Pilot Study on the Application of Light-Absorbing Fabric in Sport Fashion

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Abstract. In the 21st century, social change has quickened and intensified, resulting in humanity now facing many new challenges. With China, the United States, the European Union, and Japan shifting their focus towards low-carbon, environmentally friendly policies as the basis of future economic development. According to fashion industry observers, the use of natural and energy-saving forward-looking fabrics is already part of this global trend, and will continue to influence the clothing industry in the future. In terms of research and development of clothing materials, recent results from Taiwan far outstrip those of other countries. In the past six years, research into light-absorbing fibers has not only echoed the international trend towards energy-saving and environmental protection, but has also produced a new and unique technology, unmatched elsewhere. However, whether in terms of cost or actual technical application, new textile materials are invariably subjected to certain restrictions during the early stage of development, and currently, light-absorbing fabrics are at such basic stage of development. In this study, a survey was conducted to determine the potential demand for using advanced materials in sportswear. Respondent exercise habits were categorized, and sportswear needs for various sports activities were analyzed. The attributes of sportswear for the top three sports were analyzed and input into a matrix to stimulate diverse design ideas. It is hoped that "needs", "choice" and "thinking" can be incorporated into future product design strategies to clearly demonstrate the core value of applying advanced light-absorbing fabric to sports fashion.

Keywords: Fibers · Forward-looking technology · Performance fabric · Health and energy-saving · Sport fashion

1 Introduction

Historically, material development and human development are closely related, and each era has its representative material, which is the driving force behind social development and technological progress. Therefore, new material development and breakthrough are milestones of human civilization. After the 1960s, with the development of modern fiber technology, high-tech fiber technology has made great strides

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worldwide, and has driven the boom in global sportswear market. Since the 1980s, Taiwan has been the world's core technology center for manufacturing functional material (Nikkan Kogyo Shimbun 1999).

The Taiwan Textile Research Institute (TTRI) is a major textile R&D institute in Taiwan, and owns unique high-end technology. Since the functional light-absorbing fabric is gradually demonstrating its unique attraction and advantages, investment into researching its development and application has already begun with support from the Innovative and Cutting-Edge Technology Program by the Ministry of Economic Affair Department of Industrial Technology. However, it seems that the development of applications for this advanced material is currently limited to interior décor. Hence effective promotion of its application in sportswear would quickly make it a favorite with designers and the sports fashion market.

The purposes of this study are:

1. Invite industry experts and designers to experiment with light-absorbing fabric. Then based on user perception of its attributes, outline possible end designs for sportswear.
2. Analyze survey to determine the needs of sportswear users to delineate the core value of design application for light-absorbing fabric.
3. Use the morphological method to identify the elements and construction of different types of urban sportswear. Illustrate these elements in a matrix to enhance application ideas for the light-absorbing fabric, and formulate a leading multi-strategy design module.

2 Literature Review

In recent years, fashion trends have revolved around Sports Fashion. The implementation of a two-day weekend in Taiwan has changed social trends, aroused health consciousness, and gradually set in motion a Lifestyle of Health and Sustainability (LOHAS) (Ray 1998). According to Turnbull and Wolfson (2002), exercise enhances positive emotions. Szabo (2003) also proposed that exercise reduces negative emotions such as anxiety and sadness, and domestic research have also shown that exercise is effective in reducing anxiety. These are the reasons for the health awareness, the pursuit of physical health and emotional health, and the motivation to exercise.

According to Schmitt, "Eliciting a response to an event usually begins with involvement". When urban dwellers can personally experience exercise at any given time, exercising becomes an urban trend and epidemic, and people begin to perceive exercise as trendy activities. For example, the Taipei Fu Bang Marathon, Taipei Highway Marathon, the PUMA Night Run, Mizuno Marathon Relay or 308 Marathon are suitable jogging activities for the family. Pine and Gilmore (1999) also pointed out that "experience is that conscious awareness of good feelings that arises when a person's emotion, physical strength, intellect and even spirit reach a certain level". More people are paying attention to and participating in less strenuous activities such as jogging, cycling, brisk walking and dancing, and correspondingly, they begin to experience a sense of well-being.

Currently, to satisfy the health lifestyle and safety concern of night time exercising by the public, many fashion brands such as TOPSHOP × ADIDAS, ADIDAS × FARM, PUMA × ASOS are promoting the use of special function material and collaborating with other industries. Urban exercise has gradually led the trend in jogger and biker apparel, with styles that are practical but fashionable (The Femin 2014). Particularly at night, poor visibility and recognition render running risky, and therefore it is safer to wear clothing with safety designs such as reflective strips or logos to make it easier to discern the runner. Using light-absorbing fabric in sportswear design is like having reflective strips so that urban dwellers can also safely exercise at night.

In this study, the sample selected for the experiment was white knitted fabric developed by Taiwan Textile Research Institute (TTRI). The light-absorbing fiber is not only consistent with international energy saving trend (Money 2009), but also leads the world with a unique core/shell construction that coats the luminescent material with polyester so that after several hours of absorbing indoor or outdoor light, it can emit light during the night. The non-toxic, washable, non-radiation "light-absorbing" fabric complies with world trend to "exercise, save energy, and protect the environment" (Chang and Chang 2009), and compared to other materials, its warmth, comfort and glow are unrivalled. In 2014, TTRI created its own LUMI LONG Light-Absorbing Finer brand. Initially there was little collaboration with fashion product design, and current applications are mainly limited to home products. Environmentally friendly fabric has become the global focus of green design, and as a green conscious material, the application of light-absorbing fiber to sports fashion could have significant advanced implication for healthy and safe living.

3 Methodologies

This research is a two-stage study. Stage 1 comprised literature review, collection of light-absorbing samples, analysis of urban exercise trend, and subject selection. Experts were invited to participate in the experiment and interviews, and the feedback analyzed in conjunction with various designs.

Stage 2 of the research comprised experiential testing by the experts. After testing the new fabric, the experts proposed ideas for product development based on user perception, thereby offering a more professional perspective and insight (Wang et al. 2005). In Chap 4, the top 3 sports and apparel design constructions are designated on the x-axis, and using a morphological approach, the attributes of sportswear were examined. For each sports type, elements from the 8 corresponding apparel styles designated along the y-axis were selected. The use of this matrix stimulates ideas for design strategies, and facilitates creative application for light-absorbing fabric.

The light-absorbing fabric produced by the TTRI was selected as the experimental object sample instead of other household light-absorbing fabrics produced by other manufacturers because the denier count of the TTRI fabric is finer, more stable and consistent with world technology and quality, and appropriate as end-fabric for apparels (Shiu 2010). The object sample, variables, subjects, sampling unit and time frame of this experiential study are as follow:

1. Object sample: 1 piece of light-absorbing knit fabric manufactured by the TTRI: 45″ × 15″.
2. Research variables: light source and intensity, exposure time, light storage time.
3. Research subjects: Textile developers and designers, urban dwellers with exercise habit, college students in design. Table 1 shows the subjects and subject characteristics.
4. Experiment and Interview: After experientially testing the light-absorbing fabric, the users proposed ideas for product needs and sportswear application from a user perspective. Table 2 shows the questionnaire items and answers.
5. Time frame: For natural or artificial light absorption, and due to the schedule and time limitation of the subjects, the researchers collected the questionnaires about two weeks after implementing the experiment.

Since this is a pilot study focusing on the future design application of advanced materials, subjects with textile industry or design background and exercise habits were selected. The subjects in the experiment and survey were divided into four groups. Group 1 comprised 3 professional textile developers; Group 2, 5 professional fashion designers; Group 3, 10 individuals with regular exercise habit; and Group 4, 15 college students in design. There were a total of 33 subjects, with 15 males and 18 females, ranging in age from 20 to 60. The subjects had a strong sense of health awareness. Subject information are as shown below.

Table 1. The 4 groups of professionals.

Subjects	Background Information	Profession
G.1	Fiber developer, fabric planner or fabric designer	industrial developer/fabric product designer
G.2	Women's brand apparel designer, sportswear business, fashion planner	industrial planner/apparel designer
G.3	Those who exercise 3 or more times per week over past years	Those with exercise habits/athletes
G. 4	Household products, visual and multi-media design field	Design students in public or private universities

This success of this pilot study on the application direction of light-absorbing fabric is contingent on whether the subjects can identify with the new material, therefore the most important part of the process is experiencing the fabric, followed by their perspective on application. The research variables are type and intensity of light source, exposure time, and light storage time. Prior to the experiment, the subjects were asked to view and describe the light-absorbing fabric. After the experiment, the process was recorded, followed by a 2–4 item narrative questionnaire. The questionnaire items are:

1. Describe your first impression of the fabric.
2. After experiencing the fabric, what ideas do you have for its application?
3. Within the last year, what are your 2 most frequent types of indoor/outdoor sports? How many times per week?
4. From the perspective of a sportswear user, how do you hope to see light-absorbing fabric used?

4 Results and Discussion

Thirty-three subjects completed the experiential test, and 32 questionnaire responses were collected, of which 28 were valid for comprehensive content analysis. Responses from the following subjects were given priority:

1. Those who recorded at least 3 or more of the experimental variables.
2. Those who provided comprehensive user perspective application ideas for the light-absorbing attributes. Since the light-absorbing experiment is the most critical part of the experience, only subjects who have experienced the day time light-absorbing and night time light-storing attribute of the fabric had a basis from which to propose application ideas for the new fabric. Therefore, based on the degree and completeness of experience, 28 questionnaires were selected while the remaining 4 questionnaires were excluded due to their incomplete descriptions.
3. Responses from the 28 questionnaires on light-absorbing material were summarized, and the content analysis illustrated as follow:

Based on the general condition of their eyesight, the 28 subjects were divided into 2 groups:

Group 1: Aged 20–43 years old, normal vision, with about 250–300° myopia.
Group 2: Aged 48–60 years old, 200–300° presbyopia.

Given the non-radiation luminosity, the Group 2 subjects felt that with or without myopic glasses or reading glasses, there was no significant difference in their perception of brightness. The results of the experiment are summarized in Table 2.

Light-absorbing materials are characterized by their ability to absorb and release light energy. After exposure to the sun or light, they are luminous in the dark. Absorption of outdoor natural sunlight is quick and effective, and brightness retention is much longer than for indoor artificial light. When used in fiber or textile products, they are soft and comfortable to the touch, can be cut, dyed, and withstand repeated washing. They are also safe, reliable and green. Their affinity for natural light, unlimited cycles of light absorption, retention and emission, and permanent use make them an energy saving green product.

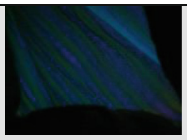
After experiencing the light-absorbing fabric, the subjects not only felt a sense of novelty, but also believed that such a technological material should not be limited to being perceived as cool, but that other functional applications should be carefully considered. Night safety was a key selling point of this fiber, particularly for places or activities that require high visibility, such as sports and hunting gear, rigging cable, and interior carpeting of theater and aircraft. The light retention attribute of the fabric rendered it highly suitable for use as safety illumination or warnings in outdoor sports, functional products, sports fashion, shoes and bags. Other uses for outdoor rescue, medical or disability care were also proposed, such as emergency packages, senior health care, infant supplies, optical sensor clothing, shoes or schoolbag for elementary school children. Using light-absorbing materials for the shoulders life jackets, or stitching the material into the upper body of lifejackets, can to enhance sea search and

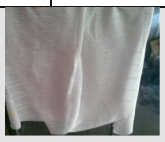
rescue in sunless condition. The material was also deemed suitable for entertainment purposes such as 3C accessory or wearable products, nightclubs, pub or cool fashion.

Table 2. Summary of the light-absorbing fabric experiment.

Light Absorbing Test Type of Light Source	Light Absorbing Test Exposure Time	Retention Test Retention time and continuity of illumination in the dark
Artificial light source —white light Artificial ligh source (a) —yellow light	1. 1 hour of exposure to artificial light source	Showed no significant brightness. Lasted about 5 -10 minutes
	2. 1-2 hours of exposure to artificial light source	Emitted faint brightness. Lasted about 20 -25 minutes
	3. 3 or more hours of exposure to artificial light source	Emitted stronger brightness. Lasted about 35-40 minutes.
Artificial light source (b) —General fluorescent tubes	1. 1 hour of exposure to artificial light source	Showed no significant brightness. Lasted about 5 -10 minutes.
	2. 1-2 hours of exposure to artificial light source	Emitted faint brightness. Lasted about 15-20 minutes.
	3. 3 or more hours of exposure to artificial light source	Emitted stronger brightness. Lasted about 30-40 minutes.
Natural light source © —sunlight ∗ Weather – clear/cloudy	1. 1 hour of exposure	2½ hours of significant brightness.
	2. 2 hours direct sunlight exposure on a clear day.	3½ hours of significant brightness.
Natural light source —sunlight ∗ Weather – clear	3. 1 hour 15 minutes direct sunlight exposure at noon on a clear day.	Almost 8 hours of significant brightness.
Natural light source ∗ Weather–sometimes clear, sometimes cloudy	4. 11 hours of exposure	Almost 9 hours of significant brightness.


(a)


(b)


(c)

∗ Regardless of white, yellow or fluorescent light, absorption of artificial indoor light was not high. An average of a 2-hour exposure produced about 30 minutes of light retention.

∗ Absorption of natural outdoor sunlight was rapid. An average of an 1-hour exposure produced about 2 hours of light retention

∗ The degree of direct natural sunlight and cloudiness affected light-absorbing brightness and retention time. Retention time was proportional to the brightness of the sunlight and exposure time.

In terms of the types of sports, the most frequently engaged activities were biking, swimming, jogging, mountain climbing, qigong, ball games, strolling and dancing. Of these, nighttime jogging, brisk walking and strolling were most frequent, followed by biking and mountain climbing. There were also 4 times more outdoor activities than indoor activities. The top 3 sports favored by the subjects were jogging and biking after work, and weekend mountain climbing, which accounted for 52.1 % of the sports selection, and with 70 % occurring after work. Survey of subjects' experience with sportswear found common demands, namely comfort, health, and safety. Evidently, light-absorbing fabric and future industry for urban exercise will be closely linked (Table 3).

Table 3. Application ideas for light-absorbing fabric from the perspectives of sportswear users.

User Needs / Sports Trend	Modern style / functional material / safety features /user-friendly design
Jogging 1	Reflective strip design / Elastic knee, ankle and wrist bands / loose Raglan sleeves / moisture control/ stretchable/ sweat absorbent/breathable / non-restrictive sleeves / functional material
Biking 2	High-contrast, double-sided reflective elastic strips/ back zipper design / comfortable / breathable / moisture control fabric / highly breathable armpits / forward curving patterns / fit / convenient pocket /fitting arms / 3D tailoring
MountainClimbing 3	Reflective strip design / comfortable and loose / moisture control /stretchable / sweat absorbent / breathable / non-restrictive sleeves or pants/ stretchable / functional material

The light-absorbing fabric tested by the subjects had absorbed light during the day, and emitted light in the dark. Table shows that among the subjects, having reflective strips or light-absorbing fabric in sportswear was a common need. Two of the subjects enjoyed early morning and nighttime walking or jogging, and hoped to see light-absorbing fabric used in jogging apparel. Therefore, integrating light-absorbing fabric into daytime wear design can allow nighttime joggers to feel relaxed and unafraid, and satisfy the safety needs of those who exercise after work.

4.1 Developing Leading Design Strategies

Pioneered in 1947 by Zwicky (Jones 1980), morphological analysis is currently used by many scholars as a design strategy to develop ideas in different fields such as domestic and foreign products, furniture and fashion design (Chen and Lai 2009). Based on the premise of improving urban sportswear and safety design, this study used systemic survey and content analysis to analyze the types of sportswear. Independent attributes were first de-constructed. The deconstructions were then inserted into a matrix to enhance inspiration for design application strategies for light-absorbing fabric.

Clothes design is complex, requiring not only creativity and fashion sense, but also comfort. Factors affecting the appearance of clothing include line, shape, texture and color, and the resulting contour and surface effect directly impacts visual aesthetics. However, in terms of sportswear, discussion of function is unavoidable, and the construction, form, material, and especially the strong performance demand must satisfy the functional needs of sportswear users. In particular, precise tailoring, pattern, sewing technique and the experience of sports experts are factors critical to the success of the sportswear design.

The types of sportswear depend on the sports function and safety considerations, and therefore the fabric, secondary materials, tailoring and shape vary accordingly. In terms of design, the human frame and appearance, which can mainly be divided into the head, limbs and torso (Jeng 1982), govern the design and inspire the construction of the apparel. In terms of clothing construction, 8 body structures significantly affect the pattern and performance of the apparel, and as shown in Fig. 1, the corresponding

patterns deemed appropriate for the light-absorbing fabric are: head—hat style, neck–collar style, shoulder—should style, hand—sleeve style, chest—chest style, waist and hip—waist and hip lines, thigh—pants style, foot-shoe. As shown in Table 4, these could be individually marked on the matrix. The attributes of the type of sportswear (or selection) for each type of sports were then inserted into the vertical axis (y-axis) of the matrix. As shown in the matrix in Fig. 8, the design style are designated by the items A1, A2, B1, B2, C1, C2 … H1, H2. The more the design attributes or types of sports, the larger the strategy configuration.

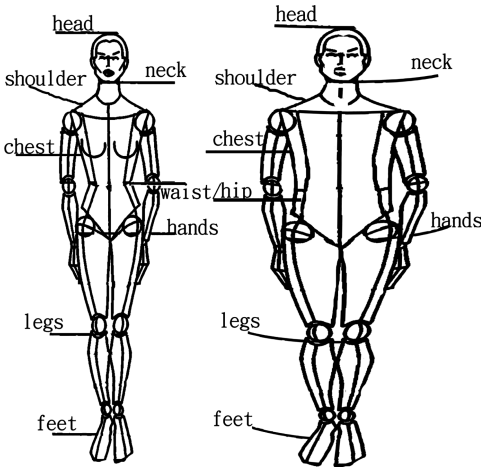


Fig. 1. 8 body structures affecting pattern and function (compiled by this study)

Table 4. Basic matrix for the sportswear form.

Design structure sports choice	A head hat style	B neck neck style	C shoulder shoulder style	D hand sleeve style	E chest chest style	F waist & hip	G thigh pants style	H foot shoe style
1 Jogging apparel attributes	Style A1	Style B1	Style C1	Style D1	Style E1	Style F1	Style G1	Style H1
2 Biking apparel attributes	Style A2	Style B2	Style C2	Style D2	Style E2	Style F2	Style G2	Style H2
3 Mountain climbing apparel attributes	Style A3	Style B3	Style C2	Style D3	Style E3	Style F3	Style G3	Style H3

The functional needs of clothing vary according to the type of sports. A complete sports outfit is called a set, such as a set of jogging outfit or a set of biking outfit. A set of jogging outfit would comprise items such as a vest T-shirts, long pants or shorts,

jacket, hand and jogging shoes. In addition to tops, a set of biking outfit may comprise items such as leg warmers, over sleeves, biking pants and shoes. However, the attribute deconstruction of an outfit is based on a single item of clothing. For example, a jogging top comprises the collar style, sleeve style, chest style and waist contour. Changing the parts of an outfit is integral to outfit construction. The combination of deconstructed details forms the different attributes of an outfit, and contributes to the overall style construction of the outfit. Based on the original prototype, the attributes of shape and shoulder measurement of tops, the chest and waist-hip ratio, or armhole measurement and activity level are important constructions of clothing style. For example,

1. Attributes of jogging outfit: breathable material, simple neckline, close fitting shoulder, light contour, comfortable shoes.
2. Attributes of biking outfit: close fitting performance and comfortable, well-fitting and well tailored, no unnecessary tailoring, mandatory helmet.
3. Attributes of mountain climbing outfit: Wide brims on hats, material must be warm, water-proof and thermal insulated, shoes and socks must be suitable for mountain climbing.

4.2 Three-Step Flow Chart

Step 1. Based on the conclusions of this study, the top 3 sports were delineated. Using morphological analysis, elements of the 8 design constructions were used for the sportswear construction, forming the x-axis, as shown in Table 8. The attribute descriptions of each part of the sportswear formed the y-axis, resulting in 8 patterns and 24 types of sportswear for each type of sports

Step 2. The attributes and design elements of the different types of sportswear were listed. Based on the relationship between the attributes and functional construction of the sportswear, the elements were combined into creative ideas, forming the rows and columns of patterns in the matrix, such as A1, A2, B1, B2, C1, C2, as shown in Table 5.

Step 3. Based on preference, functional attributes and design constructions were selected. With clear corresponding functional attributes and clear intersecting relationship among the corresponding design constructions, selected designs in the matrix are marked and coded so the information then developed and transformed into designs. Hence the greatest advantage of such a matrix is its capacity for a diversity of ideas, thereby enhancing the quality of design strategies for sports fashion.

A systematic selection strategy for attribute construction inspires application ideas for light-absorbing fabric and functional materials. Based on construction needs and attributes, a design can be integrated, reinforced and converted into the new design and style. Figure 2 shows the design transformation.

Table 5. Matrix design strategy code: (A1B2C3D3E3F1G3H3), that is (1, 2, 3, 3, 3, 1, 3, 3)

Design Construction / Sports Type	A Hat Style	B Collar Style	C Shoul-der Style	D Sleeve Style	E Chest Style	F Waist -Hips	G Pants Style	H Shoes Style
1.Jogging Apparel Attributes								
2.Biking Apparel Attributes								
3 Mountain climbing Apparel Attributes								

※ Ideas for apparel construction and design: cap, small collar, flat should, composite fiber Raglan sleeves, wide hip hem, layered elastic culottes, tight elastic stockings, heavy duty low ankle shoes. Easy, carefree and stylish.

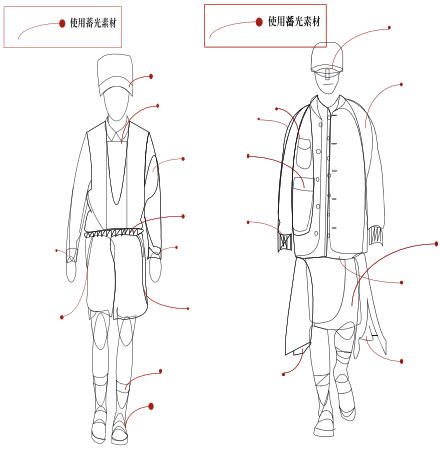


Fig. 2. Design transformation draft: designs with suitable light-absorbing areas (compiled from this study)

5 Conclusions and Suggestion Recommendations

Besides working hard for their living, the average office workers also seek adequate leisure and exercise to maintain a sense of health and security. Maslow's (Abraham H. Maslow) theory of hierarchy of needs divides needs into 5 levels, namely physical needs, safety needs, social needs, esteem needs and self-actualization needs. He believes that everyone has the need to grow, but that lower level needs must be met before pursuing higher aesthetic needs. In other words, regardless of general physical activities or specific exercise, both are health-promoting behaviors (Ni 2004). However, well-designed and functional light-absorbing sportswear can enhance a sense of safety and agility during exercise, and increase health awareness.

Using "experience" to explore future product design, this study clearly demonstrated the core value of applying light-absorbing fabric to sports fashion. The study also constructed a pilot model of design application for light-absorbing material, as shown in Fig. 3. On one hand, information about the technological material was obtained through experience, and on the other hand, perception of user need was based on experience and learning. Such complete "emotional empathy" is integral to the "need" to "choice" to "thinking" decision-making process of developers. Experiencing the fabric, and understanding and empathizing with sports safety needs enhanced the "More ATTENTION, More PATIENCE and Willing to learn & use" process of needs assessment, thereby making usefulness and physical safety the core of sports fashion design. In addition, the attitude of "health-safety", "friendly-function" and "fashion-feeling" are expressed in sports fashion design. In conclusion, this experiential pilot design module can be further applied to other high-end advanced materials to further the understanding of new technological materials, increase the added value of creative design application, and enhance design education. It is hoped that the 「HS + 4F」 concept can be further studied, verified and developed for style design in sports fashion.

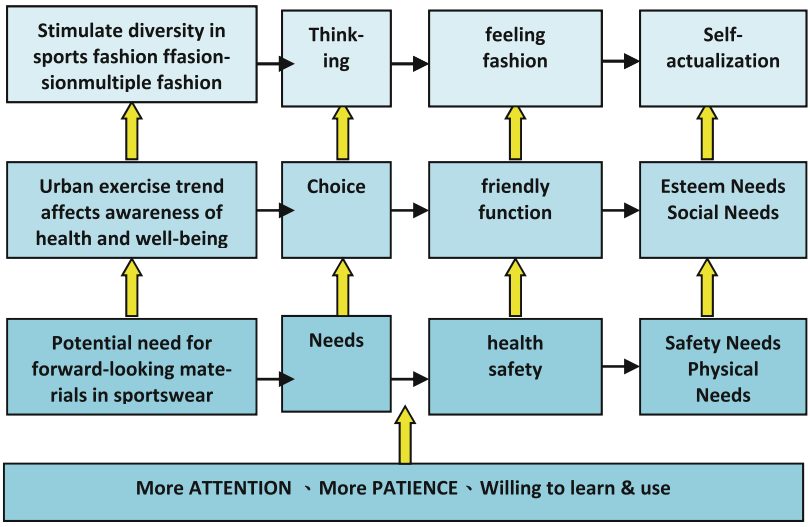


Fig. 3 Pilot model for light-absorbing fabric design (compiled from this study)

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