, Prof. Purba Joshi, for being extremely helpful and trusting me. Her expert advise and helpful comments on my work has helped me to drive my work in a proper direction and reach my goal.

I also extend my gratitude towards all my batch-mates, juniors, who have always supported me and inspired me throughout this Project. I also want to offer my appreciation towards IIT Bombay for all the help and facilities they have provided.

Content

Introduction

Ataxia is a neurological disorder characterized by a lack of muscle control or coordination of voluntary movements. It affects various aspects of motor function, including gait, speech, and fine motor skills. Ataxia can result from damage to the cerebellum or its connections in the brain, as well as other parts of the nervous system. It can be acquired through factors such as injury, stroke, or certain medical conditions, or it can be inherited, with genetic mutations causing various types of hereditary ataxias.

Ataxia is considered a rare disorder, but its prevalence varies globally. Certain forms, such as spinocerebellar ataxias (SCAs), have been reported worldwide, while others may be more common in specific populations or regions. While precise epidemiological data on ataxia prevalence are limited, studies suggest that its incidence is higher than previously recognized, with estimates ranging from 8 to 40 cases per 100,000 individuals.

Genetic diversity plays a significant role in ataxia, with numerous gene mutations associated with different types of the disorder. Some forms, like Friedreich's ataxia, have a higher prevalence in certain ethnic groups, while others, like SCAs, can affect individuals of various ethnic backgrounds. Advances in genetic testing have facilitated the identification of specific genetic mutations linked to various types of ataxia, improving diagnostic accuracy and enabling targeted therapeutic approaches.

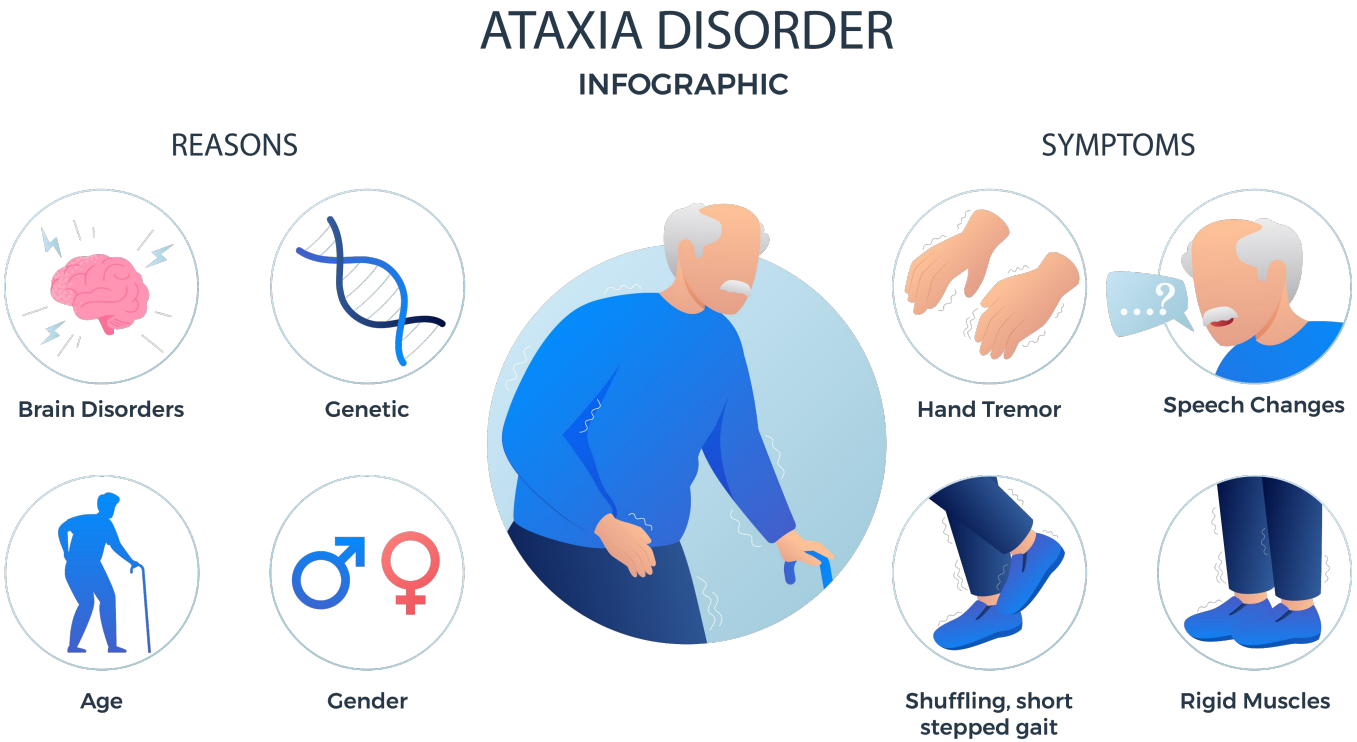
Ataxia research and awareness efforts are ongoing worldwide. Organizations, patient advocacy groups, and research institutions collaborate to support patients, raise awareness, and advance understanding of the disorder. International conferences and research collaborations contribute to global efforts to improve diagnosis, treatment, and support for individuals with ataxia.

Despite progress in diagnosis and management, ataxia poses significant diagnostic challenges. Its heterogeneous nature and overlapping symptoms with other neurological disorders can complicate diagnosis, leading to delays in treatment initiation. However, improved diagnostic techniques, including genetic testing and advanced neuroimaging, have enhanced the ability to identify specific types of ataxia and tailor treatment strategies accordingly.

There is currently no cure for most types of ataxia, but treatment focuses on managing symptoms, improving quality of life, and slowing disease progression where possible. Therapeutic interventions may include physical therapy, speech therapy, assistive devices, and medications to alleviate symptoms such as tremors or muscle stiffness. Research into novel therapeutic approaches, including gene therapy and targeted molecular interventions, holds promise for future advancements in ataxia treatment.

Introduction

Support networks for individuals with ataxia exist worldwide, providing resources, information, and community for patients and their families. These networks offer emotional support, educational materials, and advocacy for research funding and improved healthcare services. By fostering collaboration and sharing knowledge across borders, these networks contribute to the global effort to enhance the lives of those affected by ataxia. In conclusion, ataxia is a complex and multifaceted disorder that impacts individuals and families globally. Continued research, awareness efforts, and collaboration across borders are essential for advancing knowledge and improving outcomes for those affected by ataxia.



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Study of Ataxia

Ataxia can affect individuals of all ages and demographics, but some forms of ataxia may be more prevalent in certain populations. Here are some key demographic factors associated with ataxia:

1. Age: While ataxia can occur at any age, certain types, such as spinocerebellar ataxias (SCAs), often manifest in adulthood, typically between the ages of 30 and 50. However, some forms, like congenital ataxia, may present in infancy or childhood.

2. Gender: Ataxia can affect both males and females, but some types may show a slight gender predilection. For instance, certain SCAs may have a slightly higher prevalence in males.

3. Genetics: Many forms of ataxia are inherited, meaning they are passed down through families. In such cases, the prevalence of ataxia may be influenced by the prevalence of specific genetic mutations within certain populations or ethnic groups.

4. Geographic location: The prevalence of certain types of ataxia may vary based on geographic location. For example, some forms of ataxia may be more common in certain regions or populations due to founder effects or genetic predispositions.

5. Socioeconomic status: Access to healthcare and diagnostic services may vary based on socioeconomic factors, which can impact the detection and management of ataxia within different demographic groups.

6. Ethnicity: Certain types of ataxia may be more prevalent in specific ethnic groups due to genetic factors. For example, certain SCAs have been found to have higher frequencies in certain populations, such as those of European, Asian, or African descent.

7. Environmental factors: While genetic factors play a significant role in many cases of ataxia, environmental factors may also contribute to the development or progression of the condition. These factors can vary widely among different demographic groups.

Overall, ataxia is a heterogeneous condition with diverse underlying causes and manifestations, and its prevalence and impact can vary among different demographic groups based on a combination of genetic, environmental, and social factors.

Symptoms of Ataxia

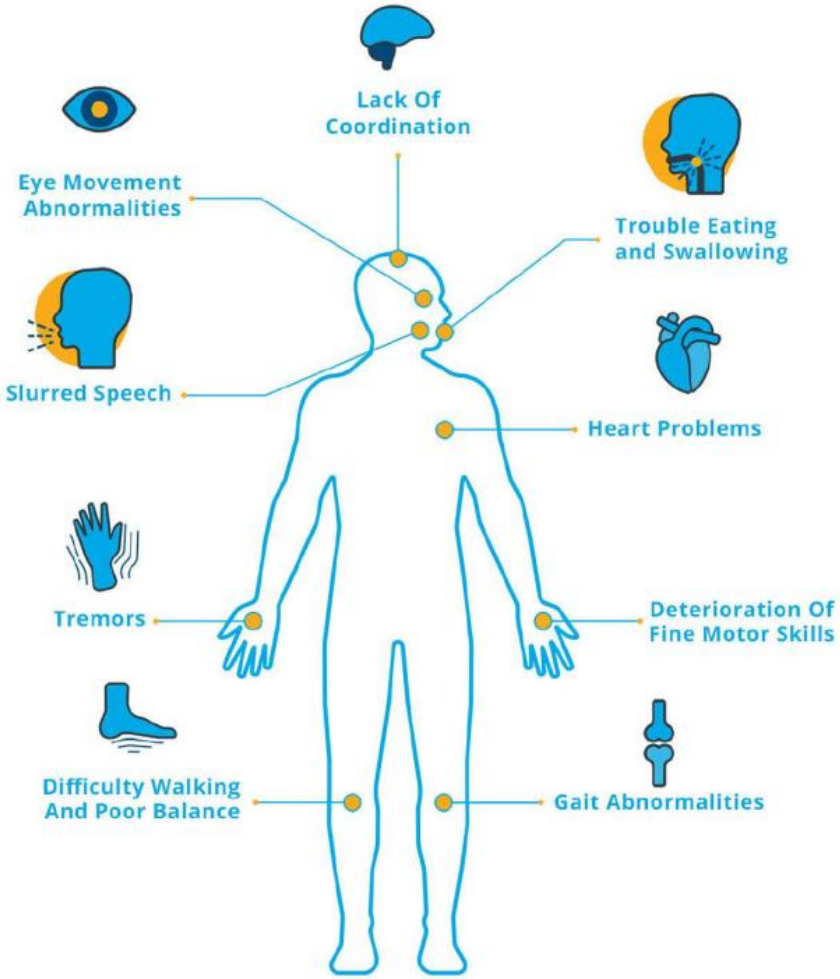
Ataxia can present with a variety of symptoms, which can vary depending on the underlying cause and type of ataxia. Here are some common symptoms associated with ataxia:

1. Gait Ataxia: Difficulty walking or maintaining balance is a hallmark symptom of ataxia. Individuals may have an unsteady or staggering gait and may appear clumsy or uncoordinated while walking.

2. Limb Ataxia: Ataxia can affect the coordination and control of movements in the arms, legs, and other extremities. This can lead to difficulty with tasks requiring fine motor skills, such as writing, buttoning clothes, or using utensils.

3. Dysarthria: Ataxia can affect speech production, resulting in dysarthria, which is characterized by slurred or unclear speech. Individuals may have difficulty articulating words, controlling pitch and volume, and coordinating the movements of the lips, tongue, and vocal cords.

4. Nystagmus: Some individuals with ataxia may experience nystagmus, which is involuntary, rhythmic movement of the eyes. This can manifest as rapid, jerking movements of the eyes, which may impair visual acuity and coordination.



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5. Tremor: Tremor, or rhythmic shaking movements, may occur in some individuals with ataxia, particularly during voluntary movements or when attempting to maintain a posture. Tremor can affect various parts of the body, including the hands, arms, and head.

6. Muscle Weakness: Ataxia may be accompanied by muscle weakness, which can contribute to difficulties with movement and coordination. Weakness may affect specific muscle groups or be more generalized, depending on the underlying cause of ataxia.

7. Loss of Sensation: In some cases, individuals with ataxia may experience sensory deficits, such as numbness or tingling in the limbs. Loss of sensation can further impair coordination and balance.

8. Fatigue: Fatigue is a common symptom of ataxia and may be related to the increased effort required to perform everyday tasks due to difficulties with movement and coordination. Fatigue can exacerbate other symptoms and impact overall quality of life.

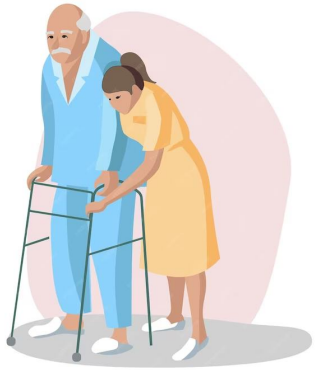
9. Difficulty with Fine Motor Skills: Ataxia can impair fine motor skills, making it challenging to perform tasks that require precise hand-eye coordination and dexterity, such as writing, typing, or buttoning clothes.

10. Balance and Coordination Problems: Ataxia often leads to problems with balance and coordination, making it difficult to maintain posture, control movements, and navigate the environment safely.

It's important to note that symptoms of ataxia can vary widely among individuals and may progress over time. Additionally, other neurological symptoms or signs may be present depending on the underlying cause of ataxia. If you or someone you know is experiencing symptoms suggestive of ataxia, it's essential to seek evaluation and diagnosis by a healthcare professional, typically a neurologist. Early diagnosis and management can help optimize treatment outcomes and improve quality of life for individuals with ataxia.

Issues faced in daily activities

Mobility and Independence
Difficulty Walking
Risk of Falls



Dependency on Caregivers
Assistance Required
Impact on Caregivers

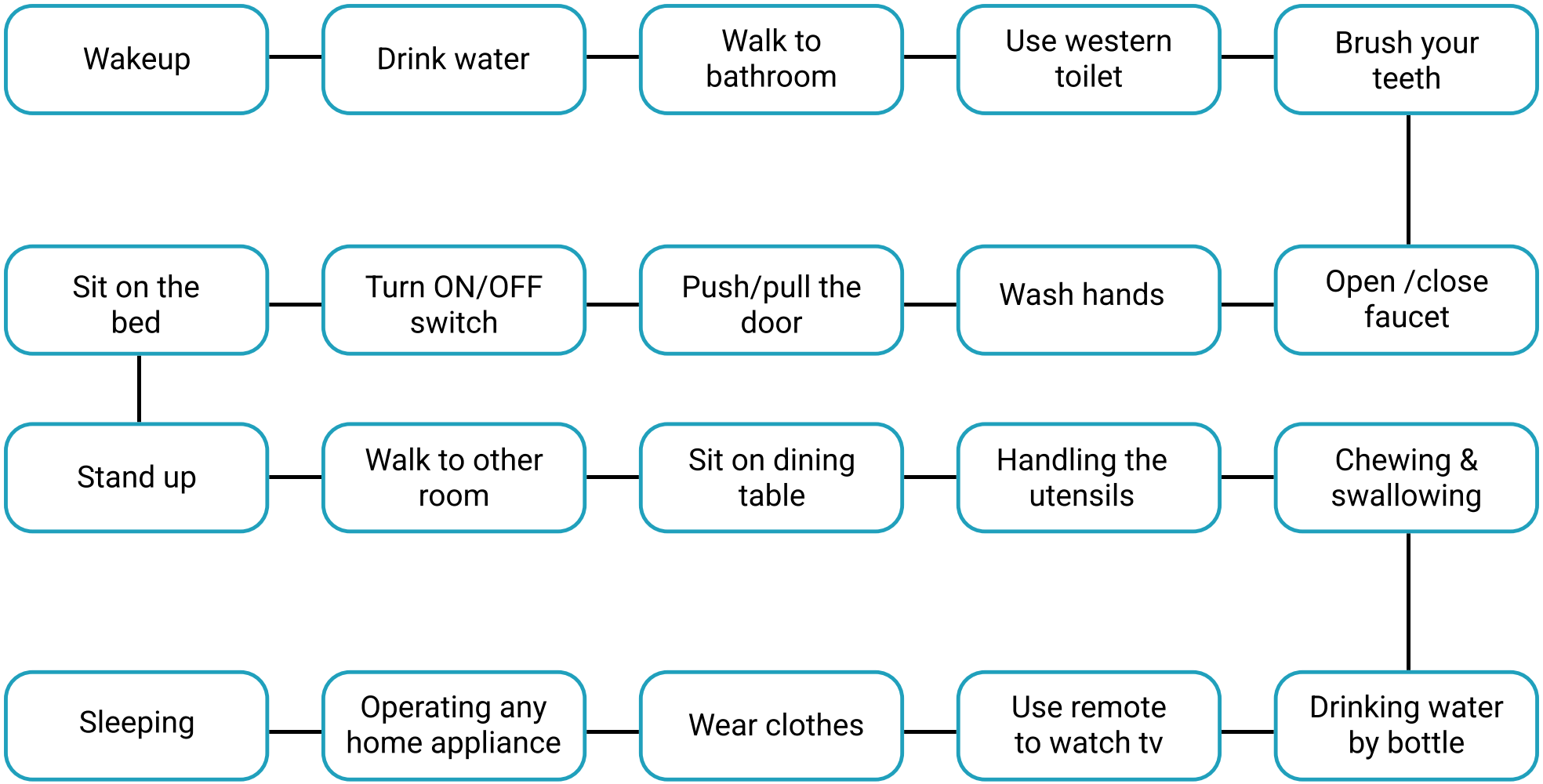
Adaptations and Assistive Devices
Use of Mobility Aids
Adaptive Equipment

Activities of Daily Living (ADLs)
Impaired Fine Motor Skills
Writing and Communication

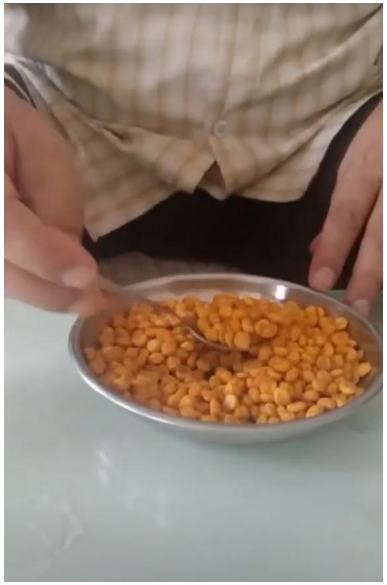
Quality of Life
Restricted Participation
Loss of Independence

https://in.pinterest.com/

Activity analysis



User Study



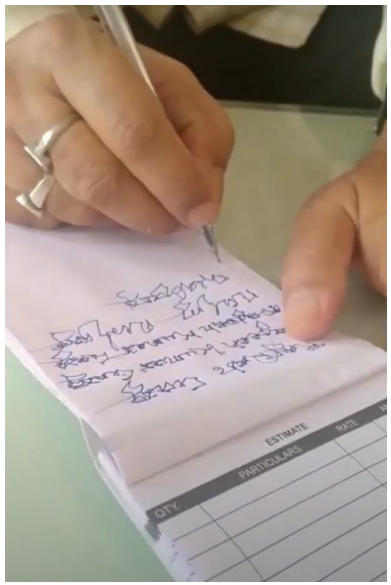
Eating

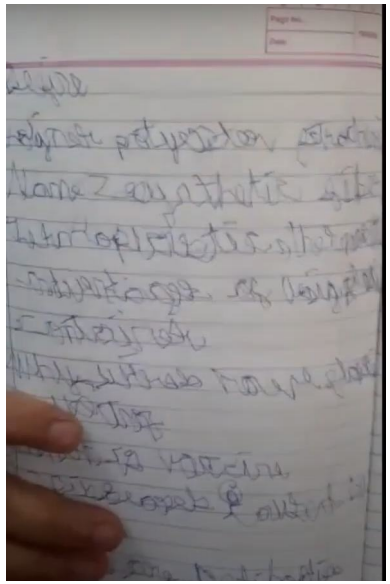
Drinking

Eating and Drinking: Participants struggled with gripping utensils or cups due to coordination difficulties. They also experienced issues with hand-to-mouth coordination, leading to spills or difficulty swallowing.

Link to the video file
https://drive.google.com/file/d/1_tbWarLUGO2f86NFScZWI79xsiNlgSnV/view?usp=sharing

User Study





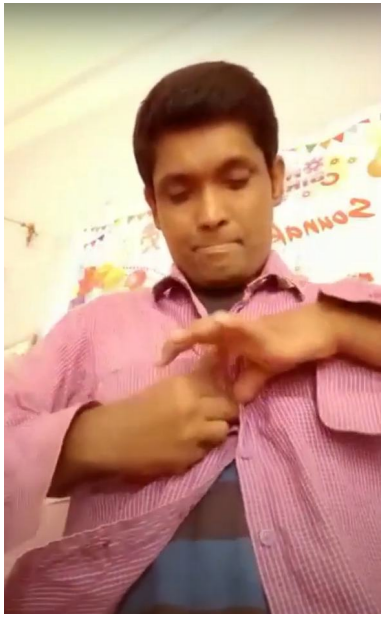
Writing

Writing: Writing tasks were challenging due to tremors or unsteady hand movements, resulting in illegible handwriting or difficulty controlling pen/pencil strokes.

Speech issues

Speaking: Ataxia affected speech articulation and clarity, leading to slurred speech or difficulty in pronouncing words accurately.

User Study



Closing buttons

Exercising

Pouring

Wearing Shirt and Putting Button: Fine motor skills required for tasks like buttoning shirts were impaired, making it difficult to manipulate small buttons or fasteners.

Exercising: Balance and coordination issues made exercises such as walking, jogging, or even simple stretching exercises challenging and potentially unsafe.

Pouring: Pouring liquids from containers was problematic due to difficulties in controlling hand movements and judging distances accurately.

Research Insights

Brushing teeth is a tedious task	need help in getting up from bed.	Gripping any object is an issue...	Exercises is also a complex task.	Uses a large cup with a small quantity of liquid.	Has to sleep on chair
early morning tasks are very difficult	Gripping objects is an issue...	dressing up require someones assistance	can’t write anything. the wrist won't move easily.	Need support while doing standing tasks	Lack of muscle coordination
Back Pain due to weak muscles	muscle stiffness causes pain.	avoids buttons and zippers in dressing	transferring require support of another person.	back always needs support to balance	finger stiffness
getting up from the recliner chair.	Changing pads causes frustration.	Need supports in the bathroom for holding	every activity is slow and time consuming	tremors are painful	eye coordination is not proper

Key Insights

Brushing teeth is a tedious task	Difficulty in speaking	Gripping any object is an issue...	Exercises is also a complex task.	Uses a large cup with a small quantity of liquid.	Has to sleep on chair
early morning tasks are very difficult	Sitting and standing is difficult	dressing up require someones assistance	can't write anything. the wrist won't move easily.	Need support while doing standing tasks	Lack of muscle coordination
Using mobile phone is challenging	muscle stiffness causes pain.	avoids buttons and zippers in dressing	transferring require support of another person.	back always needs support to balance	Closing and opening the door lock is difficult
getting up from the recliner chair.	Changing pads causes frustration.	Need supports in the bathroom for holding	every activity is slow and time consuming	tremors are painful	neck tremors affects eye sight

Holding **Balance** **Stability** **Motion** **Targeting**

Design Opportunities

1. Sitting and standing assistive aid for balance and stability.

2. Walking assistive aid to be used at home.

3. Hand tremor stabilizing device while performing a certain task.

4. A product which helps in opening and locking the door.

5. Assistive aid which provides a stable sleeping posture.

Among the identified design opportunities, the most pressing is addressing the sleeping issues of individuals with ataxia. Prioritizing this concern, our focus will be on developing an assistive aid tailored to provide optimal sleeping support. This aid aims to assist people with ataxia in achieving a stable and comfortable sleeping posture, particularly in an upright position.

By addressing the challenges associated with sleep disturbances in this population, our design seeks to enhance their overall well-being and quality of life. This targeted approach acknowledges the critical need to alleviate the specific challenges faced by individuals with ataxia during sleep.

Design Objective

To provide a better posture while sleeping in a sitting position to the people living with ataxia so that they can have a better and a comfortable sleep.

Design Brief

To design a product for people living with ataxia which provides a support on the back and neck which eventually helps them in having a better sleep.

Design consideration

Ergonomically designed
Easy ingress and egress
Comfortable over the body
Adjusting shouldn’t require efforts/pressure
An ease of shifting positions while sitting

Priority Matrix

Must have Comfortable support for neck Easy ingress & agress Ergonomic shape	**Should have** Soft cushion material Minimum need of efforts
Could have Foldable design Adjustable head size Multiple attachment	**Won't have** Electronics inside

Creating a priority matrix helped to organize the design considerations for a wearable neck support cushion in priority and here are the factors which were considered.

1. **Comfort:** Comfort is paramount for a wearable neck support cushion. Consider factors like material softness, breathability, and ergonomic design.

2. Support: The cushion is to provide adequate support for the neck. Evaluating how well the cushion aligns and supports the neck and head to prevent strain.

3. Portability: Since it's wearable, portability is essential. Assess factors like size, weight, and ease of packing for travel or storage.

4. Durability: The cushion should withstand regular use without losing its shape or effectiveness. Consider materials and manufacturing methods that ensure longevity.

5. Adjustability: People have different neck sizes and preferences, so having adjustable features like straps or inflatable components can enhance the cushion's usability.

6. Aesthetics: While not as critical as comfort or support, aesthetics play a role in user satisfaction. Consider the design, color options, and overall appearance.

Understanding the Sleep Cycle

There are four stages of sleep divided into two categories. The first three stages fall into the category of non-REM (rapid eye movement) sleep. The fourth stage is REM sleep.

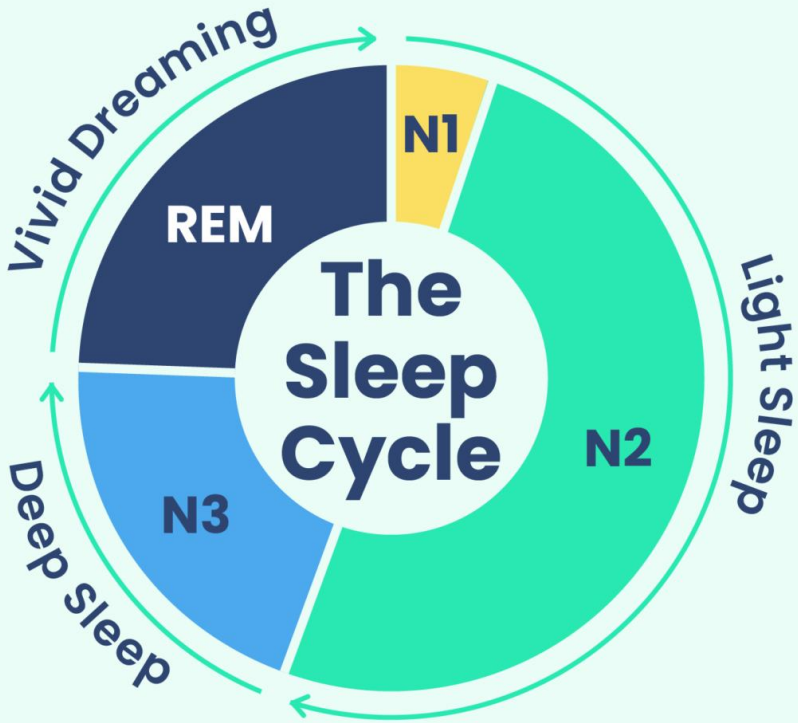
Stage 1, you've just dozed off and started transitioning to stage 2.

Stage 2 involves further slowing of activity in the brain and body.

Stage 3 is the deepest part of NREM sleep. In this stage, your muscles and body relax even more, and brain waves show a clear pattern of slowed activity

Stage 4 is the only stage of REM sleep. During this time, experience temporary paralysis. the most intense dreaming takes place during REM sleep.

The REM sleep stage is believed to be essential for the brain, enabling key functions like memory and learning. As the night goes on, it's normal to spend a greater percentage of time in REM sleep with most of it occurring in the second half of the night.



https://www.sleepfoundation.org/stages-of-sleep

Sleep issues with Ataxia

Obstructive sleep apnea

The muscles controlling airway function become relaxed during sleep, leading to repeated pauses in breathing during sleep due to blocked airways. This worsens ataxia symptoms, including fatigue, cognitive issues, and overall quality of life due to impaired coordination and balance.

Waking up due to Tremors

When individuals with ataxia experience tremors during the night, it significantly disrupts their sleep patterns. These involuntary shaking can cause frequent awakenings, preventing them from reaching deeper, restorative sleep stages. Consequently, they may suffer from excessive daytime sleepiness, fatigue, and decreased cognitive function.

Restless leg syndrome

RLS causes uncomfortable sensations in the legs, creating an irresistible urge to move the legs to alleviate discomfort. This leads to difficulty falling asleep and frequent nighttime awakenings. The combined impact results in heightened daytime fatigue, impaired cognitive function, and decreased quality of life.

periodic leg movement

Periodic leg movements (PLMs) are the involuntary jerking or flexing motions that can occur throughout the night, leading to frequent awakenings and fragmented sleep. Consequently, they experience daytime fatigue, irritability, and difficulty concentrating. PLMs worsens existing challenges in coordination and balance, worsening symptoms of ataxia during waking hours.

Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) is when your breathing gets interrupted during sleep because something blocks your airway. This can happen many times throughout the night, making it hard to get a good night's rest. People with ataxia, a condition that affects muscle control, are more likely to have OSA because their throat muscles might already be weak or uncoordinated.

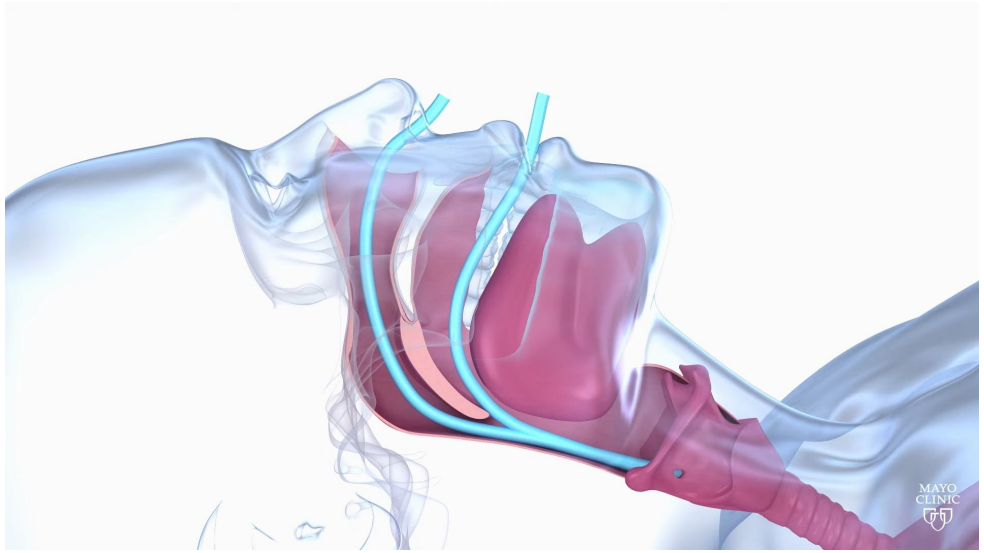
Here's how OSA affects people with ataxia:

1. Airway Blockage: When you sleep, your throat muscles relax, and sometimes they relax too much, blocking your airway. This happens more often in people with ataxia because their muscles might be weaker.

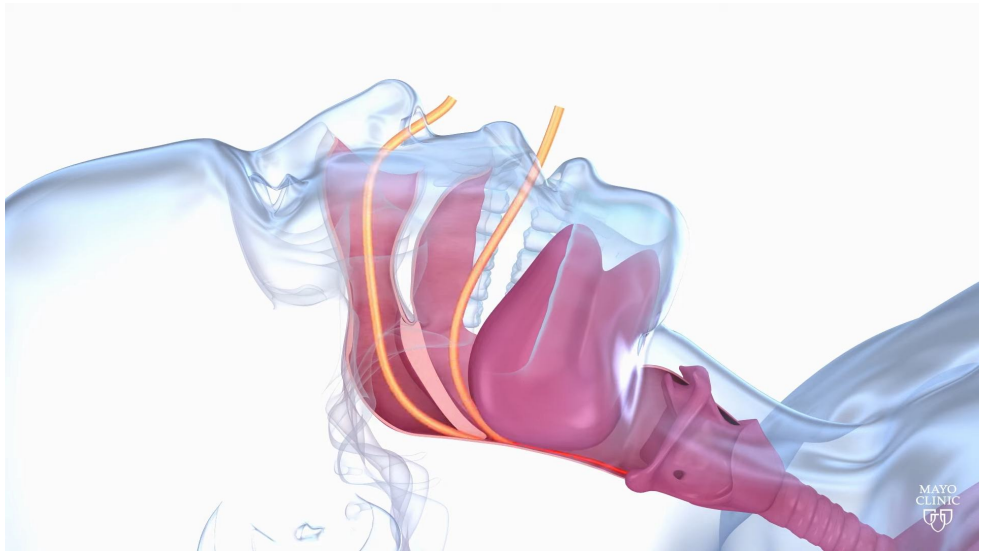
2. Breathing Pauses: When your airway gets blocked, you might stop breathing or breathe very lightly for a short time. Your body wakes you up briefly to restart your breathing, often with a snort or gasp.

3. Interrupted Sleep: These breathing pauses mess up your sleep cycle, so you don't get good, restful sleep. You might wake up feeling tired during the day, have trouble staying awake, or feel fuzzy-headed.

4. More Tiredness and Problems: Bad sleep because of OSA makes ataxia symptoms worse. You might feel even more tired, have trouble moving smoothly, or find it hard to focus on things.



Normal people



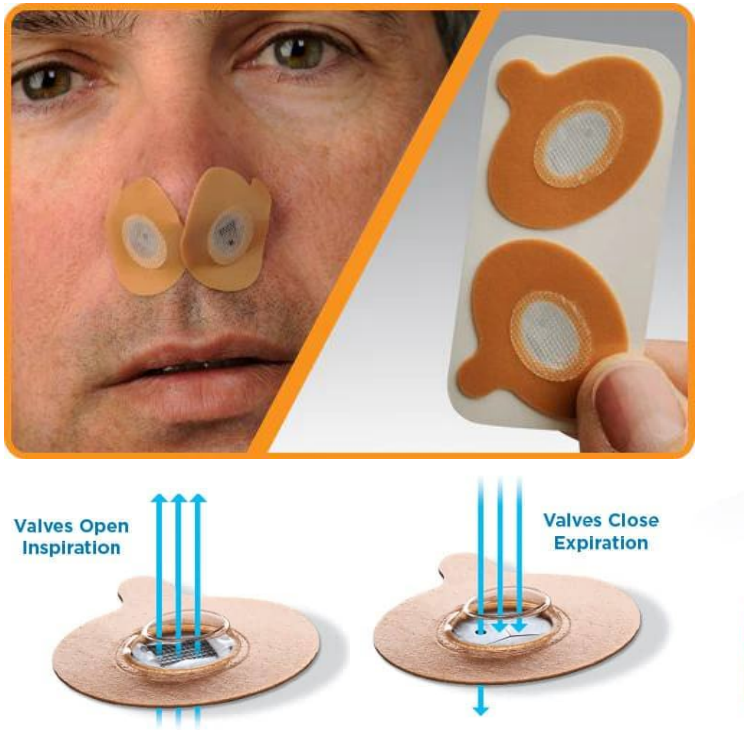
People with Ataxia

https://www.youtube.com/watch?v=I2xZH8n2JpU

Existing Assistive Products

CPAP

Continuous Positive Airway Pressure



EPAP

Expiratory Positive Airway Pressure

https://www.amazon.in/ *https://in.pinterest.com/*

Existing Assistive Products

https://www.amazon.in/ https://in.pinterest.com/

Existing Assistive Products

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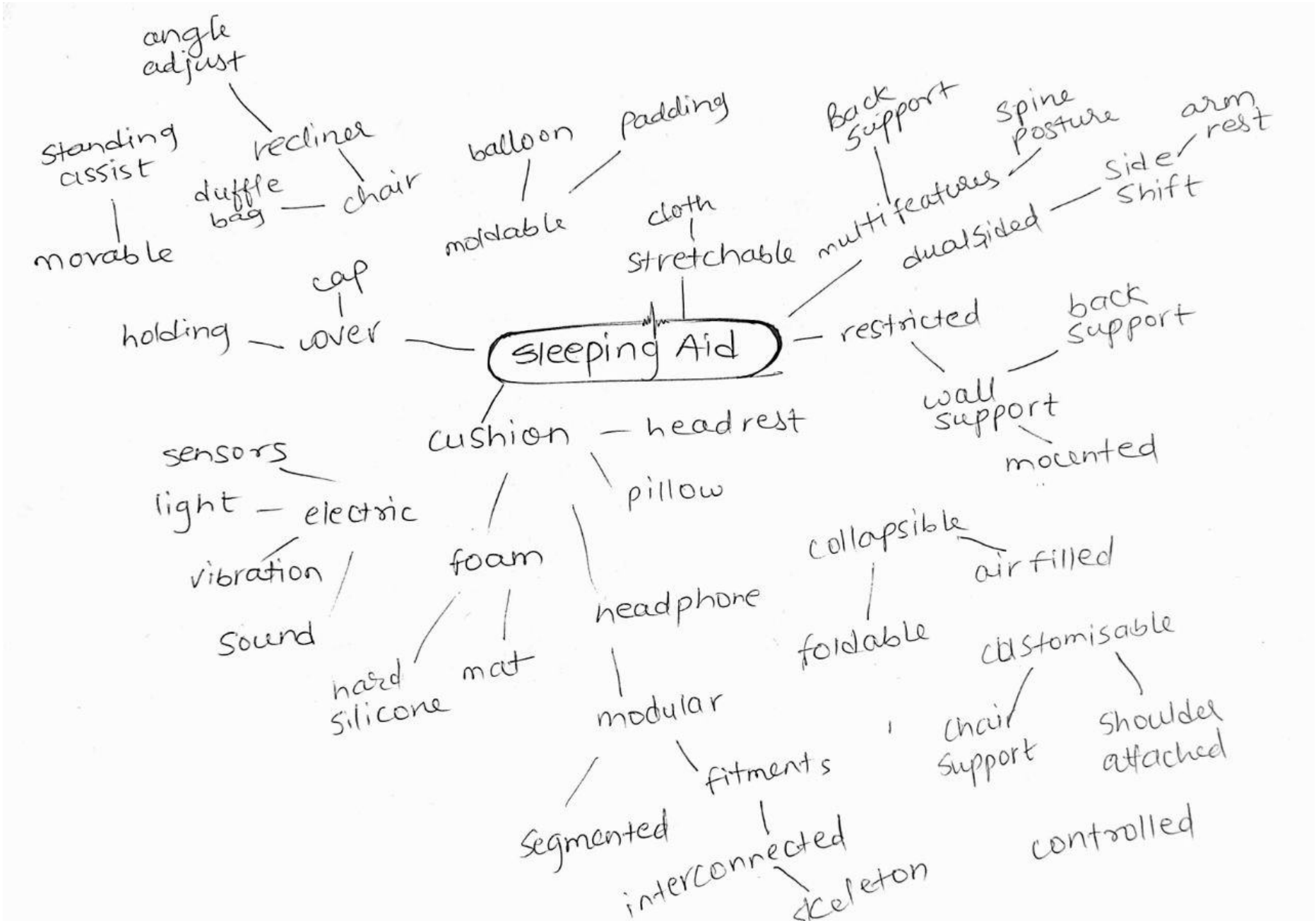
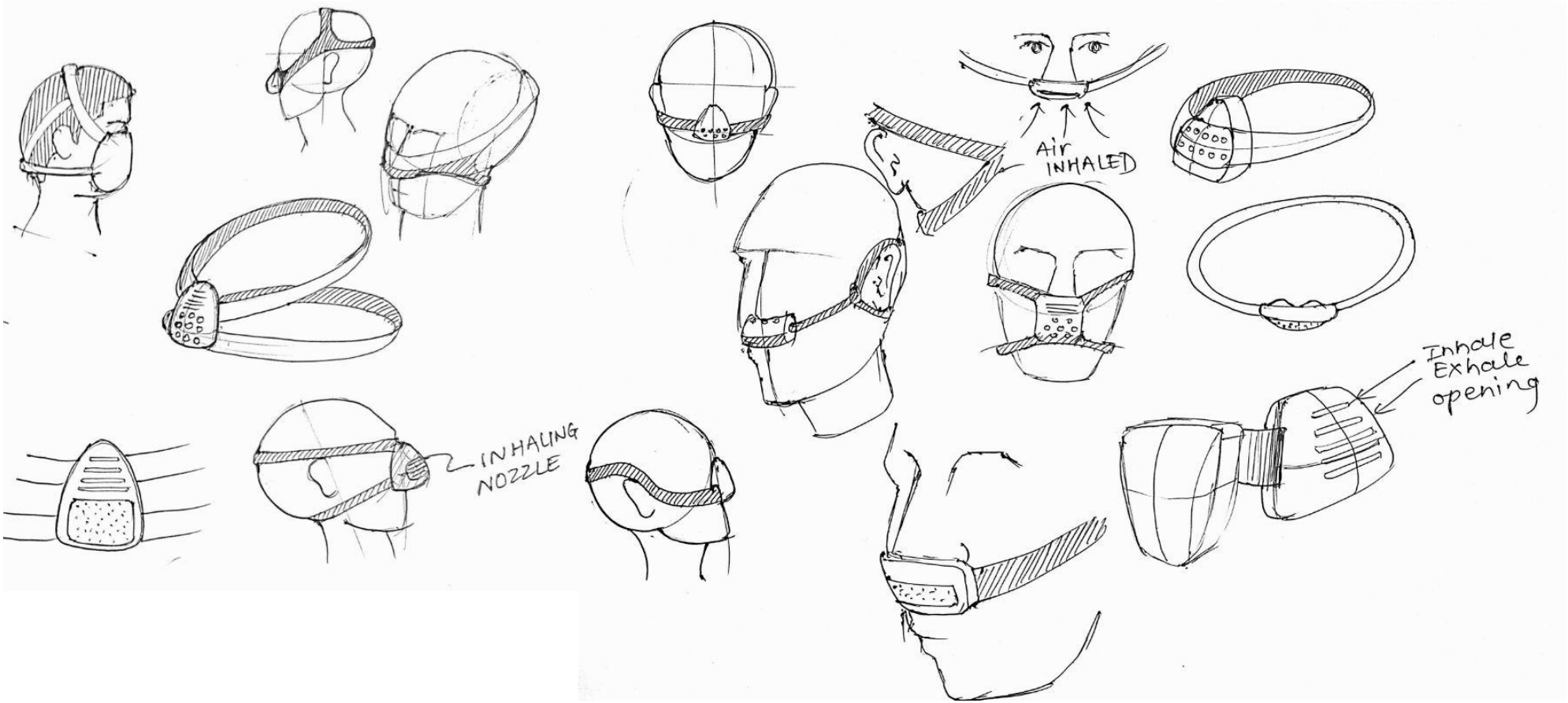
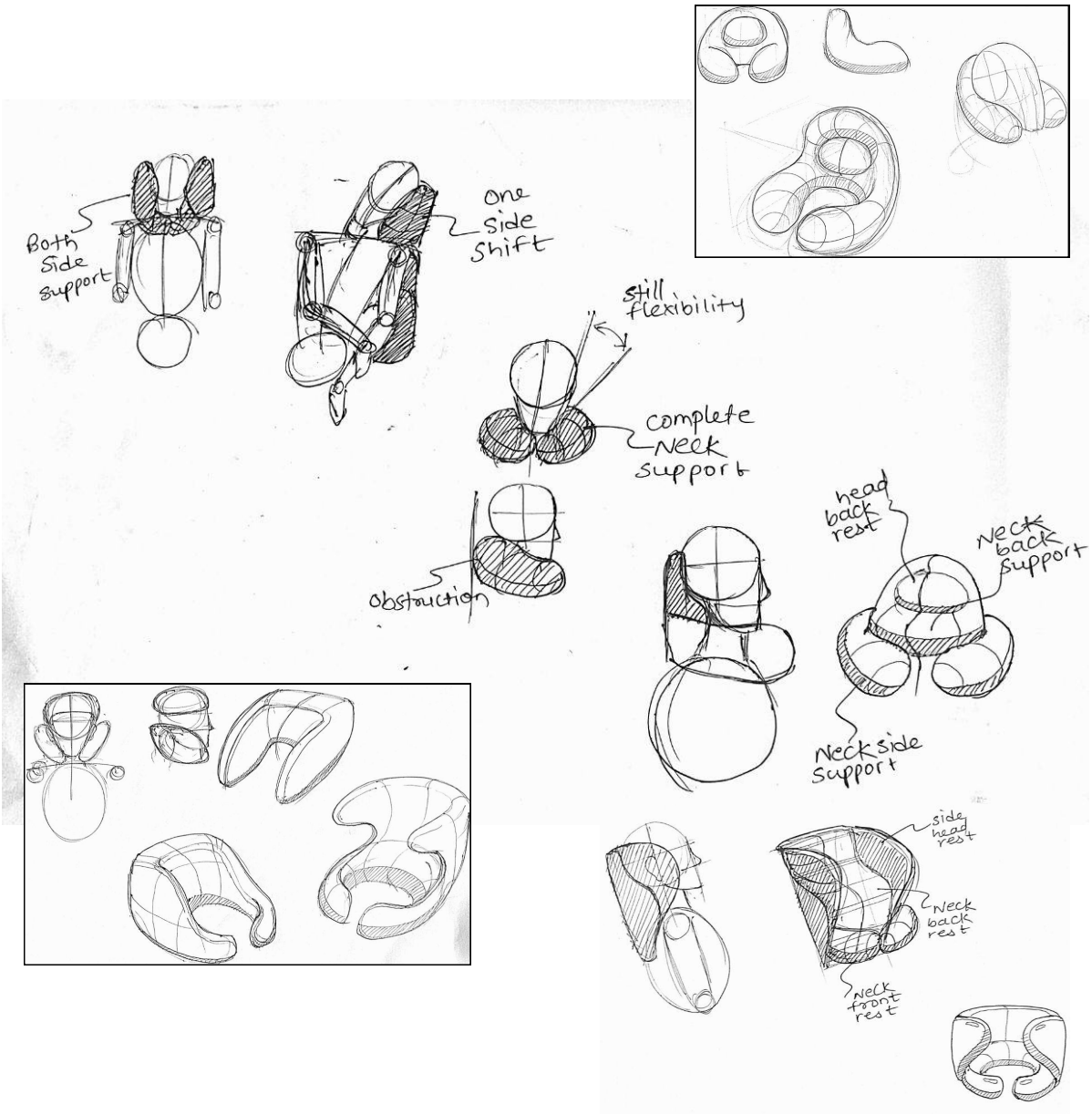
Brainstorming Ideas

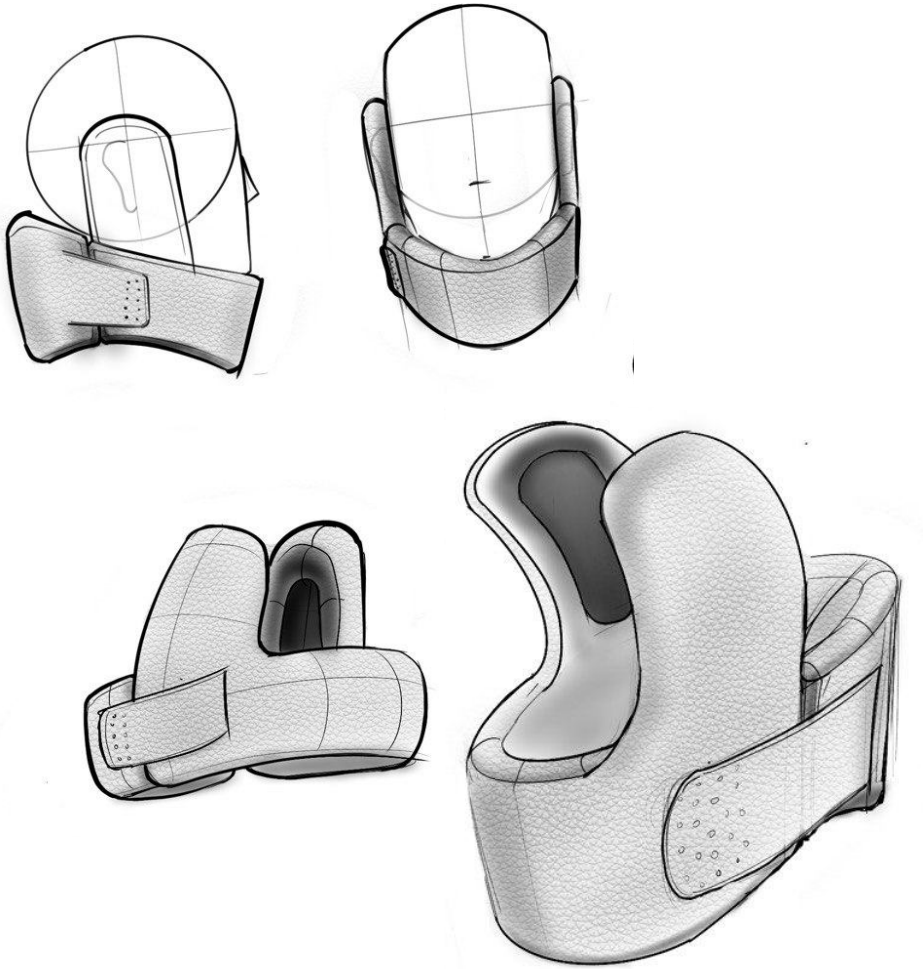


E-PAP Strap

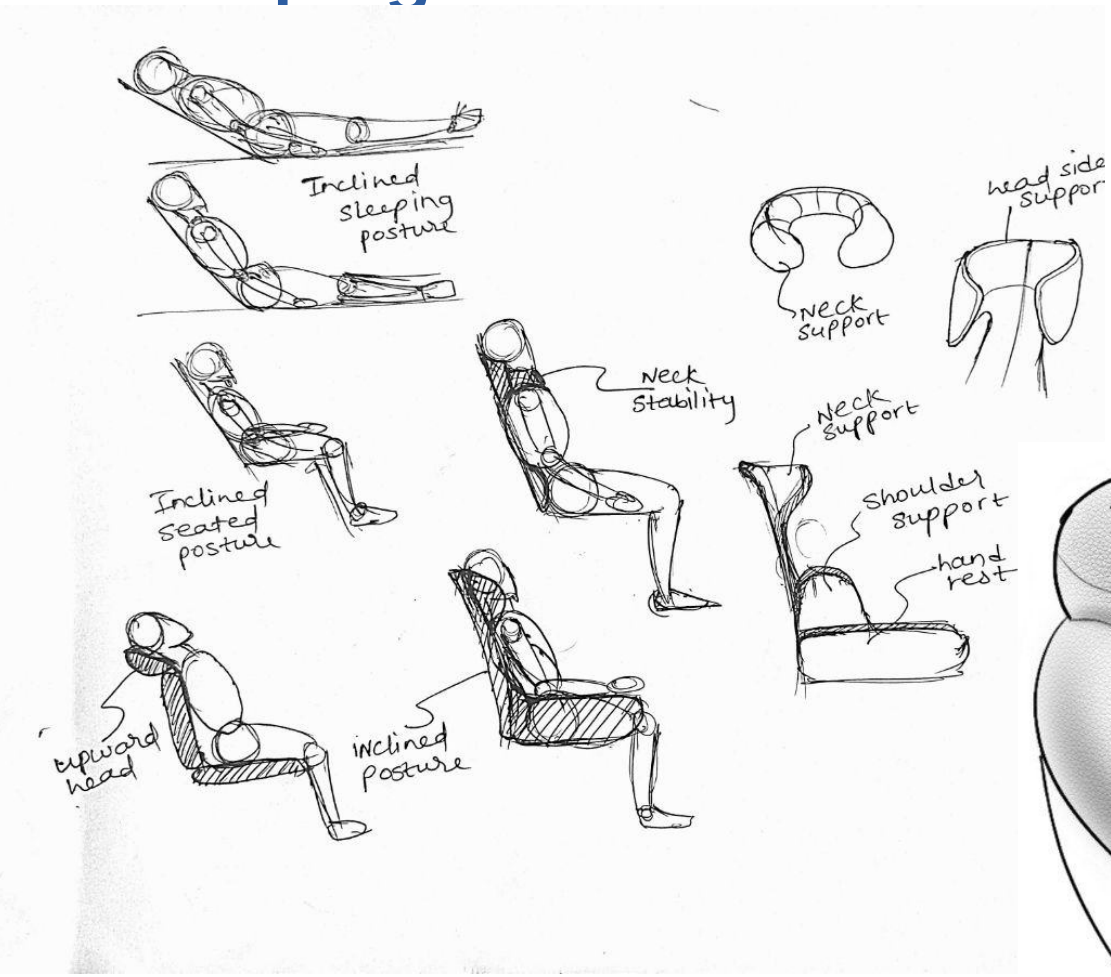


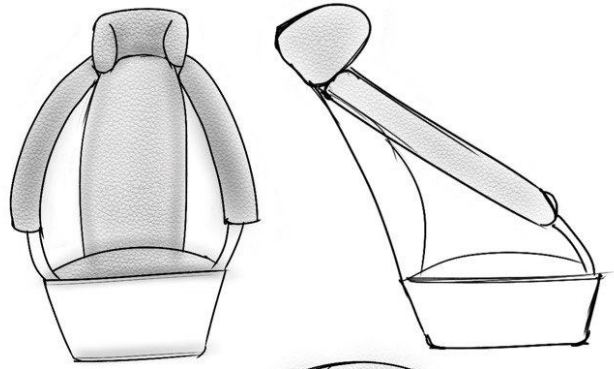
Neck & Head Support

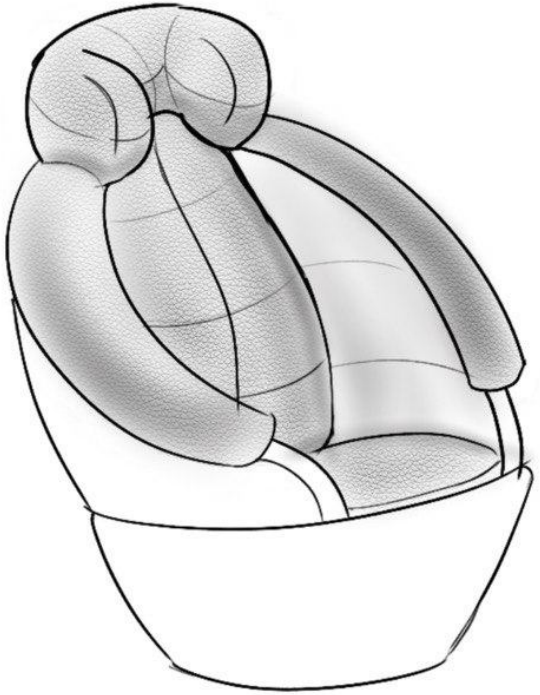


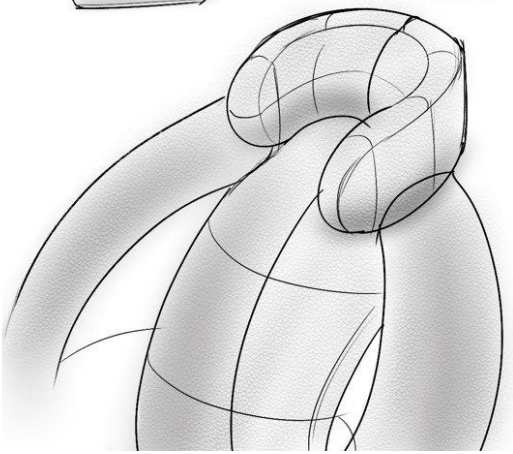


Sleeping chair

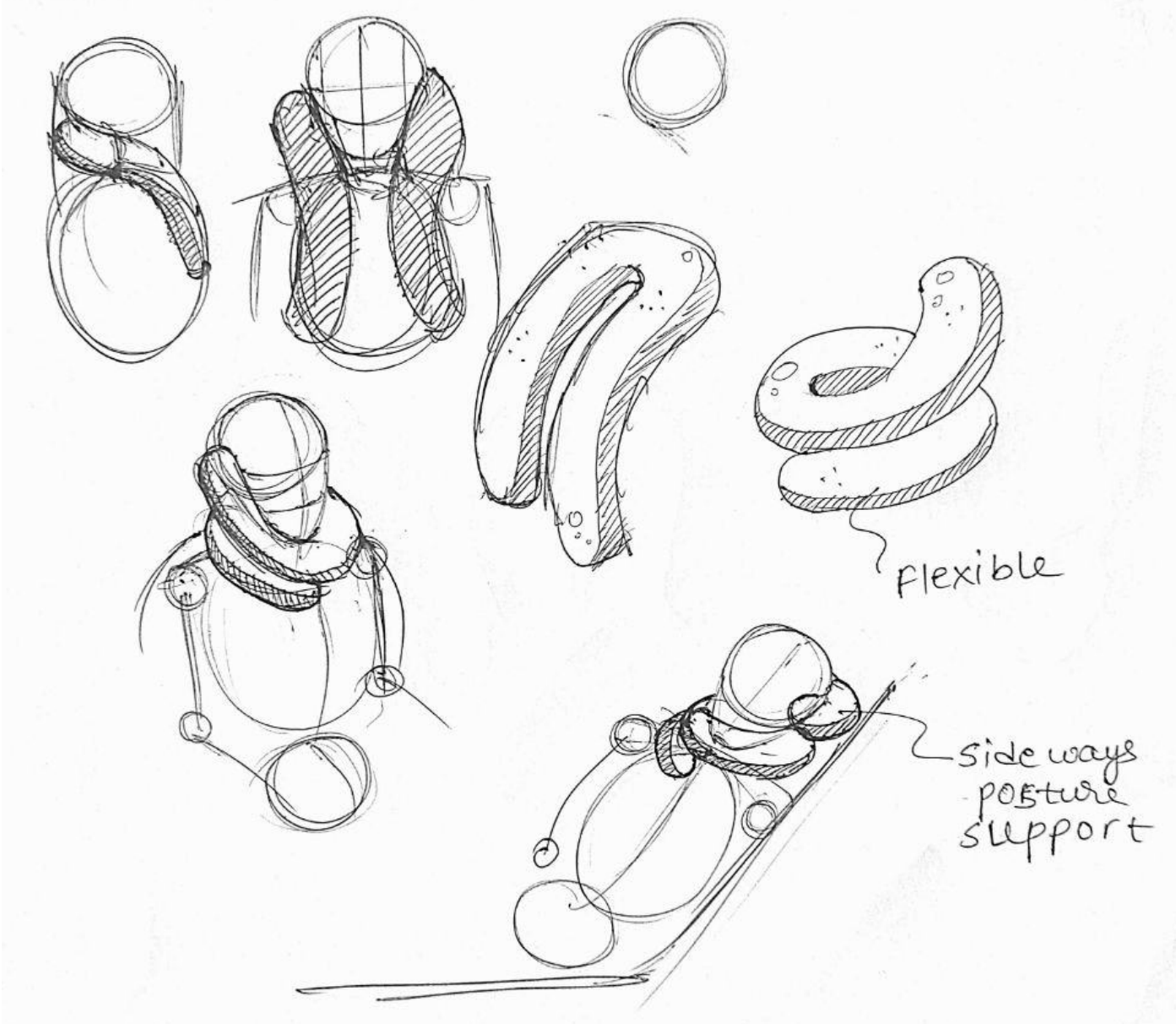




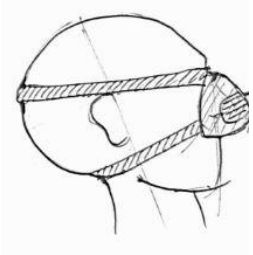




Flexible cushion

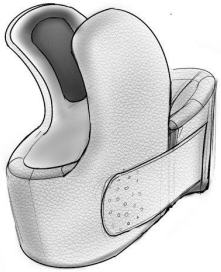


Ideas Evaluation



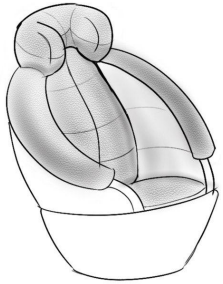
EPAP Mask

- Mouth also need to be cover
- Ensure no leaks during exhale
- Pressure might not buildup
- Might become uncomfortable



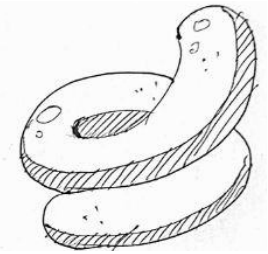
Neck & Head Support

- Backhead support is required
- Adjustments for neck angle and small movement is desired
- Easy to attach & detach



Sleeping Chair

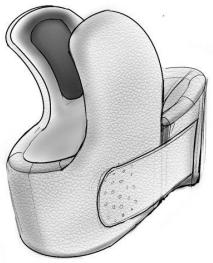
- Cant standardize it for everyone.
- Not feasible for different height people
- Multiple attachment would be preferred instead of a chair
- Something portable is desired



Flexible Cushion

- Cant cover different orientation
- Adjust everytime while changing sleeping orientation
- More efforts required to adjust.

Further Exploration



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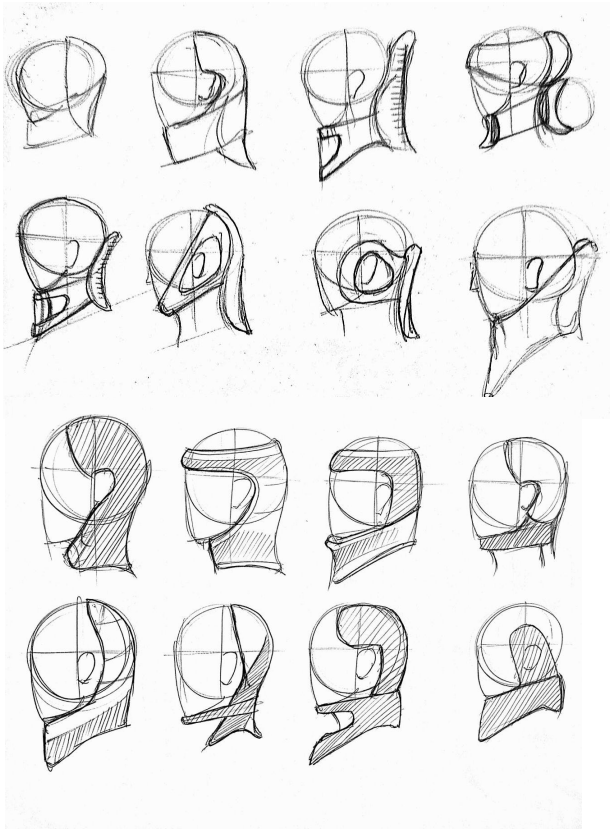
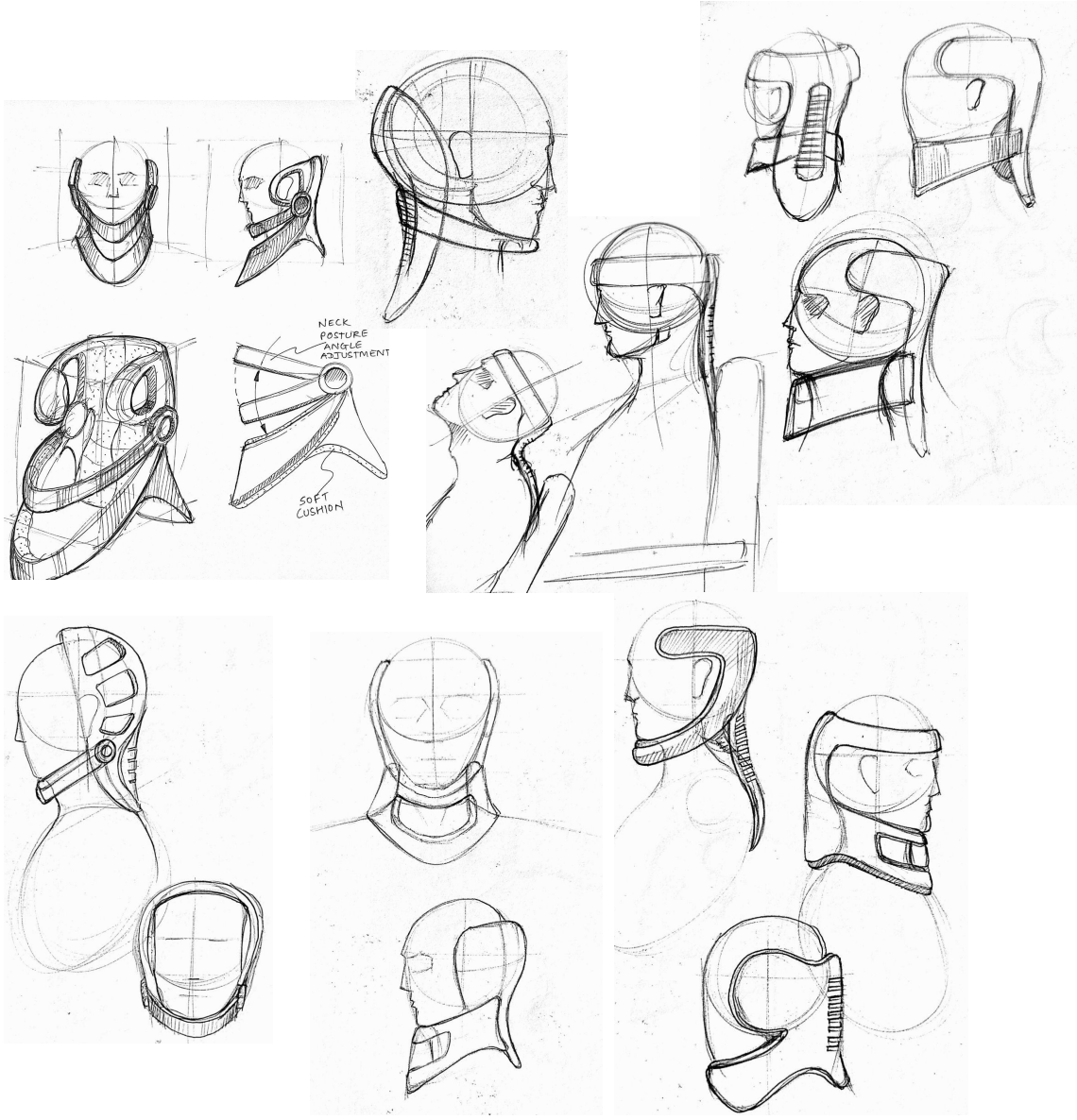
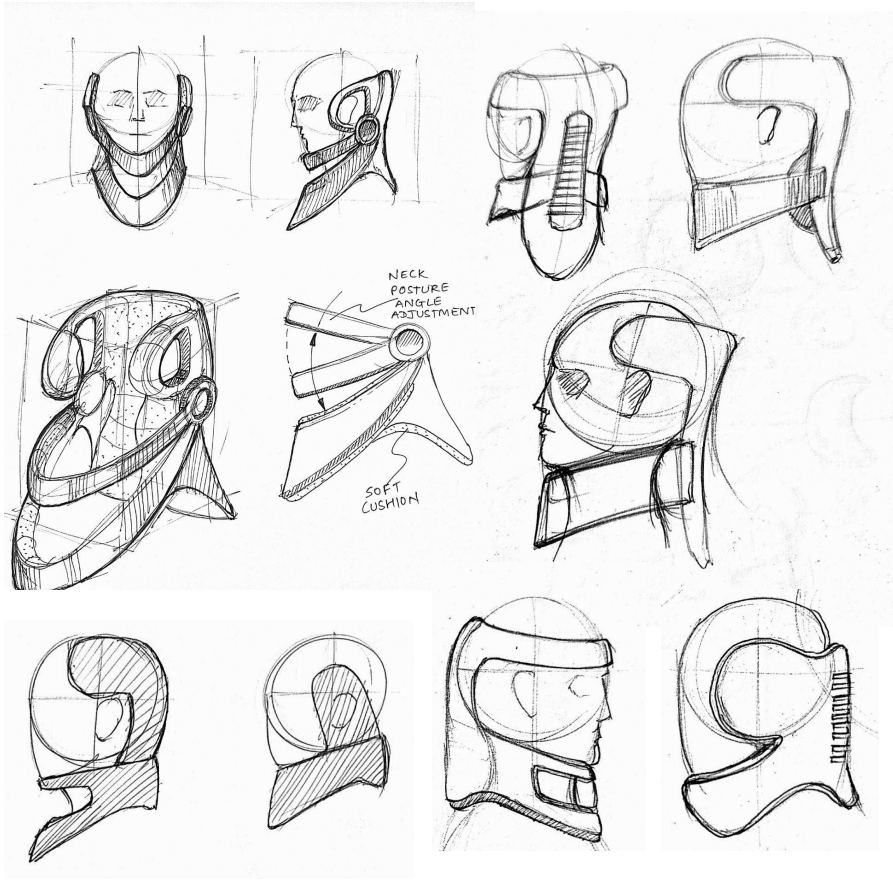
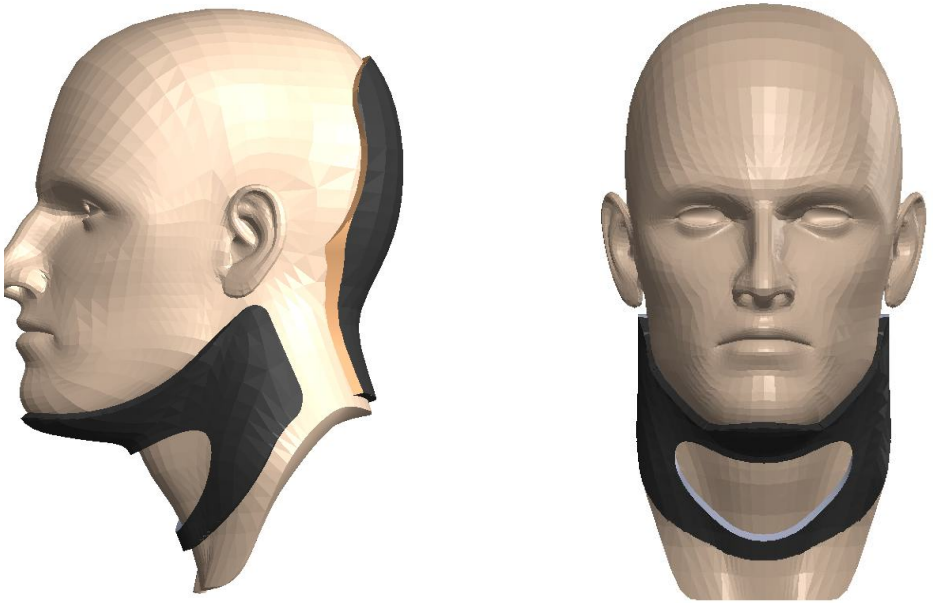




Concept 01



Cluster 01



Neck & Head Support

Mockup testing concept 01

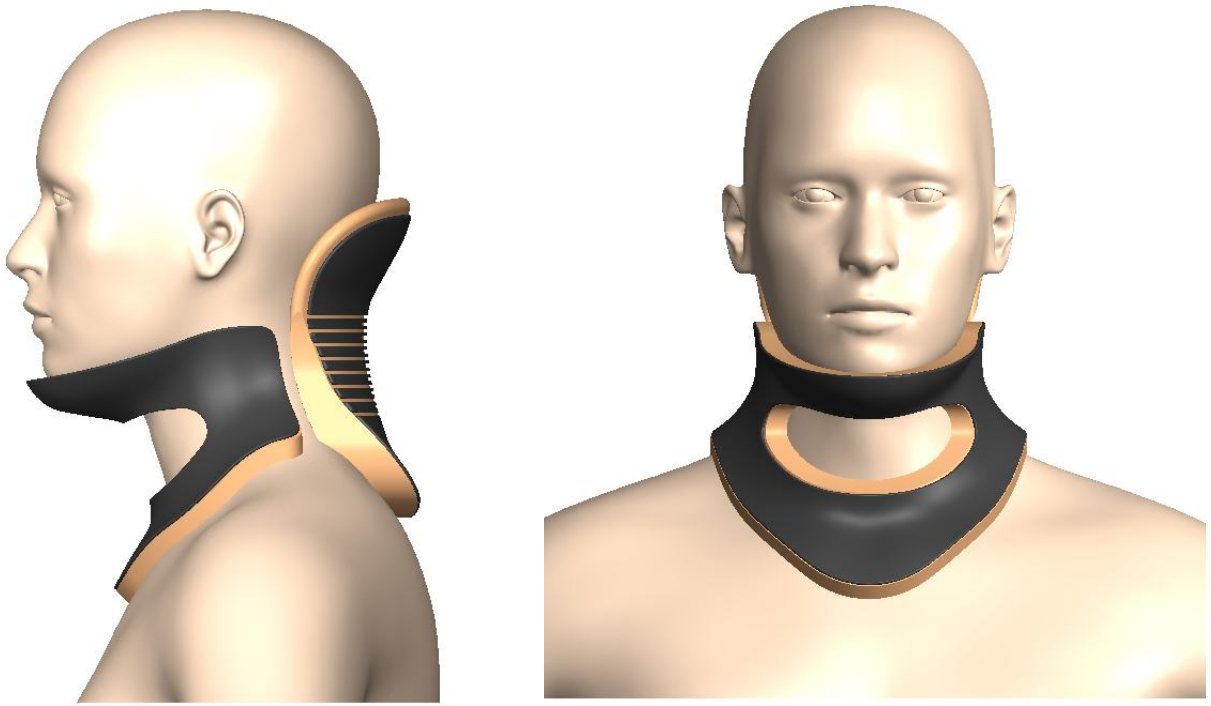





Iterated Concept 01

Modifications

- Increased base area
- Back Neck curvature support
- Improved Chin support
- Easy to wear and adjust.



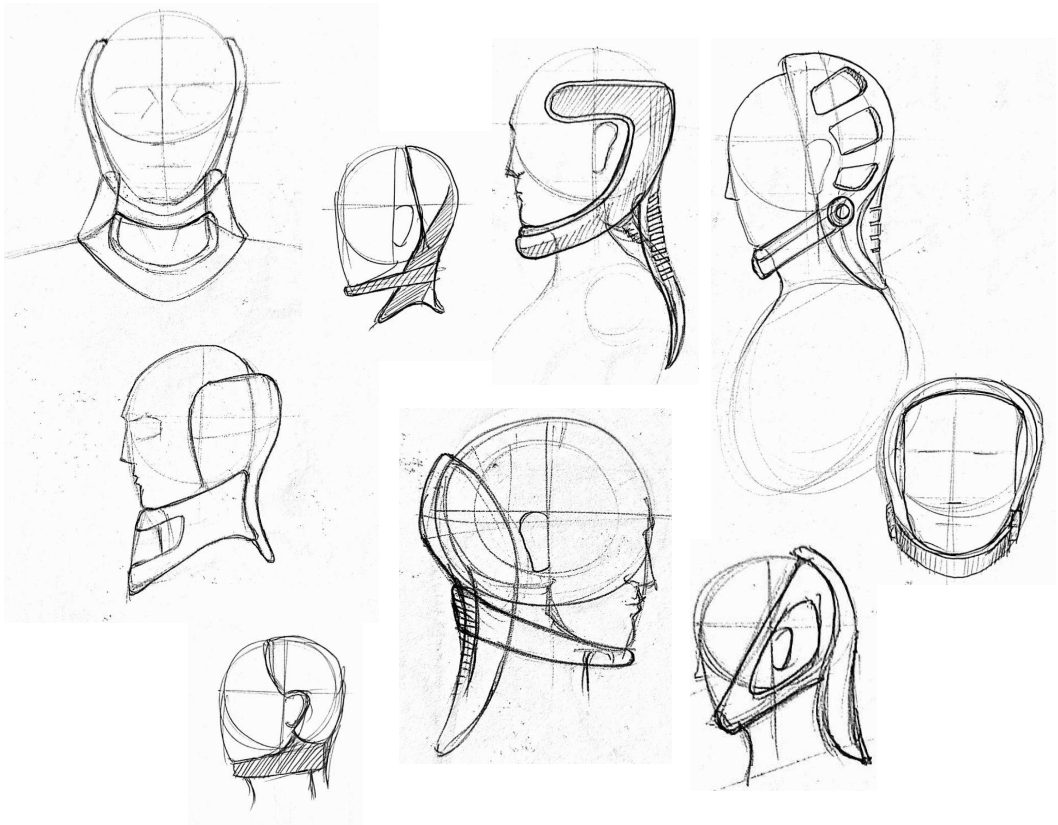
Neck & Head Support

Mockup testing 2.0 Concept 01

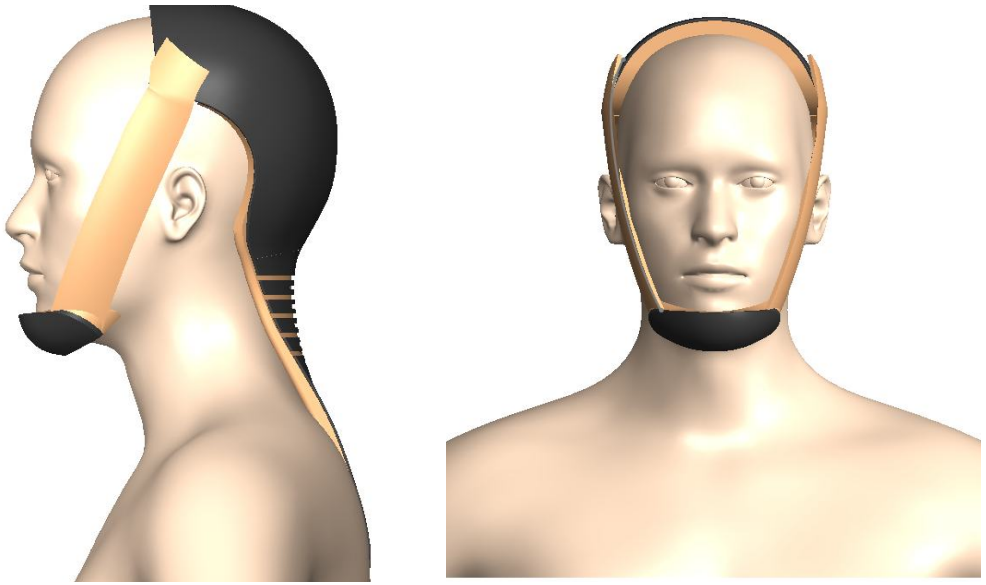





Concept 02



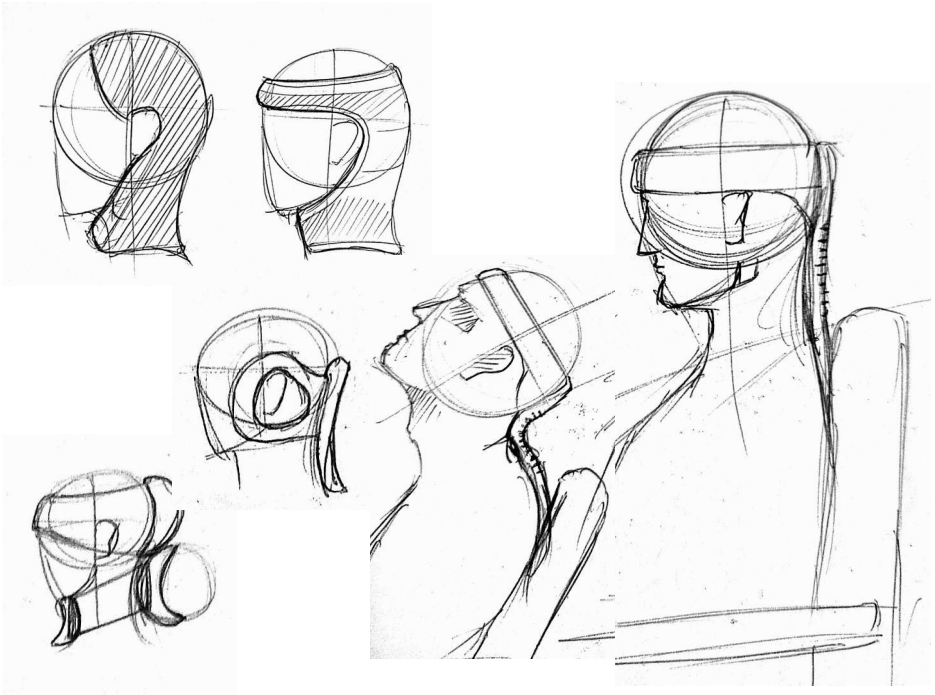
Cluster 02



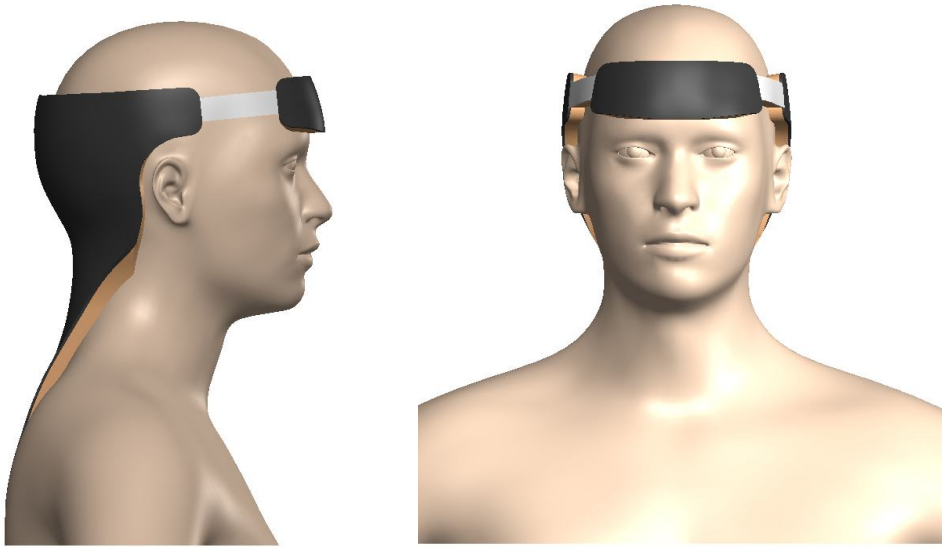
Chin & Head Support

Mockup testing Concept 02

Concept 03



Cluster 03



Forehead & Backhead Support

Mockup testing Concept 03

Concept evaluation

FACTORS	CONCEPT 01	CONCEPT 02	CONCEPT 03	REMARKS
Form perception	4	4	4	Semantics should be optimised
Posture	5	3	3	Neck should not get restricted
Comfort	5	3	2	Soft cushion and microfiber gives comfort
Ingress/Agress	4	4	4	Less efforts should be required
Neck Movement	3	3	3	Leverage of neck movement is desired
Adjustability	4	3	2	Adjustable strap is desired
TOTAL	**25**	**20**	**19**	**Concept 01 was found better than the rest**

Final design improvements

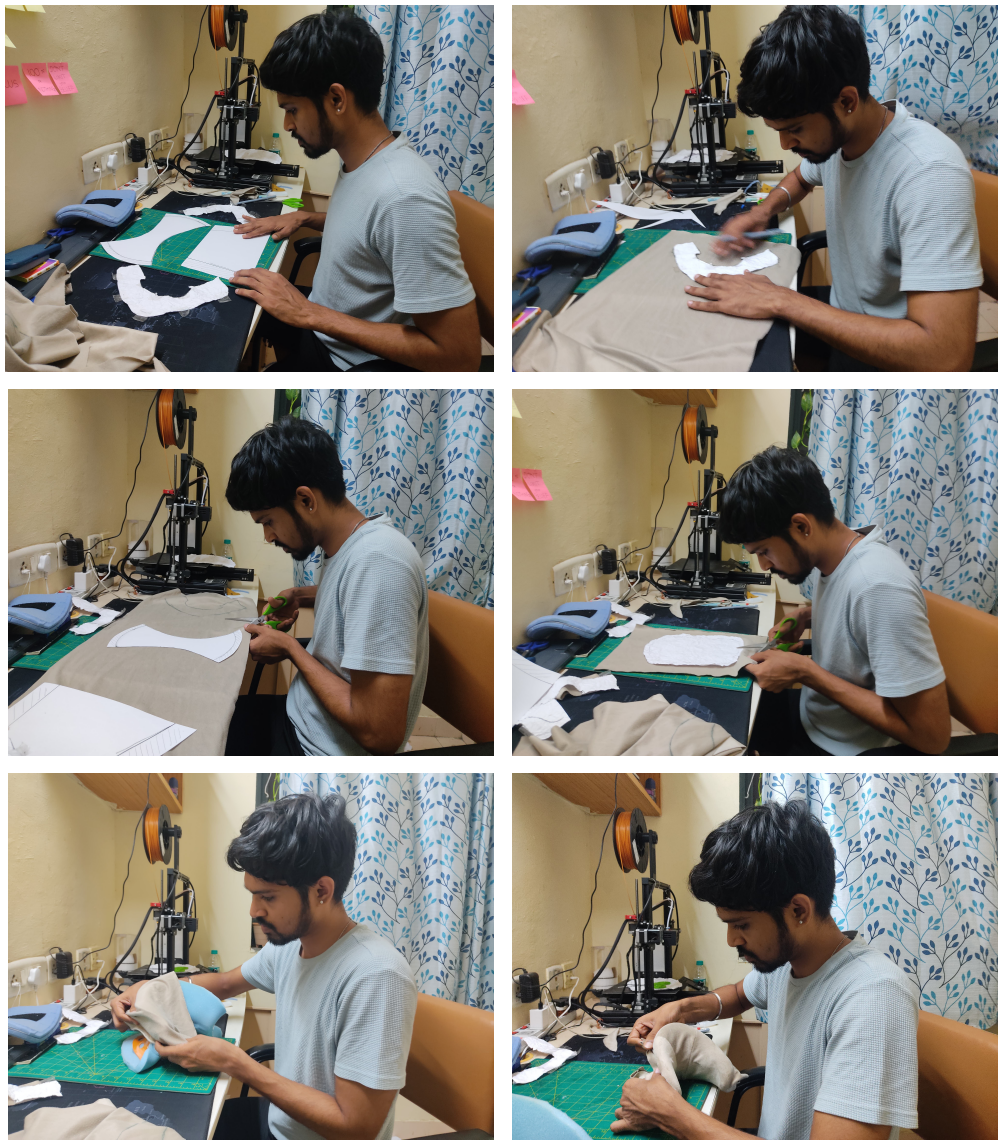

Semantics need to be optimized:
While wearing, the user should not feel confusing about the orientation of the product. To avoid human error, design decisions for semantics need to be made like adding a cmf, variations in proportion or stitching of fabric


Soft cushion and microfiber for more comfort:
Selection of appropriate fabric is crucial for the user to feel comfortable and should align with the personal care product standards. Cushion should be well placed covering every area.


Neck should not get restricted:
Leverage of neck movement is desired Certain degrees of freedom should be given for the user to adjust the position and move the neck from time to time.


Ease of ingress/agress.
less efforts should be required while wearing and removing. Strap poition has to be changed and bought at the front.

Adding the fabric



Here's an elaboration on each step of the process for adding fabric to this product:

1. Selecting the right fabric:

- This step involved choosing the appropriate type of fabric based on factors such as the product's intended use, desired aesthetic, durability requirements, and budget constraints, the fabric's texture, color, pattern, stretch, and breathability.

2. Making the stencil based on the form of the product:

- Before cutting the fabric, a stencil was created based on the shape and dimensions of the product.
- The stencil served as a guide for cutting the fabric pieces to the correct size and shape.
- Due to the complexity of the product design, the stencil was made from paper which was easy to trace around.

3. Cutting the pieces of fabric:

- Using the stencil as a reference, the fabric was cut into individual pieces according to the required pattern.

4. Stitching all the pieces of fabric:

- Once the fabric pieces were cut, they were assembled and stitched together to form the final product.

5. Putting on the product and fixing:

- After the fabric components were stitched together, they were placed onto the product
- The fabric was securely attached to the product using sewing techniques, adhesives, or other suitable methods.

Final Prototype


SUZUKI

User Testing Results

FACTORS	RATINGS	REMARKS
Form perception		Visual clues prevents confusion
Body Posture		Keeps the posture in a right position
Comfort		Felt relax due to soft cushion and microfiber
Wearing / Removing		Wearing is easy , fitting takes time
Neck Movement		Has leverage to move except sideways
Tightness Adjustability		Tightening is easy
Ease of Shifting positions		Comfortable to switch positions
Ergonomics		Blends with neck curvature
OVERALL		**I would like to have one.**

References

1. https://en.wikipedia.org/wiki/Spinocerebellar_ataxia

2. https://academic.oup.com/sleep/article/46/Supplement_1/A432/7182438?login=true

3. https://www.ataxia.org/wp-content/uploads/2019/04/Sleep-Difficulties-in-Patients-with-Cerebellar-Degeneration.pdf

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5. https://my.clevelandclinic.org/health/symptoms/17748-ataxia

6. https://www.mayoclinic.org/diseases-conditions/ataxia/symptoms-causes/syc-20355652

7. https://www.sleepfoundation.org/stages-of-sleep

8. https://www.youtube.com/watch?v=I2xZH8n2JpU

Thank you