

# Utilizing End User Knowledge in the Designing of Intelligent Workwear

This paper contributes in the field of design to the overall knowledge of the utilization of the end users' expertise in design and product development processes and adds to the knowledge of designing complex and highly technical products. The paper describes the ways of utilizing end user knowledge and expertise in a process of designing and evaluating an intelligent workwear concept. The special focus of the paper is on the methods and models for collecting and utilizing the end user knowledge. The paper also maps the motives and consequences of the utilization of the user knowledge in the case and critically evaluates the possible problems of the utilization of the knowledge as well as its benefits and shortcomings in this particular case.

The presented case is part of a research project funded by the Academy of Finland through the Proactive Computing research programme. The ongoing Methods and Models for Intelligent Garment Design [MeMoGa] research project is conducted by the University of Lapland during the years 2003–2005.

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## INTRODUCTION

The growing need for products that are designed for users' specific needs calls for an increment in the use of user-centered design and production processes. The user-centered methods require knowledge of the needs and expectations of the users as well as the different contexts in which the products are used. The accelerating renewal of technology and constantly shortening development cycles – especially in the field of information technology – are easily seen in contradiction with the methods of user-centered design. However, the confrontation between industrial product development processes and the principles of user-centered approach is not necessarily insurmountable.

The problems of designing complex and highly technical products for particular users are tackled in the ongoing Methods and Models for Intelligent Garment Design [MeMoGa] research project. Our background research in the project has revealed that a piece of intelligent clothing is not perceived only as a piece of clothing in the traditional sense, but also as a technological device. This new clothing hybrid, called intelligent clothing, can be identified by its new electronic and textile-technology features, and it cannot be successfully developed through the traditional clothing design processes. The idea of an omnipotent designer is already outdated. The design and development processes of complex and highly technical products require collaboration of multiprofessional teams.

The MeMoGa research project is funded by the Academy of Finland through the Proactive Computing research programme. The project has started in 2003 and it will be finished by the end of the year 2005. The MeMoGa research project consists of five separate elements: background research, concept design, 3-D simulations and virtual prototyping, usability evaluation, and final concept.

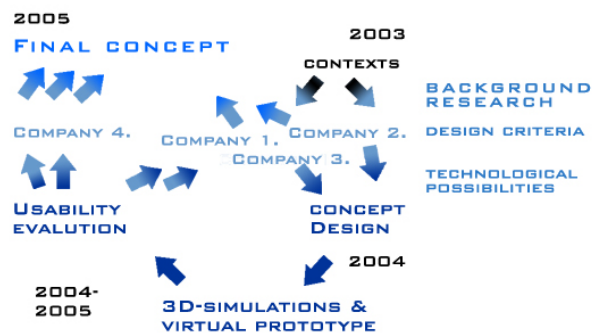


Figure 1: MeMoGa project Research Design

This paper focuses on the methods and models of utilizing end user knowledge in the designing of an intelligent workwear concept within the MeMoGa research project. The end user

knowledge is utilized in three different ways in the project in three separate phases. The first phase has been the collection of user knowledge through background research; the second was the utilization of user expertise in the concept design process. Finally the user knowledge will be utilized through the evaluation of the concept. These three phases are individual parts of the MeMoGa project. Each part has its own methods, goals and also realizers. The background research was done by researchers; the concept design process involved a multiprofessional team of designers, users and consultants; and the evaluation is carried out by the project's research personnel. These three phases are the frame of the user-centered approach of the MeMoGa project and represent a wide range of user-centered methods in product development. Distributing the expertise and communicating the information from one phase to another is an essential challenge of the project and this is why conducting all these three elements takes two years of the project.

The emphasis of the paper is on the phases that have been completed so far, that is, the background research and the concept design process. The paper also introduces the concept's evaluation phase to an extent allowed by the still ongoing work. In addition to presenting the methods of data collection and processing the paper also reviews the goals and motives of the decisions concerning the above-mentioned issues. The phases of utilization of the user knowledge are critically examined by evaluating the realized goals and benefits as well as the possible problems and shortcomings of the implemented practices. We conclude the paper with a summary of how the gathered information and applied methods may be used outside the context under discussion.

The authors of the paper have a twofold relation to the case in question. Two of the authors are involved in the MeMoGa project as researchers and one of them participated in the concept design phase of the project as a clothing designer.

### **THE MEMOGA RESEARCH PROJECT**

The MeMoGa research project analyses the conceptual framework offered by the theoretical bases of research on clothing and dress and its applicability to the study of ubiquitous computing and the services, activities and social situations found in intelligent environments. A particularly salient focus in the project is to determine how the approaches identified may be used in elaborating models and strategies for research on the usability and acceptability of wearable intelligence and in developing design methods. The research concentrates on products yet to be designed, simulations and product concept designs.

The project studies the usability and acceptability of wearable intelligence using 3-D simulations and animations. In addition, it creates and studies wearable intelligence product concepts that can be easily adopted by different users and are accessible for as many of us as possible. In pursuing these aims, the project will develop context-sensitive research methods and models.

The study also affirms the value of multidisciplinary approaches to understanding the needs of the end users when smart and complex products for apparel industry are designed. Smart products and intelligent garments are a complex phenomenon, where numerous factors and processes are in transactional relation with each other. By blending the perspectives of several disciplines into one study, it is possible to achieve increased understanding on how new design products attain their usability and acceptability. The results of the research and concept design project can also be utilized in product development in the apparel industry. [1]

### **CONDUCTING THE BACKGROUND RESEARCH**

While many guidebooks on product development offer valuable insights into the actual organizing and managing of design teams and processes, they often rather lightly bypass the important part of understanding the users. Still, it is commonly agreed that knowledge of user needs and requirements cannot be increased in an engineering vacuum [11].

In the designing of complex and highly technical products that are intended to be responsive to the needs of specific users there is a great demand for user-centered approaches. The utilization of end user knowledge is not merely a question of mapping the functional requirements for the products or asking for a wish list from the users. The purpose of collecting user knowledge is to be able to anticipate the emerging needs, wants and desires of the users by examining the existing problems, needs and contexts in which the products are used. This information can be attained and utilized in the product development processes on a wider scale than by designers only.

In business life the phase we have replaced with the background research is sometimes referred to as the Fuzzy Front End of new product development. [3] The phase of gaining understanding of the users and the contexts of use as well as the identification of the users' needs and expectations does not essentially have to be uncertain and vague. There are several ways of collecting an extensive reserve of user knowledge. Quite a few of the methods have been originally adopted from outside the design discipline, especially from the social sciences [5].

Our approach in the background research has been realized through semi-structured interviews and questionnaires. [6] The interviews covered a set of issues that were considered in advance to have significance in the designing of the intelligent workwear. The interviewees were also given an opportunity to raise issues that were of particular importance to them. The questionnaires were used to add more specific information into the data e.g. about the interviewees' background and their opinions on the current workwear.

The interviews were recorded on video- and audiotape. The audio recordings were transcribed and then analyzed by the research team. The videotaped interviews were used as a backup in situations where the audio recordings were somehow obscure. The collected data from the interviews was analyzed with both qualitative and quantitative methods where appropriate. In some cases the qualitative data was also processed into quantitative data by, for example, transforming the data into frequencies.

### **The users and their working environment**

In this paper the term 'user' refers to the people who actually use the work-wear on a daily basis. It includes workers representing various tasks and different levels of organizations in different companies of the heavy industry. The data of the background research was collected through two rounds of interviews. The first round of interviews was arranged in two heavy industry companies during 2001 and 2003. In the selection of participating companies special attention was paid to their location in order to avoid local bias in the results of the study. On national level the study covered companies representing Southern, Central and Northern Finland. In the selection of the sample, attention was paid also to different working conditions and workers' educational backgrounds, among other things. This ensured that the results will speak for national needs in heavy industry workwear, encompassing diversity of the users and their different requirements and expectations.

The first interviews were conducted among workers in the construction and steel industries. The second round of interviews was carried out in the previous two companies and also in an automation and control technology company for comparison in 2003. In the last company, both two interview rounds were combined into a single interview.

*The interviewees.* The average age of the workers in company A was 41 years, in company P 49 years among the officials and 46 years among the factory workers. The average duration of current employment was 14.5 years in company A and 9.5 years in company P. The average age of the workers in company M was only 37 years whereas their average duration of current employment was 10 years.

All of the participating workers in the background research were male except for one female. This was directly due to the gender distribution in the companies' personnel. The total number of persons interviewed in the background research was 49 in the first round and 58 in the second round. The detailed distribution can be seen in figure 2.

Company	Interview Round I	Interview Round II
A	18 persons	18 persons
P	12 persons	21 persons
M	19 persons	
<b>Total</b>	49 persons	58 persons

**Figure 2: The number of interviewees**

#### The goals and themes of the background research

The main objectives of the background research were to identify and document user needs and expectations and to attain the true requirements the workwear needed to meet. The attempt was also to gain understanding of the working environment as well as the contexts in which the workwear would be used.

In the first round of interviews the main focus was on human – garment relations where the garment was analyzed with Lamb & Kallal's "A Conceptual Framework for Apparel Design". [9] The so called FEA model suggests that the functional, aesthetic and expressive properties of a garment are inseparable parts of a whole and there is no reason to distinguish between functional apparel design and fashion design. All of the three elements should be somehow present in the designing as well as in the final product. The emphasis between the three elements can vary according to the garment's primarily intended use. The functional properties of the garment are clearly emphasized in workwear but the expressive and aesthetic properties are still of relevance to some extent.

The use of the FEA model as a foundation for the clothing related questions of the background research interviews aimed to ensure that the gathered data would provide sufficient information of all the three essential properties of the workwear. This made it possible to avoid concentrating excessively on the functional properties of the garment, which are, naturally, emphasized in heavy industry workwear.

In the second round of the interviews the focus was on the usability of wearable intelligence. The second round dealt with information about the interviewees' experiences and attitudes towards technology as well as their conceptions of intelligent garments. The interviews also addressed questions about the user's expectations concerning wearable intelligence and the possible prerequisites relating to the use of intelligent

garments. The themes of the second round of interviews concentrated also on the working environment and socioeconomic status.

#### THE RESULTS OF THE BACKGROUND RESEARCH

The research data was divided into six categories through analysis. The categories were named according to their contents as 1) The worker in the heavy industry – ordinary Finnish male? 2) The working environment and communication 3) The conceptions and experiences of technology and intelligent garment 4) The hopes and prerequisites for the use of intelligent garments 5) Conclusions – similarities between the companies 6) The services and features expected from intelligent workwear. The essential readings of the six categories are presented under the following subtitles.

##### The tasks and the working environment

The turnover of the workers in the companies is very low except for the youngest employees. Still, as a result from the physically wearing work only few are able to continue working until the official age of retirement. The reasons for the numerous early retirements due to the health reasons can be found in the working environment. The drafty factory halls, the wide temperature range, the exposure to heat, the uncomfortable working positions and the strain of the shift work can be considered as explanatory factors. It became one of the primary goals of the project's research and concept design to improve the well-being of the employees in the workplace.

The work in the companies' production is typically shift work and includes both indoor and outdoor tasks. It does not have particular seasonal nor occasional exigency. The work is perceived as customary and unchanging. The typical day seems even too typical. New tasks are welcomed as a positive sign resulting from well performed prior tasks.

The nature of the work as physically wearing is moderated by the machinery that takes care of the heaviest work. The workers themselves perceive the work more wearing on the physical level than on the mental level. The evening shifts are experienced heavier than the morning shifts. Information technology has had only little impact on the actual tasks in the factory hall. However, the tasks in the supervision and planning of work have been influenced more by the new technology.

In company P the tasks are mostly performed independently. Yet there is often a co-worker within sight. In practice the work in the evening and overtime have to be done alone in the unit if not in the factory. The safety of the solitary worker is ensured with a mobile phone. In the factory the communication between co-workers is mainly oral; often even shouting or signs because of the noise. There are radio- and mobile phones available in the factory. In addition, the workers in the offices and control rooms use email, fax and inter-company mail. Messages from the supervisor are passed either directly or through co-workers generally in oral communication. Some of the general issues are also informed on the notice board. The workers' own mobile phones are used only in an acute situation. The workers in company P did not see an immediate need for a communication system because the factory was considered to be fairly small. However, some of the workers believed that a communications system could be of assistance. The supervisors for their part wanted to maintain the traditional means to communicate with the workers.

##### The workplace related injuries and health risks

In company P's factory the most common accidents and injuries were tripping over something or stepping on a nail.

Getting trapped and squeezed between prefabricated units and falling down were among the more common threats as well. In company A the dangerous situations varied depending on the task in question. Eye injuries were on the top of the workplace injury statistics. Other common causes of injuries were heat, sparking and splashes. The workwear has a particularly significant role in the prevention of the heat and spark caused injuries. The parts that needed special protection in the current workwear were arms, legs and the front. A fire in the factory was commonly considered to be a potential dangerous situation. Often the injuries and accidents happened to the novice workers, such as the temporary workers in summer jobs. As their experience increased the workers learned to avoid the potentially risky and dangerous situations.

Safety at work is influenced and increased both by learning by doing, professionalism and experience as well as the attitude. All of these factors were considered to be lacking from the new employees which caused them to be a considerable risk factor. Yet the accidents and injuries were not confined to the novice workers. The experienced workers were seen to sometimes develop routines that neglected the safety whereupon the consequences could prove to be harmful.

### **The current workwear**

A common opinion was that the current workwear was considered adequate even though wishes were expressed to improve it. The workers regarded their lack of knowledge about options relating to the workwear as a problem. The conception of the adequate workwear was essentially based on not knowing about potential better solutions. The workers were blind to the inadequacy of their workwear and were not able to demand any improvement.

All of company A's workers were given a fire resistant protective uniform which was either a one- or a two-piece suit according to the worker's preference. Company P provided all the workers identical and predetermined workwear, which was supplied by a clothing rental firm. The maintenance of the workwear was handled by the employer, which was seen as a positive thing. The same outfit and protective shoes were used year-round in both factories. The clothing was adapted to circumstances by adding extra layers of clothing when needed. The workers believed that if they were required to acquire their workwear themselves, the quality, condition and quantity of the garments would decrease substantially.

*The primary deficiency in the workwear.* The deficiencies in the current workwear were mapped in the background research in order to observe in design the previously experienced discomfort and complication. The unsatisfactory details mentioned regarding the current clothing included, for instance, an insufficient number of pockets and their poor design. The interviewees also complained that the current workwear did not have enough dirt resistance. Dirt and dust penetrated to the inner layers of clothing to some extent through the cuffs and at ankles. Even though the dirtiness of the workwear was mainly considered as a negative thing it was also seen to signify the positive aspect of diligent working.

In company A the weakest point in the current clothing was the material. Even though the material was fire resistant the qualities of the material were not sufficient for the circumstances in the foundry. The clothing conducted too much heat to the body despite proper clothing in the inner layers. Also the features designed to make the clothing breathable were inadequate. This was also considered to be the biggest problem of the current workwear in company P.

The interviewees also highlighted hopes for improved durability and shrink-resistance of the clothing. At the same time, they wished for material that would also be dirt resistant

and damp-proof. The interviewees also felt that the clothing did not sufficiently protect against cold.

### **The expressive and aesthetic qualities of the clothing**

The visibility of the current workwear was considered to be fairly good. Visibility, which affects safety in the workplace, was acquired mainly through the use of bright colors in the clothing and/or the helmet. The interviewees did not wish for any particular improvement in this aspect but some of them hoped for more colorful clothing. The coloring of the clothing was generally hoped to reflect the company they worked for and be distinguishable from other companies, although there were differing opinions on this question as well. The so-called representative qualities were expected from the workwear primarily in the superior tasks and on behalf of the personnel whose tasks involved direct contacts with partners in co-operation.

The distinguishing nature of the workwear was also mentioned from the perspective of standing out from the co-workers. It was seen somewhat beneficial for the persons in the leading positions as well as for the summer trainees and other temporary personnel. Otherwise the clothing should not reflect the person's position in the company hierarchy. A feeling of equality was hoped for among the workers and this was seen to come true in identical workwear.

The aesthetic qualities of the workwear had a clearly lesser meaning to the interviewees than the functional and protective attributes. The aesthetic qualities were not seen relevant in proportion to the actual work. However, the interviewees brought up the idea that the appearance of the workwear has meaning in communicating about the company's success and creating a positive company image both to the workers of the company and to non-members of the work community.

When the appearance of the clothing was addressed as a factor of work motivation it became obvious that the appearance of the clothing is not to be taken as less significant in the designing of workwear. The clothing as a factor on motivation seemed to be related to the workwear's ability to communicate a positive corporate image. Having evaluated the results we could say that the current workwear had to be improved also to increase work motivation. This could be achieved also by enabling the clothing to be better adapted for various tasks and circumstances. At the moment the workwear was perceived as a so called compromise solution that should suit all the tasks in the factory but was not especially good for any of them.

The appearance of the workwear also had an impact on the way the workers experienced themselves as part of the company. A pleasing appearance of clothing definitely created a more positive impact on the company spirit.

### **The conclusion and evaluation of the background research**

Based on the analysis the most important characteristics of the working clothes for heavy industry were evaluated to be functionality, safety and ease of donning and doffing. The appearance of the workwear and the expressive qualities were considered to have less significance. The appearance of the clothing had significance only to a lesser degree especially to the workers who worked in a closed factory environment. The more the tasks of the person included involvement with non-members of the work community the bigger the significance of the appearance of the workwear.

In order to examine the preferred appearance of the workwear we used a series of five pictures of different working clothes to raise opinions and discussion. The pictures were generally considered to have a positive impact on the outcome of the interview even though the interviewees experienced some difficulty in commenting on the aesthetic appearance of the

workwear. Questions on the workwear's functionality were much easier to address in the interviews altogether. In general it was easy to gather information about the functional attributes of the workwear. The questions about the aesthetic and expressive qualities of clothing were probably somewhat more abstract than the concept of functionality, which seemed to be easy to structure with well-defined problems.

Pictures were also helpful in the interview when asking about the interviewees' conceptions of the existing technology and intelligent garments. In some cases the pictures created new conceptions for the interviewee. This came out in cases where the respondent had very little prior knowledge of intelligent products.

The primary prerequisite for adopting an intelligent garment was functionality. The development of the conventional qualities of clothing – such as breathable and protective features – was found to be the highest expectation also for intelligent working clothes. New electronic functions as well as protection for heat and dirt were expected as well. Desirable services mentioned were communication devices and an alarm and security system. Other important services mentioned, to be integrated in the workwear, were updating features as well as an electronic desk and an electronic notebook with pen.

The technological appliances in the clothing were expected to be easy to use, even self-directing. The design of the applications and the technological appliances in general is expected to be convenient, small and lightweight. Nevertheless, the appearance of a product was regarded as a secondary quality in comparison with functionality.

The interviewees had a moderate attitude towards technology in general. Technology was seen as a means to an end and not as a value in itself. Consequently, the interviewees were not classified as early adopters of new technology. Rather than being enthusiastic in purchasing technological devices as they enter stores, they were typically patient to wait for the devices to be developed further to better suit their needs and expectations and to wait for the reduced price. However, as a user of technology the interviewee is willing to accept wearing technological devices close to the body.

The background research results suggest that clothing combined with intelligence will be adopted if it is conceived to be practical and useful. The attitude toward intelligent clothing was mainly positive among the interviewees. The negative conceptions related primarily to the possible high costs as well as the anticipated heavy and large appearance. In workwear the visibility of intelligent features is acceptable to some extent, and the features should primarily be related to communication or otherwise facilitate working. The final expectations were that intelligence would eventually be fused into clothing so that the user won't have to be aware of it.

In general, workwear was expected to be lightweight and easily maintainable yet durable. The cut of the outfit should be relatively lean. Due to the need to use several layers of clothing under the workwear during the wintertime the workwear should be suppler and the ease of use of the workwear should be increased altogether.

#### **Delivering the background information to the designers**

The interviews accumulated knowledge of the current workwear, working environment and different tasks and working situations of the workers in the heavy industry. On the basis of this information it was easier for the designers to understand the aspects of designing an intelligent workwear concept for the heavy industry.

The background research provided rich and multidimensional material for the design process. The only mentionable lack in

the information was found in the collection and analysis of the data that would have produced a deeper view of the expected changes in future working environments and tasks. The interviewees were certainly experts on the present state at the factories but the background information could have benefited the mapping of the foreseeable changes. This was of interest especially because the goal of the design process was not only to solve the current problems of workwear but to be available for future working environments as well.

Since the background research was done by researchers and not the designers themselves, the results of the background research were presented to the design team through lectures and research reports. The concept design process started with familiarizing the designers with the existing solutions and concepts of wearable intelligence as well as the analyzed information of the background research among the end users. The background research reports played an essential part in the orientation. The key definitions of policy for the concept were elaborated on the basis of the background knowledge. The research reports also guided in determining which needs and matters should be considered the most significant ones.

#### **THE END USERS AND THE CONCEPT DESIGN PROCESS**

Concept design is an early phase of the product design process where the product reaches a tentative composition. There are different opinions on the goal and the pursued outputs of the concept design phase. Often, it is conceived to yield a physical object that can be tested, evaluated and refined into a more detailed definition of the product. [13] However, the evaluation of a concept does not always require a physical object. The main functions and features of the product regarding the functional, aesthetic and expressive qualities can be evaluated, e.g., with simulations. In this case, the given task for the design team was to produce visual material and information of the solutions in the concept to build a 3-D presentation of the concept for evaluation purposes at a later stage.

The concept design team consisted of four graduate design students. The team included two clothing designers and two industrial designers working tightly together and crossing the traditional limits of their own fields. The group was supported by consultants of material technology, electronics and physiology as well as project personnel supervising the work. The end users were represented by three companies that had been involved in the background research as well. Each company had two representatives in the design process.

The utilization of user expertise in the concept design phase had elements from both user-centered and participatory design approaches. The utilization of user knowledge through background research represented the model of user-centered design whereas the participatory design approach was applied in the concept design phase where the users' involvement in the process was more active and direct.

The representatives of the end users participated by commenting on the ideas and presentations twice during the design process. All consulting and commenting took place in a virtual learning environment engineered for the concept design. The users had access to a limited area in the web based environment, which included a discussion area, folders for the material to be presented and commented as well as information about all of the participants in the process. The design team brought most of the ideas and material to the environment during the process, but at the same time the team controlled what they wanted to show to the user representatives at each stage.

The three-month long design phase was sectioned into three stages which were divided by a week-long evaluation period between the stages. The evaluation week was designated for

free commenting on the sketches and other material produced by the design team. The week was scheduled especially for the end users who participated in the project voluntarily on their working hours. The consultants were able to follow the advancing process incessantly within the realms of their possibilities and comment on the outcome in every turn. The consultants were also available for the design team to help with problems or answer any emerging questions within their field of expertise. In the beginning of the concept design the consultants also provided some background information of the existing solutions in the field of wearable intelligence.

### **Integrating users into the design process**

The material presented in the first week for evaluation consisted of five scenario-like fictional stories and evocative profiles presenting different services and operational environments. The aim was to give for consideration several pictures based on various foundations, aiming to find out the most evident direction to proceed to and the possible weaknesses of the different profiles. The intelligent garment was not given a visual look or a physical form at this stage of the process.

The end users perceived well the scenarios, which were presented in a relatively abstract form. They also seemed to distinguish between the key differences of the five profiles. However, they considered the most appealing services somewhat futuristic and unconvincing as for the practical feasibility at this point, which affected the evaluation of some of the profiles and scenarios. The consultants were not able to assess the presentation from the point of view of the end users' work and tasks. Instead, they commented predominantly on the details of the field of their own expertise.

After the first evaluation week the design team began to concretize the solutions for the desired services and visualize the appearance of the concept. On the basis of the comments from the consultants and the end user representatives the concept design team searched for ways to combine the approved and desired services as extensively as possible. The team took an uncritical stand at this point and tried not to rule out any of the approved services. The ambition was to present more detailed solutions on a wide scale during the second evaluation week to achieve a deeper understanding of the potential acceptability and usability of the services designed. The consultants commented on the outcome simultaneously as the process advanced and the concept became more focused.

The second evaluation week proved to be a slight disappointment from the designers' point of view, especially because the expected collaboration and conversation did not emerge in the virtual learning environment – due to the end user participants' lack of time, among other things. However, the end users' brief comments on the second presentation reminded of the development and improvement work to be done on the service solutions.

As the background study already suggested the end users were not highly concerned with the visual appearance of the clothing. Despite this fact their comments on the visual aspects of the concept were given a role of a rough guideline in elaborating the final appearance.

The role of the users in the design process was welcomed by the design team. One of the main reasons for integrating the users into the design process was to strengthen the opportunities for the creation of functionally and aesthetically appealing workwear. In practice, their participation was less active than had been hoped for. The participation of the end users was limited due to the fact that they participated in the process only during their working hours. In order to improve the utilization of end-user expertise the role of the end-users in

the design process should be aimed towards more participatory approaches. In reality, the participation of the true end-users is not as uncomplicated as the designers might assume.

### **THE EVALUATION OF THE CONCEPT**

The design phase is presently followed by work on an interactive multimedia presentation, which presents the virtual prototype consisting of a 3-D animation, an interactive 3-D model, text, pictures and simulations. The end users evaluate the product concept and the services integrated to the concept by reviewing the presentation. The evaluation will be completed by the end of 2005.

In evaluation we will find out how the intelligent workwear combining new materials, technology and applications may fit in different heavy industry work contexts. As been confirmed in the background research phase the end-users were often blind to the inadequacy in their workwear and not able to demand improvements. This is why the end-users should be given an opportunity to discuss the suggested solutions using a virtual prototype and bring forward the possible advantages and disadvantages of the concept for their work before further development.

The presentation also provides opportunities for evaluation of the concept without endangering the safety and wellbeing of the end user. The use of 3-D modeling and the test of usability based on it will enable the researchers and designers to analyze the concepts and products yet to be done in an early phase of product development and to eliminate the errors and shortcomings in design which might severely compromise the usability of the products. [15]

The evaluation and interviews relating to it aim to produce information about the usability and acceptability of the designed concept of intelligent workwear in various working environments within different industries. The evaluation will also make it possible to develop and improve the research and design methods for intelligent garments as well as the tools for the study of usability and acceptability in general. The evaluation presentation is intended to assist the users to assess the applicability of the suggested solutions in their authentic working environments and situations.

Usability can be understood in various ways. It can be seen as an attribute which defines the whole design process, the product, use of the product or user's experiences and expectations of the product. There are differences in what is attempted to achieve with the study of usability. The result of usability testing or evaluation may be seen as a generic result, when using representative groups of users. For some the usability evaluation is a context-based operation and that is why the results should be treated as subjective and case-specific information. [7] In this project the evaluation is seen as an experiment in the search for usability but not as a total confirmation. The results of the evaluation are taken as guidance rather than as an absolute truth of the usability of the product. [12] In the evaluation of the intelligent clothing concept specified information is searched for developing and producing a physical prototype. The purpose of the evaluation is to strengthen the possibilities of realization of the users' expectations. The purpose is not to look for generalized results but for a direction where to proceed to produce a successful product. In other words, the evaluation stage gives an opportunity to find out which features of the concept could be worth developing further as suggested and which features should be redesigned to meet the needs of the users.

The evaluation of the concept carried out in the project is a mixture of existing usability testing methods in contemporary industrial design and electronic industry. Yet it is structured to especially suit for the evaluation of intelligent clothing. The

combination of origins is chosen because the contemporary clothing industry does not recognize usability testing as one of its methods in the concept phase of the product development process. In the clothing industry usability testing is traditionally conducted merely for a piece of clothing at the end of the design cycle by carrying out experiments with end-users for gathering user-feedback [4]. Usability evaluation conducted with an interactive prototype is not supposed to replace experiments with physical prototypes entirely but to serve purposes that cannot be satisfyingly achieved with a physical prototype of the concept.

### **The methods and materials**

The evaluation of the intelligent clothing concept's usability and acceptability is based on two previous versions of usability evaluations conducted in WearCare and I-sport research projects during the years 2001 – 2003 in the Textile and Clothing Department at the University of Lapland. [14] These two prior versions have been based solely on the clothing-theoretical approach for addressing the usability of intelligent clothing. Both evaluations have been conducted with qualitative methods, using discussion controlled by a semi-structured framework for gathering data. In the third version the evaluation is taken further and three different methods for gathering data are applied. This change has been made to find out how quantitative and more independently performed methods could work in conducting the evaluation in a more time-saving and economical way.

In the presented case the existing methods of usability testing have been adapted to the specific setting of testing an intelligent garment concept. Alterations to the chosen methods have been made especially in order to gather data through the same framework as in the early stages of the project to structure specified questions for evaluating the usability of intelligent clothing. The data gathering apparatus is also supplied with a section called 'profile' to complete the user information. This section is for collecting data on the users' experiences with computers and conceptions of intelligent clothing. This data is compared with the results of the usability evaluation to find out if the users have particular attitudes to intelligent clothing because of their user experiences with computers. Computers are used here as an example of technology, since they are the most frequently used indicator of attitudes to new technologies [2], and further, in many cases intelligent clothing is a piece of clothing enhanced by a computer.

### **The aim of evaluation of the intelligent clothing concept**

The collected data from the usability evaluation gives an opportunity to study intelligent clothing as workwear, with the interest in the added "intelligence". The evaluation also helps to detect if the added intelligence would change the conception of workwear substantially or change the meaning of the workwear in the working environment to some extent. The collected data also gives a possibility to study what is the impact of new technology on the conceptions of intelligent clothing and how the experiences with technology are transferred to the conception of intelligent clothing.

The comparison of qualitative and quantitative methods used in the evaluation assists to develop the chosen modes of operation as an efficient tool for conducting usability evaluations. The interactive multimedia presentation is studied also with the help of a questionnaire which is included in the end of the presentation. This gathered data is aimed to add information about how informative, communicative and usable the presentation is. This study is carried out as part of the CoDes (Facilitating Social Creativity through Collaborative Designing) research project at the University of Lapland.

### **Conducting the evaluation and analyzing the gathered data**

The evaluation of the concept is carried out among employees who use workwear either daily or periodically when working or visiting heavy industry factories. The employees that take part in the evaluation may be new end-users that have not participated in the previous stages of the research project. In addition, at least one new company is collaborating in the evaluation to study how the concept suits factory workers in other fields of industry. This is of particular interest in the development of solutions and features that could be of benefit to different working contexts.

The evaluation is carried out using three different methods. These methods are a pair interview, a kiosk questionnaire and a web-based questionnaire. The pair interview is conducted using the co-discovery-method to gather qualitative data. In this method participants, who know each other, are invited as pairs to evaluate the concept by discussing it with help of a questionnaire included in the presentation. This data is audio- and videotaped to be transcribed and analyzed later.

The advantage of this method is that there is no interviewer in the traditional sense taking part in the evaluation situation, and this is why the discussion may flow quite spontaneously. This may yield data that can not be captured using, for example, a structured questionnaire or a strictly structured interview. The disadvantage of this method is the analyzing of this qualitative data, which does not give any solid information and is quite time-consuming. [8] Five pairs of employees from each company are invited during a working day to participate in the evaluation using this method.

Looking for less time-consuming ways to carry out the evaluation we are trying out also two new ways to gather quantitative data for a quicker analysis – a "kiosk" questionnaire and a "web-based" questionnaire. In all of these evaluation options the same interactive multimedia presentation is used with a Lickert scale questionnaire and some open-ended questions. The "kiosk" questionnaire could also be called as a "semi-independent" method, in which an investigator is present to help the participant to conduct the evaluation but not interviewing or trying in any other way to take part in the evaluation session. The evaluation in this method is done by using a laptop. The data is saved to a database in the laptop.

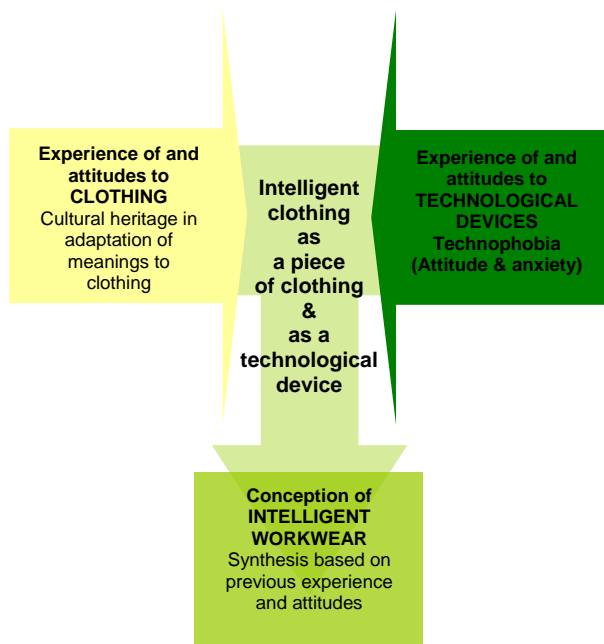
The "web-based" questionnaire is filled totally independently, which means that the participant is given an address to a website, where he or she can carry out the evaluation at any time using, for example, his or her own personal computer that is connected to the Internet. The data is saved as in previous method to a database, but this time on the web. After a certain period of time this database is closed and the collected quantitative data from both databases are analyzed with the help of computer-based tools and using quantitative methods. The advantage in gathering quantitative data with the help of a questionnaire is that the method is cheap, quick and performed totally independently. Furthermore, the presence of the investigator is not needed and the participant is also freed of possible investigator's influence. But this independency also makes it impossible to ensure that a suitable number of participants completes the questionnaire; and those who complete the questionnaire will most likely be the ones with rather extreme opinions about the issue in question [6].

### **CONCLUSION**

Through the analysis of the data, it was perceived that the intelligent workwear is expected to be perfect in two ways. Firstly, intelligent workwear is expected to be perfect as a piece of clothing. Secondly, it is expected to be a perfect technological device. Consequently, a piece of intelligent



clothing is no longer a piece of clothing in its traditional sense, but also a technological device. Accordingly, there is a great possibility that people will transfer their previous experiences of and attitudes to technological devices to intelligent clothing because to them it is a new technological device. [10] This process is shown in figure 3. However, it should be noted that the conceptions of intelligent clothing are not thoroughly explained by reviewing peoples' experiences and views of clothing and technological devices separately. While the intelligent garment is a product hybrid combining features from both the traditional clothing and technological devices, it is at the same time a new product in itself.



**Figure 3: Structuring the conception of intelligent workwear**

Background research is seen as a valuable source of information for the intelligent garment design, because the clothing is gradually re-shaped to give it a new form close to that of technological devices. This new clothing hybrid – called intelligent clothing – can be identified by its new electronic and textile-technology features. These new features have an impact on how individuals articulate their conception of intelligent clothing. This should be reflected on the development of intelligent garments in order to produce clothing that suits the individual's needs as a social and physiological being.

When designing new, complex and highly technical products the need for user knowledge changes. In addition to bringing the user into the process as the expert of his current needs and expectations the user should also be asked to tell his experiences and conceptions of technology. These conceptions seem to have an impact on the way that the intelligent garment is perceived because in a way the intelligent garment appears to the users as a technological device.

It is evident that the user does not have the answer to the question of what the intelligent product of the future should be like. Instead, user expertise on the current products and contexts of use can be utilized as a valuable part of the development processes of new and complex products. The utilization of user knowledge can be of valuable assistance in defining points of departure and goals of the design processes as well as in the evaluation of the suggested solutions.

The approach presented in the MeMoGa project enables us to integrate the user as part of the multistage product development process of complex and highly technical products. The user-centered approach is valuable in a situation where the development of the clothing hybrid, which consists of new technologies and traditional clothing, is yet time-consuming and expensive, because there is no established practice to rely on. The cycles of neither electronic industry nor clothing industry can solely be used as a starting point; instead, a new practice should be formulated.

The methods introduced in the paper aim to increase the understanding of the user at an early stage of developing a piece of intelligent clothing. The methods are structured for mapping the traditional clothing needs and experiences of current clothing in general and in specific contexts. On the other hand, they aim to gather data on people's conceptions of existing intelligent clothing and experiences of and attitudes toward technology in general. The approach also addresses the factor of acceptability of intelligent clothing, which, as an area, is still rather unknown and unformulated, if even studied at all.

The presented stages of utilizing user knowledge add special value to the testing and evaluation of concepts and products that might endanger the safety and well-being of the user when testing them in authentic circumstances. The presented model enables the utilization of user knowledge for products yet to be done at an early phase of product development. The model may prevent design shortcomings which might severely compromise the usability of the products as well as prove costly and time-consuming due to potential, unnecessary prototyping.

The paper has been an extensive presentation of the user-centered approach of the MeMoGa Project. The presented methods have proved to improve utilization of the knowledge of end-users through the examination of their intelligent clothing needs. In the future the presented approach could be of assistance in the development processes of intelligent clothing, especially because it has become evident that the traditional knowledge of the user does not provide a basis for intelligent clothing design.

The approaches in clothing design need rethinking to introduce new technologies as a part of clothing and to take them into account in the process. The adaptation of the product development cycle from the electronic industry may produce more suitable ways to study the usability of intelligent clothing than a direct adoption of the existing modes of operation from industrial or electronic design and product development. The development of the processes is aimed to avoid poor experiments in the integration of clothing and new technologies due to insufficient further knowledge. Instead, there can be the real needs, experiences and conceptions of users behind the production of a successful product.

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