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Design and Development of Embroidery Using Photoluminescent Thread on Safety Gear Apparel

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Abstract
This study addresses low visibility in low-light conditions, a major cause of nighttime accidents, by evaluating photoluminescent thread embroidery jackets. Unlike traditional high-visibility gear, these jackets provide self-sustained illumination, enhancing safety for motorcyclists, roadside workers, and outdoor enthusiasts.
User feedback confirmed the jackets' effectiveness in improving visibility, comfort, and design appeal, while highlighting the need for improved glow intensity and durability. With further refinements, this innovation promises to reduce accident risks and become a vital tool for nighttime safety.

Keywords: Photoluminescent jackets, Nighttime safety, Low-light visibility, Safety apparel, User feedback.

INTRODUCTION

Low visibility is a leading factor in roadside traffic accidents, emphasizing the importance of high-visibility clothing to improve safety. The human eye detects bright, contrasting, and prominent objects more effectively, making these garments essential for accident prevention. High-visibility apparel is widely used across professions and activities, including by road construction workers, emergency personnel, cyclists, and pedestrians. These garments enhance visibility, ensuring that individuals can be easily noticed in low-light or hazardous situations, thereby minimizing risks, and promoting safety.
Keeping the problem in mind, jackets for the bike riders are embroidered with photoluminescent threads were planned to be developed, which glows during the night or dark times which helps to prevent the accidents during the night times due to the absence of light or low light conditions.
Luminescent glow threads are classified as photoluminescent materials. Also referred to as glow yarn, these innovative luminous filament yarns are created by blending, melting, and extruding polyester chips with photoluminescent pigment. An image of photoluminescent material is shown in Figure 1. These threads are versatile and suitable for various embroidery applications. After absorbing visible light for approximately 10 minutes, they can emit a glow in the dark for over five hours and can be reused repeatedly.

Fig. 1. Photoluminescent thread

LITERATURE REVIEW

Introduction to Photoluminescent Technology

This literature review by Zhao et al. (2020), explores the use of photoluminescent threads in apparel, examining the materials, technology, design considerations, and applications in safety gear. Photoluminescent (PL) materials, which absorb light and re-emit it over time, have been increasingly used in various applications, including textiles. [1] The integration of photoluminescent thread into apparel, particularly for safety gear, offers significant benefits in enhancing visibility under low-light or dark conditions. This is particularly important in high-risk environments, as suggested in McKenna et al. (2019), such as construction sites, roadways, and emergency services, where visibility plays a crucial role in reducing accidents and improving safety outcomes. [2]

According to Ha, (2017), Photoluminescent materials are substances that absorb and store photons from ambient light sources, then re-emit them as visible light in low-light conditions. Historically, photoluminescence has been widely applied in fields like signage, emergency pathways, and industrial safety gear. Research into the chemistry and physics of photoluminescent materials, specifically strontium aluminate and zinc sulphide, has shown these materials are highly effective in applications requiring prolonged glow-in-the-dark effects. [3]

Photoluminescent Materials in Textile Applications

The application of photoluminescent materials in textiles is an emerging field. Textiles embedded with photoluminescent compounds are designed to increase visibility in low-light environments, which can play a critical role in personal safety. Researchers like Lee et al. (2019), have studied the stability and durability of these materials in fabrics, evaluating wearability, washability, and long-term photoluminescence performance, which is crucial for integrating them into apparel. [4]

Photoluminescence refers to the emission of light by a material that has absorbed photons. According to the study made by Xie et al. (2019) the most common photoluminescent materials used in textiles include strontium aluminate ($SrAl_2O_4$) and zinc sulphide (ZnS), both of which have high glow-in-the-dark properties. [5]

Embroidery with Photoluminescent Thread

Embroidery is a common technique used to incorporate photoluminescent threads into textiles. Machine embroidery allows for precise control over the placement of photoluminescent threads, which can be used to create specific patterns, logos, or safety markings on apparel. According to Zhang et al. (2018), photoluminescent embroidery is an effective way to integrate safety features into workwear and uniforms, as it enables the creation of both functional and decorative designs that increase visibility at night or in dimly lit environments. [6]

Advantages of Photoluminescent Thread in Safety Apparel

The use of photoluminescent threads in safety apparel, such as in workwear, outdoor clothing, and sportswear, offers significant advantages over traditional reflective materials, especially in cases where external light sources are insufficient to activate reflectivity. According to Choudhury and Paul (2018), photoluminescent textiles can independently enhance visibility, making them particularly useful for nocturnal environments or emergency situations where light levels may be inadequate. [7]

Future Directions and Recommendations

According to the article published by Jang & Lee, (2023), for photoluminescent thread technology to become a standard in safety apparel, researchers recommend further advancements in material engineering, focusing on increasing the durability of the glow and resilience to environmental factors. Additionally, incorporating photoluminescent threads into everyday clothing could enhance user acceptance and broaden usage, especially in urban areas with high pedestrian and cyclist traffic. [8]

METHODOLOGY

Conceptual development and design boards

Theme Selection

The design process started with the theme selection. The theme that was chosen was “eccentric thinker”. An eccentric thinker is someone who breaks away from traditional thinking, approaching problems with creativity and unconventional ideas. They challenge established norms, offering fresh insights and original solutions that often lead to innovation and new opportunities. By designing a garment under the theme of an "eccentric thinker," it creates a wearable piece of art that captures a mindset and lifestyle centred on uniqueness, boldness, and individuality. It becomes more than just outerwear; it is a statement piece that resonates with those who see themselves as boundary-pushers, original thinkers, or simply individuals who appreciate a bit of edge and artistry in their wardrobe.

Mind Map

The design process started with mind mapping for the word “eccentric thinker” and following that, many branches were made which was relevant to that. This can be clearly seen in the following Figure 2.

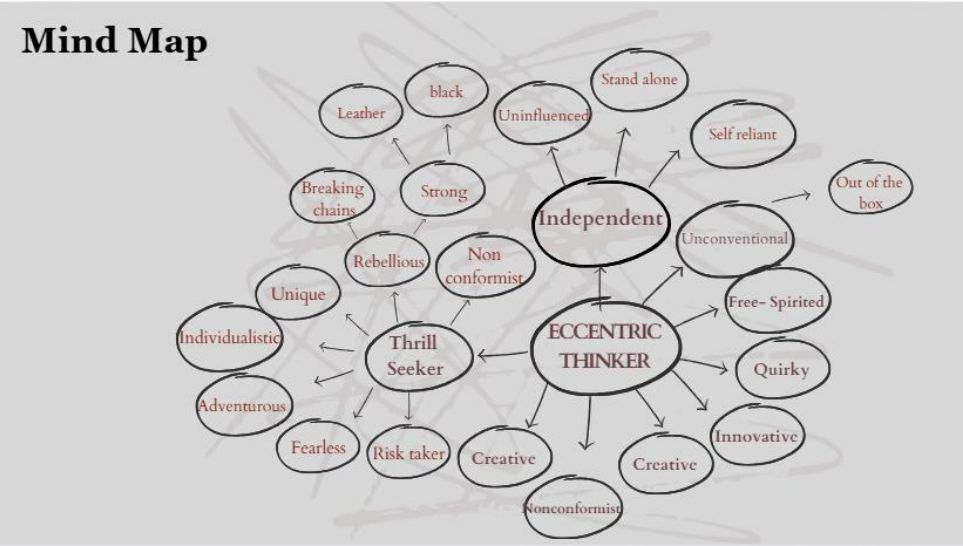


Fig. 2. Mind map

Story Board

The title which was given for the story was "The fire within". The developed story board can be clearly seen in Figure 3.

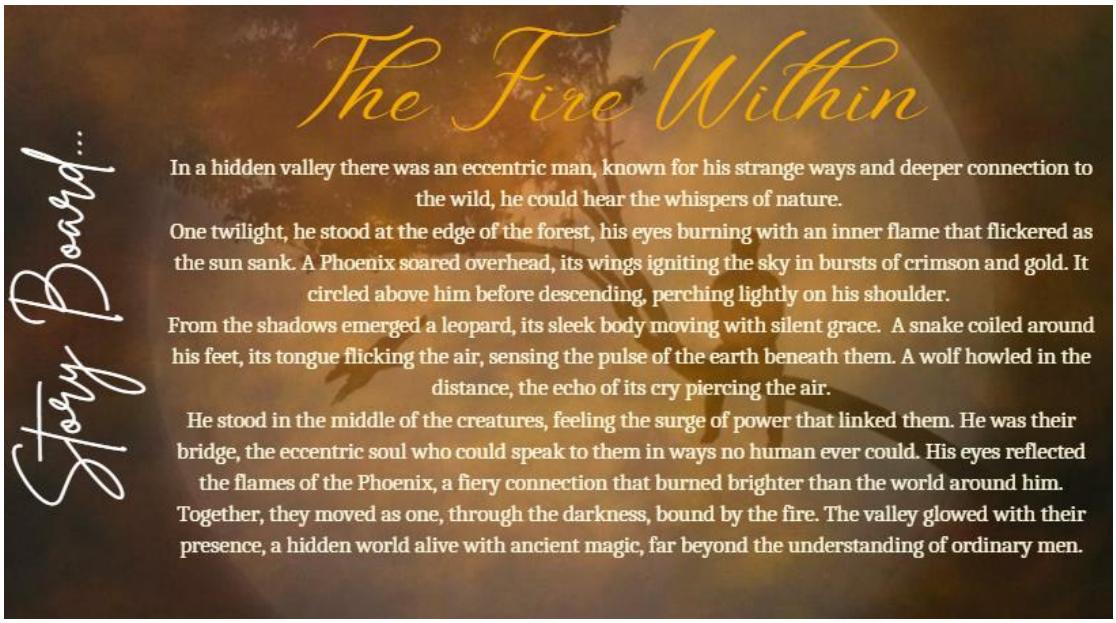


Fig. 3. Story Board

Mood Board

"Eccentric thinker" was the theme choosen, which signifies a person who is independent, bold, courageous, refuses to follow the written facts and thrives to frame or discover something new and unconventional. It shows the characteristics like thrill seeker and daring to do things.The deveopled mood board is shown in the Figure 4 and it's significance is been listed below.

Fig. 4. Mood Board

Pheonix bird's image has been added to represents the power of reinvention, uniqueness, and resilience,

qualities shared by those who think and act differently, pushing the boundaries of thought and convention. The phoenix embraces its own death by fire—a powerful symbol of courage. It willingly undergoes destruction, knowing it will rise again. This mirrors the courage required to face challenges, failures, or the unknown, a trait seen in those who dare to be different.

Snake image added symbolizes the idea of transformation. Since snakes shed their skin, they symbolize the shedding of the old self and the embracing of new beginnings or personal growth.

Jaguar image symbolize strength, independence, protection, and grace. It is known for its hunting skills, strength, and fearlessness. Its courage is demonstrated in its ability to take down prey much larger than itself. This makes the jaguar a symbol of bravery and fearlessness, as it faces danger head-on and dominates its environment. Jaguar navigates the darkness with confidence and precision, symbolizing the courage to face the unknown or venture into uncharted territories. Its connection to the night further emphasizes its bravery in dealing with unseen dangers and challenges.

A wolf image symbolizes loyalty, strength, freedom and courage. Whether representing strong family bonds, independence, primal instincts, or personal transformation.

The imagery of burning eyes is a potent symbol of courage and daring. It reflects intense focus, passion, fearlessness, and the inner fire that drives individuals to confront challenges, take risks, and push boundaries.

The neon color changing woman evokes the feeling of being unique, different, courageous to take decisions and to stand out alone and be notable.

A image of a person wearing leather jacket is been added. Leather is closely tied to the concept of boldness due to its associations with strength, rebellion and adventure. Whether as a protective material in dangerous environments or as a fashion statement that challenges norms, leather embodies a daring, fearless attitude, and a willingness to stand out.

A black background can evoke a sense of power, intensity, and elegance. A black background is powerful due to its ability to create contrast, evoke strong emotions, and convey sophistication and authority. Here, it enhances the effectiveness of the message. The combination of boldness, elegance, and depth makes black backgrounds a compelling choice for creating a powerful visual statement.

Bike tire prints are made to enhance the look and relevance to the objective of the project.

3.2 Market research and design finalization

The survey was conducted to understand the requirement of the objective of the project and to make it more effective according to the need. The main objective of this survey is to understand the market needs and according to the survey findings designs are finalized.

This survey aims to gather insights into bikers, cyclists, pet owners, awareness, usage, and opinions on the effectiveness of radium threads (reflective embroidery) in enhancing visibility and preventing accidents during nighttime.

It was an online survey, conducted over the internet using survey platforms know as Google Forms. Total of 63 responses were received. This survey can be adjusted to suit specific needs or target different groups, such as pedestrians, pet owners, cyclists, or vehicle drivers.

3.2.1 Interpretations from the survey

3.2.1.1 Market Interpretation

After the survey was conducted the following information was found out, and based on these information designs were developed and constructed:

- Most of the respondents surveyed were from the age group of 45-54 and 35-44, in which majority of them were male who drive motorcycles several times a week and month. Their primary purpose to drive was mountain biking, competitive motor cycling and commuting.
- Most of the respondents prefer driving car during the night times because of the fear of bike accidents during the night times due to lack of insuffient lighting and visibility
- The major reasons based on the conducted survey for night accidents caused for bikers and cyclists were, unable to spot people at night and lack of visibility and insufficient streetlights.
- More than half of the respondents surveyed were not aware of photoluminescent threads (reflective threads) as a safety accessory used in embroidery for biker and cyclists.
- More than half respondents don't use these reflective elements because they are not aware of them and are not sure how effective they are.
- 57% of the respondents prefer to use the reflective element on their jackets for bikers and cyclist nighttime safety.
- Many think that photoluminescent thread embroidery are more effectively improving visibility during low - light conditions at nighttime and many said it made a difference in visibility when using reflective tapes compared to when we don't use them.
- Many preferred that there should be more awareness campaigns about the use of photoluminescent threads for cyclists and bikers.
- Most of the respondents prefer wearing yellow embroidery and followed by light green glow or red glow of the photoluminescent thread.
- 57.1% of the respondents preferred that the embroidery should be placed at the back of the jacket to have more effectiveness in the design and its usage.

3.2.1.2 Regarding the design aspects

- Many wanted innovation in designs and newness
- Bikers wanted a classy, bold, and strong designs
- Many preferred having wordings at the back of the jacket along with the motif design
- Wordings in the form of a catchy phrase.
- They want to make sure it is resistant to water (due to frequent washing).
- Material should be resistant to wear and tear.
- Material should not spoil the design of the outfit.
- It should be made trendy and it should stick with the current trend.
- Quality and a durable embroidery are preferred more.

3.3 Design Development

The design was developed/ created based on the inspirations created from the design boards. Motifs were inspired from the mood created by the mood board. The motifs were then refined according to the interpretations from the survey after understanding the needs of the consumer and the market needs.

3.4 Embroidery Digitizing of the Developed Artwork

The designs were developed using wilcom embroidery software. All the designs were done using a single color because only light green radium thread was used. The images were imported in jpeg form from adobe illustrator to the wilcom software and tracing was done. All the stitches were done in satin.

Complex fill tool was used to trace every object. The stitch density was 0.38 mm for all the images. The digitized embroidery artworks using Wilcom Embroidery Studio can be observed in the Figure 5, 6, 7, 8 and 9.

The other design information such as design name, total number of stitches, total stitch time, front used, total height and total width for each design can be clearly seen in the Table 1.

Table 1 Design informations for the digitized embroidery designs

S.No	Design Name	Total No. of Stitches	Total stitch time	Front used	Total height	Total width
1.	Phoenix Design	31,769	1 hour 37 mins	Goudy Sans	11.869 inches	10.837 inches
2.	Tiger Eye Design	20,548	1 hour 3 mins	Copper Plate	7.490 inches	11.540 inches
3.	Eye Design	21,398	1 hour 2 mins	Viking	10.126 inches	11.406 inches
4.	Tiger Two Design	18,914	58 mins	Thrill	11.200 inches	9.644 inches
5.	Wolf Design	23,532	I hour 6 mins	Gaelic	12.602 inches	9.845 inches

Design 1

Fig. 5. Phoenix Design

Design 2

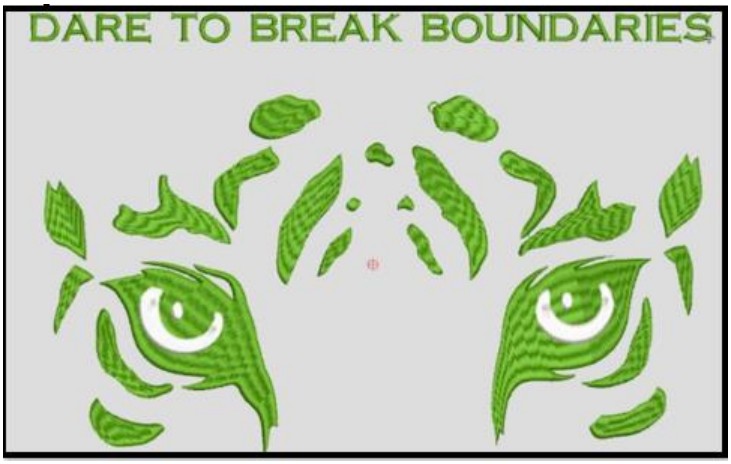


Fig. 6. Tiger Eye Design

Design 3

Fig. 7. Eye Design

Design 4

Fig. 8. Tiger Two Design

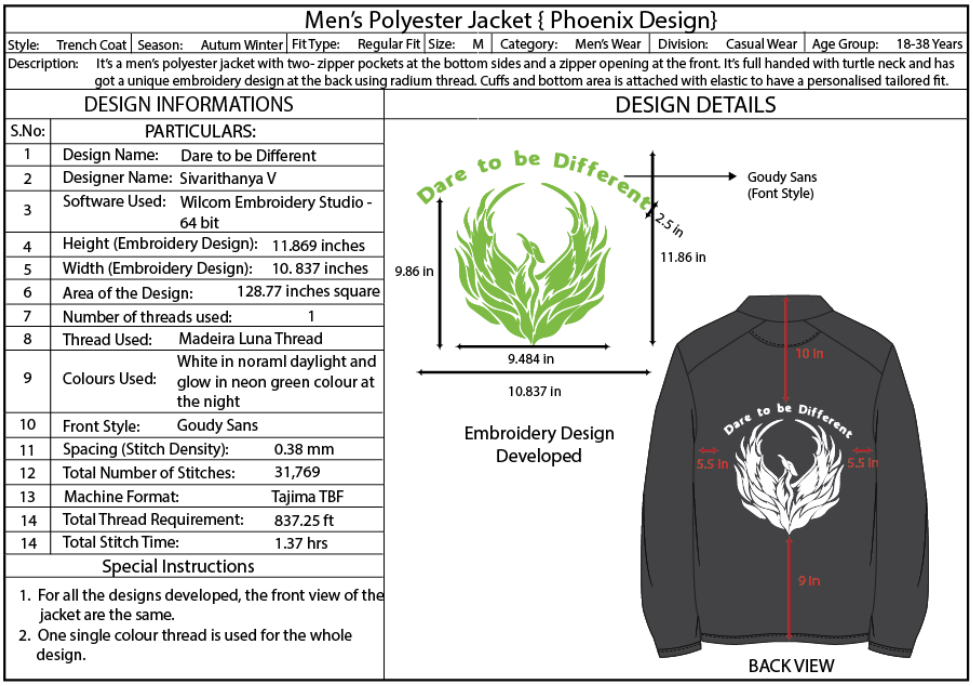
Design 5

Fig. 9. Wolf Design

3.5 Tech Pack

Garment and design tech pack for each design were developed using adobe illustrator, a sample of the design tech pack developed is shown in Figure 10.

The contents of the design tech pack include design name, designer name, software used, height and width of the embroidery, area of the design, number of threads used, colors used, front style, spacing, stitch density, total number of stitches, machine formats, total thread requirement, total stitch time and along with it some special information about the design tech packs were also added. It includes a detailed sketch of the embroidery, the measurements of the embroidery and the placement of the embroidery on the jacket.



Men's Polyester Jacket { Phoenix Design}

Style:	Trench Coat	Season:	Autum Winter	Fit Type:	Regular Fit	Size:	M	Category:	Men's Wear	Division:	Casual Wear	Age Group:	18-38 Years

Description: It's a men's polyester jacket with two- zipper pockets at the bottom sides and a zipper opening at the front. It's full handed with turtle neck and has got a unique embroidery design at the back using radium thread. Cuffs and bottom area is attached with elastic to have a personalised tailored fit.

DESIGN INFORMATIONS		
S.No:	PARTICULARS:	
1	Design Name:	Dare to be Different
2	Designer Name:	Sivarithanya V
3	Software Used:	Wilcom Embroidery Studio - 64 bit
4	Height (Embroidery Design):	11.869 inches
5	Width (Embroidery Design):	10. 837 inches
6	Area of the Design:	128.77 inches square
7	Number of threads used:	1
8	Thread Used:	Madeira Luna Thread
9	Colours Used:	White in noraml daylight and glow in neon green colour at the night
10	Front Style:	Goudy Sans
11	Spacing (Stitch Density):	0.38 mm
12	Total Number of Stitches:	31,769
13	Machine Format:	Tajima TBF
14	Total Thread Requirement:	837.25 ft
14	Total Stitch Time:	1.37 hrs

Special Instructions

1. For all the designs developed, the front view of the jacket are the same.
2. One single colour thread is used for the whole design.

Fig. 10. Phoenix Design Tech pack

3.6 Raw material requirement

The raw material requirements needed for the start of the embroidery includes:

- Maderia Luna Thread
- Jacket
- Backing

Table 2 shows the necessary information about the raw materials used to develop the products.

Table 2 Raw material requirement

S.No.	Raw materials required	Brand	Cost	Quantity	Place of procurement
1.	Luna Thread	Maderia	₹ 2,576 – 750M (Price of one thread)	2	SHREE SHAKTI ENTERPRISES (No. 33, Sakthi Complex, Gajalakshmi Theatre Road, Tiruppur-641604, Tamil Nadu, India.)
2.	Jacket	CNMN	₹499 (cost of one jacket)	5	Amazon.com (online platform)
3.	Backing	Gupta Brothers	₹ 580	2 yards	Gipta Brothers Nandram Market, Kolkata, West Bengal (contact made through Indiamart)

3.7 Steps in machine operation

The embroidery was done using Barudan embroidery machine and the garment was loaded to the 15-inch frame.

- Design

Designs are initially worked and developed using Wilcom Embroidery Software

- Export Design

The digitized design will then be exported to a DST File.

- Documents needed

Production sheet for each of the design are been sent to the machine operator with EMB and CSC format.

- Input DST

It is then followed with, input the DST file from the digitizing software into the embroidery machine.

- Start

The production then starts with hit with the start button and the result will be the design being embroidered with the Barudan Embroidery Studio.

- Final Act

Watch the vibrant embroidery will be produced finally.

- Post Embroidery Procedure

After the embroidery was over, the jacket was taken out of the frame and the excess foam was cut. The

foam fads away and disappears when washed.

3.8 Costing

Table 3 Costing of one jacket

S.No.	Particulars	Amount In ₹
	Jacket	499
2.	Glow thread	595
3.	Backing	116
4.	Miscellaneous materials (frame, clip)	15
5.	Labour	100
6.	Electricity	45
7.	Overheads	20
	Sub total	**1,390**
8.	Profit @ 10%	139
	Cost of one Jacket	**1,529**

The costing of the photoluminescent thread embroidered jacket is clearly been seen in the Table 3.3. According to the cost sheet the cost of one jacket is around ₹ 1,529. And the cost of five jackets will be around ₹ 7,645, with inclusive of 10% profit for each jacket.

3.9 Final look

At the day light the embroidery seems to be normal, white in color, but when the light goes off or in the dark atmosphere the embroidery glows neon light green in color. The jacket when exposed to sunlight for one minute, glows at the dark for a long time. After the jacket was worn, at the bright light region and under the street lights, the embroidery resembled the normal white embroidery. When, the jacket was seen in a dark region, the embroidery glows in dark green color.

The sample final look of design on the jackets can be seen in Figure 11 and 12, the glow of design in low light conditions can be observed in that.

Fig. 11. Phoenix design glow.

Fig. 12. Tiger eye design glow

4. Results and Discussion

4.1 Consumer survey on consumer behavior of purchasing the developed glow jacket

A survey was conducted using google forms. The survey was conducted to understand to feel, suggestions, opinions, and the feedback of the consumers after using the product. This will be useful to understand the market for the product, changes to make to make it a better one, pitch for the idea in the market, Etc. It also aims to understand the overall experience of wearing the jackets, including comfort, weight, fit, and the feel of the photoluminescent material. This can provide insight into any physical limitations or discomfort riders may experience. Evaluate overall satisfaction with the jacket, from the photoluminescent feature to comfort and style, to determine whether riders would recommend it to others or purchase it again.

4.2 Discussion

The interpretation from the following survey is that many prefer to wear the jackets occasionally and several times a week while riding. Majority of the people prefer to wear the developed jackets while they are on long distance touring and off-road/ mountain biking. Mostly people are neutral and suggested “somewhat” about photoluminescent embroidery for visibility during night rides or low-light conditions. The major reason for the purchase of the developed jacket would be style and design and for visibility and safety purpose. People feel that visibility is high an important factor concerning while driving at low light conditions. Most of the people after using the jacket, suggested that it is extremely comfortable to wear. Mostly the respondents are very satisfied with the style, pattern, placement of the design in the jacket. Most of the respondents does not feel safer while riding at night or in low-visibility conditions, with the jacket and its functionality. Most of the people survey feel that design/style of the jacket in your decision to wear it for rides is highly important. Most of the people surveyed are neutral to recommend this photoluminescent embroidery jacket to fellow riders. Most of the people are interested in more designs or colors for the photoluminescent embroidery. They prefer more unique designs and wanted an all-over embroidered jacket rather than at one place.

5. Conclusion

This study highlights the potential of photoluminescent thread embroidery jackets to improve road safety

by enhancing visibility in low-light conditions, a major factor in traffic accidents. The jackets emit a glow, making the wearer more visible to drivers. Survey results show that while the embroidery designs are bold and eye-catching, awareness of photoluminescent threads is limited, suggesting a need for awareness campaigns. Quality and durability are also important, with high-quality Madeira Luna thread ensuring long-lasting designs.

The jackets have strong market potential, particularly for night riders and outdoor enthusiasts, offering a safety feature that appeals to cyclists, runners, and workers. Future research could focus on the jacket's durability under various conditions and the addition of features like LED integration.

In conclusion, the photoluminescent jacket is a promising development in rider safety. Continued improvements in design and materials will make it an essential tool for nighttime visibility and safety.

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