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Smart protective textiles for older people

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Abstract: This chapter considers the application of smart textiles and wearable technologies to enhance the functionality of a multi-purpose, protective 'clothing layering system' for the benefit of older people. Little has been done to address physical and cognitive limitations when developing smart textile products and services appropriate to the real-world needs and aspirations of active older users. The author looks at how the appropriate design of smart clothes has the potential to promote independence and wellbeing, and may enable participation in healthy exercise in the everyday lives of the active ageing.

Key words: smart clothes, layering, active ageing, older people.

9.1 Introduction

There is a lack of understanding of the actual and potential role of wearable technological advances in everyday lives of older people, and developments have often failed to address their aspirations. As technical textiles merge with wearable electronics and information communications technologies, many textile-based products have been developed with little concern for aesthetic appearance, comfort and ease of use. Such advances may be utilised to promote health and wellbeing but may not be readily accepted by some older users due to badly designed user-interfaces that have small controls or displays that may prevent someone with a minor impairment from using them effectively. Little has been done to address physical and cognitive limitations when developing these new products and services to ensure that they are appropriate to the real-world needs of older users.

This chapter considers design innovations in smart textiles and wearable electronics that may be introduced into the various layers within a functional clothing system, with the potential to protect and enhance the autonomy, independence and wellbeing of older people. As Huppert (2003) explains 'Simple alterations in the design process and its outputs will attract the growing body of older consumers, and result in older people, in general, leading more fulfilled and independent lives, to the benefit of individuals, families and the society at large'.

The author recognises that design practitioners must be central to the future cross-disciplinary product development team, in addressing design requirements for the protection of the ageing, related to the demands of their lifestyles. This chapter introduces design challenges to do with the changing ageing body and describes a range of textiles and applications in a shared language that may be understood by designers, older people, their families, and their carers, in order to introduce textile-based products, enhanced with unobtrusive assistive technology, with controls that are easy to operate, to older people who will willingly wear and enjoy them.

9.2 The demands of the changing body

9.2.1 The active ageing

The ageing community may be segmented as the Active Ageing, approximately 60–75, and as fourth age, for people over 75, or those who are dependent on care. 'We are now living in a unique historical period. Never before could people expect to live so long. Never before have physical and mental capabilities remained so high into advanced old age' (Huppert, 2003). Today, the average age of death in the UK is around 80, with diseases and impairments often rare until advanced old age. However, our images and expectations of ageing are derived from the way in which individuals aged in the past. Older people today are fitter and more capable than in the past, and their capabilities are related to how actively they use them. 'Consumer research and marketing have failed to realize the relationship between changes in the leading values, views, and behaviours of the marketplace and the New Customer Majority' (Wolfe and Snyder, 2003). Clothing is a major contributor to how people define and perceive themselves and the 'Baby Boomer' generation has been accustomed to making choices in the design of their clothing throughout their lives, since their teenage years in the 1960s. Throughout this period, great innovation has taken place in technical textiles with, most recently, the emergence of smart textiles and wearable electronics, with the potential to enhance health and wellness, and offer a range of protection to the ageing body.

In terms of chronological age, certain physiological changes in the older body result in clothing that may be uncomfortable due to inappropriate fit, styling, proportion and weight, and also difficult to put on, take off and fasten. Much impairment is due to restricted levels of physical activity. 'Older people have the greatest need to maintain their exercise levels, and those with some disease related impairment may have the most to gain' (Metz and Underwood, 2005). Fall-related injuries are a major cause of pain, disability, loss of independence and premature death, with worldwide statistics reporting that approximately 28–35% of people aged of 65 and over fall each year, increasing to 32–42% for those over 70 years of age (World Health Organisation, 2007). 'There is growing evidence that keeping fit and supple in old age is a good way to protect the body from a number of medical problems, such as high blood pressure, heart disease and osteoporosis, as well as helping to prevent falls and broken bones' (Metz and Underwood, 2005). 'It is a mistake to think of the older user as a wheelchair user or as severely disabled, hard of hearing or partially sighted. Older users are that vast number of people who, in advancing age, have little discernible impairment, but have a strong drive to remain independent and to contribute to the community, but are hampered by inappropriate design' (Huppert, 2003).

9.2.2 Monitoring vital signs

Vital signs include body temperature, respiratory rate, heart rate (pulse), and blood pressure, all of which may be observed, measured, and monitored to enable the assessment of the level at which an individual is functioning. Normal ranges of measurements are liable to change with age and medical conditions. Body temperature may be checked for any signs of systemic infection or inflammation in the presence of a fever or for hypothermia caused by prolonged exposure to low temperatures. Respiration rates and difficulty in breathing may increase with fever, illness, or other medical conditions. The pulse rate gradually decreases from birth to adulthood, then increases with advancing old age. The pulse rate will generally increase with elevation in body temperature and also as a result of pain, as well as with emotions, such as fear, anger, anxiety, and excitement.

High blood pressure, or arterial hypertension, can be an indicator of many problems and may have long-term adverse effects as a risk factor for strokes, heart attacks, heart failure and arterial aneurysms; and it is a leading cause of chronic renal failure. High blood pressure tends to increase as people get older, and even moderate elevation of arterial pressure leads to shortened life expectancy. Below the age of 55, men have a greater chance of having high blood pressure than women of a similar age, while women are more likely to have high blood pressure after the menopause than before. Some diseases lead to a disruption in the flow of fluids, leading to swelling in the legs, ankles and feet, known as oedema. A blockage of the lymphatic system, resulting from cancer or lymph gland inflammation, can also lead to leg and wrist swelling. Preventative lifestyle changes are recommended to ensure good cardiovascular health and help prevent the onset of disease, such as dietary changes, increased exercise, giving up smoking and losing weight.

Homeostasis, in relation to the thermal regulation of the ageing body, has a direct relationship to textile selection. In terms of protection of the clothing microclimate, clothing can impede evaporative heat transfer by disallowing movement of water vapour across the various layers, creating a microenvironment next to the skin surface. The surface area coverage (and permeability) can determine the extent and nature of this microenvironment. As perspiration increases, there is a reduction in the capacity of evaporation to remove heat energy and this means that most of the sweat from the body becomes trapped within the fibres and textiles. Clothes saturated by sweat can affect the thermal characteristics and influence further heat transfer rates. Textiles may be selected to reduce the effects of sweating, through 'wicking away' moisture.

9.2.3 Physical performance

Physical exercise can improve physical performance in later life, as well as aspects of intellectual performance. Particular aspects that decline with age, and which are important for functioning, include mobility, dexterity and the ability to reach and stretch (Metz and Underwood, 2005). 'To perform physically at a level which ensures an independent lifestyle requires adequate muscle strength, muscle power, flexibility, balance and cardiorespiratory endurance' (Huppert, 2003). Muscle strength begins to decline quite sharply from around age 50. Hand strength, for those of 75+, is less than half of the value for young adults. Muscular strength is rarely used without movement, so muscular power (which combines strength and speed) is required in dynamic activities such as climbing stairs, rising from a chair, getting onto a bus or out of a bath. Muscle power tends to decline even more sharply than muscle strength (Huppert, 2003).

Physical capabilities are influenced by the size and shape of the body. From mid-adulthood, people begin to lose height, with the average height of 65–74 year olds being 5 cm less than the average height of those aged 16–24. This height difference is almost double for those aged 75+ (Department of Health 2002). Other bodily dimensions also change with advancing age; feet become broader, waistlines thicken as the ratio of body fat to muscle changes. Physical strength is generally related to body size, with women physically weaker than men at all ages, and with weaker muscles and a poorer power-to-weight ratio. Their disadvantage is even greater on weight-bearing activities, such as walking and stair climbing (Huppert, 2003).

Flexibility and adequate range of movement are essential for many activities, with loss of range, especially in the shoulder joint, common in old age. Arthritis causes swelling and pain in the joints, and limited movement and weakness in the arms and hands, resulting in poor dexterity and restricted flexibility while dressing and undressing, and difficulty in getting a firm grip or in making precise finger movements (Metz and Underwood, 2005). Double actions, such as push and twist, are particularly difficult for people with poor dexterity. Balance requires a complex integration of sensory inputs followed speedily by precise motor reactions. To restore equilibrium of the body mass, to avoid falling after tripping, requires rapid powerful movements, and these decline with age, resulting in a greater tendency to fall (Huppert, 2003).

9.2.4 Sensory capabilities

'To obtain information about the world around us, we rely on our five main senses – vision, hearing, taste, smell and touch. Physiological changes occur in all our sense organs as we age, reducing our sensitivity to incoming information' (Huppert, 2003). As the lenses of the eyes lose some of their ability to accommodate, older people will find a decline in their ability to see detail, focus on near objects, discriminate differences between levels of contrast, adapt to changes in brightness, and manage in extremely bright light. A yellowing of the lens will cause impairment in colour perception. Older people will experience hearing loss that may cause problems in demanding listening situations, such as detecting faint sounds in the presence of background noise. Amplification can improve some aspects of hearing but those who are hard of hearing often show symptoms of depression and may become socially withdrawn or, alternatively, cope with their difficulty by doing most of the talking rather than struggling to listen (Huppert, 2003).

Perception of taste is intimately associated with sense of smell; different odorants stimulate different receptors at the back of the nose. There is little loss in ability to identify odours up until the age of about 65 but, beyond that age, impairment can be marked, affecting appetite regulation and food selection, reducing pleasure from fragrances and putting people at risk from an inability to detect dangerous smells, such as decaying foods or leaking gas. 'The skin, source of most of our tactile sensations, declines in sensitivity with age the same as other sensory receptors' (Wolfe and Snyder, 2003). Touch is a combination of the stimulation of three types of receptors on the skin: pressure, pain and heat/cold. As ageing skin receptors die off, hands become less sensitive to pressure. Points touching the skin need to be further apart for an older person to recognise two sources of pressure rather than one, leading to a reduced ability to differentiate between shapes and textures (Huppert, 2003).

9.2.5 Cognitive capabilities

'The ability to function independently is as much related to our mental capabilities as to our physical capabilities. The term cognition refers to the set of mental capabilities by which we pay attention to the world around us, interpret the information that comes in from our senses, learn and remember, solve problems and make decisions' (Huppert, 2003). While mental capabilities decline, impairment may be evident only when elders face a situation that is novel, demanding or complex. Mental abilities, based on information acquired over long periods of time, tend to remain stable, whereas abilities that require the rapid assimilation and analysis of new information, tend to decline quite sharply. Cognitive ability is influenced by physical disorders, depression, medication, stress levels and amounts of sleep and, with ageing, these factors may increase cognitive impairment. However, '80% of those aged over 80 do not have dementia, and many of these individuals show little evidence of cognitive impairment even in their 90s and beyond' (Huppert, 2003). Learning and new experiences can result in the formation of new connections between brain cells, with 'use it or lose it' applying as much to the brain as to our muscles (Hultsch *et al.*, 1999).

When constantly bombarded by sensory information, people must be selective while, at the same time, monitoring other sources of information so as not to miss important or dangerous signals. The ability to sustain and shift attention between incoming sources decreases with age, especially when doing two or more things simultaneously. Literacy remains essential for understanding instructions, such as the functionality of electronic devices or taking medication, and in understanding information derived from print, internet, and street signs. Much information is verbal, although the meaning of symbols should be remembered to prompt appropriate actions. Numerical and calculation skills also decline while, 'at any age, our ability to understand numerical concepts and solve numerical problems depends on the way in which the information is presented' (Huppert, 2003). Visual–spatial abilities tend to decline significantly; for example, when walking or driving around a new environment or following a map.

Older people may forget to perform an action, such as posting a letter, keeping an appointment or taking medication, but, being aware of their frequent memory lapses, are more likely to use memory aids such as diaries, alarms and other reminders. As with other cognitive capabilities, the degree of decline or impairment in resources to deal with complex decisions is strongly associated with education and experience. Problem solving and decision-making are also influenced by social and political attitudes, cultural background and individual attitudes towards taking risks. Increasing life expectancy has placed a high value on independence and self-reliance, meaning that executive function capabilities are more important for older people than ever before (Huppert 2003).

9.2.6 The psychological feel-good factor

Some attitudes remain largely unchanged from youth – hence the common feeling that what is odd about growing old is that you do not feel any different (Metz and Underwood, 2005). The most basic life value is the will to live, and the most basic behaviour consists of acts in service of self-preservation. 'Survival scenarios are the sum total of everything needed for a safe, comfortable, and pleasurable existence' (Wolfe and Snyder, 2003). 'There is an increasing emphasis on disciplining the body through virtuous nutrition and physical exercise, together with social engagement' (Metz and Underwood, 2005). 'Most design-oriented research on older consumers tends to focus on older people in isolation, rather than within the context of their extensive kin network with its implications for time use, communication, travel and spending' (Huppert, 2003). In terms of outdoor activities, 'surveys find that walking is by far the predominant activity reported in surveys of older people, half the men in their 60s and 40 per cent of women reporting this' (Metz and Underwood, 2005).

This chapter looks at the application of smart textiles that may enhance the functionality of a multi-purpose, protective 'clothing layering system' for the benefit of older people. It looks at how the appropriate design of smart clothes has the potential to promote independence and wellbeing, and may enable participation in healthy exercise in the everyday lives of the active ageing.

9.3 The clothing layering system

9.3.1 The sports-type layering system

The functionality of the sports type 'layering system' is driven by textile innovation as a basis for the application of emerging smart textile technologies into lightweight, compact and easy-care protective clothing for the ageing community. The system typically comprises a moisture management base-layer, mid insulation layer(s), and a protective outer layer. Textile innovation now embraces the concept of the 'soft shell' that incorporates a hybrid mix of the protective attributes of the outer shell garments with the comfort and insulation of mid layers. In addition, with the introduction of textile-based sensors, there is a need for a close fitting 'skin layer' for men and suitable intimate apparel for women. Key aspects of the maintenance of comfort are effective moisture management and thermal regulation through the application of special fibres and fabric constructions, and the provision of ventilation within the garment(s). In the case of the ageing wearer, elements of personal protection may be incorporated into the system. To function effectively, the garments, and components within the layering system, should benefit from technical and aesthetic design coordination in terms of style, fit, silhouette and movement, as well as suitability and positioning of details and closures (McCann *et al.*, 2009). The layering system may now have enhanced functionality to help address demands of the ageing body through the incorporation of smart textiles in both clothing and accessories. The design, overall comfort and the usability of the technology interface are key to user acceptability.

9.3.2 Base layer/skin layer

The base layer is normally of knitted construction, with varied structures placed around the body to aid moisture wicking and offer increased support and protection. Older people may be at risk in relation to survival in extreme cold if a high moisture level is absorbed within the garment base layer and the temperature drops. There are obvious advantages in the application of high moisture wicking, quick drying textiles for the onset of incontinence. Microcapsules containing specific additives, such as aroma therapeutic essential oils, may be impregnated into the fibres. The attributes of stretch fibres have revolutionised the technical and aesthetic design and comfort of 'underwear' and intimate apparel, and may be incorporated, in varying percentages, in warp and weft knitted structures, laces and nets, woven constructions and narrow fabrics. The properties of elastomeric and mechanical stretch are of particular relevance to garment design for older figure types. A varied percentage and direction of stretch enhances comfort and fit in providing engineered areas of support or enhanced movement that enables the wearer to put on and take off the garment with greater ease. Stretch also contributes directly to garment fit and to the embedding of textile sensors and wearable electronics to be held in appropriate locations within garments, currently found in close fitting base layer garments and bras for sport and for medical applications.

9.3.3 Mid layer

The mid 'insulation layer' may be varied in thickness, or bulk, to effect its ability to trap 'still air' for heat retention. It may be made up of more than one garment, with examples such as jackets, smocks, gilets, traditional knitwear and felted garments. Typically, the insulation is made up of lightweight man-made down, sliver knit constructions known as fibre pile or fake fur, and increasingly sophisticated developments in knit structure fleece fabrics, primarily in weft knit, and predominantly of polyester fibre. Fleece pile garments may have 'body mapped' engineered knit in varying patterning, depths of pile and finishes, to provide variable protection around the body (McCann *et al.*, 2009). Older people are susceptible to cold and may benefit from adaptations of existing and emerging technologies initially adopted in performance sportswear, such as heated panels. Mid layer garment design should be compatible, in terms of cut and styling, with that of the base and outer layer garments, to avoid impeding movement.

9.3.4 Soft shell

The 'soft shell' layer incorporates many of the protective elements of outer shell garments, combined with the comfort and insulation of mid layers. Soft-shell fabric technology is normally a laminated assembly of two fabrics with a membrane in the middle. Typically the layers comprises a combination of polyester or nylon woven face fabrics backed by light-weight, to high loft, knit constructions with an inner membrane intended to allow airflow through the fabric but prevent water from penetrating from the outside. These garments are designed to be water repellent rather than waterproof and do not require seam taping. The fabrics are softer and less noisy than more protective 'hard shell' garments and often have a degree of stretch to enhance comfort and fit. As extreme protection is not required on a daily basis, this category of garment, if designed to suit older people's style requirements and figure types, may offer an attractive solution to adaptable and comfortable lightweight protection for everyday use.

9.3.5 Outer layer

The outer layer, or 'shell', provides protection for the clothing microclimate from the ambient conditions. This may be provided by waterproof breathable textiles in a range of variations on woven or knit structure protective textile assemblies with additional properties and finishes, such as abrasion resistance, for more extreme requirements (McCann *et al.*, 2009). Outer garments have become increasingly lightweight, fitted and stylish, with enhanced comfort, through moisture management, in hydrophilic or micro porous waterproof 'breathable' membranes with stretch properties. The concept of 'Body Mapping' identifies areas or 'zones' for the placement of textiles in relation to comfort factors such as ease of movement and articulation, predominant posture, moisture management, thermal regulation, impact protection, environmental protection and enhanced visibility. Novel joining methods, such as the heat bonding of seams, zip insertions and laminated panels, have revolutionised appearance and reduced bulk. Heat bonding also contributes to the encapsulation of wearable electronics, as safety and communication devices, with their textile-based switches and controls. To date, such garments have seldom been designed with consideration of the style and usability requirements of older wearers.

9.4 Smart protective textiles for older people

9.4.1 Defining smart textiles

Emerging wearable electronics have the potential to provide additional functionality within the clothing layering system, in monitoring activity, movement and positioning, temperature regulation and subsequently, over time, provide sufficient data to detect behavioural changes. Smart textiles may provide significant new understanding of the effects of ageing and alert the user, by providing informative feedback. Technological advances permit power and signal pathways to be integrated into garments, and accessories to facilitate applications such as heart rate, temperature and respiration sensing, location monitoring, and social and emotional contact. Smart textiles may be defined in three subgroups; 'passive smart', which sense environmental stimuli, 'active smart', which sense and react to the environmental condition or stimuli, and 'very smart', that can sense, react and adapt their behaviour to the circumstances (Van Langenhove *et al.*, 2007). Smart textiles require a sensor, an actuator (for active smart textiles) and a controlling unit (for very smart textiles). 'Passive Smart' textiles, used in clothing applications, may provide attributes such as UV protection, conductivity and embedded optical sensors. 'Active Smart' textiles provide functionality such as shape memory materials, thermo-chromic dyes with chameleonic characteristics, hydrophilic waterproofness, moisture management and phase change properties. Electrically heated textiles are also within the Active Smart category. 'Very Smart' textiles may deal actively with life threatening situations, comprising a unit with cognition, reasoning and activating capacities. Textile-based sensors for monitoring vital signs are in this category (Ajmera *et al.*, 2007). For examples see Table 9.1.

9.4.2 Size and shape

A key design consideration, throughout the garment layering system, is in addressing the changing size and shape of the ageing body with consideration of fit, movement, and the accommodation of predominant postures for both wearing as well as putting on and taking off the garment. Changes in bodily dimensions, including age-related shrinkage in height, should be considered in the design of clothing and accessories. The placement of wearable electronics, with textile-based sensors, for the recording of vital signs and/or positioning and movement, is critical in relation to the size and shape of the body. In the SizeUK National sizing survey, completed in 2004, three-dimensional body image processing was used to capture body measurements to determine the size and shape of a cross-section of the population (www.size.org). Body scan measurements may be stored on a database to

Table 9.1 Examples of applications within the smart clothing layering system.

	Skin layer and intimate apparel	Base layer	Personal protection	Mid layer	Soft shell	Outer hard shell	User interface
Passive Smart – *do not involve any alteration to the environment*	Moisture management. Mechanical stretch. Elastomeric variable stretch. Engineered knit 'body mapping'.	Moisture management. Thermal regulation. Seamfree engineered knit 'body mapping'.	Spacer fabric. Impact protection. Innovative engineered spacer knits, e.g. Baltex (Karl Meyer).	Insulation: knitted fleece, fibre pile, down, etc. UV protection e.g. Solumbria, Coldblack® and Tencel Sun.	Moisture management. Water repellence.	Moisture management. Windproof/ waterproofness/ breathability: coatings and laminates.	YKK easy access, open ended zip.
Active Smart – *have sensors and actuators that tune functionality to the environment*	Micro-encapsulation and antimicrobial additives, e.g. silver. X-Static, SmartSilver, Polygiene.	Micro-encapsulation and antimicrobial additives. Yarn based warming underwear, e.g. WarmX	Memory spacer knits, e.g. Baltex. Silicon coated shock absorbing Deflexion™ (Dow Corning).	Garments with heated panels and controls, e.g. Polartec®Heat® and Fibretronic Heat-wear.	Active smart membranes. Phase change materials (PCMs). Far infrared rays, e.g. Energear (Schoeller)	Phase change. Biomimicry, e.g. Outlast, Schoeller, C-change. Visibility/ reflectivity.	Magnetic snap fastenings.
Very or Ultra Smart or Intelligent – *sense, react and adapt to environmental conditions or stimuli*	Textile-based sensors for vital signs monitoring: heart rate etc., e.g. Santoni seamless knit (Adidas), Shima Seiki whole garment knit (Smartlife)	Scan2Knit for customised DVT support. Far infrared rays to improve blood circulation, e.g. FIR-TEX.	Spacer fabrics with embedded sensors.	Textile-based sensors. Accelerometers for posture, positioning and activity monitoring.	EY Technologies iCon Fibre smell detectors. Soft controls: GPS: positioning and movement. Lighting, LEDs. Power (Solar). Alarms (Recco).	EY Technologies iCon Fibre smell detectors. Soft controls: GPS: positioning and movement. Lighting, LEDs. Power (Solar). Alarms (Recco).	Flexible screens, textile controls, speakers, etc., e.g. Fibretronic ConnectedWear. Watch, e.g. Sony Ericsson Live View, Smartphone.

be retrieved for individual customers to inform the customisation of garments made to measure. In theory, this process may also make it easier for people with disabilities or restricted mobility to purchase clothes that fit (Metz and Underwood, 2005).

9.4.3 Smart protection within the skin layer

This section discusses:

- vital signs monitoring,
- compression garments,
- support hosiery.

Vital signs monitoring

Wearable electronic devices for physiological monitoring have been introduced predominantly in the areas of performance sport and corporate work wear, and in medical applications. Design-led garments have been developed predominantly for young athletic figure types with little consideration for the less predictable figure types and postures, and the relatively restricted movement and agility of older people. Typically, textile-based sensors are either incorporated into seamfree knit garments, such as those using Santoni technology (Adidas) or Shiema Seiki engineered knit (Smartlife); or in more restrictive straps (Zephyr). Heart-rate sensing apparel links wearable technology to the promotion of health and wellness; for example, through the Adidas miCoach programme. Seamfree Santoni knit sports bras, and close fitting vests for men, use textile-based sensors incorporated into the structure of the garments, based on technology initially developed by Textronics. A separate heart rate monitor snaps into a small pocket within the garment and sends heart rate feedback to the miCoach Pacer or Zone. The system is described as a personal training solution, to help motivate the wearer towards reaching their personal fitness goals, combining real-time coaching with an intelligent web application, the miCoach Zone. On entering the wearer's age, the web application calculates the appropriate target training zones. LED lights in the wristband clearly display the wearer's heart rate zone as they exercise, making it possible for the individual wearer to train at an appropriate intensity (http://www.adidas.com/uk/micoach).

SmartLife® Technology's 'softsensor' system is based on knitted sensor structures, integral to the garment's manufacture, and based on a dry interface with no reliance upon gel-based facilitation, forming 'a wide variety of on-body, dry sensor wearables and traditional garments for the monitoring of real time vital health signs, such as ECG, heart rate, EMG, respiration, tidal flow and other sensory inputs – all to comparable clinical quality standards' (www.smartlifetech.com). It is claimed that the e-textile data integrates seamlessly with wireless, mobile and existing equipment, either in the home, the clinic or in a pocket. In terms of user-interface, the 'textile integration automatically ensures their position is easily located, and the wearer requires little introduction or support instruction for either the set-up or the ongoing and compliance of routine remote monitoring.' Data collected by these washable garments can be transmitted in real time via Bluetooth to a remote computer, PDA, or cell phone.

The Zephyr Bio Harness™ measures critical vital signs (ECG, heart rate, breathing rate, skin temperature) and contextualises the information with the individual's physical activity, using an accelerometer that monitors activity, and posture. Radio interfaces, such as smart phones and tactical radios, transmit the data to those who care and need to make critical decisions based on an individual's physiological status (www.zephyr-technology.com). Although the garments and straps described include textiles to facilitate the monitoring of vital sign information, a physical device is still required for data transmission and processing. Advances in electronic engineering allow these devices and processor to become much smaller and more ergonomic (W. P. H. Burns, 2010, personal communication).

Compression garments

Maintaining good blood circulation in the body plays a major role in maintaining good health as the means by which oxygen and nutrients are carried around the body. Improving poor circulation is central to helping stave off a manner of debilitating disorders, from diabetes to heart disease to varicose veins or the inability to think clearly. Compression garments can assist in enhancing circulation and are commonly recommended for anyone where this is lacking, including athletes, surgical patients, oedema patients and anyone with a sedentary lifestyle. An effective means of treating oedema is the use of high-quality compression hosiery that provides compression support at the ankles, with the compression gradually decreasing up the leg. This improves venous return in the leg and helps to lessens the pooling of fluid in lower extremities. Compression clothing is designed to improve and accelerate healing, promote improvements in blood flow, and reduce the risk of soreness and injury from strenuous exercise. Variable stretch engineered knitted textiles may offer targeted support in maintaining muscle alignment and a reduction in the loss of energy in athletic performance. Additional reinforced taping, outlining and supporting muscle groups, contributes to the aesthetic appearance of the garment. In swimwear and in other athletic sports applications (e.g. Adidas), it is claimed that bonded seaming and appliqué constructions offer support and muscle control, to promote proprioception.

Support hosiery

Body scanning directly informs the design and fit of customised compression hosiery. The William Lee Innovation Centre (WLIC), in Manchester, has created a system called Scan2Knit based on Shima Seiki technology, in a project led by Dr Tilak Dias in the research of three-dimensionally shaped and seamless fibre assemblies for technical textiles and apparel applications. Bespoke medical garments have been developed for people who have developed severe ulcers through age, infection or injury, to improve the effectiveness of compression bands that apply pressure, which forces lymphatic fluid towards a functioning lymph node. The specialised computer-assisted manufacturing process involves scanning the leg and foot with a 3D limb scanner, to construct a 3D model from the scans, with the information then transmitted to a dedicated computerised flat-bed knitting machine. A bespoke stocking is then accurately engineered to apply a prescribed 3D pressure profile to the leg. The Scan2Knit technology has also been adapted for the manufacture of compression sleeves for the treatment of lymph oedema. The WLIC has collaborated with an industrial partner, Advanced Therapeutic Materials Ltd, to commercialise the innovative Scan2Knit technology. A two-year patient study using this has taken place at Withington Hospital in Manchester, commencing in September 2006 (Dias *et al.*, 2011).

A German company, WarmX, produces a range of ergonomically designed, electrically-heated clothing for outdoor sport activities, as well as for the professional working environment of both men and women. It is claimed that sufferers from muscular tension and certain back or renal problems benefit from the soothing and analgesic effect provided by heat applied directly to the skin. WarmX heatable, one piece, seamless, flat-knitted tights are wireless, with warming zones placed directly against the skin, at the feet. The tights are constructed from a blend of 49% cotton, 9% elastane and 40% nylon, with 2% pure silver plated onto polyamide threads woven into the underwear, with a greater percentage in the foot area, to warm up directly on the skin. As well as conductivity to enable heating, the silver combats bacterial increase and odours. A mini power controller is situated in a small pocket in the upper left side front of the tights or, alternatively, an extension power controller may be worn in a trouser pocket. The tights, and a range of other heated garments, are powered by a Li-ion battery with a guaranteed retention of 80% maximum capacity after 500 recharge cycles. The power controller and charger are offered separately (http://www.warmx.de).

9.4.4 Smart protection within the base layer

This section discusses:

- far infrared rays technology,
- antimicrobial additives,
- phase change materials.

Far infrared rays technology

The company FIR-TEX (Far Infrared Rays TEXtile) claim that their technology captures thermal radiations emitted by body heat, then, reacting like a 'reactive mirror', uses thermal Far Infrared rays to send energy back into the cells and tissues of the body. The Far Infrared frequency is said to deeply penetrate the skin layer to resonate with the water and organic molecules of the body. As the FIRs interact, the water molecules are set into a rotation state, resulting in energy transfer as the thermal reaction increases tissue temperature. The human body is said to react to this phenomenon by dilating blood vessels, resulting in improved blood circulation with more oxygenized blood reaching muscles and tissues. This technology is claimed to reduce abnormally-shaped blood cells and also to enable the separation of blood cells to become less 'sticky' (from sugar/protein). This is intended to optimise the delivery of oxygen and the elimination of waste gases from the entire organism that, if achieved, instantly improves the aerobic energy system and puts less strain on the heart. Evidence from tests claims that FIR-TEX technology can improve the wearer's balance, mobility and global performance due to improved blood circulation (Wilson, 2010).

Antimicrobial additives

Antimicrobial silver additives have been introduced to provide protection from hospital-acquired infections, with evidence that clothing is a key carrier (Anon, 2010). A variety of textile treatments contain silver, which contributes to eliminating odour-causing bacteria and athlete's foot fungus. X-Static has a layer of pure silver, permanently bound to the surface of a fibre, containing about 15% pure silver, manufactured to retain traditional textile and tactile characteristics. Whilst X-Static has anti-microbial properties, it is suited to provide additional features such as heat transfer and anti-static properties due to silver having the highest electrical conductivity rating of any element. With its conductive properties, this fibre system is also claimed to have many health and circulatory benefits.

Another antimicrobial product, SmartSilver, has been bound into the material of a range of hospital clothing. It is made of 75% recycled polyester and 25% cotton, called ‘Do NO Harm’, and was launched in the US by NanoHorizons.

Sweden’s Polygiene ionic silver technology (www.polygiene.com) also claims to have permanent resistance to odour-causing micro-organisms, with 100%-recycled silver ions that continuously migrate to the textile surface where they effectively suppress microbial growth.

Phase change materials

Temperature-regulating phase change materials (PCMs) were first introduced by Outlast Technologies Inc. as paraffin wax ‘Thermocules’, encapsulated into acrylic fibre and subsequently into viscose. This technology absorbs, stores and releases body heat, adopting latent heat principles – the heat released or absorbed by a chemical substance or a thermodynamic system during a change of state or phase transition. As the body heats up, the wax stored in the phase change molecules turns to liquid and stores the heat. As the body cools down, the wax solidifies and, in so doing, releases the stored heat back to the body. Products must be worn next to the skin for ultimate function. Recent examples include T-shirts and long trousers, designed to wear under maintenance workers’ uniforms, in a fabric made up of 48% Outlast, 48% viscose and 4% spandex (Anon, 2010). A new generation of Outlast’s ‘Adaptive Comfort’ technology consists of bicomponent fibres with a polyester sheath and a core injected with the PCM. Initially available as a staple fibre but with a filament version to follow, it is claimed that this fibre retains all the characteristics of conventional polyester, such as low moisture absorption, moisture transport, good wrinkle resistance and durability, but with the ability to regulate heat (Swantko, 2002).

9.4.5 Protection within the mid layer

This section discusses:

- sun protection and
- heated garments.

Sun protection

With ageing, the skin’s layers lose the ability to retain fluids with a loss of some of the fatty deposits under the skin and a loss of elasticity, resulting in the skin becoming wrinkled, dry and easily bruised. To minimize these effects, direct sunlight should be avoided. The sun’s damaging UV rays promote skin cancer, with many cases of melanoma diagnosed each year and many people dying from this disease. For elders, 80% of UV damage has occurred in childhood and adolescence, when people were not aware of the risk of exposure. The Ultraviolet Protection Factor (UPF) measures the amount of UV radiation that penetrates a fabric and reaches the skin. For example, a white T-shirt provides only moderate protection from sunburn, with an average UPF of 7, while a long-sleeved dark denim shirt offers an estimated UPF of 1700, which amounts to a complete sun block. If one can see through a fabric, then UV radiation can penetrate it and the skin. In general, clothing made of tightly-woven fabric offers best protection, with darker fabrics more effective than lighter colours. For example, the UPF of a green cotton T-shirt is 10 versus 7 for white cotton, and a thicker fabric such as velvet, in black, blue or dark green has an approximate UPF of 50 (http://www.skincancer.org/sun-protective-clothing.html). Moisture wicking fabric constructions may perform badly in the sun and lose up to 50% UV protection when they become damp or stretched. While 'a wet t-shirt on a swimmer provides at best an SPF [sun protection factor] of 3; dry, the shirt offers on average a factor of 7' (Brody, 2006).

To prevent new problems for older people, garments should be made of tightly woven fabric, with fine fibres in dark colours, in long sleeved and long trouser styles, with a loose fit to aid cooling. For example, Sun Precautions (USA), has developed Solumbra, a tightly woven, lightweight, cotton-soft and nylon-based material with an SPF of 30, which, even when wet, claims to block out 97% of harmful UVA rays (UV type A) and the UVB rays that cause sunburn (Perman, 2004). Lenzing's Tencel fibre is relatively eco-friendly; it is based on man-made cellulosic fibre manufactured from wood pulp, and is claimed to be 100% bio-degradable. For sporting activities, 'Tencel Sun' has permanent pigment integration coming from minerals, with protection due to moisture absorption that swells the fibres, claiming to provide long-term protection from solar radiation, with an SPF of 110 (www.lenzing.com).

Coldblack® technology, developed by Schoeller Textiles, is said to reduce the heating up of textiles exposed to sunlight and offer protection against UV rays, through a combination of absorption and reflection (www.coldblack.ch). Schoeller acknowledges that light coloured textiles reflect both visible and invisible rays of sunlight with both light and heat radiated back. In contrast, dark fabrics absorb both types of radiation and therefore absorb heat. Coldblack® claims to reduce the absorption of heat rays, particularly in darker colours, and guarantees a minimum UPF of 30 when applied to any textile in any colour without affecting the look or feel of the product. The UPF value can vary depending on the structure and thickness of the material with tight structures recommended. Normally black textiles without coldblack® absorb up to 90% of the heat rays, and heat up accordingly, while textiles with coldblack® are claimed to reflect up to 80% of the heat rays and therefore stay noticeably cooler (http://www.coldblack.ch).

Heated garments

Fabric-based heating elements are now being embedded into clothing, gloves and other accessories. The fleece fabric producer Polartec has introduced Polartec® Heat® panels that can offer instant warmth in a fitted garment that can either stand alone or work within a layering system. Using a lithium-ion battery pack, the conductive heat panels are incorporated into the garments to provide warmth beyond that which the wearer's body heat can generate. A wireless remote control enables the wearer to change the heat levels easily. The core garments, in male and female fit, are in lightweight textiles but the detachable Polartec® Heat® components, that include the heat panel, the battery pack, and the remote control, are not washable (www.polartec.com/warmth/polartec-heat/). A comparable product, the Fibretronic HEATwear system, is co-branded with Ripcurl in a padded gilet. This fabric heating panel is powered by a rechargeable Li-ion battery weighing 160 grams, with four power settings available and providing between 3 to 6 hours of continuous heat. An LED control switch is integrated in the chest of the garment to enable the wearer to understand the operation of the heat settings (http://fibretronic.com).

9.4.6 Protection within the soft shell layer

This section discusses:

- novel manufacturing techniques and
- textiles to enhance wellbeing.

Novel manufacturing techniques

Hybrid 'soft shell' garments have a relatively soft and quiet handle and provide lightweight, stretch, water repellent and breathable protection that, with appropriate design, may offer an ideal product for protective outerwear for older people. Heat-bonded seaming contributes to clean design lines, with the potential for encapsulated, textile-based electronics and soft switches as the user interface for wearable devices. Garment design is becoming increasingly sophisticated, with typical features such as an outer face in a water repellent stretch nylon weave laminated to a soft inner fleece fabric having a medium length pile and a waffle structure, for improved breathability. Typically these 'sandwich' constructions, used in protective areas, have an inner membrane while side panels may be un-laminated for comfort and freedom of movement. Enhanced protection may be provided in shoulder sections with an additional layer of laminated, abrasion-resistant material. The design may have additional protective features, such as reflectors (Recco) on the arms to provide enhanced visibility and to help locate people in trouble by bouncing back high frequency signals emanating from search teams.

Textiles to enhance wellbeing

'Energear' is the name given to a soft shell fabric innovation, promoted by the innovative Swiss textile producer, Schoeller Textile, as a further example of a textile 'based on the ancient knowledge about the capacity of certain minerals to radiate Far Infrared Rays (FIRs). The material matrix has been formulated to ensure that the energy radiated by the body is reflected back to the wearer, with the additional energy recovered positively affecting performance capacity and wellbeing.' The reflection of the FIRs claims to promote blood circulation and increases oxygen levels in the blood, with positive effects on the body in performance enhancement, prevention of premature fatigue, improved regeneration, faster warm-up phase, increased concentration capacity and general wellbeing. In tests on 'people in an active, aerobic phase wearing energear™, a lower pulse rate and an increase of air intake could be observed. Improved performance capacity and lower acidity due to the increased air intake were recorded.' A range of Energear soft-shell fabric qualities offer wind and weather protection for leg wear, and jackets for activities such as trekking and urban wear (www.schoeller-textiles.com/en/technologies/energear.html).

9.4.7 Protection within the outer layer

This section discusses:

- biomimicry and
- sensory protection.

Biomimicry

It is no longer necessary for older people to wear heavy, stiff and noisy waterproof garments. Innovations in waterproof/breathable and windproof protection, adopted in sportswear, offer an attractive alternative to relatively heavy traditional outerwear, with multi-functional, exceptionally lightweight fabrics suitable for recreation, travel and urban wear, having low packing volume. For example, 'Schoeller-aeroshell' and 'Schoeller-spirit' fabrics are manufactured as two-way stretch, semi-transparent, 3D honeycomb constructions that incorporate branded c_change technology. C_change is a phase change textile based on bio-mimicry related to a study of fir cones, which expand and contract in humid or dry conditions to create a balance of breathability and waterproofness. The uneven surface of the lotus leaf has also been mimicked, in nano scale, in Schoeller's self-cleaning

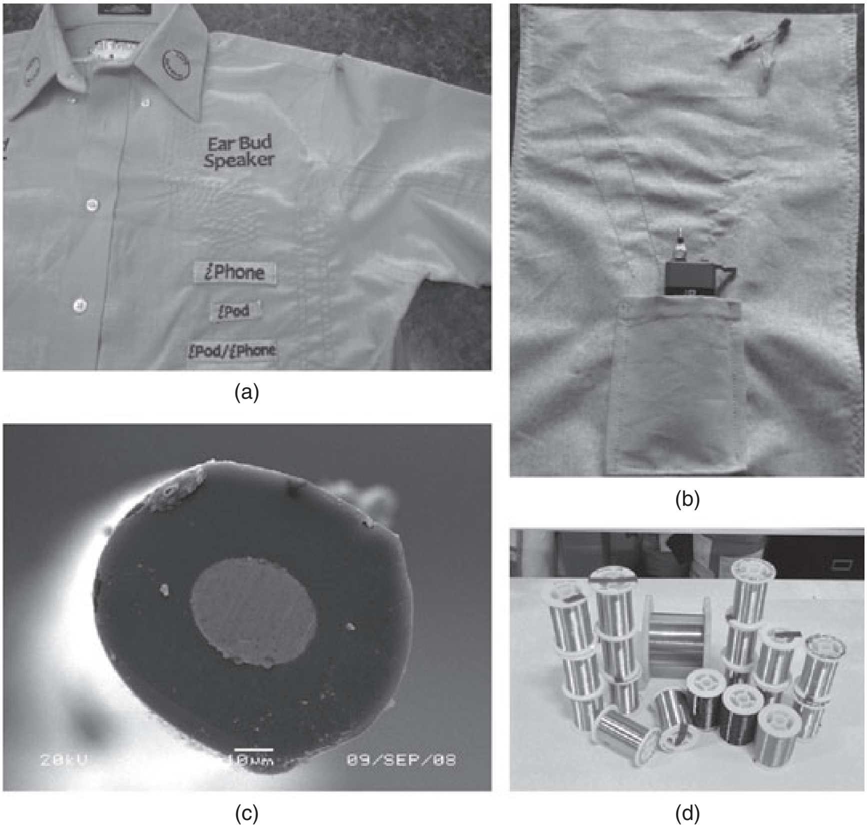
NanoSphere finish that has moisture repellency and stain proof attributes. Additional functionality may be added to outerlayer garments from treatments such as tick and mosquito protection (INZECTIC™) and, as already mentioned, heat and UV protection (coldblack®).

Sensory protection

Smart fibres that can sense dangerous smells can be designed and incorporated into garments giving the users an early warning of dangerous environments. R. Perera, of EY Technologies, USA (2010, personal communication), states that the biggest hurdle has been the lack of textile-grade insulated micro conductors, but that there is now the potential for nano particles to be introduced as sensory protection for smell detection in outer layer garments. Intelligent fibres, acting as electro chemical captors, can be formulated to detect harmful gases such as carbon monoxide, gasoline, household gas, fumes and bio threat material. EY Technologies have introduced insulated 'iCon-75' fibre, a novel commercial method of producing fine, insulated, highly conductive filament yarns that are flexible and can be soldered for incorporation into fabrics for use as wearable electronic circuitry. These fibres can also be integrated into garments for entertainment and communication applications, with a town walking global positioning system (GPS) envisaged for people having visual disabilities (see Fig. 9.1).

iCon-75 fibre is a textile-grade fibre containing an insulated conductive core that has been specially designed for sensor applications. For example, to achieve the maximum surface area (current), round fibres are not preferred in sensor applications. However, for textile processing easiness, round-shape fibres are always preferred. Additionally, the current generated on the fibre surface must be transferred to the metallic core through the insulating sheath. Thus the iCon fibre must be designed with conductive channels that connect the surface to the conductive core. The round fibre is extruded with a core (60%) of a lower-melting point metal within a textile grade sheath of a higher melting point polymer. The fibre is of 25–75 microns (human hair is 110 microns), and is comparable to 5 denier PET. The filaments are fine, yet strong and flexible, with fibre-like qualities and may be produced with multiple polymer options. They can be woven, knitted, or braided, and finished, either visibly or invisibly, on standard equipment, leading to intelligent, wearable products with improved conformability, flexibility and comfort, and may be machine washed, dried and ironed. The filaments are produced in a variety of colours in 25+ microns on spools of 5000 metres, in blends of nylon, wool and PET, with either a single conductor or multi conductors.

Properly chosen nano-powder chemistry, applied on EY Technologies iCon fibre as a coating, can react with dangerous fumes, generating



9.1 EY Technologies smart shirt prototype (a and b) with iCon fibre (c and d). (Courtesy of R. Perera, EY Technologies.)

electricity by an electrochemical ion exchange mechanism. This surface electricity can be transferred to the conducting metallic core which can then activate an audible or visible signal built into the garment. In order for the system to work, the incoming fumes should create an electrical potential between two wires connected through the alarm system. One way to achieve this potential difference is to have two conductive fibres having two different surface chemistries. When a toxic gas comes in contact with the surface of each fibre, they will produce two differing potentials and the system will act as a battery. If the two fibres (now acting as electrodes) are connected through an alarm system, this will result in a current flow through the system, triggering the alarm (current flows from the higher potential to the lower potential). It is not even necessary to have two surface chemistries. The same results can be obtained using one chemistry, by changing the concentration of active particles applied on each fibre. In such a situation, one fibre will have higher potential than the other. These fibres and fabrics can also be used as strain gauge sensors, temperature sensors and as structural integrity monitors (R. Perera, 2010, personal communication).

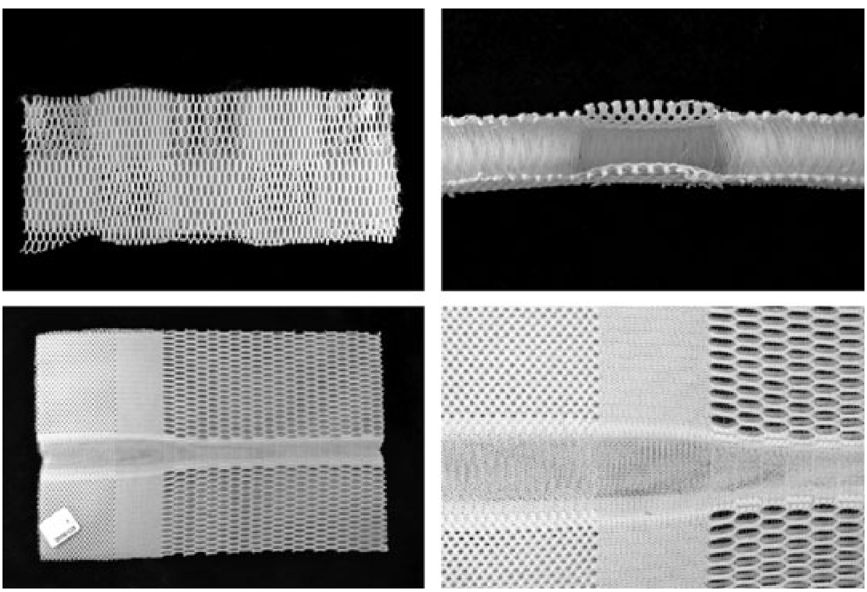
9.4.8 Smart body protection

The psychological 'feel-good factor' is directly related to the reliability of, or the perception of the reliability of, the garment system. Designers must give consideration to vulnerable areas of the body in anticipating injurious hazards and commonly occurring accidents – in particular, falls. Positioning and movement may be tracked in terms of detecting falls but also, from a more positive view point, in monitoring progress in keeping fit or in exercise for rehabilitation. The incorporation of stretch sensors in stockings, knitted sleeves, or other garments, may be used to track the wearer in terms of angle of movement for training or rehabilitation and/or alert the person regarding the need for movement to reduce interstitial fluid build-up and reduce blood stasis in lower limbs. Smart textile structures may provide lightweight personal impact protection for older people. Researchers have found that among walking elderly adults, the risk of hip fracture can be reduced by 80% if a hip protector is worn at the time of a fall. (Sheil, 2008). There are on-going developments in inherently flexible phase change materials that harden on impact and then revert to a flexible state once the impact has passed, which have the potential to offer protection to older people.

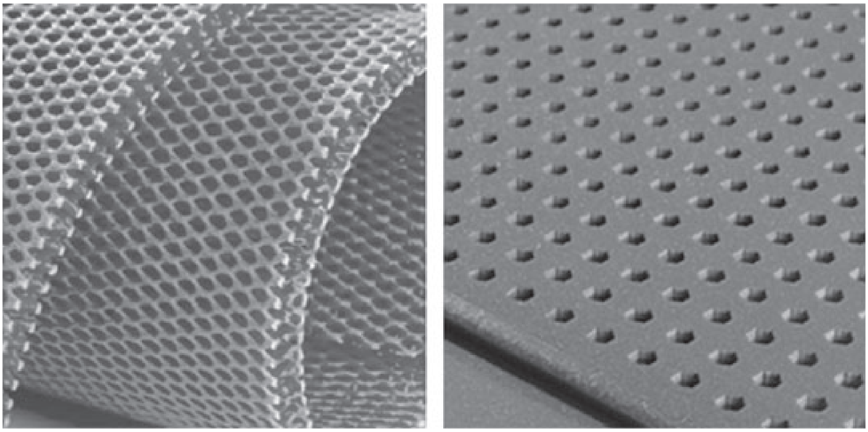
Baltex is a specialist knitter, leading innovation in spacer textiles in the UK. Their 3D knitted spacer fabrics are primarily produced on double needle bar warp-knitting machines in thicknesses that vary from 3 mm to 20 mm, using both warp-knit and weft-knit technologies. The warp knitted structures consist of two separately produced layers that are joined back to back, may be produced from different materials, and can have completely different structures. The yarns that join the two face fabrics can either closely join the layers or space them apart, with this 3D space as the special feature of such structures. Spacers can also be knitted on weft machines, in 3D structures on a circular machine, or on electronically controlled flat machines. In providing added dimension, spacer fabrics are being widely used as for the replacement of foam, cushioning and neoprene products. With the possibility of knitting different fibres on different faces, in different thicknesses and surface designs, many properties can be achieved for a range of end uses. Principal advantages of spacer textiles include breathability, insulation, compression strength, durability and pressure redistribution, with the potential for recycling. Yarn selection can vary from natural to synthetic fibres, and microfibres, to include polyester, polyamide, Kevlar and Nomex (Baltex, 2010, personal communication).

Spacer fabrics may be produced in a range of weights and depths, suitable for plasters and bandages to mattresses, and may be heat moulded for applications including footwear soles, compression bandages, orthotics and body armour. Stretch, and two-way stretch, may be added for use in orthopaedic bandages and slings. One product is described as a 'memory spacer' that, when shaped, retains its curved form, offering enhanced comfort, fit and protection of the body in healthcare and military applications, in addressing the shape of arms, knees, elbows, breasts, etc. Rib spacer constructions provide relative rigidity with regular open channels to enhance airflow within the textile assemblies. Some qualities may be produced in a range of different colours with added functionality such as softeners, fire retardancy, infrared reflective treatment, and silicon and fluorocarbon finishes. Branded fibres and treatments may be added, such as Coolmax polyester for enhanced wicking and Polygiene with antibacterial properties. Further innovative engineering of spacer knit constructions has been possible through the development of the knitting techniques, in collaboration with the machinery producer, Karl Meyer (see Fig. 9.2). A body mapping effect may be knitted into the fabric repeat through the variegated engineered patterning of stitch structures and the varied depth of the spacer monofilament areas.

The chemical producer, Dow Corning, has introduced the brand name 'Deflexion', which embraces two smart textile technologies for extreme



9.2 Examples of engineered spacer fabrics by Karl Meyer. (Photographs by David Bryson.)



(a) (b)

9.3 Deflexion from Dow Corning. (a) S-range and (b) TP-range impact protection textiles (http://www.dowcorning.com/content/deflexion/deflexionmaterials/).

protection (see Fig. 9.3). The S-range features the application of silicone on open spacer knit constructions that remain relatively soft and flexible under normal conditions, but can absorb and disperse the shock of impact. 'Unlike bulky hard-armour component systems, Deflexion™ protective textiles can be incorporated directly into garments and accessories to shield the wearer against high energy impacts.' The fabric may be multi-layered for increased protection and may be bonded to other textiles using silicone adhesives. Prepared protective parts, cut to ergonomic shapes, may be fully integrated into a garment or inserted into a pouch or cavity. This fabric technology has been tried and tested in extreme sports clothing, for example, in motor bike clothing, by Rukka, Finland and is to be launched in sailing wear as Henri Lloyd's Shockwave range (Rogers, 2010).

Dow Corning's TP-range combines the properties of silicones with thermoplastics and is available as flat sheets, either with holes for maximised airflow, or as a solid sheet (see Fig. 9.3). The versatility of the technology enables the development of different surface effects, and, in cutting the material to any desired shape, provides an appropriate design and feel for targeted applications. In two thicknesses (3 mm and 8 mm), this material offers varied levels of protection and is relatively thinner and lighter than other protective systems and will sustain performance even at low temperatures. This product has end-uses in body armour for sports, in sport accessories, and as protection for sensitive equipment and electronics such as laptop computers, cell phones, cameras, footwear, and luggage. It also has applications in personal protective equipment with the potential for electronic devices, such as impact measurement or accelerometers, to be integrated with the material using a compression over-moulding process. Dow Corning has recognised that clear point-of-sale material and instruction manuals are required to aid designers in the application and promotion of both these technologies (http://www.dowcorning.com/content/deflexion/deflexionmaterials).

9.5 Usability of the technology interface

9.5.1 Older people's familiarity with technology

Many studies have revealed that today's older people have become competent users of high-technology products where they perceive that those products deliver something of value to them (Metz and Underwood, 2005). The mobile phone has enabled older people to maintain communications with family and friends, and even to text grandchildren. Improvements in computer interfaces have enabled older people to produce letters with corrections to typing errors. Older people are capable but slower, and those over 50 are the fastest growing group of internet users in the UK; as a group they spend more time on line than any other age group of the population. However, researchers have identified a number of characteristics elicited from usability tests with ageing users of various types of technological equipment. They identified that older people have longer response times, difficulty in collecting a lot of information in a short time, excessive responses to voice messages, repetition of errors, difficulty in noticing changes on a screen and, generally, have a lack of initiative. They noted a better response to items that are easily identified as interactive with, for example, large buttons (Harada and Akatsu 2003). Customising the product to a user's needs by modifying its characteristics, may, for example, involve increasing the font size of visual displays. At present, customisation is usually done by the users. In future, information held on a smart card inserted could effect the customisation automatically (Metz and Underwood, 2005).

9.5.2 Sensory design considerations

Sensory design considerations, in terms of materials selection in garment features and trims, should take account of touch or handle, in terms of dexterity and grip, protection for the eyes, and the avoidance of impeding hearing, taste, and olfactory capabilities. Textile and other surfaces should address the diminished tactile sensitivity of elderly wearers, with changes in texture used for both tactile pleasure as well as for practical end-use and safety (Wolf and Snyder, 2003). Textile switches and touch sensitive displays may aid dexterity, as alternatives to control buttons that may not be further reduced in scale on wearable devices. The design of fastenings and packaging should take account of a loss of muscle power and, where possible and appropriate, products should be adjustable. Tasks should be achievable using one hand rather than two, to allow for strength variation between the hands, and to allow for balance support while undertaking the task (Huppert, 2003).

Sports gloves have been developed that feature textile-based joystick controllers incorporated in the back of the hand (e.g. Fibretronic's five-function controller for the internationally recognised sports brand, O'Neill). These battery-powered gloves activate heating technologies such as copper wires, nichrome wires, metal 'mesh' systems and carbon fibres. The joystick controller connects to a wireless transmitter located in a waterproof pocket in the cuff of the glove. The transmitter sends the joystick commands to the wearable device, such as an iPod, via a wireless receiver unit which connects to the iPod through the dock connector port. In addition, gloves may be designed with ergonomically placed treatments that enhance grip and dexterity. The Ambit iPhone Gloves, by Outdoor Research, are designed to enable the wearer to answer a call on a touchscreen phone without exposing their hands to cold weather. Patented technology, called TouchTec™, made by Broleco Inc., allows the screen to sense the touch of leather, enabling the use of a touchscreen with gloves on (Regenold, 2011) . Heated clothing for extremities, for hands and feet, would be beneficial for the elderly as well as sufferers of Reynaud's syndrome and other disorders.

Fibretronic is promoting flexibility of a choice of wearable electronic devices for the customer to use within a garment within their standardised 'Connected-wear system.' The system has two parts: a soft keypad or joystick, which is integrated into the garment, and a controller module which connects the garment to a range of personal electronics such as a mobile phone or a music player. Apparel manufacturers can integrate Fibretronic's controls into a wide range of garments to be compatible with selected electronic modules that may be transferred between Connected-wear enabled garments with easy attachment and removal (http://fibretronic.com/connectedwear). This allows a mix and match of modules, and the facility to update the system with additional functions as products are developed. Fibretronic is proactive in looking at the design requirements of the rapidly growing ageing market, who seem reassured by garments that have technologies that may be upgraded.

In terms of putting on and taking off garments, 'choosing the right fastening for a piece of clothing could significantly alter the effectiveness of the item as a whole' and 'getting it right could be a matter of life and death', states Eric Sitbon, founder of Systemmag, Paris. Sitbon (2010) has developed an alternative to traditional closures based on several magnetic fastening systems used to close and adjust clothing. Magnets, made of magnetised ceramic, can have the strength of the fastening adapted to suit the end-use.

The magnet closures are silent and the fibres do not get caught up and damaged, as with hook and loop fastenings. The magnets open instantly, are adjustable (for example, to tighten or loosen collars and cuffs), are waterproof and work well in cold conditions. Applications include clothing and footwear, wrist supports and watches. Clothing products using the system may be machine washed.

In terms of hearing, audible signals should be adjustable where possible, so that both volume and tone can be altered to suit the user. A combination of audio and visual signals increases the chance that messages will be received. Lower frequency sounds should be used to convey important messages. Fibretronic has launched a Bluetooth enabled module that incorporates a speaker, microphone, call answer/hang-up button and speaker volume controls, with a mini USB port for battery charging. The module, designed to be waterproof, may be attached to a garment using Velcro, allowing the wearer to take calls without removing their mobile phone handset from the safety of a pocket. The embedded speaker allows the user to listen to music stored on their mobile phone if so desired.

Changes in visual acuity call for special consideration in choosing an appropriate font, font size, and type and adequate word and line spacing, as well as appropriate surfaces, colours, degree of glare, back lighting, angle of light, etc. Electronic arrays to enhance visibility should be designed with displays that are simple, uncluttered and concise in prioritising important information. Clear graphic symbols should be used as an adjunct to words where possible. Surfaces should be non-reflective, and brightness and colour contrast high. Blue–violet–green combinations should be avoided. Product designers whose work includes design of instrumentation should likewise take these visual changes into account in designing gauges and controls.

9.5.3 Design implications for cognitive capabilities

Designs with the rapid presentation of information where quick decisions are required should be avoided, as older adults process information more slowly than younger adults. Competing inputs, from the same or different senses, increase difficulty in switching attention to monitor multiple sources of information. The users' knowledge should be taken into consideration when deciding what information is to be displayed and how it is to be displayed. A user looking at their current heart rate simply sees numbers. This information is useful only if the user knows what is a good or bad heart rate for their age. However, that user may prefer this information in the form of two colours, red and green; red meaning an unhealthy heart rate and green meaning a safe and healthy heart rate. By using this method, the cognitive load placed on the user is reduced. The use of a glanceable display further reduces this cognitive load. Progress in a task can be represented in a glanceable way with the use of cultural metaphors. A user completing a walking activity can be shown a screen with textual information complimented with a flower metaphor. The more walking the user does, the more petals will appear on the flower. When the flower is full of petals, then the activity is also complete (Burns *et al*., 2010; Consolvo *et al*., 2008).

9.5.4 Powering the devices

Wearable technology within the garment layering system demands power for voice and data communication, health monitoring, emergency, and surveillance functions, as well as infotainment – all rely on wireless protocols and services. Portable electronic devices, such as mobile phones, cameras and GPS, need a wireless, mobile, and sustainable energy supply in order to overcome the problem of batteries running out of power when urgently needed. Solar panels are an environmentally safe way of powering or charging devices while outdoors.

Photovoltaics, as thin film solar cells and panels, may be integrated into jackets, coats, backpacks and accessories. The production process uses thin film deposition where thin layers of silicon are deposited onto flexible substrates, such as polyethylene terephthalate (PET), without compromising the structure due to the silicon layers being only micrometers thick.

Maier Sports, working in conjunction with partners from the 'Solartex' project, developed a prototype ski jacket in 2006 whereby flexible solar cells could generate up to 2.5 watts of power in optimum sun conditions, with photovoltaic elements positioned in ergonomically sound exposed areas such as the shoulders and the back. Ultra-thin, washable micro-cables, sewn into the material, directed the electrical current to a universal point, where a variety of devices or batteries could be charged. Poppers were used to connect the photovoltaic elements to the cables. From a user perspective, a photovoltaic system should be easy to use, comfortable and reliable, offer a universal socket for different charging adapters and devices, and deliver energy at an affordable price. For older users, this demands parts that should be attractive, integrate well with garment design, and be relatively lightweight, washable and maintenance free.

9.5.5 Design to promote safety and security

When engaging in knowledge elicitation of older peoples' design requirements, the issues around safety and perceived danger do inhibit autonomy, independence and a sense of adventure. Individuals, as well as groups, fear the risk of getting lost, being attacked or falling over. Continuing advances in microelectronics create opportunities for improved assistive technology devices. Some applications related to personal safety and security include the daily management of the home; for example, in controlling access, in terms of who is entitled to enter, and the ability to summon help and/or acquire other services such as location and route finding. Tracking and positioning devices, such as radio-frequency identification (RFID) and GPS, may be used to monitor activity, movement and posture in sports training and in practice. These devices may also be used, with ethical issues addressed, to track those who may be at risk. Geofencing, the ability to set an invisible GPS fence around a predefined area, has been used to monitor and help persons suffering with Alzheimer's disease (Doughty and Dunk, 2009).

9.6 Conclusion

Smart textiles, in appropriately designed applications, have the potential to provide a range of protective attributes in clothing applications that may enhance the autonomy, independence and wellbeing of older people in their everyday lives. To date, many of the developments in textile-based wearable devices have focused on medical end use, with little concern for design aesthetics. Research findings inform us that the motivation for older people engaging in healthy exercise will be increased if, at the same time, the activity provides joint or individual pleasurable experiences, an enjoyment of nature, a sense of adventure, education and entertainment, as well as increased fitness and the prevention of ill-health rather than enforced rehabilitation (Bieker, 2010). In order to encourage the uptake of clothing with emerging technologies with a view to improving the quality of life of older people, the design and functionality of wearable technology should be attractive and fit for purpose, as well as easily understood, easy to use, and easy to service.

This demands the design of smart textile-based products that are attractive and pleasurable to wear by virtue of an appropriate blend of form and function, embracing aspects of size, shape, proportion and fit, balanced with appropriate aesthetic style considerations. A key factor in the adoption of smart textiles and wearable electronics, in combination with the overall clothing comfort and appearance, is the design and usability of the technology user interface. Designers and technologists must therefore work with older participants, their peers, family and carers, to capture and understand their real user-needs and aspirations. It is also important to note that reasonable physical demands can play a positive part in maintaining most older people's physical activity, which in turn reduces physical decline. 'Designs which largely avoid physical demands, such as voice-activation, are valuable for those with severe physical impairment, but may be a disservice to the average older person' (Huppert, 2003).

This chapter has introduced a breadth of emerging technologies, described in plain language, to support a design-led, cross-disciplinary approach in the selection of smart textiles and wearable technologies for protective clothing applications for older people. It has looked at the functionality of a sport-type clothing layering system and a breadth of smart textile technologies and garment manufacturing techniques emerging within the performance sport and corporate wear sectors, that have the potential to be adopted and adapted to suit the requirements of older people. The author recognises that the hybrid product area of smart clothes and wearable technologies, with particular consideration of the health and wellness of older people, requires a new shared language to inform effective communication within cross-disciplinary product development teams that, ideally, will begin to adopt a co-design approach with older participants and all relevant stakeholders.

9.7 Sources of further information and advice

- Coldblack, Schoeller – http://www.coldblack.ch.
- Connectedwear by Fibretronic – http://fibretronic.com/connectedwear.
- FIR-TEX – www.fir-tex.com.
- Lenzing – www.lenzing.com.
- MiCoach – http://www.adidas.com/uk/micoach.
- Outlast – http://www.outlast.com.
- Polartec – http://www.polartec.com.
- Polygiene technology – www.polygiene.com.
- Size UK – http://www.size.org.
- Sizemic – http://www.sizemic.eu.
- Smartlife – www.smartlifetech.com.
- Warmx – http://www.warmx.de.
- Zephyr Technology – www.zephyr-technology.com.
- www.myseniorhealthcare.com.

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