INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

DESIGN 2004

# BENEFITS & CHALLENGES OF COLLABORATION IN SMART CLOTHING DEVELOPMENT

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*Keywords: new product development process, design management*

## 1. Introduction

Smart Clothing represents the convergence between the electronics and apparel industries. Its development involves large number of emerging technologies. The term 'smart clothing' in this paper refers to the garments and fashion accessories that contain intelligent functions based on electronic technologies. Because of its hybrid nature, a multi-disciplinary approach is required. The real challenge is to make the different perspectives complementary rather than conflicting. Nevertheless, literature research reveals that a strategic approach and New Product Development (NPD) process for such collaboration is uncommon [Ariyatum and Holland 2003]. As a result, a new approach and NPD process are needed. An in-depth understanding of all disciplines involving in smart clothing development is required in order to formulate the new strategic approach and NPD model. As a result, this paper intends to examine and present the current work methods employed by different disciplines involved and elicit personal opinions. This information will give an insight into the benefits and challenges of collaboration, and indicate how to make the differences complementary.

## 2. Aims and Objectives

This paper aims to investigate three key issues: 1.) the NPD processes of smart clothing development, 2.) the work methods each discipline employs and personal opinions on these methods, and 3.) opinions of key people concerning smart clothing and its future design direction. This information will be analysed in order to identify the benefits and challenges from the different perspectives as well as how to reduce the conflicts. Finally, this information will be utilised together with other primary and secondary research to formulate a new NPD model. To achieve this aim, there are five objectives to be completed.

1. Gain an in-depth understanding of the work methods and the ways of thinking of each discipline.
2. Identify similarities/differences between smart clothing development and the established approaches.
3. Identify what are considered the problems, benefits and challenges of this collaboration.
4. Find out how these design developers see the future and design direction.
5. Analyse information to find out how to reconcile the different views and reduce conflict.

## 3. Research Methods

There are two methods employed in this research. Firstly, literature research is conducted in two areas:

1. NPD process that an individual or a particular team employ to develop smart clothes
2. NPD process in electronics and apparel industry of a particular company

Secondly, the semi-structured interview and questionnaire interview are chosen to study the work methods, NPD processes in practice and personal opinions, as it allows the respondents to describe

what is important for them and ensures that all crucial topics are covered. In this way, the richness of the cultural issues can be examined. Since it is important to understand every type of discipline involved; the interviewees are selected based on their expertise, responsibility and organisation. The criteria are:

1. The interviewees represent key disciplines involved in smart clothing development (table 1). These disciplines are selected based on the expertise which they offered in smart clothing development.
   - Designer Manager: Responsible for product strategy and design specification development, and managing the design. However, the design specification is generally created by the whole team.
   - Smart Clothing Designer: Responsible for concept development and producing prototype of garment. In many cases, this work was carried out by fashion designer and product designer.
   - Intelligent/Technical Textile Technician: Responsible for sourcing the materials and applying them according to the design specification (in terms of appearance, properties and functions).
   - Electronics Technician: Responsible for developing electronic parts due to the specification.
   - Technical Textile Designer: Although this discipline is not currently involved in smart clothing development, there is a potential need for this expertise – smart textile development.
   - Trend Researcher: At present this discipline is not involved in smart clothing development. Since smart clothing is very much looking into the future, this discipline is potentially required.

**Table 1. Profiles of each interviewees**

| **Expertise** | **Profile of the Interviewees** |
|---|---|
| Design Manager | • Design manager of international electronic product company.<br>• Responsible for Design and Development (D&D) team and product development. |
| Fashion Designer | • Fashion Curator for British Council and Former Course Director of MA Fashion<br>• Senior research fellow in School of Fashion & Textile in a leading design college<br>• Currently involved in several research projects on smart clothing |
| Product Designer (Former Lecturer) | • 5 years experience in product design with 2 international awards<br>• Involved in many electronic product developments with international companies |
| Smart Clothing Designer | • Develop technical clothes for professional and amateur athletes<br>• Involved in smart clothing and technical clothing development since 1998 |
| Technical Textile Designer | • Textile designer and project manager in the R&D sector since 1998<br>• Responsible for new field of production e.g. flexible & sound-insulating fabric<br>• Current research is optical fibre that can transform data & textile circuit broad |
| Electronic Technician | • 4 years experience in smart clothes development with the pioneer in this field<br>• Involved in a big joint-venture project between electronics and clothing company |
| Intelligent Textile Technicians | • Senior researchers in Fibre Material Science who set up 'Smartwear Lab'<br>• Conduct many basic and applied research and product developments in intelligent textiles & smart clothing field. Current project is special clothing for the fireman. |
| Future Trend Researcher | • Trend researcher in one of the UK biggest research and strategy consultancy<br>• Conduct future trend research for international electronic product companies |
| Sportswear Designer & Lecturer | • 8 years experience as a Programme Leader of MA Performance Sportswear<br>• Expertise in technical textile & technical clothing with fashion design background |
| **Expertise** | **Profile of the Interviewees** |
| Fashion Accessory Product Management | • Responsible for benchmarking (competitors analysis and trend research)<br>• Part of the product management team in the international fashion watch company |

2. The interviewees are the members of smart clothes development team or potential smart clothes developers. As they are the potential users of the new approach and NPD model, it is important to address their requirements. Thus, the research outcome will be comprehensible and useful for them.

3. It is preferable if the interviewees have previous work experience in electronics or clothing industry. Hence, the conventional NPD processes and smart clothing NPD processes can be compared.
4. In order to investigate varied work methods and different opinions of smart clothes developers, the interviewees are selected based on the project in which they are involved e.g. joint venture project.
5. It is preferable if the interviewees have conducted and published research in the smart clothing field.
6. Further interviews with the professionals in related fields (namely sportswear and fashion accessory) are conducted, because their areas are of interest to smart clothing developers.

The same set of questions was used in every interview. These questions can be divided into four groups:

1. **Interviewee's profile:** Each interviewee was asked to summarise briefly their educational background, expertise, job, and the responsibility within the organisation and the development team.
2. **The current development team:** The interviewees was asked to explaine briefly about their development team (e.g. what type of disciplines involved, what is the responsibility each member has, how the team exchanges the ideas, etc.) and the NPD process they currently employed.
3. **Opinion on working practice:** Each interviewee was asked to describe their opinion on their expertise in comparison with the other related areas. For instance, the product designer was asked to compare between product design and fashion design. If the interviewees had the experiences in smart clothing development and the electronic or conventional clothing development, they would be asked to identify the similarities and differences between these two processes.
4. **Opinion on the future of smart clothing:** All interviewees was asked about how they anticipated the future and what would be the appropriate direction for smart clothing in the future.

The responses are collected, analysed, and compared to find out the similarities and differences in term of vision, design direction, and problems. As a result, the benefits and challenges of collaboration are identified. Finally, the conclusion on how to utilise the knowledge to formulate a NPD model is deduced.

## 4. Results

The result of this research can be divided into two parts: the result from literature research and the result from the primary research. Both results are presented in the comparison tables (see table 2- 5) in order to demonstrate the similarities and differences in terms of approach, work methods and opinions.

### 4.1 Result from Literature Research

The results presented below address two issues: 1.) NPD process in smart clothing field (table 2) and 2.) NPD process in electronics and apparel industry (table 3). For the first review, three research papers on smart clothing development are selected, as they give an insight into how the developers develop smart clothes. Two papers are from the academic field [Dunne, Ashdown and McDonald 2002, Co 2000], and one paper is from a collaboration project between an academic institute and apparel company [Rantanen *et al* 2000]. For the second review, NEXT's Product Selection Process [NEXT 2003] and DTI's Design Flow [DTI Electronics Design Programme 2002] are chosen, as they represent 'typical' NPD processes. Processes shown in columns 2 and 3 are similar to that of electronic products because of their functional approach (see table 3).

**Table 2. NPD Processes in Smart Clothing Development**

| **Project Title** | | |
|---|---|---|
| Computation and Technology as Expressive Elements of Fashion | Smart Jacket | Cyberia Project |

| **Type of Smart Garment** | | |
|---|---|---|
| Wearable Computing Embedded in Prototype Garments | Prototype Garment with Self-heating and Monitoring Function | Survival Prototype Garment for the Arctic Environment |
| **Organisation(s)** | | |
| Program of Media Arts and Sciences, MIT | Department of Textile and Apparel, Cornell University | Reima-Tutta, University of Lapland<br>Tampere University of Technology |
| **Development Process 1** | **Development Process 2** | **Development Process 3** |
| 1. Conducted background research on fashion and garment construction.<br>2. Identified the ' Design Space' | 1. Identify the user: a young recreationally athletic individual living in a climate with cold winter | 1. Identified the potential area: a garment for an experienced snowmobile user to survive in harsh winter environment |
| **Development Process 1** | **Development Process 2** | **Development Process 3** |
| 3. Developed the 'Design Parameter' to assist the design and evaluate the outcomes.<br>4. The method was very much 'trial & error': develop a design and prototype; examine the outcome; identify the new approach; and repeat the same process again.<br>5. Analysed, compared and evaluated all design works.<br>6. Drew the final conclusion. | 2. Identify the user needs and the problem situations<br>3. Draw a rough outline of architectural requirements.<br>4. Develop a preliminary aesthetic design reference.<br>5. Divide design into sub-categories before developing design alternatives for each.<br>6. Identify evaluation criteria and select the alternatives<br>7. Final evaluation & selection | 2. Collected information through the interviews with the users<br>3. Identified the key problems, key issues & the relationship.<br>4. Specified basic requirements and system requirements.<br>5. Developed the prototype according to the design spec.<br>6. Conducted washing tests and functionality tests indoor and outdoor in arctic condition.<br>7. Drew the final conclusions |

**Table 3. NPD Processes in Electronics and Apparel Industry**

| **Process** | **Organisation** | **Description of NPD Process in Practice** |
|---|---|---|
| Product Selection Process | NEXT PLC | 1. Designers identify the key international trends from all the fashion capitals<br>2. Designers make a season plan based on trends & Merchandisers' sale figures<br>3. Designers create the themes via mood board, swatches & magazine images<br>4. Designers and Buyers develop the design direction and the key strategy<br>5. Product team makes a decision on production plan, suppliers, timetable, etc.<br>6. Designers create and send 'design pack' containing sketches to the suppliers<br>7. Suppliers produce samples for approval by NEXT's product team<br>8. Product team proposes the range at a pre-selection meeting<br>9. Product Director and Managers approve the complete range for production.<br>10. Merchandisers & Technologists manage, chase and monitor suppliers as well as control the quality to ensure that the new season will be launched on time<br>11. Meanwhile, the Buyers and Designers start working on the next season |
| Design Flow | Electronics Design Programme, Department of Trade an Industry (DTI) | 1. **Concept Definition Phase:** Process starts with user needs and market research. The output is 'User Requirement Specification.'<br>2. **Analysis Phase:** The team converts 'Requirement Specification' into 'System Specification' by evaluating the requirements and partitioning the required function into a set of smaller functions – Top-down process.<br>3. **Design Implementation and Verification, Validation and Test:** The team converts the 'System Spec' into a list of parts. Components are created and assembled due to the required functions – Bottom-up process. Verification (System spec), validation (User spec) and test are required at every stage.<br>4. **Initial Manufacturing:** Verification and test continue to ensure that the design, tools and materials are ready for the volume manufacturing.<br>5. **Volume Manufacturing:** Products are produced and launched to consumers. |

Each one started with the user requirement identification that was converted into the system requirement. Since the system requirement was complicated, it was partitioned into sub-categories. As a result, each part was developed and tested separately before combining at the end of the process. Example 2 and 3 took wearability and social acceptance into consideration. However, the processes

did not express much about fashion design because the functional clothing development which is widely adopted by smart clothes developers usually takes a practical approach like those of product design. A process shown in column 1 is different due to its experimental approach.

Although, the developer carried out background research in the fashion field, the outcomes were far from a fashion design standard due to the limited fashion design skill. This illustrates the need for the fashion input.

Because of different product nature, electronics and apparel product development processes place emphasis on different activities. Electronic products comprise of many components, technologies and mechanisms, partitioning is therefore a centre of the process. The process is called 'Design Flow', because the design work is partitioned into a number of 'sub flows.' The major challenge is to make the features comprehensible and accessible through interface design. For the apparel products which have to deal with many changes (namely consumer taste, culture and fashion trend), identify the 'right design' at the 'right time' is crucial. Therefore, the designs require many amendments and approvals to ensure that the design fits the consumer requirements at the particular time. The product development is limited by short development time, competitive price, supply-chain system and uncertain consumer behaviour.

### 4.2 Result from Primary Research

The result covers three issues: 1.) the work methods of each discipline and 2.) personal opinions on working practice (table 4) and 3.) design direction of smart clothing in the future (table 5).

**Table 4. Work Methods and Personal Opinions of the Key Disciplines**

| Type of Discipline | Work Methods | Personal Opinions |
|---|---|---|
| Design Manager | This person manages D&D team which includes human factors, user interface, covers engineering, industrial design and graphic design. To avoid communication problems, all members are interdisciplinary.<br>Their NPD process is general. It includes strategy planning, technology development, design and implementation and sale. | The team requires more disciplines from social science areas in order to look at the product from the user's point of view. Moreover, design should be placed earlier in the process. The value of the electronic product is hidden. Since the real cost is a technology that is incomprehensible for the user, the design role is very important. |
| Fashion Designer | In a team, a designer is usually at the top of the hierarchy. The research is similar to a process an artist uses to get inspirations. Fashion designer works with a pattern-cutter and a technician. Designer creates concepts and sketches, while the pattern-cutter and technician turn them into models | All fashion designers have radically different approaches to design. There is no accepted methodology. Thus, they are extremely intangible. Although, major advances in clothing design usually result from technological breakthrough, the industry is slow to embrace technology. |
| Product Designer | According to the functional approach, market and product research is important. Normally, the designer has several meetings with the clients to clarify key issues and create a plan. Although, the designers cannot change electronic configuration, they can suggest an innovative idea to engineers and solve the problems together. | This designer suggests that 'different product should be designed differently.' The priority is inherent function, user perception and target market. For electronic product, the user interface is the most important issue. Product design has less design freedom than fashion design, as many aspects limit the design. |
| Smart Clothing Designer | This development team includes industrial design, clothing design, textile engineering, telecom, production, marketing, software and hardware development and sales. In the previous joint project, one partner created the concept and clothing design, the other partner designed and built the electronics and this team assembled the garment. | The fundamental problem of smart clothes development is the differences between the electronics production and the clothing/textile production. For this person, combining clothing, electronics and communication are the big challenge. As a result, the team need to (re-)organise and develop the process further |
| Technical Textile Designer | The process is similar to that of invention: identify the problems; study materials and structure; source out materials and test; design a number of weaves with several combinations of materials; produce the samples; test; analyse the result; redesign. | Developing technical textile is entirely different from normal textile design. The normal textile design is limited by time and trends. On the contrary, the technical textile design is a slow process with many uncertainties and unexpected problems. |
| **Type of Discipline** | **Work Methods** | **Personal Opinions** |

| | | |
|---|---|---|
| Technical Textile Designer | The process is repeated until the team finds the design with the right properties. During the process, designer has several meetings with the clients to exchange the ideas. | Communication is a major problem because the technical textile designer has to deal with more disciplines than the typical textile designer does. |
| Intelligent Textile Technicians (two interviewees) | The joint project normally includes design, business and technical people. The research is planned together, but each work is done separately. The team usually meets 3-4 times a year. In the joint-projects, the fashion design team creates the design and prototype before this team can source and apply materials to the model. They conduct user research, develop works and test. | Their research is very much from textile point of view, as they focus on materials and properties. For other research group, textiles are still like a normal textile. As smart fabrics are unable to provide their promise(s) currently, smart clothes are not functional yet. It is noted that presenting with a real model and real fabrics make the discussion between members easier. |
| Electronic Technician | Electronic company did not intend to develop clothes, as people would not buy clothes from electronic company. As a result, this electronic team produced prototypes and presented them to the fashion company in order to find a partner. In the previous joint project, the fashion partner created garment and its scenario, while this team designed the electronics. | Technical issues (e.g. compatibility, etc.) are still significant problems. However, the key problem is a language barrier. Electronic people do not understand the technical terms, fashion calendar and its deadline. To work with the different industry successfully, each partner should be concerned about the other industry's development and manufacturing process. |
| Future Trend Researcher | This team studies trends in three areas: technology, society and business, and how they affect the lifestyle. For visual strategy research, the team conducts lifestyle research in the major cities and identifies new directions. To find out the latent needs, they conduct an observation, as the user cannot visualise non-existing product | Making the results comprehensible for the design team to address in the design is very important. Therefore, this research team uses both visual and verbal form to describe them. To find new direction, it is important to look at the problem from a different angle. The key is to explore issue from both positive and negative sides. |
| Sportswear Designer & Lecturer (two interviewees) | The process is user-centred. As every part and pattern serves functions, the designers need to understand human body, sport activities, technical textiles and target market. In many cases, designers create concepts, make prototypes, test each part and combine them together. Some designers develop concepts and the other discipline interprets them into more functional design. | Sportswear design is fabric-driven. It is a straightforward practical approach with excitement and innovative ideas. All designers have a passion for sport and designing functional products. Sportswear design is similar to that of smart clothes, as the materials are chosen based on the properties. Purchasing criteria may be similar, as they are based on the functions. |
| Fashion Accessory Product Management | The team is responsible for the development of product line. Their success comes from the regular fashion trend research and close relationship with external companies. | Main challenge is to bring emotion into a technical product. Fashion and technology are equally important. New development in materials & trend interpretation is the key |

The principal findings in terms of work methods and personal opinion on working practice are:

1. Every discipline has a very different approach to their design problems. It is difficult to change the ways they work and the approaches they take.
2. Respondents report no problems working with other disciplines. However, most of them admit that it is difficult to express what they want to the other disciplines without knowing technical terms used in the different areas. As a result, each participant requires an understanding of the other disciplinary work methods and technical terms to some extent.
3. As many of the development teams are joint ventures, each task is carried out separately. Thus, the project brief and initial meeting is very crucial. In many cases, the projects were carried out in a linear form. For example, the garment is designed and prototyped before smart textiles are selected; then electronic parts can be designed and placed accordingly.
4. To ensure that every part fits perfectly, each discipline should take the others' development processes and manufacturing processes into consideration. For instance, the electronic technician reported that he studied the partner's manufacturing process and developed the designs accordingly.

**Table 5. Personal Opinions on Smart Clothing's Design Direction**

| Type of Discipline | Smart Clothing's Design Direction |
|---|---|
| Design Manager | The biggest challenge is looking at what technology can provide and filtering what people do not want. It is important to understand the cultural impacts and change people's perception of fashion versus product. Purchasing criteria of both products should be examined. Technology should be developed from the user perspectives. Target market, life cycle, social acceptance and sustainability should be addressed. |
| Fashion Designer | Future lies in collaboration between different disciplines to create a product where technology is invisible and clothing performs the functions as always with a few discrete extra functions. Development teams need to get beyond 'stereotyping creative & tekkies'. |
| Product Designer | Smart clothing nowadays does not look realistic because of the technical limitation. It should take functional approach and pay more attention to social acceptance. It can be a wearable item like a strap, which might be more suitable than clothes. |
| Smart Clothing Designer | As production methods are developed and the devices can be integrated in the fabrics, there are plenty of possibilities & opportunities. This team will continue designing and producing simple bodyworn devices. To make people take wearable and smart clothes seriously; developers should thoroughly develop useful & functional designs. |
| Intelligent Textile Designer | In the next 5-10 years, every piece of clothing will include some electronics. The fastest growing sector is medical products, especially with help of nanotechnology. Pressure sensor, temperature controls and entertainment area are also the interesting fields. |
| Electronic Technician | Integrating electronics into clothes requires a functional reason, as it leads to many technical problems. One solution is using a modular system & a universal interface which allows any device to be plugged in the garment. However, it limits the devices' functionality. The other way is producing devices very cheaply that they can be fitted into every garment. At present the direction for the mass has shifted to monitoring and healthcare. The interest moved to sportswear, as it is more experimental and innovative |
| Intelligent Textile Technicians | Many of the products available market have not been really useful. Moreover, they are complicated and expensive. However, many prototypes for elderly people and those in healthcare and sport area seem to be useful and have a potential market. The future lies on what people want from these clothes. At present nobody knows these latent needs. |
| Future Trend Researcher | Many issues need to be explored e.g. fashion vs. function, the reason(s) behind people's purchasing and using electronic devices & clothes, etc. Study from user point of view. |
| Sportswear Designer | The garments should work well without technology. It should be simple. Elderly people are an interesting group, as many functions are useful for them and they value things for a longer period than the younger age group. Co-branding should be considered. |

To summarise, the new design directions of smart clothing are:

1. As the technologies take a long time to develop and test, most disciplines believe that smart clothing applications should take a functional approach like product design or technical clothing design.
2. As a result, the interest has been shifted from fashion, communication and entertainment to the physical monitoring, sportswear and healthcare. This new approach helped expand the market, as the target ranges from children to the elderly, while the previous ones are limited to young people.
3. Since the applications have longer life cycle than ordinary garments, apparels like sportswear, workwear and garments for extreme conditions represent a suitable choice.
4. Social acceptance is very important. The end product does not have to be fashionable, but it should work well without technology and has the discrete functional features. Some people suggest that it should be wearable item rather than the clothes, as it is probably easier for the users to accept. Moreover, smart garments should have a simple design; therefore, it will be less transient.
5. Experts from the related disciplines agree that the main challenges are going beyond the existing creativity, overcoming technical issues, making applications from different brands compatible, coordinating the purchasing criteria of electronic and fashion goods, and managing co-branding.

## 5. Key Conclusion

It is clear that the NPD processes of smart clothing are more similar to those of electronic product design than those of fashion design. Nevertheless, it does not mean the smart clothing should take the electronic product approach, as most commercialised smart garments resulted from the development team that took functionality, wearability and user requirements into consideration. It is likely that smart clothing development will take the functional approach like product design and functional clothing design (namely sportswear and workwear), since smart clothes require the practical functions and good appearance. Moreover, most disciplines suggested that it might be an appropriate approach. Besides, the existing NPD processes of smart clothing are similar to those of product design and functional clothing design. As a result, it is possible to adopt certain ideas from these areas. Nevertheless, smart clothing design is very complex; therefore, none of disciplines understand every aspects of design. Hence, the works were usually divided and assigned to several groups. This is different from product design and functional clothing design in which the designers understand most of the aspects, e.g. activity, material and manufacturing process. However, a method that reconciles all aspects so they are perceived and interpreted through one point of view may reduce the number of possibilities. Therefore, the key benefit of this collaboration is that all the aspects are perceived and interpreted by many different people. This increases the chance to explore all the potential opportunities. As every discipline has a different way of thinking and work methods, it is difficult for them to communicate and exchange ideas with each other. As a result, the key challenge is that every discipline should learn from the others and explore the different way of thinking and working. It is important that every discipline to go beyond their creative boundary. If the fashion task is carried out with technological consideration and technology is created with the fashion design in mind, the smart clothing development can achieve the optimum balance between fashion design and technology. Moreover, the conflict can be reduced. To conclude, the strategic approach and NPD process should address how each discipline goes beyond their existing creative boundary. Nowadays although certain NPD models mention this issue, it does not appear to present as part of the process. As a result, it is difficult to adapt the processes into collaborative work. Therefore, this new approach and NPD model should present this issue clearly as part of its structure.

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