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A smart yoga mat system designed for visually impaired people

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By

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Thesis Committee

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Abstract

Globally, nearly 2.2 billion people are visually impaired, while 39 million are blind at present. Due to various factors, it is difficult for the blind to exercise. Though associations for blind people and disabled schools provide more possibilities for sports training for visually impaired people, these resources cannot reach everyone in need because of location and foundation limits. The project aims to make fitness more accessible for visually impaired people to help them keep healthy. Thus it could support their confidence and independence as they expected. Furthermore, society's awareness of visually impaired people's difficulties while exercising then, more studies could be built on the accessibility of fitness equipment for more feasible solutions in the near future.

A smart yoga mat that used Somatosensory technology and the tactile response was designed to reach this aim. Qualitative interviews, Wizard of Oz, prototype testing, and other design methods were used to test the design's usability.

Introduction

The project focuses on the accessible design area, especially the health needs of fitness. In all ages of visually impaired people, the total exercise time was significantly lower than in other disability groups(Marmeleira et al. 2014). The prevalence of obesity was 13.2%. The relationship between disability type and obesity status was found to be significant. But for visually impaired people to begin working out at the gym both mentally and physically.

Keywords

Visually impaired people, soft robots, sense of touch, accessible design.

Problem statement

How could design help encourage visually impaired people to begin exercise not only to reduce obstacles but also to give them confidence, motivation, and a sense of security?

Project Overview

Obsveration

Difficulty achieving standard movements is one of the problems of visually impaired people. Like MetroBlindSports(Klein 2022) and blindyoga(Noe 2020), those sites provide VIPs with voice guidance for yoga and other sports. The testers who wore the goggles and used the voice guidance needed more time to understand the movements than those who used the video guidance, about 2-3 times.

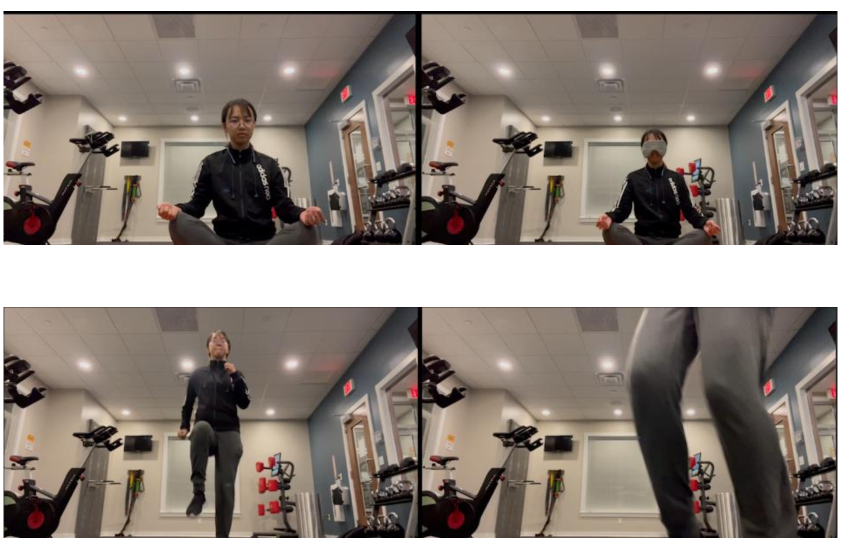

Fig.1 Compairation of doing exercise with or without sight

Difficulty seeing one's movements and comparing them to standard actions are also contributing factors. Testers without blindfolds corrected their actions through mirrors.

Perception of position and orientation

By observing VIPs doing yoga, they were more cautious when moving steps. Long-term visual deprivation increases tactile acuity, and they trust this sense more(Wong, Gnanakumaran, and Goldreich 2022). For example, to determine the location by touching the wall. Vision plays an essential role in spatial cognition, and the lack of vision makes VIPs more difficult in movements that require a lot of turns and movements(Thinus-Blanc and Gaunet 1997). At the same time, visual deprivation has a significant impact on the static and dynamic balance of both VIPs and blindfolded sighted persons, especially the muscle control of the lower extremities(Giagazoglou u. a. 2009). The test subjects exhibited significant center of gravity instability when squatting or standing on one foot, such as tree pose and chair pose.

After an interview with a yoga instructor, the most common problems for all practitioners are the back and spine. For example, the back is not straight, and the body's center of gravity is tilted.

To sum up, the difficulties in learning yoga for VIPs mainly come from a lack of sense of position and direction, balance problems, and difficulty correcting movements by comparison.

Yoga movements study

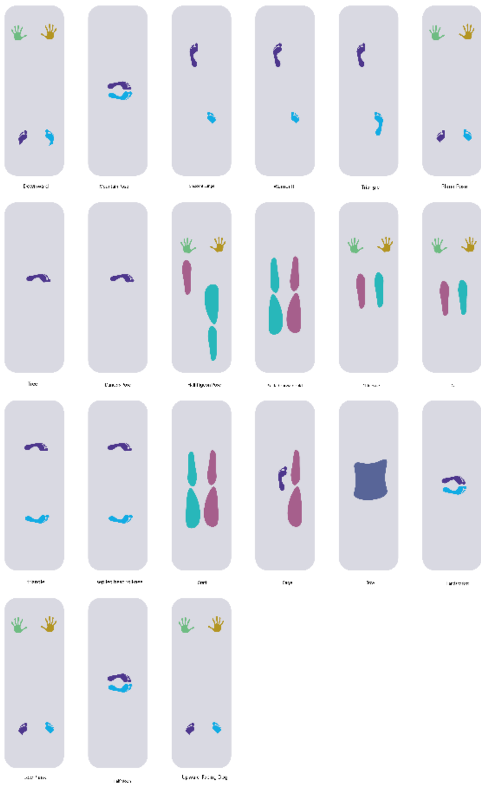

Fig.2 Basic yoga moves' hand, foot, and limb positions

Forty-eight common yoga movements were recorded to study the regularity of movements and the position of the limbs on the yoga mat(Bubnis 2019). Positions of hands, shoulder, feet, and crotch were recorded as an orientation of bones simplified motion data segments during four yoga training groups(Balasubramanyam et al. 2020).

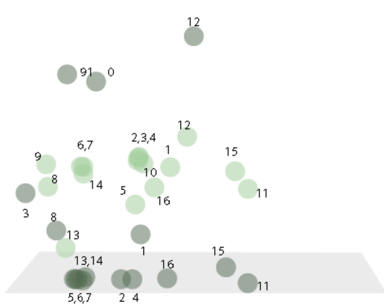

Fig. 3 Upper limb movements of yoga

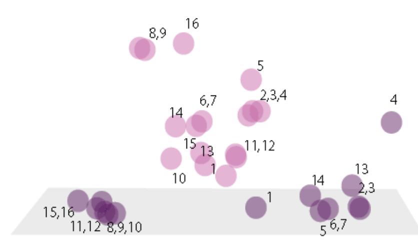

Fig.4 Lower limb movements of yoga

The way to get upper body movement in yoga is to rotate in a wide range. In contrast, the direction of the lower limbs in yoga is characterized by a small range of sliding, and the crotch is basically in the same horizontal line.

Turnings and Positions

A previous study(Rector, Bennett and Kientz 2013)used a motion capture camera to catalyze the yoga movement. The position and angle are hard to control when they turn their body. A motion capture camera is designed to guide blind people doing yoga on the right. They used two crossing yoga mats to increase the space.

Limitations of camera capture were: challenging to recognize when they are sideways, requiring a vast foot range of motion if they are out of capture range. Since the yoga movements need a lot of turns, the above problems may be caused by this factor.

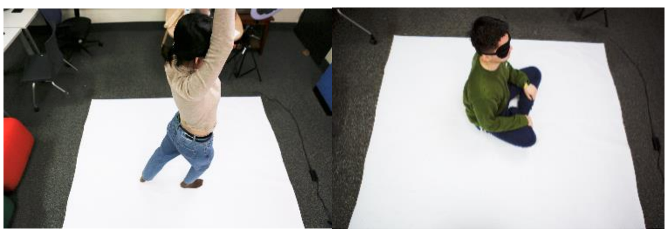

Fig. 5 User test for angles and turnings with eye cover

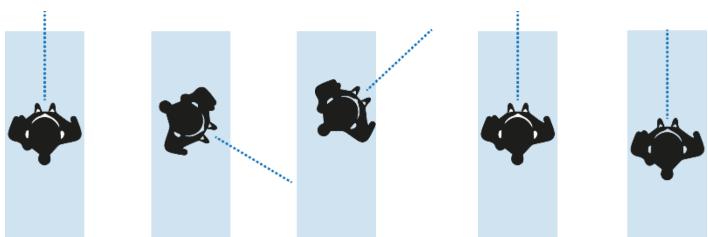

Fig. 6 Doing yoga with turnings

Fig. 7 Doing yoga without turnings

Performing multiple sets of yoga moves deprived of vision produces many positional movements. By recording the position of the test subjects, I found the most common problem causing positional drift was when they turned around because testers could not calibrate their position to return to the center visually.

Movements that reduce turns could relatively maintain their position, further improving by using a yoga mat with centerline and position markers. Able-sighted people need to face a mirror or be guided by video, so they need to turn around. For example, you need to face the front when performing tree positions and meditation.

Testers were asked to perform yoga movements in a particular area. They moved forward or backward and sat down. The subject's body range in different postures was recorded. According to previous research, all motion commands did not turn around. There is no yoga movement of turning around, and the yoga mat's shape is designed for this purpose. I recorded the range of motion of four test subjects making different yoga moves and created models and sketches based on the size.

Fig. 8 Prototype

How do people go forward and backward naturally?

Through brainstorming, I think of the treadmill's power, the waves pushing people's feet, the pet's Inverted hair, and the fish's scales. What they have in common is to create different drags or thrusts. People tend to take steps in the direction of less resistance. For example, on grass, people prefer to follow the way where there are more Footprints because there is less resistance.

Material selection

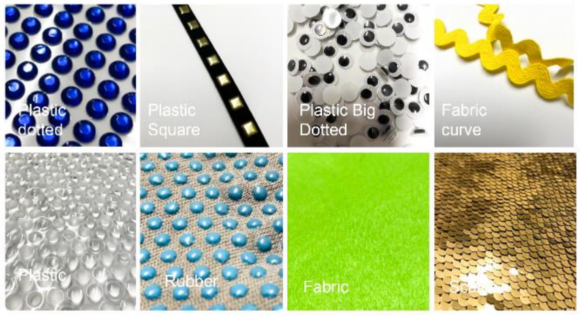

Fig. 9 Material tests

In the test, although the material of scales is stiff to touch, the different functions of resistance in different directions inspired me. By combining different top materials and base materials, you can feel which shape or material can make people feel different resistance. The final choice is commonly used in yoga mats, rubber, and artificial leather for safety and anti-slip considerations.

Technology

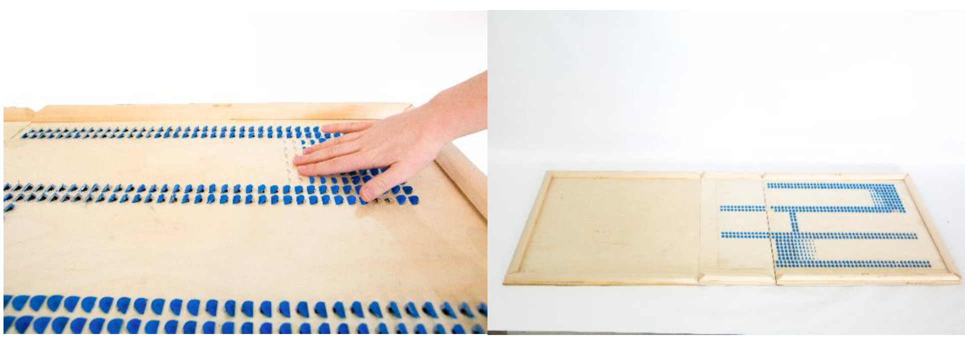

Fig. 10 Material prototype

Based on the concept of scales material passing through the direction of the monomer to create different resistances, I made a material sample of the idea. Only the designated channel allows the foot to glide in this sample, and there is resistance everywhere else. After that, I discussed its feasibility with mechanical professionals. They thought that to meet this design required a lot of mechanical structures, and it was not realistic to control each cell to complete the rotation one by one. Perhaps more elements could be combined to reduce the number of turning servos. At the same time, they believed that the control structure could not be directly under the mat, thus preventing damage.

Other feasible technologies

The soft robot uses an air pump to control the air pressure in the silicone or rubber to bend the whole body in different directions. This technology uses fewer components to allow robots to generate more flexible movements. The previous experiments studied the morphological changes of different structural monomers during pumping and degassing(Walker et al., 2020). I chose a monomer similar to chart 1and chart 2 for simulation and experimentation. They are dot-like and strip-like films.

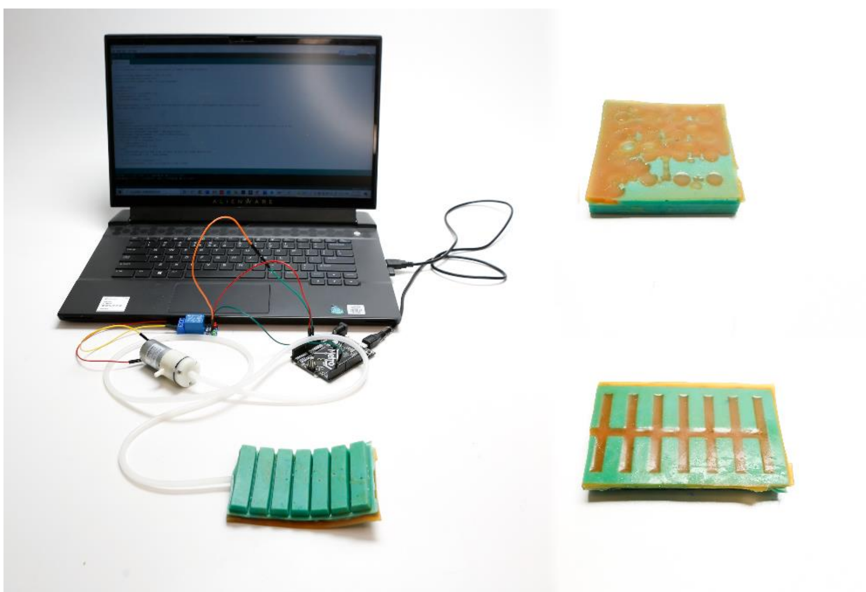

Fig. 11 Silicone molding test

I used modeling and 3d printing to make structural molds for these two textures and used silicone molding. Then use the air pump to test them. After the dot pattern is inflated, the film of the inflated part is relatively thin. If the film thickness increases, the monomer again becomes challenging to identify.

Patterns

Fig. 12 Test with different patterns

Different sized dots, lines, and arc patterns are 3d printed for the test. Testers step on the patterns to get a feel for which pattern provides more resistance and is more comfortable.

At the same height, curved and straight patterns were considered more comfortable, and circular patterns were supposed to generate more resistance.

Gesture corrector technology

Common postural correction techniques use inertial, gyroscopic sensors to measure spine tilt or flexion sensors to measure skin stretch. Intelligent Gesture Correctors, such as UPRIGHT GO, can detect the degree of bending of the neck by pasting it on the back. Upright Go can simultaneously visualize body data on the mobile app.

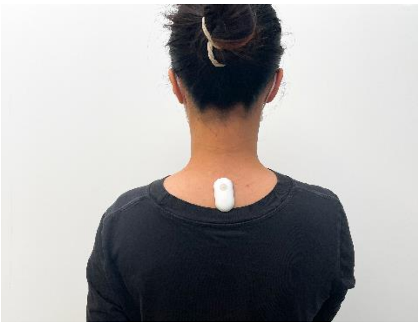

Fig. 13 Test with UPRIGHT GO

Gesture correctors often use vibrations or sounds to alert users of incorrect posture. Previous studies used gyroscope sensors to detect left and right shoulder balance and the inclined angle of the spine(Pratheep et al., 2021). I wanted to remind in more exciting ways, like the rising and falling of the music.

Foot recognition and motion analysis

Capturing motions through the camera is helpful for gesture recognition, but it is difficult to recognize in non-line-of-sight situations. An Embedded-based Smart Yoga Mat (ESYM) design uses a pressure sensor to transfer the information to the pattern generator to compare the action data in the database to provide voice guidance(M. C et al., 2019).

Color

Color contrast enhancement enables people with low vision to better distinguish images(Choudhury and Medioni 2010). I choose color combinations with high contrast and hue differences to easily help people with low vision distinguish the borders. A set of 7:1 furniture collections designed by HomePro, use contrasting colors to enhance the outline of the furniture, thereby enhancing the recognition of the furniture in visually impaired people(Noe, 2020). This design philosophy will be applied to subsequent designs. Finally I chose high-contrast colors as the edge, surface, and button according to this principle.

Final Design

Fig. 14 Final design photoshoot

This smart yoga mat is designed to help VIPs learn yoga moves more intuitively. The main difficulties with yoga for VIPs are recognizing position, maintaining balance, and learning posture and self-correction. It creates a wave-like thrust that allows users to move forward or backward in yoga, combining sound, vibration, and voice guidance to enjoy the movement freely and without worries.

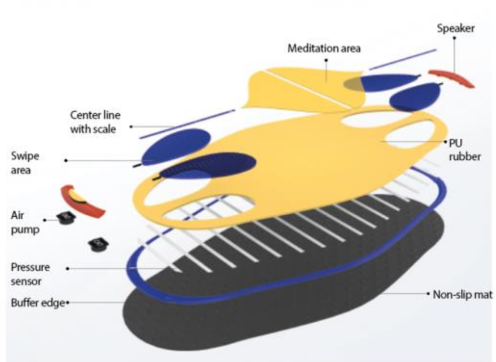

Fig. 15 Structure

The final design surface uses PU rubber, widely used in yoga mat production. This material absorbs sweat and is slip-resistant. The main area of the foot slide is also used using the PU rubber compared with this part. Beneath that is a layer of force-sensitive resistors. The bottom is rougher non-slip rubber. The border, center, and buttons use high contrast colors to help Low Vision People identify the edge. The top switches are more significant and could be found. It can be spotted either using feet or hands.

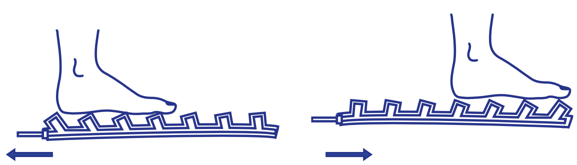

Fig. 16 Texture change with pump expansion and contraction

Fig. 17 Texture on the prototype

Forward and backward thrust is created by pressurizing and decompressing the rubber through the air pump. The user could naturally feel the fiction through this mechanism, just like the sea wave.

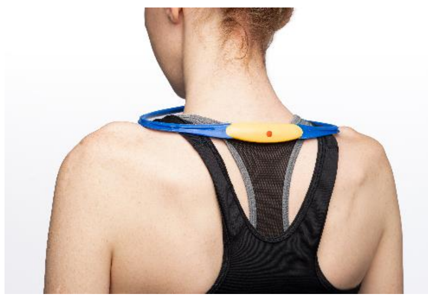

Fig. 18 Gyroscope design

Use the gyroscope on the neck and the force-sensitive resistor on the yoga mat to construct the user's posture and position data and compare it with the standard posture data. When the user's feet need to move forward, the air pumps at both ends of the smart yoga mat will pump air, causing thrust to push the user on. Conversely, the air pump will pressurize, making the texture open and going the foot back. In addition to voice guidance, vibration and music remind the user to correct the posture of the user's spine center of gravity shifts or the gesture is incorrect.

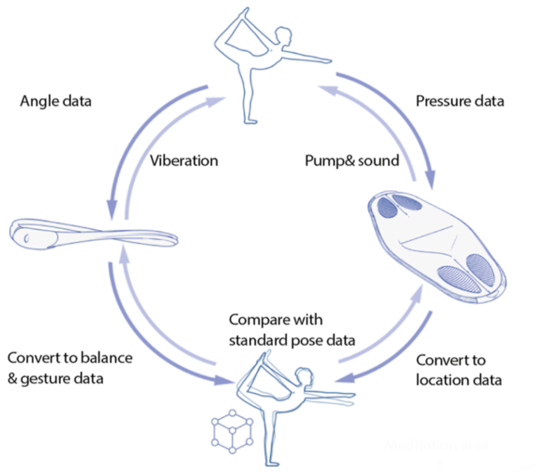

Fig. 19 System map

Conclusion

Through this project, I interviewed visually impaired people who love fitness. Sports are a part of their lives, even if some of them are having a hard time at first. Exercise makes them more confident, and I'm impressed by that. So I want to help ease their difficulty doing yoga.

To refine my design, I might look further into the interaction of sound and gesture next. Do more user testing and find new solutions if possible. Working mockups are produced to test the technology and user experience.

As mentioned above, haptic technology is widely used to design VIPs. But energy efficiency and feasibility need to be considered in future related field designs based on structure and use.

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