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Interaction design in smart textiles clothing and applications

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11.1 Introduction

This chapter suggests that shifts in the textiles, electronics, and information and communication technology sectors will give rise to the area of intelligent textiles and clothing. The technical textiles industry in the USA and the EU is growing. The western clothing market has segmented into two distinct areas: low-cost, high-volume and high-end specification goods, for example sports performance, and designer-led fashion. The textiles industries of the USA and the EU are focusing on technical textiles for high-specification products, partly in response to the approaching end of the 'Multi-Fibre Arrangement'. Since 1974, the world trade in textiles and garments has been governed by the Multi-Fibre Arrangement. This agreement provided the basis on which industrialised countries have been able to restrict imports from developing countries. It expired at the end of 2004. In recent years the market growth in clothing has been fuelled by the emergence of new fibres, new fabrics and innovative processing technologies. This trend, in which technical innovations in textiles will become more important than the fashion content itself, is set to continue. The market has also been boosted by changes in consumer lifestyles. Many of these new developments have come from the technical textiles industry. High tech fabrics must continue to cross the boundary into everyday fashion apparel as well as into home interior furnishings to meet the challenge of future lifestyle needs and consumer requirements. Products that win will be those that enhance life quality in some way, and have added value in terms of functionality and performance. As we advance into the knowledge age, objects and material technology are forecast to pervade our material environment. The market for technology products generally is growing. What consumers require of products is changing, gravitating towards higher-order needs that stimulate the intellect by providing experience and sensory and emotional fulfilment. Such products are set to become the new commercial imperatives of the developed world.

The integration of smart functionality into clothing and other textile products will fundamentally change the cultures of clothing and interior products. It will also radically alter the relationship that people have with them and, hence, the way these products are designed and the materials used to produce them are developed. This chapter highlights key developments in computing, such as ubiquitous computing and human–computer interaction. It suggests, through current research in fashion and textiles at Central Saint Martins College of Art and Design (CSM), London, that the design of textile products will converge towards computing and the field of human–computer interaction design. The areas in which textile materials might develop, the ways in which different sectors of industry will need to collaborate and possibly converge for these developments to occur and the implications for the development process are also highlighted.

11.2 Knowledge age: dematerialisation of information and communications technology and the rise of ubiquitous intelligence

We are advancing into a knowledge-based economy, where ideas and information mean capital, and access to information and communication systems are the drivers. Science is increasingly affecting all aspects of our lives through products and services, as the market for technology products expands. According to Philips Electronics, based in the Netherlands, 'Our environment of the future will consist of invisible interactive systems that will be embedded in our living spaces and clothing, creating an ambient intelligence that could form a natural part of our life' (Marzano and Arts, 2003). The silver and black plastic products that currently house electronics and computers are set to vanish as technology dissolves into our material environment, i.e. interiors, buildings, furniture and clothing. As technology becomes dematerialised and embedded within these hitherto dumb products, such products will become active and intelligent. They will be the future mediators of technology. Our contact with these everyday objects will become a central focus in our lives, facilitating new methods of accessing entertainment, knowledge and communication. The following paragraphs contain examples of new methods of accessing information that have been in development over the last twenty years.

The area of ubiquitous computing is involved with how people access the computer intelligence embedded within everyday objects and devices, whose user interface is intuitive. Mark Weiser, chief technologist at Xerox Parc research centre, Palo Alto, CA, USA, is the father of ubiquitous computing, which he has dubbed:

> the third wave in computing. First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine staring uneasily at each other across the desktop. Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives. (Weiser, 1996)

IBM (International Business Machines) has identified:

> four major aspects of pervasive computing that appeal to the general population: Computing is spread throughout the environment; users are mobile; information appliances are becoming increasingly available; communication is made easier between individuals, between individuals and things, and between things. (Ark, 1999)

Pervasive computing is about systems that are embedded everywhere, which do not require the user to understand their inner workings.

There are various initiatives and research centres that address these shifts, for example the EU Disappearing Computer initiative, the IBM Almaden Research Centre, USA and the Massachussetts Institute of Technology, MIT Media Lab, USA. These initiatives examine the relationships we have with computer intelligence and how we interact with it. Also, there has been much activity in the last ten years in wearable computing driven by the computing sector. A good example of the ubiquitous computing vision is Smart Paper by Gyricon, which combines the best of modern computing technology with the best of established technology, the book. The vision of the paperless office has never materialised – in fact, we are using more paper now than ever before. This is because no one wants to read text off a computer display; the printed word on paper simply looks better. By coating paper with electronic ink, the contents of a book or a newspaper can change on command or continuously, when it is downloaded wirelessly.

Steven Mann is regarded as one of the inventors of wearable computing. A professor in the Computer Engineering Research Group at the University of Toronto, Canada, Mann has been working on his *WearComp* (wearable computer) invention for more than twenty years. He brought his inventions and ideas to MIT in 1991, which contributed to the foundation of the MIT Wearable Computing Project. Mann views wearables as a means of 'personal empowerment':

> Wearable computing facilitates a new form of human–computer interaction comprising a small body worn computer system that is always on and always ready and accessible. In this regard, the new computational framework differs from that of hand held devices, laptop computers and personal digital assistants. The *always ready* capability leads to a new form of synergy between human and computer, characterized by long-term adaptation through constancy of user-interface. (Mann, 1998)

Research in the area of wearable input devices that tries to address the notion of intuitive interaction, for example, the *Gesture Wrist* and *Gesture Pad* by Sony Computer Science Laboratories. 'These devices allow users to interact with wearable or nearby computers by using gesture-based commands' (Rekimoto, 2001). The researchers formulated a series of gestures that the wearable computer recognises as input signals. The gesture configurations, however, are not based on what might be considered intuitive human gestures, but on invented gestures.

The area of affective computing, pioneered by Roz Picard at MIT's Media Lab., has grown out of wearable computing. Affective computing is concerned with educating a computer (wearable or non-wearable) to recognise physical and physiological patterns and translate these into emotions. For example, 'expressions of emotion such as a joyful smile, an angry gesture, a strained voice or a change in autonomic nervous system activity such as accelerated heart rate or increasing skin conductivity' (Picard and Healy, 1997). By integrating sensors into clothing, a computer can sense a user's emotional status, enabling it to understand what its user wants and to effect responses that adjust to the user's patterns. Assumptions of emotional status are made on the basis of physiological behaviour, and much testing has been done on wearable computers (wearables) to test out emotion theories (an area of research in psychology, on which there are several classic theories) to attain a realistic assessment of the emotional meaning of physiological patterns. These tests are underpinned by the work of research psychologists who have been studying emotion and its relation to behaviour. Picard's team has developed a number of prototype affective wearables, such as earrings that measure blood volume pulses, sandals that gauge skin conductivity and glasses that check facial expressions.

From ubiquitous and wearable computing has arisen the field of human–computer interaction design. Interaction is the means by which users input changes to and receive feedback from an information technology (IT) system. Interaction design involves 'human cognition, context of use, platform of access, task analysis and user experience' (Macdonald, 2003). Interaction design comprises a distinct set of skills required to design the forms through which people can successfully use information technology in ways that are meaningful. 'As products and services are increasingly being created using information technology, interaction design is likely to become the key design skill of this century' (Macdonald, 2003). Examples of institutions across the globe engaged in human–computer interaction design include the Interaction Design Department Royal College of Art, UK, the Interactive Institute, Ivrea, Italy, the Things That Think Group, MIT, USA and the Almaden Research Centre, IBM, USA.

11.3 New commercial imperatives

Running in parallel with, and complementary to, the rise of ubiquitous computing and access to information are changing consumer requirements. The societies of the developed world are gravitating towards a culture that will be focused firmly on human senses. As we diverge from a purely material culture, a culture firmly focused on human senses is becoming epitomised by a requirement for more intensive experiences and higher order meanings. According to Maslow's hierarchy of needs theory, there are two levels of need, basic and meta, along which people constantly strive to move. Now that basic needs have been met in the developed world, people are striving to satisfy meta or higher-order needs. Meta needs include cognitive, aesthetic, self-actualisation and self-transcendent. Hence, the transition from making and marketing a product to developing non-tangible concepts that satisfy the demands of higher-order needs is underway and gaining momentum. Such needs include ideas, sensory and emotional fulfilment, cultural experiences and entertainment that stimulate the intellect. 'A new segment is emerging in the consumer market place, . . . "the Shedders" who . . . 'want to collect experiences, not possessions' (Quelch, 2002).

But what constitutes an experience? Wright has proposed a framework for analysing experience, which is made up of two parts. 'The first part is concerned with describing experience from four points of view which we refer to as the four threads. The second part is concerned with how we make sense in experience' (Wright, 2003). An experience is described in terms of its structure, our sensory and emotional engagement, and the actions and events over time and in a place. 'Experiences do not present themselves to us ready-made, people actively construct them through a process of sense making' (Wright, 2003). This process consists of our expectations, responses, interpretations and reflections of an experience.

In *The Experience Economy*, Joseph Pine and James Gilmore suggest that companies are moving beyond services, into experiences, in order to differentiate themselves. 'The experience economy is a new stage of economic offering.' Pine suggests that consumers must be drawn into the offering much like a viewer watching a theatre performance, but the viewer must also be an actor and participate: 'The consumer – sorry, the guest, must be drawn into the offering such that they feel a sensation. And to feel the sensation, the guest must actively participate' (Pine *et al.*, 1999).

Elements that stimulate our senses (sight, touch, sound, taste and smell) form our experiences of our environment. Products have always engendered some kind of sensorial quality. Intelligent materials will provide a new array of sensorial qualities, which will have an impact both on how we experience our surroundings and how we interact with them. An intelligent world will be one in which our interactions with products become ever more intuitive, using materials and systems that are responsive to our methods of communication, such as through touch and the use of body language. Intelligent materials will improve the control we have over our material environment and facilitate our creative interaction with it as we seek to be co-creators, tailoring experiences to correspond to our various moods. Gershenfield has stated that:

> in the laboratory and in product development pipelines, information is moving out of traditional computers and into the world around us, a change that is much more significant than the arrival of multimedia or the Internet because it touches on so much more of human experience. (Gershenfield, 1999)

As a result, we are seeing the rise in the industrial design community of what is termed experiential design, a method that is engaged with the value of the experience the user derives from using a product that will eventually become ubiquitous in all areas of design practice. To build a body of knowledge with which to frame experiences, designers have to investigate how people use, engage and feel about things and places.

11.4 Design and development: multidisciplinary collaboration

If the predictions are correct, a life where intelligence is embedded into everything is going to make the process of developing products and materials much more complex than traditionally has been the case, as it will encroach on different sectors and involve many complex issues. 'Dozens of smart fabrics and interactive textiles-enabling technologies are under development today, yet few of the OEMs or end-users of SFIT-enabled (smart fabrics and interactive textiles) solutions know about these technologies' (VDC, 2003). In other words, formal channels of communication do not currently exist between the users and the developers, nor between the discrete sectors that will be involved in developing materials. The development of electronic textiles is underway in defence research agencies in the USA, but it may be some time before such textiles enter the commercial domain.

To address this lack of dialogue, mechanisms are needed to bring the different industries closer. For example, the author coordinates the network Smart Textiles for Intelligent Products, funded by the Engineering and Physical Sciences Research Council, UK. This network is a think tank for future intelligent or smart consumer products and applications in the context of societies and markets of the future. It seeks to create new formal channels of communication by bringing together all sectors that will be involved in the design, development and production of the products into a new hybrid community. Those include: application-based industries (sports, clothing, medical, automotive, gaming, architectural and interior environments), defence agencies, cognitive science, social science, computing, electronics, electrochemistry, textile and fibre engineering, the design community (fashion, textile, industrial, interior designers and architects), economists, business and markets specialists, and lifestyle trend forecasters. Careful consideration has to be given to facilitating liaisons between people of different sectors, as each speaks a different language and thinks in different ways. Also, these various industries have discrete cultures, whose timescales for development and production vary hugely. Through its workshops, the smart textiles network aims to break down these barriers. There are two levels of workshop. The first comprises technology special-interest workshops, which bring together users with the different fields of expertise required to develop smart textile platforms, such as textile actuators and sensors and displays. This workshop brings together the potential users with the developers of materials. The second type of workshop explores the bigger picture by looking at projections of the future of society, lifestyle, work, travel, economics and markets, which members use to brainstorm collectively about possible product scenarios for the future. It is envisaged that these scenarios will set a trajectory for the development of smart textiles.

11.5 A new language for textiles: combining the real and the virtual

Given the vision of dematerialising information and communication technology (ICT), and the fact that much of our living environment is made from textiles that are familiar and 'friendly', soft and tactile, the ICT industries are now expressing a keen interest in textiles. One of the concerns consumers often have about new technology products is their tendency to become more sophisticated, thereby making them difficult to use and adapt to. Therefore, high tech must not make our products more complicated by having more components; rather, high tech should become seamlessly integrated into everyday objects without altering their character, and enhance their function. This section looks at how the design of textiles and clothing can converge with information and communication technology, and play a key role in this emerging genre of intelligent products and environments.

Embedded intelligence will completely alter the relationship that people have with everyday products and environments. No one yet knows how people will react to or engage with technology worn on their bodies or integrated into their homes. Intelligence has no tangible form. Seamlessly embedded intelligence will change the way designers design and develop products, as the focus will no longer be solely on the physical form of the product, but about intangible features, such as the notion of experience and emotional fulfilment that affect all the senses. If people are increasingly going to search for challenging experiences, then designers must create a context for experience. The designers' task will become one of giving form to virtual content. In the realm of human–computer interaction, content is seen as service, experience, communication and access to information. Intelligence will give the designer greater scope for creativity, a new tool with which to explore and apply computer intelligence in new ways. It will also challenge the role of the designer. Will the designer become more of a facilitator and enable users or wearers to be inventive by means of the technology? When the interface between the user and technology becomes truly ubiquitous, where the user does not need to understand the inner workings of the technology, then the potential of people to be inventive with the technology will be enhanced.

There are a number of fundamental issues that need to be understood before technology can be applied to the body or integrated into people's homes in a way that is truly meaningful. Addressing these involves a multidisciplinary effort, which examines conventions and cultures of product use and experience.

> As the human–computer interface becomes more pervasive and intimate, it will need to explicitly draw upon cognitive science as a basis for

> understanding what people are capable of doing. User experience and situation should be integrated into the computer system design process. (Selker and Burleson, 2000)

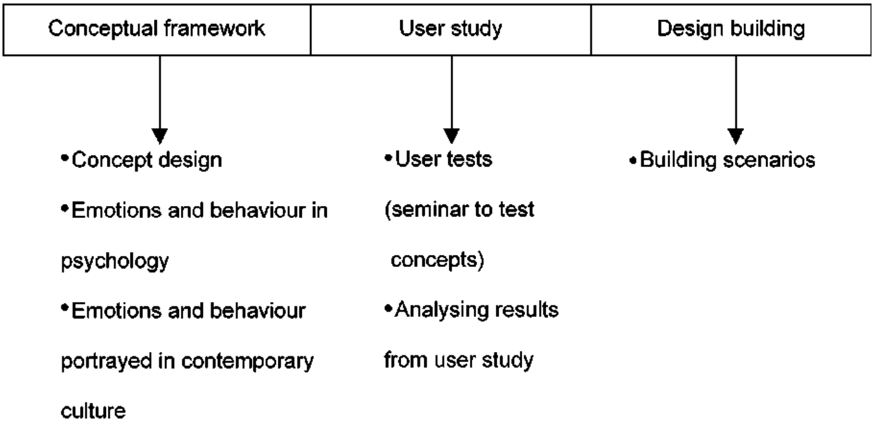
In examining the established roles and places that objects have in our everyday lives, and the psychology of interaction with and cognition of products, the human sciences and the designer of clothing and products should be involved in the designing of systems and materials from the outset.

Referring again to Smart Paper, Gershenfield has stated that:

> Choosing between books and computers makes as much sense as choosing between breathing and eating. Books do a magnificent job of conveying static information; computers let information change. We're just learning how to use a lot of new technology to match the performance of the mature technology in books, transcending its inherent limits without sacrificing its best features. The bits and atoms belong together. The story of the book is not coming to an end; it's really just beginning. (Gershenfield, 1999)

By building on what we know of existing products, like the Smart Paper example, we can begin to extend and augment the utility of clothing and other textile products, such as furnishings and building materials. 'Augmented reality offers designers of electronic products the powerful notion that we can interact with electronics through everyday real objects, with their inherent richness of interaction' (Djajadiningrat *et al.*, 2000).

Researchers in textile, clothing and interior environment design at CSM, London, are exploring the interface of intelligent technology as well as extending the application of computer intelligence, building on existing cultures of clothing and products. Disseminating concepts and ideas in the public domain has the potential to excite market demand and, therefore, prompt the development of materials. CSM researchers are exploring the application of existing technologies, such as wireless communications, textile antennas, chromic display materials, textile switches, textile circuits and microcomponent welding technology, in new ways. For example, the author's research, funded by the Arts and Humanities Research Board, UK, is entitled 'Interactive and Experiential Design in Smart Textile Products and Applications'. It is well known that textiles have their own language that is at once tactile, sensorial and visual, which textile and fashion designers have traditionally exploited to engineer or express a look, a concept or idea, by carefully composing and manipulating the many facets of its special vocabulary. The language of textiles will be expanded exponentially as a result of the integration of electronic technologies to build smart textile systems. This research aims to discover what new codes of interaction and experience will arise when textiles are transformed from a passive into an active, intelligent state. The notion of clothing as a tool box will be conceptualised. These tool boxes will



11.1 Design methodology.

enable the user to experience a sense of being creative, to communicate more expressive and emotional messages, and to engage in social interaction and gaming. The visual look and haptic qualities of smart clothing and interior environments can be customised by the user through non-verbal channels of communication that are intuitive, such as by gesturing and touching. The research seeks to rationalise the function of ICT-content together with conventional interaction with everyday clothing and their cultures, and map one onto the other to ascertain what new interactions and experiences will arise.

The interaction design process is an iterative one, where known conventions about how people use and experience products are used to map a conceptual framework for form of content and experience. The method used here makes reference to the methodology explored by the University of Art and Design, Helsinki, Finland (Mattelmäki and Keinonen, 2001). The framework is based on observations and research on how people use, interact with and experience conventional clothing and interior environments: the social psychology of people's clothing use and behaviour; sensory perception of textiles; how people communicate their emotions through non-verbal channels, such as body language; how people communicate through wireless communications systems, such as mobile phones and the internet; how expressive communication is portrayed in contemporary culture in terms of language, moods and colours. User group tests are based on a seminar in order to test conceptual assumptions. The results are fed back into the framework, which is then used to build prototype designs. These are also tested on user groups and are again fed back into the framework. This concept design method is now gaining momentum, and is illustrated in Fig. 11.1.

The following design scenarios suggest a way in which textiles and clothing can converge with information and communication technology. The scenarios make reference to a newly emerging area of expressive interaction, interpersonal and haptic (sense of touch) communication, and gaming. For example, the Super Cilia

Skin is an interactive membrane that was developed at the MIT Media Lab. The skin functions as a computer output device capable of visual and tactile expression, allowing gestures to be seen or an image to be felt via an array of actuators mounted onto an elastic membrane.

> Most computational tools rely on visual output devices. While such devices are invaluable, influential studies in neurophysiology have shown that physical experience creates especially strong neural pathways in the brain. When people participate in tactile/kinesthetic activity, the two hemispheres of the brain are simultaneously engaged . . . assuring that new information will be retained in long-term memory. (Raffle, 2003)

Another example of interpersonal communication fusing haptic technology is ComTouch, again developed at the MIT Media Lab. ComTouch is a handheld device that translates finger pressure into vibration, thereby augmenting voice channels of communication. 'A device that conveys touch might allow for more expressive interactions' (Chang *et al*., 2002).

11.5.1 Tools for remote interpersonal communication

The aims of this scenario are to develop: a clothing concept that facilitates the sending of expressive messages to friends or partners by conveying a sense and experience of touch or presence through clothing; and clothing that is a mobile aid that facilitates the expression of other aspects of human communication, supporting the user's need for subtle communication and complementing existing channels of communication.

This scenario is built on some conventions and cultures of clothing and textiles as expressive media. One of the main attributes of textiles is that their huge range of tactile qualities (cool/warm, hard/soft), as well as acoustic properties, has a certain effect on the way people feel and respond to them. Sensory science or psychophysics is an emerging area of experimental psychology that was first applied to product areas such as food. It is now being applied to textiles to measure people's subjective experiences of textiles when touched. Psychophysics is being developed for use in e-commerce applications where the tactile qualities of textiles need to be conveyed visually. Touch is an important part of human interaction and communication, for example, warmth and affection are often conveyed through touch. Also, people communicate through gesture or body movement, which constitutes a type of language, a 'language of emotions' according to Darwin (Darwin, 1965). Clothing is an emotional medium; it envelops us, is our second skin and is in some way an extension of our body. 'Dress is the way in which individuals learn to live in their bodies and feel at home in them. Dress is . . . an intimate experience of the body' (Entwistle, 2000). Therefore, this scenario builds on the close bond we have with our clothing, which connects people through touch and gesture and allows more expressive interactions to take place remotely. The

Table 11.1 Tools for remote interpersonal communication

Emotional expression or mood	Sending message/ switching action	Receiving message/change effected (in recipient's clothing)	
		Display	Actuator
Warmth	Gentle squeezing of arm	Yellow	Squeezing sensation
Love	Stroking of arm	Red	Soft tactile
Affection	Embrace/arms wrapped around the wearer	Yellow	Hugging sensation

conceptual framework for remote interpersonal communication is illustrated in Table 11.1.

Sending the message: The signal that is sent is based on the relationship that the sender has with the recipient. The message can be purely non-verbal, an expression of how the sender is feeling or a feeling that he or she wants to convey, or illustrative, reinforcing verbal messages over the telephone. The sender's interactions (or switching actions) with his or her clothing are based on conventions of touch and gesture associated with expressive communication and/or touch or gesture that serve to back up verbal communication. For example, emotional expressions that demonstrate affection could be conveyed through touch and gestures such as an embrace or stroking an arm/sleeve. The garment consists of pressure-sensing and gesture-sensing textiles connected to a textile antenna by a textile circuit, to which a communications chip is welded. When the pressure-sensing textile is pressed or stroked, or when the gesture sensor senses a gesture or movement, a signal containing a code is sent to the communications chip. Each type of pressure or gesture is assigned a code.

Receiving the message: The change effected in the recipient's clothing is based on translating the expressive meaning of the touch or gesture into colour or tactile configurations, realised in a chromic display material. The pressure or gesture code is picked up by the receiver's antenna, causing the communications chip to send a signal to the display on which a colour appears. The emotion expressed by the sender is translated into a colour, which is based on known colour psychology and cultural values of colour. Colours are purported to have emotional, physical and behavioural values; for example, in many Western cultures the emotional value of red is love, vitality, courage, passion and danger. Colours have positive and negative effects on us, caused by their energy entering our bodies. By being able to effect a change in colour in the receiver's clothing, the sender can either let the recipient know how he or she is feeling or influence his or her mood. The receiver's garment is composed of a textile antenna and communications chip, which are connected either to display materials or to actuator textiles by textile circuits.

Touch and gesture can be conveyed more literally using actuator textiles; for example, an embrace sent could be conveyed through the contraction of the fibres of the textile, causing the garment to hug the body. Touch can also be tactilely sensed, for example, where different haptic qualities of textiles can be conveyed. Configurations of haptic qualities are based on research conducted on the sensory properties of various types of textiles. The concept could also be extended to include interior environments, where a sense of presence can be conveyed via furniture and furnishings.

11.5.2 Tools for social interaction and social gaming

'Social interactions are the focus of our existence. We are social animals, and for any technology to be useful, it must eventually support socialization' (Ark, 1999). The aim of this scenario is to develop clothing concepts that facilitate social interaction by provoking and eliciting emotional responses. People can interfere and interact with the clothing of others in the vicinity by changing the visual appearance (colour, pattern), tactile quality or shape of the clothing.

This scenario is built on some conventions of clothing as an expressive medium and on the social nature of humans. Clothing facilitates social interaction, as it is a means of making the body social. It can create a sense of belonging or enable anonymity through a process of managing personal appearance to form a total composite image, thereby provoking responses from others. Clothing can be used as a channel of communication, where 'one person would *say* something to another person with the intention of effecting some change in that other person. . . . The effect on the receiver is important in that it is the effect on the receiver that constitutes social interaction' (Barnard, 1996). The effect can be an emotional response, change of behaviour or state of mind. People express and communicate their emotions through their behaviour and body language. 'Bodily, non-verbal communication operates within a social context, but also . . . the messages conveyed by bodily expression are about the society itself' (Douglas, 1971). The conceptual framework for this scenario is based on people's clothing behaviour, as well on explorations into the social behaviour of people. This scenario is also built on the emerging area of personal electronic data exchange and on the fact that gaming is becoming more of a social activity. The vCard is an electronic business card, which is a new means of sending business cards to people via electronic devices. Developers of electronic games, such as Sony, are looking into making gaming less of a solitary activity and more of a social one. The conceptual framework for social interaction and social gaming tools is illustrated in Table 11.2.

Active clothing can augment people's interactions with each other in social spaces by eliciting responses. The wearer can attract attention to himself or herself, let other people know how he or she feels or simply have fun by changing the appearance of someone else's clothing; for example, by sending someone a colour.

Table 11.2 Tools for social interaction and social gaming

Emotional expression or mood	Sending message/ switching action	Receiving message/change effected	
		Display	Actuator
Being playful	Squeezing or tapping arm, shoulder	In recipient's clothing: orange	In recipient's clothing: squeezing sensation
Sending personal message	Positive body language	In recipient's clothing: yellow	In recipient's clothing: pressing sensation
Social gaming	Gaming actions	In recipient's clothing: hit spots	In recipient's clothing: hit sensation

As in the previous scenario, interactions between people are based on gestures and actions as communicators of emotion, which serve to trigger changes in either the sender's or the recipient's clothing.

11.5.3 Tools for creativity and gaming

The aims of this scenario are to develop textile concepts of clothing and the interior environment that facilitate a sense of being creative by allowing the user to be a co-creator. The user or wearer customises the visual appearance (colour, pattern), tactile quality or shape of the textile, thus giving the wearer a sense of self-expression.

This scenario is built on some conventions and cultures of clothing. Clothing facilitates individualistic expression, allowing individuals to differentiate themselves and to declare their uniqueness.

> It seems that more and more people are becoming addicted to the feelings they get when they do wear something new. Those feelings may be of increased or reinforced uniqueness or of pleasure in presenting a different appearance to the world. Individuals may also derive aesthetic pleasure from either 'creating personal display' or from appreciating that of others. (Bernard, 1996)

Clothing can also serve to reflect, hide or generate mood. Sometimes, by expressing a mood, the wearer can influence other people's moods. This scenario is also built on the celebrity culture or limelight syndrome, prevalent in Western cultures, and on the field of gaming. Companies such as Sony and Microsoft are looking at ways of making gaming more interactive and fun; for example, researchers at Sony

Table 11.3 Tools for creativity and gaming

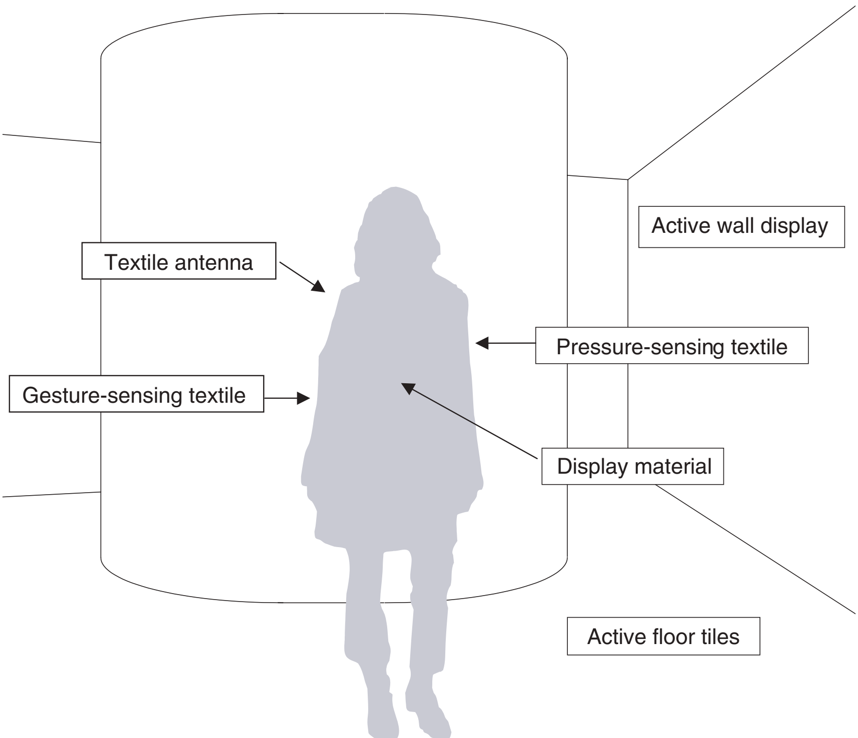
Emotional expression or mood	Switching action	Change effected	
		Display	Actuator
Customising aesthetics: personal display	Virtual paint-box: drawing hand down sleeve effects brushed colour changes	User's clothing: any colour	User's clothing: change in size, shape, tactile quality
Role play/fantasy: celebrity, icon, film character	Role play actions	Mediated environment: provides context	User's clothing: force feedback
Game/sport: e.g. Jujitsu	Jujitsu actions	Mediated environment: provides game context User's clothing: hit spots	User's clothing: force feedback

are investigating the use of gestures as game commands to replace the joystick. The conceptual framework for creativity and gaming tools is illustrated in Table 11.3.

Clothing can be customised to alter the aesthetics, colour, pattern, shape and size of clothing according to the size, taste and mood of the wearer. The wearer can be expressive by changing aesthetics and effects, for example, changing light, colour and patterns, shapes and textures. Gaming or role playing can be enhanced by mediated environments, where the space is also smart or active. Mediated spaces have no interface; people simply speak and act as they normally do, and the space understands them. In a mediated environment the user can live out fantasies and engage in games, sport, performance or role playing/acting in their own homes, for example, where body actions are read and sent to a wall display. By monitoring performance, the clothing can augment sports activities, for example, by embedding sensors in running shoes or in the flooring, facilitating feedback on technique. Clothing can also enhance performance by providing extra strength, which may be of particular benefit for those with injuries or disabilities.

11.6 Technology enablers

The term 'smart' is used to define a material that reacts in a particular way when exposed to stimuli such as environmental changes, for example, temperature or electrical currents. The following technologies are examples of developments and applications in the field to date, and illustrate the types of textiles and systems that will be used to explore the design scenarios. A range of conductive textiles has



11.2 Location of active materials in clothing and in an environment.

been tested for their properties as antennas and circuits by Cliff Randell, Matthew Chalmers and Henk Müller who are members of the UK computing research project, Equator, in collaboration with the author. Figure 11.2 illustrates the location of active materials in the concepts of active clothing and environments.

11.6.1 Conductive textiles: switching and sensing

The first attempts to make smart textiles dealt largely with the area of integrating electronic functionality into textiles for the transmission of signals, using conductive fibres such as carbon with mounted electronic components to build smart textile systems. Fabrics made from conductive fibres are used to sense pressure for keyboards, such as the PDA keyboard by ElecSen, UK. This type of conductive textile can sense pressure as well as the degree and type of pressure, so that the system can differentiate between pressing and stroking. Softswitch, UK, is made from conductive textile materials and a quantum tunnelling composite (QTC) with unique pressure-controllable switching properties. Applications exist: in pressure sensing, for example car seats; in switching, for example, switches that allow electronics to function within clothing; in the medical field, for example, to monitor the position of hospital patients while in bed or in wheelchairs to prevent sores.

11.6.2 Conductive textiles: transmission of signals

Philips Research, UK, used knitted conductive fibres to produce a textile mechanical sensor that can measure gestures and movements. Infineon, Germany, has woven textile circuits from silver-coated polyester fibres.

11.6.3 Conductive textiles: generation of heat

Changes in the colour of fabrics can be triggered by sending an electrical impulse through a conductive fabric on which thermochromic ink is printed, as was done by International Fashion Machines, USA (a spin-off from MIT) in their development of Electric Plaid. Gorix, USA, has used conductive fabrics as heating elements for temperature-controlled car seats and performance outerwear.

11.6.4 Conductive textiles: antennas

Conductive copper and silver-coated nylon fibres have been shown to act as antennas. Philips Research, UK, and Randell, Baurley, Chalmers and Müller have tested such textiles.

11.6.5 Wireless networks: using the human body as a network

Researchers from NTT DoCoMo Multi-media Labs and NTT Microsystem Integration Labs in Japan have used the body's electrical field to transmit data at an Ethernet-like 10 megabits per second. The network, ElectrAura-Net, uses a combination of the electric field that emanates from the body and a similar field emanating from special floor tiles to transmit information.

11.6.6 Biometric sensing

The scenarios could be extended further by the use of textile systems that sense the physiological signals of the wearer (sweat sensors, respiration monitor, pulse/heart monitor, body temperature sensor, brain activity monitor), which would allow the textile system (clothing and environment) to recognise how the wearer is feeling and respond accordingly.

11.7 Future technology enablers

Many electroactive polymers are currently being developed by the electrochemistry industry, a convergence of electronics and chemistry. The electrochemistry sector is developing electroactive polymers for what are being termed plastic electronics. Examples of these include polymer light-emitting diodes (LEDs), which are printed by ink jet onto flexible substrates for flexible displays and packaging by companies such as Plastic Logic, UK, a spin-off from the Cavendish Laboratory, Cambridge University, UK. The Cavendish Laboratory is also developing plastic electronic circuits from polymer transistors, as well as sensors and memories for smart electronic devices. The future of truly smart textiles lies in the potential for technology convergence, where these electroactive polymers or molecular electronics are processed into or fabricated onto, fibres and fabrics. If transferred to the textiles industry, these polymers will make possible the production of soft intelligent textile products that will permit a broad spectrum of functions and capabilities.

11.7.1 Electroactive polymers: light-emitting

Visson has pioneered a light-emitting fabric, where conductive fibres are coated with electroluminescent polymers. The electrons within the polymer become excited upon the application of an electric charge, thus generating photons, which is coloured light. Clemson University, USA, has developed dynamic colour-responsive chameleon fibre systems. Hollow polyaniline, an inherently conductive fibre, is coated with an electrochromic substance; the hollow fibre membrane transports ionic charge carriers to the electrochromic coating, acting as dopants to turn the colour on or off.

11.7.2 Electronic ink (E-Ink)

The principal components of electronic ink are millions of tiny microcapsules. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid. To form an E-Ink electronic display, the ink is printed onto a sheet of plastic film that is laminated to a layer of circuitry. The circuitry forms a pattern of pixels that can then be controlled by a display driver. E-ink is printed using existing screen-printing processes onto virtually any surface, including glass, plastic, fabric and even paper. Philips and E-Ink are to launch a new flexible electronic display in 2004.

11.7.3 Electroactive polymers: power

One of the biggest problems in wearable and integrated electronic technology is power. Power Paper's core technology is an innovative process that enables the printing of thin, flexible and environmentally friendly energy cells onto a polymer film substrate, by means of a simple mass-printing technology. Power Paper cells are composed of two non-toxic, widely available commodities, zinc and manganese dioxide, which can be printed onto virtually any substrate.

11.7.4 Electroactive polymers: actuators

Actuator polymers are a new breed of polymer that responds to external electrical stimulation by displaying a significant displacement in shape or size. When a current is applied, the polypyrrole polymer's accordian-shaped molecules stretch out like human muscles; when the current stops, the polymer contracts. Electroactive actuator polymers are currently being investigated by institutions such as the US military for the next generation of battle suits. The Jet Propulsion Laboratory, NASA, USA, is using them to attempt to develop artificial muscles for applications such as miniature gripper arms for robots to be deployed in explorations. If fibres could be fabricated from actuator polymers, textiles that change their shape and surface texture could be realised.

11.7.5 Future fabrication: nano

The application of intelligent functions into textiles using the aforementioned electroactive polymers will rely on nanotechnology. 'The currently existing multibillion-dollar world market influenced by nanotechnology is supposed to affect nearly any industry sector in the future' (Institute of Nanotechnology, 2003). Nanotechnology will be the next industrial revolution following the knowledge age. Future developments in biotechnology and nanotechnology could make it possible to alter the basic characteristics of almost any substance. 'From a commercial viewpoint, such developments would enable manufacturers to tailor their products and product performance characteristics exactly to the needs of their customers' (Textiles Intelligence, 2002). Nanotechnology is the creation of functional materials, devices and systems through the control of matter on the nanometre scale. Research is being conducted on modifying the surfaces of fibres, and on grafting materials onto fibres to create multifunctional, responsive and adaptive fibres. The main aim is to tailor a hybrid nanolayer of polymer film that will afford a number of functions and properties, for example, colour change. The electronics sector is developing nanowires that are grown from vapours of atomic ingredients and that act as diodes or other electronic components.

11.8 Conclusions

The development of fundamental textile technology platforms for application to a new genre of intelligent products and environments will require cross-sectoral consultation and collaboration. Also, to ascertain where the market pull that will influence the direction of the development of materials might come from, concepts and ideas should be floated in the public domain. The information and communication technology community will need to collaborate with those in design and the human sciences, if intelligent products and systems are to be embraced by consumers.

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Central Saint Martins College of Art & Design is the largest of the five colleges that constitute The University of the Arts London. The University of the Arts London is the largest institution for education and research in art and design in Europe.

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