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The Effects of Smart Textile on the Future Fashion Design Technology

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Abstract: Smart textile can be described as textiles that are able to sense, to react and adapt to their environment. It is also considered as a new garment product which has the features of interactive reactions by applying both fashion and technology. Due to the evolution of technology, smart textile and intelligent garments have been introduced to the consumer of the 21st century and become an important platform for high-tech innovations. Smart textile will have great impact in the future; however, it is difficult to improve product development and commercialization. Therefore, the purpose of this research is to add an incredible advantage of smart textile in the fashion field by conducting a questionnaire survey and making focus groups with the effects of smart textile. This paper investigates the strategic thinking that orient to organize, plan and perform smart textile on the future technology. As a result, this analysis can be used to find that there are two significant effects on the future fashion design technology including healthcare and sportswear. From the thorough investigation into the industry of smart textile, the research proves that intelligent garments will be the future fashion design technology that materials inherit textile performance. Besides, it is also considered the functions that are useful and match the consumers' lifestyle and fashion trends.

Keywords: *Textile Design, Smart Textile, Fashion Design, Future Fashion, Technology*

Introduction:

Nowadays, clothing is not only the apparel products but it is also the fashion products. Aesthetics is an integral part of the success in fashion and apparel industry. However, the living standard becomes higher with every passing day so the technical aspects have strong influences in the fashion development. This is the reason why smart textile attracted attention since it first appeared in the 1980s.
The fashion industry views smart textile as a good opportunity to incorporate new technologies which helps it evolves. Experts in this field suggest that smart textile will have great impact in the future [1]. Smart clothing designers are accustomed to taking into account the interactions between human physiological reactions and physical characteristics of garment. The wearer should not be limited in comfort and mobility as a result of intelligent adaptation in clothing [2], [3], [4].
It is true that smart textile will have great influence on the future fashion design technology. However, it is difficult to improve product between development and commercialization. Therefore, the purpose of this paper is to add an incredible advantage of smart textile in the fashion field by conducting a questionnaire survey and making focus groups with the effects of smart clothing. This paper focused on how fashion, technology and commercialization can make harmonious coexistence in a functional apparel product.

Materials and Methods:

1. Methods:

In this paper, there are two research methods was done. Firstly, literature research is conducted to help build up the understanding of smart textile. The development process, the functional analysis and the information about future design direction were conducted in order to understand smart textile and clothing more thoroughly. Secondly, the questionnaire interview is chosen to consider personal opinions as the work method. This secondary method allows the respondents describe what is important for them and the effects of smart textile on future fashion design technology. Moreover, this method ensures that the research topics are covered as well as the richness of the cultural issues can be examined.

2. Materials

The questionnaire was designed for two focus groups including medical group and entertainment/sports/ recreative group. This section mentioned about personal concerns, desirable products, functional aspects related the vision of smart textile in future fashion design with the questionnaire of desirable future products.
Most of the questions were in multiple-choice form. The images also used in the questions where they were required to make the choice as comprehensive as possible. The results were analysed with SPSS program.

3. Participants:

The participants are the potential users as the targets of the survey. The potential users described by smart clothing developers were rather broad. They included several groups of people with different demographic background. The most common targets usually described as young and design conscious individuals who were interested in advanced technology [5]. The proportion of respondents is shown in *Table 1*.

Table 1: Group of Participants

Age / Group	18-22	22-27	27-35	Total
Medical group	14	28	18	60
Entertainment group	31	37	22	90
Total	45	65	40	150
Percentage	30%	43%	27%	100%

Results and Discussion:

Development Process of Smart Textile and Clothing

Smart textile was first developed and applied in the wearable computing field by a group of physicists and Ph.D. graduates with the idea of attaching small computer systems to garments. The analytical results based on the literature review indicate that there are four periods in the development process of smart textile and clothing including the 1st period (1980~1977), the 2nd period (1998~2001), the 3rd period (2002~2005), and the 4th period (2006~today) as shown in *Figure 1*. Each period has the significant information related to smart textile as the following:

1. The 1st period (1980~1977)

This period is considered as the first stage of smart textile by doing research and development (R&D). Most research and product development focused on wearable computing and applications of advanced technologies such as integrating and displaying sense which bring a lot of opportunities to textile manufacturers [6].

2. The 2nd period (1998~2001)

This period is the stage of smart textile and clothing in both R&D and market. Most applications were textile with several hard electronic components such as circuit board and hidden linings inside. The applications became more wearable, but they could not meet requirements of the mass market [7].

3. The 3rd period (2002~2005)

This is also the stage of smart textile and clothing in R&D and has more smart clothing in the market. The applications of smart textile and clothing dramatically increased in the mass market and also expanded like sportswear, protective clothes and work wear. Moreover, sensory fabrics can detect pressure and movement as well as adopt in healthcare and sportswear products. The approach of smart textile has changed from a technical concern to the mass market [8].

4. The 4th period (2006~today)

This stage is for the high fashion brands for smart textile and clothing development. It means that intelligence of smart clothing is not limited to manage personal devices which the wearers are carrying. The approach has changed to accept, analyze and transform information from environment to assist the user. Some applicants create wearable energy sources from solar power to the wearer [9].

Figure 1: Timeline of smart textile and clothing development

Function Application of Smart Textile

Smart textile should be developed on the function application of comfort, protection and mobility based on the physiological basics of humans to implement the smart applications that maintain the comfort and usability of ordinary clothing as shown in *Figure 2*.

1. Comfort

Comfort is a state of physical ease and freedom from pain or constraint. The other meaning of comfort is the easing or alleviation of a person's feelings of grief or distress. Smart textile can be described as textiles that are able to sense, to react and adapt to their environment. Thermal comfort and tactile comfort are the two elements related to the feelings of human beings.

Human body constantly generates heat from the metabolism and loses the heat to the environment, so it should have a balance between the rates of heat production and heat loss. Thermal balance is closely related to the transport of conservation of heat and moisture throughout the garment system [10].

Tactile related to the sense of touch with the meaning of the interaction between the fabric and human skin will stimulate various sensory receptors on the skin. Tactile feeling is related more to pressure comfort which includes heaviness and tightness rather than prickliness, itchiness, and roughness.

2. Protection

Clothes are fibres and textile material worn on the body restricted to human beings which depends on physical, social and geographic considerations. Physically, clothing serves many purposes for protection from hazardous activities to hiking or cooking.

Textile protects humans from rough surfaces, rash-causing plants, insect bites, splinters, thorns and prickles by giving a barrier between the skin and environment. It also insulate against cold and hot

conditions. Besides, it can provide a hygienic barrier for keeping infectious and toxic materials away from the body as well as provide protection from harmful of UV radiation.
Smart textile was designed based on the demands of the body for functional clothing with the considerations of anthropometry, ergonomic, thermo-physiological regulation and psychology.

3. Mobility
Mobility concerns in performance of sportswear such as football suit, volleyball suit, swimsuit, diving suit and so on. The ease of movement depends on garment design and the relative size between body and clothing. Therefore, high stretch fabrics have provided opportunities for the functional clothing to accommodate for tight-fitting and body movement.
Functional clothing was designed in order to satisfy the functional demands so it conflicts with the aesthetic demands. It is truth that when functional clothing was made for carrying laptop computers or cell phones. It must be huge and awkward looking batteries additionally attached. It seems hard to fully satisfy both functional aspects and aesthetic aspects so people should choose between practical usefulness and aesthetic demands.

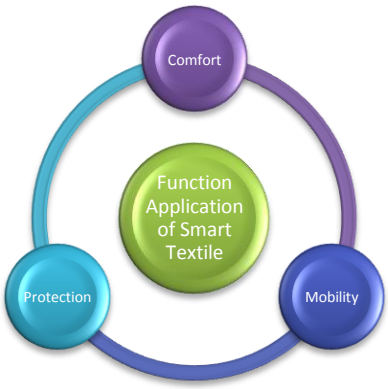

Figure 2: Functional aspects applied on smart textile

Based on the desirableness of human beings, the smart clothing with the challenge of applying technical aspects and aesthetic aspects need to be done for the preference of the user. Although functional aspects have strong influences in smart clothing development, it is hard to expect fashion industry to adapt itself to technology. Therefore, before designing smart clothing, it should be made a decision for choosing a decisive factor of form and function. However, for most cases, consumers want to enjoy most advanced technology without losing their fashion sense because functional products designed awkward in style simply cannot attract users' attention.
The functional aspects can survive in an aesthetic purpose without having the practical aspects. For example, nowadays, many shoes are designed similar to sports shoes but the people who wear them may never actually indulge in any sporting activity [11]. Fashion designers borrow the high-tech textiles originally intended for extreme sports and use them for ready-to-wear and haute couture [12].

Future Design Direction of Smart Clothing
The major applications of smart clothing can be classified into four groups such as (1) military group, (2) medical group, (3) communication group, and (4) entertainment/sports/recreation group [13]. The growth rates vary dramatically by the application segment. According to the information on United State market segments provided by British Chambers of Commerce (BCC), the highest growth is expected in consumer entertainment, medical status monitoring and military applications. However, the rates of smart clothing application depend on the culture of each country so there are two of the four applications including medical group and entertainment/sports/ recreation group will be studied.

1. Design Direction for Medical Group
Health monitoring is a general concerns for patient requiring continuous medical assistance and treatment. In order to increase mobility for such patients a huge effort has been pursued for the development of wearable systems for the monitoring of physiological parameters such as respiration, cardiac activity or temperature of the human body. Smart textile plays a growing role in these developments since they ensure the comfort to the users.
There is 3 degree of technology integration in Smartshirt^{TM}, Lifeshirt^{TM}, and Wealthy is in *Table 2*.

Table 2: Degree of Technology Integration for Medical Group

Degree	Technology	Function	Integration	Method
Smartshirt^{TM}	Optical fiber	Signal transfer	Integration	Woven
	Processor	Data transmission	Embedment	Pocket
Lifeshirt^{TM}	Electrode	Cardiopulmo -nary signal	Contents	Inserted in slit
	Respiband	Respiratory data	Embedment	Sandwich -ed in between linings
	Processor	Data transmission	Handheld	
Wealthy	Electrode	Electrocardio -gram	Integration	Knitted
	Piexoresis -tive sensor	Respiratory data Body movement	Contents	Pocket
	Tempera -ture sensor	Skin temperature	Embedment	Sewn on lining
	Processor	Data transmission	Contents	Pocket

Smartshirt^{TM} by Sensatex uses plastic optical fiber in order to transfer signals at a regular interval and detects the injuries. Lifeshirt^{TM} was first released by Vivometrics for emergency-services workers with the processor unit. This unit acquires data from the

sensors and transmit them to the remote medical centre in real-time through wireless network and made remote patient monitoring possible. Wealthy was one of the first EU projects (*Figure 3*) to set up comfortable heath monitoring system based on textile sensors, advanced signal processing techniques and modern telecommunication systems.

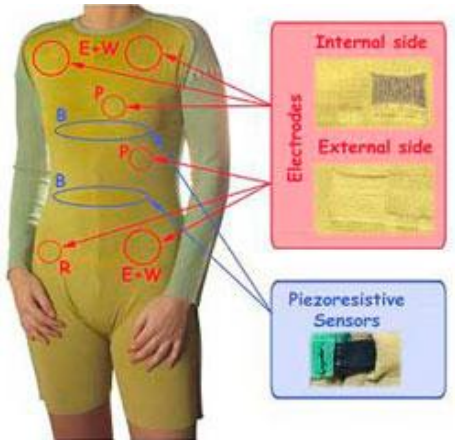

Figure 3: Functional aspects applied on smart textile (Source: Engadget, from http://www.engadget.com)

2. Design Direction for Entertainment/Sports/ Recreation Group

Entertainment is a form of activity that holds the attention and interest of an audience, give pleasure and delight. In order to satisfy the needs of the human beings, most recent commercial products for entertainment/sports/recreation group are based on Fibretronic Embedded Textile Devices. It is created by embedding micro printed circuit board within the structure of fabrics and bonding it for permanent fixation. In 2009, Fibretronic released a developer kit of their keypad technology for DIY application. This kit is developed to fit to any jackets or bags allowing people to create their own smart clothing.

Factor Analysis on the Future Design Direction

Factors were analysed in this research related to two focus groups including medical group and entertainment/sports/recreation group with three factors like factors of personal concerns (FPC), factors of desirable products (FDP), and factors of functional aspects (FFA).

1. Factors of Personal Concerns (FPC)

The findings from the questionnaire related to factors of personal concerns reveal that the personality of medical group is different with entertainment group. The results of factor analysis are shown in *Table 3* including fashion concern, health/well-being concern, high-tech concern, adventurous concern and price concern.

According to the career of two focus groups, medical group consists of doctors, nurses, therapists and other professionals in the medical care. The medical group has the main responsibility to care for patients as well as to avoid future health problems. The medical group experiences emotional and psychological health problems so they often find significant barriers to seeking help, particularly in light of a culture within the profession. Therefore, the highest score in terms of health or well-being concerns (36.7%) is the most chosen by medical group. High-tech concerns are chosen followed by health concerns with the percentage of 31.7%, then the other factors including fashion concerns (13.3%), adventurous concerns (10.0%) and price concerns (8.3%).

Another focus group is entertainment/sports/ recreation group. The characteristics of this group are work-life balance, travel, benefits, culture, skills, experience, education and so on. The career in this group is so broad including students, actors, actresses, athletes, technicians, engineers and etc. Consequently, the highest score in this group is high-tech concerns (31.1%). Then, fashion concerns (27.8%) and adventurous concerns (22.2%) are chosen followed by high-tech concerns. The less concerns in this group are health concerns (12.2%) and price concerns (7.7%).

Table 3: Factor Analysis of Personal Concerns on the Future Design Direction

Groups / FPC	Medical group	Entertainment group
Fashion concerns	8 (13.3%)	25 (27.8%)
Health/Well-being concerns	22 (36.7%)	11 (12.2%)
High-tech concerns	19 (31.7%)	28 (31.1%)
Adventurous concerns	6 (10.0%)	20 (22.2%)
Price concerns	5 (8.3%)	7 (7.7%)
Total (Percentage)	**60 (100%)**	**90 (100%)**

2. Factors of Desirable Products (FDP)

The findings from the questionnaire related to factors of desirable products reveal that medical group has also chosen the item similar with entertainment group and the items different from entertainment group. The results of factor analysis are shown in *Table 4* including fashion items, electronic items and smart items which applied both fashion and electronics.

Smart items received the top score in both medical group (55.0%) and entertainment group (56.7%). However, medical group chose electronic items more than entertainment group with 26.7% for medical group and 18.9% for entertainment group. Conversely, entertainment group had the higher percentage of fashion items than medical group with 24.4% for entertainment group and 18.3% for medical group.

Table 4: Factor Analysis of Desirable Products on the Future Design Direction

Groups / FDP	Medical group	Entertainment group
Fashion items	11 (18.3%)	22 (24.4%)
Electronic items	16 (26.7%)	17 (18.9%)
Smart items	33 (55.0%)	51 (56.7%)
Total (Percentage)	**60 (100%)**	**90 (100%)**

3. Factors of Functional Aspects (FFA)

The findings from the questionnaire related to factors of functional aspects reveal that medical group concerns the functional aspects having similar one and some different from entertainment group. The results of factor analysis are shown in *Table 5* including practical aspects, new style aspects, high quality aspects, good design aspects, environment aspects and multipurpose aspects.

Both medical group and entertainment group have chosen the top score for multipurpose aspects as 28.3% for medical group and 31.1% for entertainment group. The smallest factor of functional aspects for medical group is new style aspects (8.3%) while environment aspects (10.0%) for entertainment group.

In medical group, the percentage in order from top to bottom as the following practical aspects (22.7%), environment aspects (16.7%), high quality aspects (13.3%), and good design aspects (11.7%). However, in entertainment group, the percentage in order from top to bottom as the following practical aspects (20.0%), new style aspects (15.6%), good design aspects (12.2%) and high quality aspects (11.1%).

Table 5: Factor Analysis of Functional Aspects on the Future Design Direction

Groups / FFA	Medical group	Entertainment group
Practical aspects	13 (22.7%)	18 (20.0%)
New style aspects	5 (8.3%)	14 (15.6%)
High quality aspects	8 (13.3%)	10 (11.1%)
Good design aspects	7 (11.7%)	11 (12.2%)
Environment aspects	10 (16.7%)	9 (10.0%)
Multipurpose aspects	17 (28.3%)	28 (31.1%)
Total (Percentage)	**60 (100%)**	**90 (100%)**

Conclusion:

Smart textile and clothing represents not only the future of the textile and clothing industry but also the electronic industry. As the convergence between these two industries brings large opportunities and challenges, it draws great attention and investment from different fields in our life. The aim of this research is to give an overview of smart textile that it orient to organize, plan and perform effects on the future fashion design technology. It can be used to find that there are two significant effects on the future design direction including healthcare and sportswear.

The questionnaire results reveal that the difference between medical group and entertainment group is based on the personality of each group. The consumers in medical group are more concerned about how the product can enhance their quality of life in terms of health and well-being concerns (36.7%). The findings are different with entertainment group. The consumers in entertainment group are more noticed about how the product can renovate their quality of life in terms of high-tech concerns (31.1%).

In fashion technology, the applications are more focused on visual or tactile feedback from the users. Most of the market analyses on smart textile points out potential of other areas than fashion and there is a focus on technical aspects of clothing rather than fashion. That is the reason why the main issue to further discuss in this paper in order to proceed in the area of smart textile. It is impressive that the questionnaire results in two focus groups are both chosen smart items (56.7% for entertainment group and 55.0% for medical group) which applied fashion and electronics in the products.

Last but not least, the highlights that the participants from the interviews through questionnaire correctly surmised that intelligent garments will be the future fashion design technology that materials inherit textile performance with multipurpose aspects and practical aspects. Many respondents pay more attention for multipurpose aspects and practical aspects in entertainment group (31.1% and 20.0%) and medical group (28.3% and 22.7%). Therefore, smart textile in fashion is a need for a multitude of methodologies enabling the transformation of technology into a meaningful form of use.

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