Six Human Factors to Acceptability of Wearable Computers

Cherrylyn Buenaflor and Hee-Cheol Kim

Department of Computer Engineering/UHRC, Inje University, Obang-dong 607, Gimhae, Gyeong-Nam, 621-749, S. Korea
cheri_0429@yahoo.com, heeki@inje.ac.kr (Corresponding author)

Abstract

Social acceptance of wearable computers is an important issue that has attracted interest since the emergence of the technology, as acceptance is the first step to successful diffusion. The user's acceptance of a wearable technology is significantly affected by technological and human factors. Since the influence of technological factors is as crucial to acceptance as human factors, we opted to focus on the target of all technologies, the end user. The present paper reviewed research focusing on the user and variables that influenced the acceptance or rejection of wearable computers. We identified and evaluated six human factors that play a key role in the acceptance of technology: fundamental needs, cognitive activity, physical aspect, social aspect, demographic characteristic and technical experience. Our aim was to help researchers, device designers, and developers evaluate the acceptability and usability of their devices.

Keywords: *human computer interaction, human factors, wearable computer, user acceptance*

1. Introduction

Computers have become increasingly portable, allowing ready access to important information. Recently, computers have been integrated into clothing and accessories as wearable computers. Although this technology is showing a promising contribution in augmenting human capabilities and abilities, intended users who actually adopt them are still limited. Aside from its considerably high cost, the failure to give utmost consideration to its end users in the design and development led to its low acceptance. For this reason, the study is driven by the principle that "technologies are meant to serve people [1]" In the same way, wearable computers are developed and intended to be used by humans, to aid in the performance of their tasks (make it easier, more productive and efficient), and to satisfy and fill their needs.

For this technology to be utilized by people, it should first gain acceptance from the intended users [2]. The act of the user to accept and use the device is affected by many factors. In the case of wearable computers, it should be able to perform two functions: first, as a computer and second, as a garment or accessory, and these will both affect users' preferences of the device. The fulfillment of these preferences or requirements will then lead to acceptance [3].

The present study reviewed the literature related to factors influencing users' acceptance or rejection of wearable computing systems and identified and evaluated six key human factors: fundamental needs, cognitive attitude, social aspect, physical aspect, demographic characteristics, and technical experience. The aim of our study was to provide developers, designers, and researchers in the field of wearable technology

with a deeper understanding of the consumer behavior underlying the acceptance or rejection of wearable computers.

2. Background: Wearable Computers

Wearable computers are electronic devices that function as a computer and can be worn, carried, or attached to the body. They are designed to be context-aware [4, 5], always on [6], and continuously worn [7] in an unobtrusive manner. Chris Baber described wearable computers in three forms [8]: computers that can be worn, information appliances that can be worn, and computers as clothing.

In particular, computer as clothing offers a new dimension in ubiquitous computing with the advantage of overcoming obtrusiveness of many devices. Sensors, circuits and wires are embedded in the garment for monitoring context surrounding the wearer. Wellness wear systems with attached biosensors are an example [9, 10]. It can acquire bio-signals such as ECG to be used in healthcare applications.
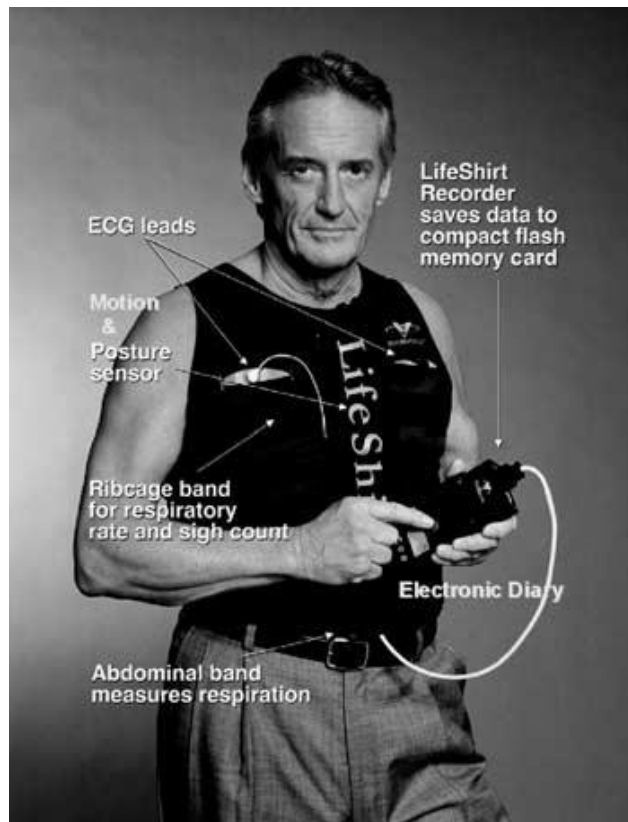
Figure 1. The LifeShirt System [9]

As interest in wearable computing technology has grown, the range of applications has expanded to including healthcare, emergency services [12], sport, fashion [13], and entertainment. Examples are illustrated as follows:

- Healthcare: wellness wear systems for obesity control, stress management, and chronic prevention and care [9, 10], and biomedical monitoring by personal area networks [12].

● Emergency Services: wrist-worn or a necklace fall detection device for the elderly [1], and smart uniform for fire-fighters and emergency rescuers

● Sports: a golf swing training system which incorporates wearable motion sensors [13], and walking promotion systems [14].

● Fashion: The fabric Luminex using colored light-emitting diode for glow-in-the-dark bridal gown, opera singers' costumes [15, 16].

● Entertainment: The MP3-playing jacket with embedded or detachable mp3 [1], and wearable technique sensing emotional context [5].

● Other applications can be specific to users' needs, work environment, or events such as vibrotactile belts that can aid blind or visually impaired persons [17], and the wearable assistant for conference and workshop visitors that informs about interesting persons and events depending on the personal interest profile of the wearer.

Being wearable, which can be considered as a part of the human body, these devices should be sufficiently small lightweight [8] so as not to give too much burden on the wearer. Although the early innovations of this technology are bulky and heavy, developers are continuously redesigning wearable computers to assemble the form of usual clothing and accessories used by people, making them as unobtrusive as possible (Figure 2).

Figure 2. Evolution of Steve Mann's WearComp wearable computer from backpack based systems of the late 1970s and early 1980s to his current covert systems. [en.wikipedia.org]

Communication interfaces such as WLAN, Bluetooth, and Zigbee are used to facilitate wireless interoperability among sensors and different components of the device itself [6], as well as other computing systems in the environment of the user such as cellphones, PDAs, and desktop computers for the storage and processing of data and information. This communication between sensors is referred to as wireless sensor network (WSN) which can be a body-area network (BAN) for sensors within the body, or personal area network (PAN) for communication with other mobile devices that belong to the user [18].

Wearable computers were developed to enhance performance by increasing ease, productivity, and efficiency, and to satisfy and fill people's needs. However, the benefits of this technology cannot be fully realized until it is accepted and adopted by

the intended users [2]. A wearable computer must be able to function as a computer and as a garment or accessory; both functions will affect the user's preference for the device. Fulfillment of these preferences or requirements underlie acceptance of the device [7].

3. Six Human Factors

In this section, we present six human factors affecting the acceptance of wearable computers, as a result of our review and survey of previous human centered studies in the area: fundamental needs, cognitive attitude, social aspect, physical aspects, demographic characteristics, and technical experience.

3.1. Fundamental needs

Duval, *et al.*, [1] evaluated the influence of humanistic needs on people's perception of the potential uses and features of smart clothes. These needs are based on the father of humanistic psychology, Abraham Maslow's hierarchy of needs in order of potential desirability, such that an individual will strive to fulfill the most basic needs (lower level) before the higher level needs (Figure 3). Duval and colleagues showed that people are strongly attracted by smart clothes that have functions such as monitoring sports activity and regulating body temperature which satisfy physiological needs.
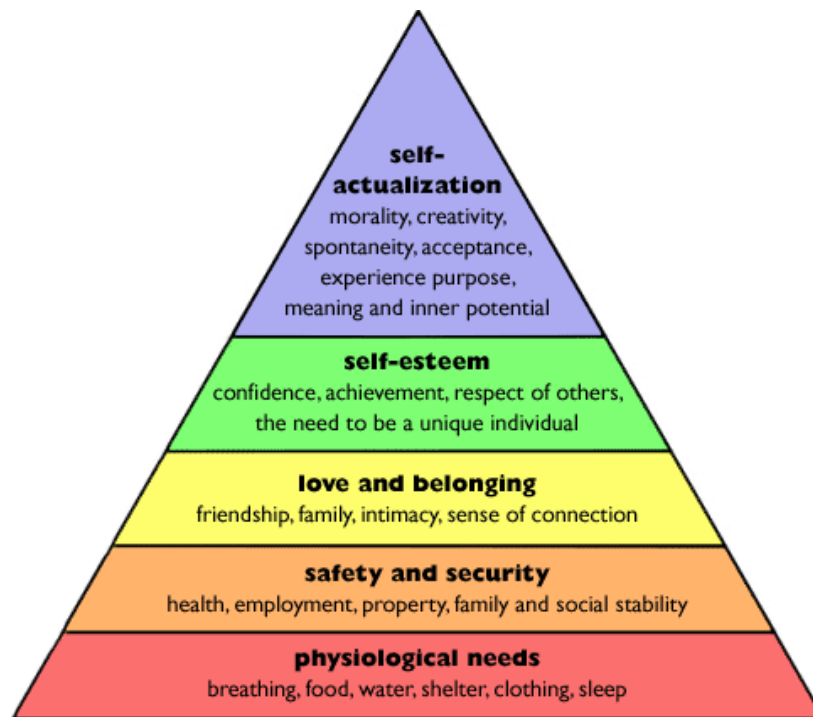
Figure 3. Abraham Maslow's hierarchy of needs

The result of their study showed that the public are strongly attracted by smart clothes with functions such as analyzing the air, monitoring sports activity, regulating body temperature and functions that would respond to emergency (Figure 4). These features satisfy the lowest human needs such as physiological and safety needs. The

recognition and integration of user needs in the development of meaningful services that wearable computers could provide is necessary to guarantee its mass acceptance.
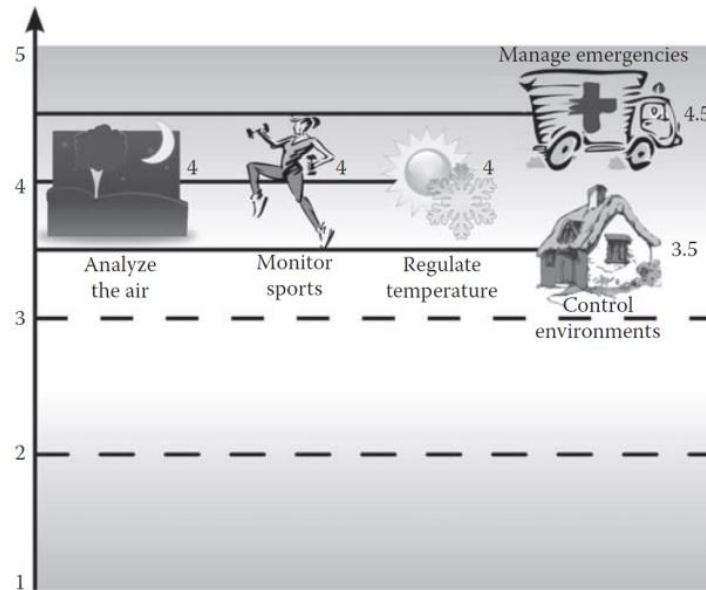
Figure 4. Acceptance of physiological and safety services (Smart Clothing Technology and Applications, Chapter 7)

3.2. Cognitive Attitude

A user's perception of a new technology significantly affects acceptance and any negative perception of the device presents a barrier to its adoption [2]. Vankatesh and Davis [19] created the Technology Acceptance Model to explain user acceptance of introduced technologies (Figure 5). It is widely used in the evaluation of systems and softwares for organizational applications.

We focused on two distinct perceptions identified by the model as affecting the intention to use a technology: perceived usefulness and perceived ease of use. The influence of these perceptions is also shown on user studies of wearable devices.

3.2.1. Perceived usefulness: It is the degree to which an individual believes that using a particular system will enhance their performance of a certain task. From the evaluation of gathered information from related research papers, it may also pertain to the belief of the user that such a device will be useful to the current situation or will be an effective and practical solution to existing problems.

Since independence is very valuable to elderly people, they would consider using a system if it is deemed useful, reliable, and provides obvious benefits to their independent life. In a study of wearable devices for mobile computer technicians, Korteum, *et al.*, [20] showed that despite serious social barriers that might dissuade technicians from using a head-mounted display (HMD) in public, most users expressed willingness to use HMDs if the system provided a significant benefit.

3.2.2. Perceived ease of use: It is the degree to which an individual believes that using a particular system would entail little physical and mental effort. A study of preferences

of clinicians and patients with regard to body-worn sensor systems found that both groups emphasized the need for a simple-to-use device [2].

Also, due to the fast paced environment in healthcare institutions, a direct, quick and easy access to data became very essential to clinicians. With a number of patients who need immediate care to attend to, it is expected that they would not be willing to utilize the system if the given amount of time and attention for its manipulation would delay the performance of their tasks [2]. When a technology is easy to learn and operate, users will be more comfortable and confident in using it, thus it is more likely to be accepted.

If a system is perceived to be complicated and difficult to use, users tend to become anxious and worry about making mistakes that would cause harm to their body as the device is worn by or attached to them. This expected danger leads to lower confidence in using the device. The same is true in the result of the study of Schaar and Ziefle [21] of the effects of the perceived benefits and fears on the acceptance of smart shirts.
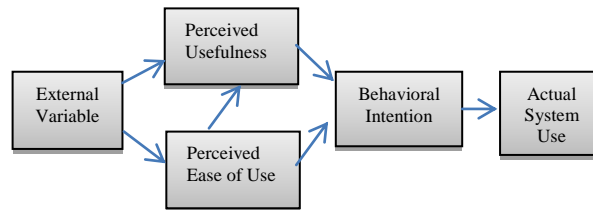
Figure 5. Technology Acceptance Model

3.2.3. Other cognitive attitudes: The perceived fear or risks that a wearable computer may bring to the user also affects its acceptance. In the study of Schaar and Ziefle [21], in evaluating the users' perceived benefits and perceived fears in relation to the acceptance of wearable computers, the author concluded that the assumed fears and perceived disadvantages primarily influence a person's acceptance, especially among women. Comparison of potential benefits of the new technology over the existing one is also one important behavior of consumers that will definitely affect the acceptance of the former.

3.3. Social Aspect

The following are the factors that are related to social relationships and interactions. Here, the term 'social' describes the nature of interactions between people, or the relationship between people [from: economics definition.net].

3.3.1. Personal privacy: People tend to be sensitive toward sharing relevant information about them especially if giving such information will bring potential harm to them in a social sense. Privacy is a critical issue, particularly in an environment of ubiquitous and pervasive computer use [22].

An enhanced jacket that identifies body condition and intense emotions, displays graphics, and informs passersby about the wearer has been vigorously rejected by potential users. Respondents indicated that they were unwilling to disclose their emotions because they considered them to be private information and potentially harmful to disclose [1]. For instance, in the study of Boscart, *et al.*, [23] about the acceptability of wearable hand hygiene device, the clinical staffs are cautious about the

type of information collected by the said device. The researchers are also aware that the staff's feeling of comfort and security in accessing and sharing their data is an important factor in the acceptability of the wearable device.

3.3.2. Social influences: People value their relationships with those close to them such as family, friends, and colleagues at work. Moreover, people tend to value the opinions and beliefs of people close to them, and that is often a primary consideration in making decisions. This notion was confirmed by a study showing that women were less willing to use smart clothing if their social network or environment did not favor the technology [20]. In the case of panic alarm systems in the form of necklace or wrist pendant, it is reported that some elderly persons are ashamed of wearing it and may reject these systems to avoid looking dependent or old [6, 24].

3.3.3. Culture: Culture is defined as the shared patterns of behaviors and interactions, cognitive constructs, and affective understanding that are learned through a process of socialization [from: carla.umn.edu/culture]. Simply said, "it is what we do, think, and feel, and it is going to rule virtually every aspect of our life" [from: dfait-maeci.gc.ca].

Culture has a significant effect on people's behavior, beliefs, and decisions. Thus, it is not surprising that culture influences an individual's acceptance and use of wearable technology. In evaluating the acceptance of some features of smart clothing, Duval et al. hypothesized that the high acceptance of artificial intelligence in Japan was affected by the users' religion [1]. Shintoist values suggest that objects may "naturally" be alive and have a soul whether it is a rock, tree, toy…or computer. Also, the acceptance of services adapting group events was expected due to the relative importance of individuals in France and groups in Japan.

3.4. Physical Aspect

Wearable computers will function as part of the human body; thus, the physical effect on the wearer will influence acceptance.

3.4.1. Physical comfort and safety: Physical comfort and safety is an essential consideration. The term comfort used in this study pertains to the absence of physical burden or disturbance on the wearer. It may determine the portability and wearability of the device [17].

Comfort is affected by the size and weight of the device and how it affects body movement. Most people prefer a portable tool that, aside from being useful and functional, has minimal bulk and weight [3]. Fear that a device may cause physical harm is a significant barrier to acceptance. Users may perceive danger from technical defects [23], and some elderly people report concern that radio waves via wireless communication may cause cancer and that sensors may cause an allergic reaction [24].

3.4.2. Aesthetic and appearance: Enhanced textiles must also be designed to look and feel pleasant [1]. Self-image is based on how people see us and may affect the way we feel about ourselves, which may increase or decrease self-confidence [16]. This emotional impact of the wearable device on the user is also one of the great influence on its adoption [16].

As a wellness-management device, a trendy wristband heart rate monitor may be accepted as a status symbol, whereas a wristband alarm device that looks too much like a technical aid may be considered stigmatizing by an elderly person [11]. The elderly

people prefer a wearable sensor or panic alarm systems that are smaller, less obtrusive and discreet, and suggested that they may be disguised into a watch or a ring as they don't want to be seen wearing a heath monitoring device [2, 24].

3.4.3. Mobility: Another related issue is the people's mobility. People are naturally mobile. They perform their daily activities with movement, whether they are at home doing their chores, at work performing their job, engaged in sports and exercise, and social activities, walking, driving, and going from one place to another. To be suitable, the size, weight, placement, and attachment to the body must be considered. The advantage of the wearable computer to be always with the wearer, hence usable everywhere, is a plus factor in its acceptance for it would be helpful for the user that needs to be mobile in the performance of his tasks.

One typical example is the clinical workplace which is very different from a normal office wherein an office worker may stay stationery at her desk most of the time, whereas a clinical staff would need to go around the hospital to attend to patients [25]. The same advantage is expressed by patients. Patients who underwent monitoring using a wireless electrocardiogram system were able to participate in physical exercise, sports, and social activities [2].

3.5. Demographic Characteristics

Among demographic characteristics, this paper focuses on the two most frequently discussed aspects: age and gender.

3.5.1. Age: People experience physical, cognitive, emotional, and social changes as they age. For example, many elderly people are not accustomed to technology, and they find computer systems difficult to understand [24]. Services of wearable computer systems that are potentially useful to and usable by the wearer depend on their age [1]. With regards to self-efficacy, most elderly people are not accustomed to technology and computer systems are hard for them to understand. They even stated that they are terrified with the computer for the reason that it might bring harm once they have made a mistake.

3.5.2. Gender. Gender also influences the acceptance of wearable devices. Schaar and Ziefle evaluated the acceptance of smart shirts in men and women and found that men were more accepting of the technology than women [21]. After evaluating the differences in perceptions of males and females over smart shirts, for example, Schaar and Ziefle concluded that males accept the said technology more than females, with the latter having a number of fears related to device's safety, ease of use, feeling of being controlled, and assumed danger for the body. Miller reported that although men and women were equally interested in scientific discoveries, women believed that they were less knowledgeable about science and technology and a higher proportion of men had a high level of interest in the use of new inventions and technologies [26].

3.6. Technical Experience

Whether or not a user has had previous exposure to various forms of technological applications has a substantial effect on their acceptance of a wearable computer. People who have had substantial technical experience tend to be more confident and are

expected to be more willing to use wearable computers than those with less technical experience.

The degree of technological experience may be an important factor in determining anxiety levels in using wearable systems [22]. Similarly, Duval, *et al.*, [1] reported that the critical features of smart clothes aroused greater interest and were more accepted in Japan than in France, which may be explained by the more dynamic and greater availability of technology in Japan.

4. Summary and discussion

Technologies are intended to be utilized by humans for the efficiency of their work and for the fulfillment of their needs. For wearable computing systems to be adopted and utilized, they must first gain acceptance from the intended users. Behaviors towards the acceptance and decision to wear such devices are influenced by a number of factors in both technological and human perspective. Focusing on the human factors, which are elicited from user-centered studies of wearable computers, 6 groups of factors were compiled as summarized below:

- Fundamental needs. Wearable computers that support the fulfillment of the most basic human needs are likely to be more accepted than those supporting the higher level of needs based on Abraham Maslow's hierarchy of needs.

- Cognitive activity. Wearable computers are accepted or rejected depending on the user's perception on its usefulness and ease of use. Perceived fears and risks may also have a strong effect on acceptance.

- Social aspect. The effect of wearing a device on the social interaction of the individual may influence the acceptance behavior. This aspect includes personal privacy, social influence, and culture.

- Physical aspect. Effects of wearing the device on the human body with regards to comfort, safety, appearance, and mobility are also influential.

- Demographic characteristics. Needs, preferences, perceptions, and the ability to adopt to new technologies are affected by age and gender.

The influence of these factors on the attitude or behavior towards the acceptance of the wearable devices will depend on who the target users are and the nature of their environment to which the device is intended to be utilized. Some of these factors can be interrelated with each other and also influences other factors.

For example, age also influences human fundamental needs, perceived ease of use, and technical experience. As with the relationship between age and fundamental needs, individual needs change as people as well change physically and psychologically, and develop different lifestyles. As with the relationship between age and technical experience, young people are more open to adopting new technologies than older adults. Their exposure to various kinds and applications of technology is directly influencing their ability to easily learn the usage of wearable devices.

5. Conclusion

Wearable computing systems must gain acceptance from the intended users before they will be adopted and used. The aim of the present study was to evaluate the

strengths and weaknesses of the technology in relation to six factors found to influence the acceptance and uptake of wearable computers.

Our findings will hopefully provide developers, designers, and researchers in the field of wearable technology with a deeper understanding of consumer behavior, thereby increasing social acceptance and penetration of the mass market.

The real purpose behind the creation of technology must be clearly understood by developers, designers, and researchers in this field. This is primarily because technology is nothing if it cannot be used by and made useful to people. A deeper understanding of who they are making their devices for must not be taken for granted in the creation of meaningful technology that will be widely accepted by the public.

Acknowledgements

References

[1] S. Duval, C. Hoareau and H. Hashizume, "Smart Clothing Technology and Applications", Chapter 7, **(2010)**, pp. 153-187.

[2] J. H. M. Bergmann and A. H. McGregor, "Body-Worn Sensor Design: What Do Patients And Clinicians Want?", Annals of Biomed. Eng., vol. 39, **(2011)**, pp. 2299-2312.

[3] K. Bodine and F. Gemperle, "Effects of Functionality on Perceived Comfort of Wearables", Proceedings of the 7th IEEE International Symposium on Wearable Computers, Washington, DC, USA, **(2003)**, pp. 57-61.

[4] V. Carlson, T. Klug, T. Ziegert and A. Zinnen, "Wearable Computers in the Clinical Ward Rounds", 3rd International Forum on Applied Wearable Computing (IFAWC '06), Bremen, Germany, **(2006)**, pp. 45-53.

[5] H. Lee and J. Kwon, "Combining Context-Awareness with Wearable Computing for Emotion-based Contents Service", Int. J. of Adv. Sci. and Tech, vol. 22, **(2010)**, pp. 13-24.

[6] J. Lee, S. H. Lim, J. W. Yoo, K. W. Park, H. J. Choi and K. H. Park, "A Ubiquitous Fashionable Computer with an i-Throw Device on a Location-Based Service Environment", 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW '07), Niagara falls, Ont., **(2007)**, pp. 59-65.

[7] J. Rekimoto, GestureWrist and GesturePad, "Unobtrusive Wearable Interaction Devices", Fifth International Symposium on Wearable Computers, Zurich, Switzerland, **(2001)**, pp. 21-27.

[8] C. Chris Baber, "Wearable Computers: A Human Factors Review", International Journal of Human–Computer Interaction, vol. 13, **(2001)**, pp. 123-145.

[9] P. Grossman, "The LifeShirt: A Multi-Function Ambulatory System Monitoring Health, Disease, and Medical Intervention in the Real World", Studies in Health Technology and Informatics, vol. 108, **(2004)**, pp. 133-141.

[10] H. Kim, T. Kim, M. Joo, S. Yi, C. Yoo, K. Lee, J. Kim and G. Chung, "Design of a Calorie Tracker Utilizing Heart Rate Variability Obtained by a Nanofiber Technique-based Wellness Wear System", App. Math. & Info. Sci, vol. 5, **(2011)**, pp. 171-177.

[11] M. Engin, A. Demirel, E. Z. Engin and M. Fedakar, "Recent Developments and Trends in Biomedical Sensors. Measurement", vol. 37, **(2005)**, pp. 173-188.

[12] S. W. Franklin and S. E. Rajan, "Personal Area Network for Biomedical Monitoring System Using Human Body as a Transmission Medium", Int. J. of Bio-Science and Bio-Technology, vol. 2, **(2010)**, pp. 23-28.

[13] H. Ghasemzadeh, V. Loseu and R. Jafari, "Wearable Coach for Sport Training: A Quantitative Model to Evaluate Wrist-Rotation in Golf", J. of Ambient Intelligence and Smart Environments, vol. 1, **(2009)**, pp. 1-12.

[14] Y. Meng and H. Kim, "Technologies to Promote Walking Behavior", The 8th International Conference on Multimedia Information Technology and Applications (MITA), **(2012)**, pp. 6-9.

[15] P. Gould, "Textiles Gain Intelligence", Materials Today, **(2003)** October, pp. 38-43.

[16] L. Dunne, "Smart Clothing in Practice: Key Design Barriers to Commercialization", Fashion Practice, vol. 2, **(2010)**, pp. 41-66.

[17] J. Rosenthal, N. Edwards, D. Villanueva, S. Krishna, T. McDaniel and S. Panchanathan, "Design, Implementation, and Case Study of a Pragmatic Vibrotactile Belt", IEEE Transactions on Instrumentation and Measurement, vol. 60, no. 1, **(2011)**, pp. 114-124.

[18] H. Alemdar, and C. Ersoy, "Wireless Sensor Networks For Healthcare: A Survey", Computer Networks, vol. 54, **(2010)**, pp. 2688-2710.

[19] V. Venkatesh and F. D. Davis, "A Theoretical Extension of the Technology Acceptance Model", Four Longitudinal Field Studies. Management Science, vol. 46, no. **(2000)**, pp. 186-204.

[20] G. Kortuem, M. Bauer and Z. Segall, "NETMAN: The design of a collaborative wearable computer system", Mobile Networks and Applications, vol. 4, **(1999)**, pp. 49-58.

[21] A. K. Schaar and M. Ziefle, "Smart Clothing: Perceived Benefits vs. Perceived Fears", The 5th International Conference on Pervasive Computing Technologies for Healthcare (Pervasive Health) and Workshops, **(2011)**, pp. 601-608.

[22] S. Kurkovsky, O. Rivera and J. Bhalodi, "Classification of Privacy Management Techniques in Pervasive Computing", Int. J. of u- and e- Service, Sci. and Tech., vol. 1, **(2008)**, pp. 55-71.

[23] V. Boscart, K. McGilton, A. Levchenko, G. Hufton, P. Holliday and G. Fernie, Acceptability of a Wearable Hand Hygiene Device With Monitoring Capabilities. Journal of Hospital Infection, vol. 70 , **(2008)**, pp. 216-222.

[24] R. Steele, S. A. Loa, C. Secombe and Y. K. Wong, "Elderly Persons' Perception and Acceptance of Using Wireless Sensor Networks to Assist Healthcare", Int. J. of Med. Info., vol. 78, **(2009)**, pp. 788-801.

[25] V. Carlson, T. Klug, T. Ziegert and A. Zinnen, "Computers in the Clinical Ward Rounds", The 3rd International Forum on Applied Wearable Computing (IFAWC), Bremen, Germany, **(2006)**.

[26] F. Rudell, "Boys' Toys and Girls' Tools?: An Exploration of Gender Differences in Consumer Decision-making for High-tech Products", Proceedings of Gender and Consumer Behavior, Salt Lake City, Utah, **(1991)**, pp. 187-198.

Authors

Cherrylyn Buenaflor received her BS degree in Business Administration from Bicol University, Philippines, in 2005. She is currently taking her MS degree in Human Computer Interaction at the School of Computer Engineering, Inje University, South Korea. Her research interests include user studies and diffusion of innovative technologies such as wearable computing systems.
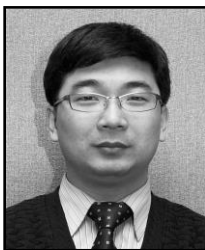
Hee-Cheol Kim received his BSc at Department of Mathematics, MSc at Department of Computer Science in SoGang University in Korea, and PhD at Numerical Analysis and Computing Science, Stockholm University in Sweden in 2001. His primary concerns are u-Healthcare, smart home technology, e-learning and Human Computer Interaction (HCI). He is associate professor at Department of Computer Engineering, Inje University in Korea. He has published many research papers in journals and conferences in the realms of HCI and CSCW.