Satisfying Fundamental Needs in Everyday Life With Wearable Computers

—

The Case of Belonging Needs

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日常生活における基本欲求を
満たすウェアラブル・コンピュータの特性

——

特に親和の欲求に関して

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Abstract

Wearable computers can improve everyday life but have not been widely adopted yet. Taking roots in psychology with Maslow's research, I investigate the importance and influence of human needs in wearable computing. His hierarchy of needs stresses the role of physiological, safety, belonging, esteem, and self-actualization needs. My hypothesis is that wearable computing can benefit from Maslow's theories to simultaneously improve the quality of life of the general public, and foster the adoption of wearables.

To lay the basis of a new direction, I propose the concept of *cyberclothes*, focusing on fundamental needs, and describe humanistic and technical requirements. The main features of cyberclothes are that they improve well-being, awareness and sociability; they have special features for use as social markers and tools, and possess some autonomy. To investigate the general public's perception of wearables satisfying fundamental needs, I gather data with informal interviews and self-completion questionnaires. The results validate my hypothesis for physiological and safety needs in France and Japan. Experiments with an enhanced jacket then clarify mixed results, validate the hypothesis for belonging needs, and provide insights in the proper design of wearables.

The prototype is an enhanced jacket with two screens, and physiological sensors to evaluate emotions. It is controlled by a JAVA-based framework, exploited by a service that displays photos reflecting common interests of wearers and interlocutors. Personalization is possible thanks to data in HTML format and to annotations in XML based on an ontology.

Satisfying fundamental needs in everyday life with wearable computers is possible in the limits of technology. The work presented here does not pretend to solve all human problems but aims at providing tools that significantly improve everyday life. To complete this work, the community should extend studies on fundamental needs, create and evaluate various cyberclothes, and consider implications beyond this field.

アブストラクト

ウェアラブル・コンピュータは、人間の日常生活の質を向上出来るが、今まで一般の人々には普及してこなかった。この論文では、マズローの心理学研究の基本概念を採り入れる事で、ウェアラブル・コンピューティングの分野における人間欲求の重要性、及びその影響について考察する。マズローの欲求段階説は、生理的欲求、安全欲求、親和欲求、自我欲求、自己実現欲求の役割を強調している。私の仮説は、マズローの欲求段階説を採り入れる事で、ウェアラブルは生活の質の向上に貢献出来るとする物である。

新たな体系の基礎を築く為、基本欲求に焦点を当てた「サイバークローズ」という概念を提案し、人文社会科学及び工学上の前提条件を述べる。より快適に生活し、意識を高め、社会性を増す事を支援する事がサイバークローズの主な特徴である。また、社会的な標識や道具としての機能を持ち、自律性を有する事も特徴としてあげられる。基本欲求を満たすウェアラブルに対する一般の人々の認識を調査する為、略式的な面接及びアンケートによる結果を集めた。フランスと日本における調査結果は、生理的や安全欲求に対する私の仮説を裏付けている。また強化型ジャケットを用いた実験は、結果を明らかにし、親和の欲求に関する仮説の正当性を立証し、サイバークローズの設計要素を洗い出している。

プロトタイプ機器として、二つの画面と感情を測る生理センサーを備えた強化型ジャケットを用いた。機器の制御はJAVAベースのフレームワークで行う。着用者とその対面相手の共通の興味を反映する写真を表示するサービスはこのフレームワークを利用している。HTML形式のデータとオントロジーを使ったXML形式の注釈を利用する事で機器のパーソナライズが可能になっている。

技術の範囲内で、ウェアラブル・コンピュータを使って日常生活における基本欲求を満たす事は可能である。本研究は人間の全問題を解決する為にあるのでは無く、日々の生活を有意に向上させる道具を提供する事を目的としている。研究者は、この分野を完成させる為に、基本欲求についてより深く研究し、様々なサイバークローズの試作、評価を行い、他分野の動向にも注意を払っていくべきである。

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3 University of Tokyo (Japan) – 東京大学
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6 Tokyo Denki University (Japan) – 東京電機大学
7 LISA (France)
8 Canon, Human-Machine Perception Laboratory (Japan)
9 Bielefeld University (Germany) – Universität Bielefeld
10 Tokyo Institute of Technology (Japan) – 東京工業大学

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16 東京電機大学

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17 LISA (France)
18 Canon、知覚システム開発センター
19 Universität Bielefeld (Germany)
20 東京工業大学

Related publications

1. Duval, S., Hashizume, H., Andrès, F.: First Evaluation of Enhanced Jackets' Potential to Support First Encounters with Photo Slideshows and Emotional Displays. *8th Virtual Reality International Conference*. (2006, April) pp75-84
2. Duval, S., Hashizume, H., Richard, N.: Physiological, Safety, and Belonging Needs: From Wearable Computers to Intelligent Environments. *International Symposium on Intelligent Environments*. (2006, April) pp85-93
3. Duval, S., Hashizume, H.: Satisfying Fundamental Needs With Wearables: Focus on Face-To-Face Communication. *Transactions of the Virtual Reality Society of Japan*. (2005, December) Volume 10, Numero 4, 495-504
4. Duval, S., Hashizume, H.: Perception of Wearable Computers for Everyday Life by the General Public: Impact of Culture and Gender on Technology. *2nd International Conference on Embedded And Ubiquitous Computing*. (2005, December) 826-835
5. Duval, S., Hashizume, H.: Cyberclothes: Personal Media in Everyday Life. *3rd International Conference on Active Media Technology*. (2005, May) 44–47
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7. Duval, S., Hashizume, H.: サイバークローズによる人の出会いの支援 － Facilitating Face-to-Face First Contacts with Cyberclothes. *9th Virtual Reality Society of Japan Annual Conference*. (2004, September) 87–90

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Chapter 1. Introduction

> “ Many technology implementations fail because the developers and implementers consider only technology factors at the exclusion of human factors.”
>
> Younghwa Lee, 2005 [48] p95.

Whether hand-held or embedded in accessories and garments, *wearable computers*[21] are small computers continuously worn by their owner. Although wearables can greatly improve everyday life, they have not yet been widely adopted by the general public. This situation might result from an excessive focus on technology and from a lack of interest in humanistic aspects. Investigating this idea, I considered psychological knowledge and focused on Abraham Maslow's theory of motivation. The fundamental needs (physiological, safety, belonging, esteem and self-actualization) it identifies are frequently overlooked in existing wearables. Therefore my hypothesis is that focus on human fundamental needs in wearable computing can simultaneously improve the quality of life of the general public and foster the adoption of wearables.

ハンドヘルド型、或いはアクセサリや電子機器に埋め込んだタイプなど様々な形があるが、ウェアラブル・コンピュータは着用者と一体となって使われる小型のコンピュータである。それらは日常生活を劇的に向上させる可能性を持ちながらも、一般の人々に広く受け入れられるには至っていない。この事は、機器の開発において技術面に過度に焦点が当てられる一方、人文学的側面が軽視されてきた事に依ると考えられる。そこで我々は心理学におけるアブラハム・マズローの欲求段階説に注目した。この理論において定義される基本欲求---すなわち生理的欲求・安全欲求・親和欲求・自我欲求・自己実現欲求---は、現存するかなりのウェアラブル・こんぴゅーたが見落としている点である。従って我々は、ウェアラブル・コンピューティングにおける人間の基本欲求に注目する事が、人々の生活の質を向上させると同時にウェアラブル機器の普及を促す事に繋がるという仮説を立てた。

21 Also called *wearables*.

1.1 Problem definition

1.1.1 Situation and hypothesis

Wearable computers are small computers that can be continuously worn by their owner. They are related to the ubiquitous field, which considers the integration of technology in garments [89] and everyday objects such as cups [31] and chairs [93]. The archetype of wearable computers is a small box attached to the belt or placed in a bag, connected to a multi-button device standing for a keyboard, and to semi-transparent glasses that display information to the wearer. However, the *garment* shapes are becoming more common. Originally the development of wearables focused on mobile solutions to replace desktop computers and laptops. Then research led to novel applications and equipment, mainly for professionals and experts. Examples include aid for navigation in buildings [78], access to battlefield data [96] and life support in arctic spaces [68]. Science-Fiction writers such as *William Gibson* envisioned advanced applications[22] and inspired research as well as discussions on their possible impact on societies.

Although wearables provide various functionalities, they still have to be widely adopted. Beside prices, one obstacle is the lack of knowledge on psycho-social aspects compared to technical issues. Optimizing components or processes [53], selecting locations for sensors [32], and investigating special environments [68] does not provide insights regarding the general public. Neither does it fulfill people's needs nor does it make life more enjoyable. Concepts like *smart clothes*, *intelligent textiles*, *e-textiles*, and *e-garments* reflect this reality: they focus on the properties of materials or on associated processing abilities [86], not on wearers. Thus, although technologies are at hand, human issues are underestimated, and investigations of laymen's needs and desires are insufficient [74].

Exploring human aspects of *everyday life wearables* is a daunting task. It requires a study of physical, psychological, social and cultural factors. To provide maximum benefits for the general public, I set priorities on wearable computers that fulfill human fundamental needs. These needs, defined by the psychologist Abraham Maslow [55], include deficit needs (physiological, safety, belonging, esteem) and being needs (such as self-actualization). As a consequence, **my hypothesis is that wearable computing can benefit from Maslow's theories to simultaneously improve the quality of life of the general public, and to foster the adoption of wearables.**

22 For example in *Neuromancer*: "[Lupus Yonderboy] wore a polycarbon suit with a recording feature that allowed him to replay backgrounds at will. [...] Case watched the suit crawl with color and texture." in [33], p87.

Ideally, this hypothesis should be validated for the whole group of needs listed above. Realistically, and taking into account time and financial resources, I investigated only the three first types of fundamental needs: physiological, safety and belonging. Additional constraints included the current state of the technology, lack of proper interfaces for the general public, and the inability to experiment devices for long periods among large populations.

1.1.2 Interest for the community

The originality of this work is its rooting in psychological knowledge. An immediate consequence is to broaden the scope of research in wearable computing. Then potential benefits depending on the validity of the theory are on one hand to clarify the influence of humanistic factors and to accordingly create wearables that improve our quality of life, and on the other hand to reveal a way to accelerate developments in the field, and foster the adoption of wearables.

The first interest of my investigations for the community is to extend the scope of wearable computing (illustration 1.1), and to define a framework that subsequent research can complement :

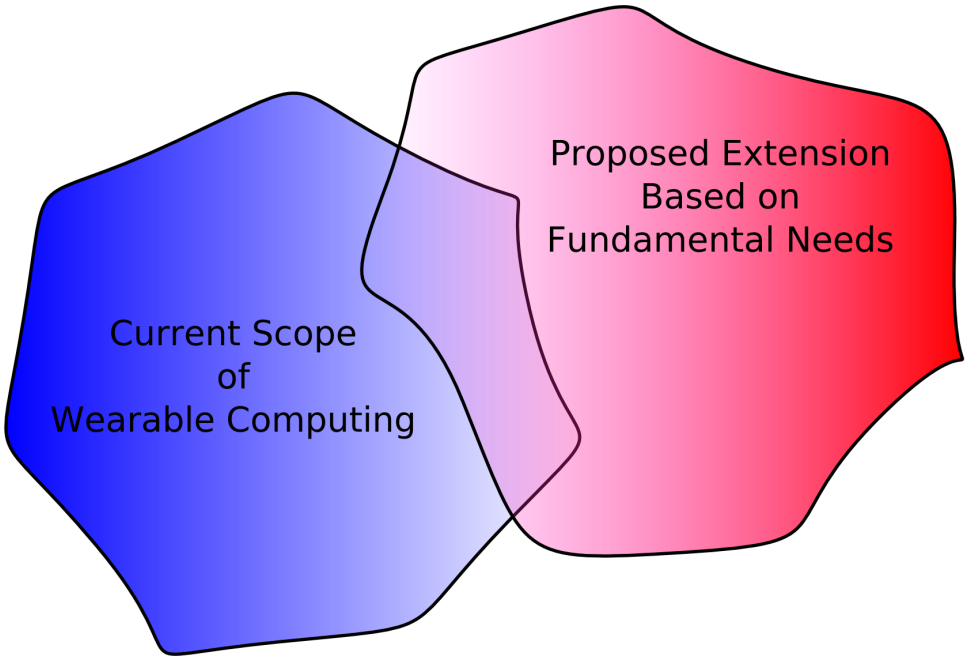

Illustration 1.1: Interest – Extend the scope of wearable computing.

Providing a new direction and guides regarding social and technical factors, this research can improve the quality and usefulness of wearables developed. Besides, the insights gained in human nature and in the *people-technology* relation can be injected in related fields such as intelligent

environments and robotics. The impact is potentially significant considering the Japanese's expected use of robots in everyday life [47][73] to solve population difficulties[23], and the situation of other developed countries. Finally there is a patent necessity to better understand the needs of, and factors (aesthetics, technical, cultural) related to, potential users of enhanced clothes [57], which leads to better design processes.

The second interest is to clarify the influence of humanistic factors in wearable computers for the general public (illustration 1.2). With the validation of the hypothesis, we acquire a dimension related to well-being and human growth. Wearable computers will help people satisfy salient needs and attain higher ones. For example, a person with health support [38] will worry less about her survival or comfort, and will be able to focus on emotional relationships and personal achievements. Because everybody reaches different states of accomplishment, devices will require personalization in order to reach their maximal efficiency. Such personalization should bear additional benefits.

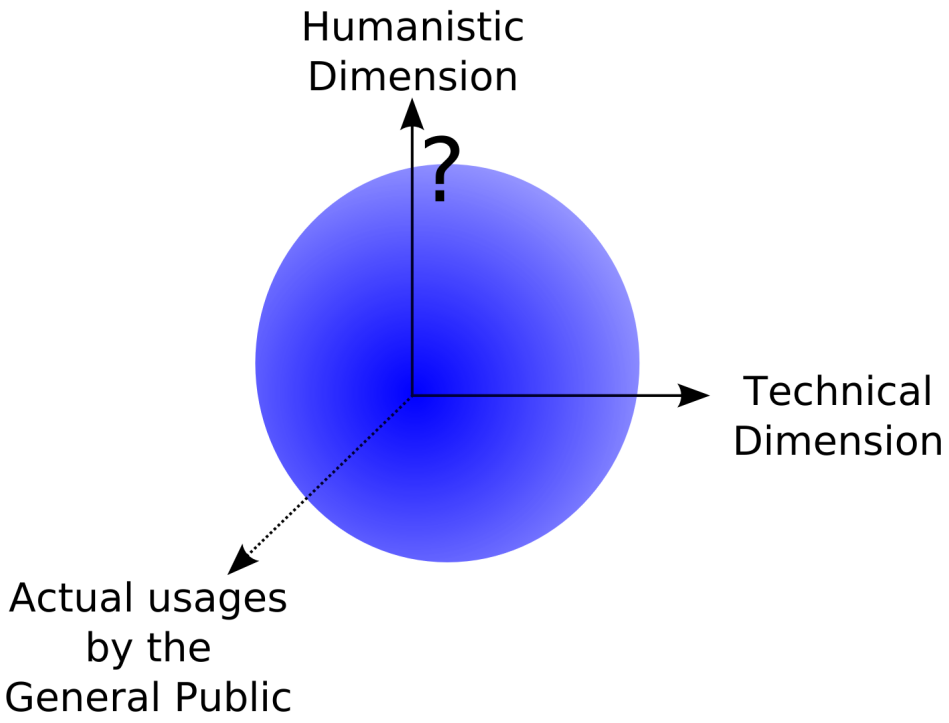

Illustration 1.2: Interest – Reveal a dimension influencing actual usages.

The third interest of this study is its potential to cause a virtuous cycle (illustration 1.3). Proving the interest of wearables should motivate researchers, accelerate the development of commercial devices, and foster their adoption by the general public. In addition, reaching a critical mass of users will enable new services and investigations.

23 Projections for 2050 indicate a lack of labor force that cannot be compensated by immigration only [62].

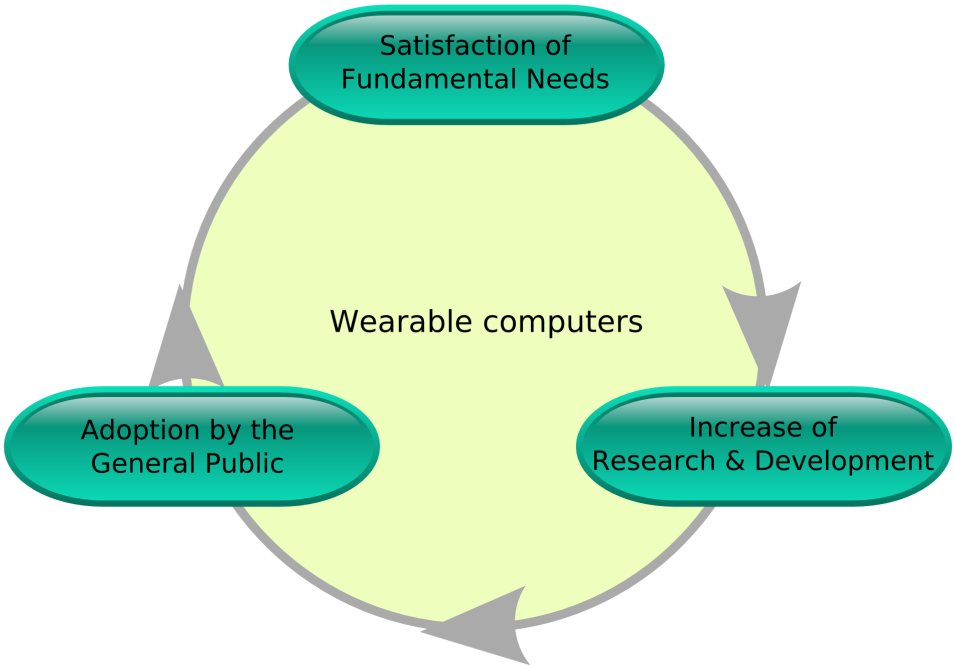

Illustration 1.3: Interest – Induce a virtuous cycle.

These three interests are strong incentives for this investigation, with benefits for potential wearers, manufacturers and the research community.

1.2 Research approach

1.2.1 Proposition of a concept

Existing concepts in wearable computing such as *smart clothes*, *intelligent textiles*, *e-textiles*, and *e-garments* focus on technical aspects [86]: properties of materials or associated processing abilities. They do not focus on wearers, on their needs or desires. As a consequence I propose a new concept: *cyberclothes*. It focuses on people's fundamental needs, taking into account requirements for uses in everyday life. Providing a human-oriented definition, the concept replaces humans at the locus of attention in the field. Based on Maslow's hierarchy of needs, it benefits from a strong theoretical background. I validate the features and interest of the concept, identify critical elements, eliminate logical and factual inconsistencies, and refine its definition with an iterative technique. Therefore the definition is several times modified, corrected and enriched thus becoming more operational.

Maslow demonstrated that human fundamental needs belong to five ordered categories: physical, safety, belonging, esteem and self-actualization. Cyberclothes are–in a nutshell–enhanced garments that satisfy one or several of these needs. In modern societies, physical and safety needs are usually well met so one could doubt the interest for the general public of wearables that support them. However, my social investigations show that such wearables can still be beneficial, for example adapting the environment to the wearers' state, or monitoring health and contacting emergency services when necessary.

To provide concrete elements about cyberclothes, three technical factors are evaluated: form, hardware and intelligence. I selected a garment form-factor because of its high potential (*e.g.* large surface, contact with the body) for services, and easy integration in everyday life for the general public. As for the equipment I considered several sensors and effectors, means to control functions without disrupting everyday activities, and feedback to the wearer. Although the use of artificial agents to support wearers seemed appropriate, I show that their acceptation is currently difficult, limiting designs to experiment.

1.2.2 Selection of investigation methods

To validate the hypothesis, I considered the state of the art, current practices, and settled for an

hybrid approach combining social investigations and experiments with prototypes.

The first natural step was to study the state of the art. Accessible sources cover research prototypes, products of companies and models by fashion designers. Because their inclusion could prove eye-opening, I also considered the properties of high-tech textiles [63][84], and works that exploit smart materials reacting for example to light [12][94], even without electronic components. Because they lack processing units, these works are not usually covered by the *wearable computer* concept. Besides, I took into account social issues. **Although studies on the perception and adoption of wearables can provide useful information, they are rare.** One was planned by IBM in 2001 to evaluate usability and acceptance of digital jewelry [59] but has not yet been carried out[24]. Another has recently been published but only deals with medical diaries [25]. Studies of other devices, such as mobile phones, are of little use because their characteristics are very different: wearables can have any number and type of sensors or effectors, and can be used for a wide range of services.

Then, I considered how to gather data about the general public. There were two approaches: social and experimental. The social approach was to gather quantitative and qualitative data with interviews and questionnaires. One advantage is the quantity of information that can be acquired from the general public, even in several countries. The main disadvantage is that people do not experience real equipment and therefore provide information on what they imagine, not on concrete experiences. Another weakness of social studies is the difficulty to design them to understand unconscious–in addition to conscious–motivations. This limits investigations to surface information, feelings and expectations, and does not provide implementation details. On the other hand, the experimental approach provides data from familiarized users, which results in deeper information on prototypes, services, and interactions. This widespread approach is recommended by the community but feedbacks are specific to assessed equipments, which narrows the scope and generalization of the results. Besides, prototypes and respondents must be co-located; technical, temporal and financial resources make it an unrealistic requirement to cover fundamental needs.

Taking into account these advantages and limitations, I opted for an hybrid solution based on social investigations and experiments. Building on the strengths of the two perspectives, it produces a more accurate account of the situation and enables a cross-validation of results. Because in Maslow's theory the satisfaction of higher needs depends on the previous gratification of lower needs, the investigations begin with physical, safety and belonging needs. **Social studies provide a first validation of the hypothesis, general information, and highlight elements of interest. Experiments then provide a second validation and clarify gray areas.**

24 E-mail exchanges with Christopher S. Campbell, IBM Almaden Research Center, 02-May-2005.

1.2.3 Controlled factors

Because social and technological aspects are mixed, the influencing factors are cultural, social, psychological, physical and technical. Although it is difficult to simultaneously control all of them, it is possible to focus on a few ones and reduce the influence of the others. To facilitate adoption and social investigations, I selected a form-factor natural and easy to imagine: garments. Finally, I took a closer look to gender and cultural factors to establish a certain universality of the results.

The focus prevailing in wearable computing led to a large technical corpus: organization of components [53], location on users' body [32], *etc.* We can reuse this knowledge while focusing on other aspects such as the form-factor. Wearables can take many forms depending on functions, trends and fashion. Although this liberty is an undeniable advantage for design, it is an obstacle to reliable evaluation. For social investigations, results must be comparable between respondents; because form-factors impact on imagination–and therefore on answers–I focused on a specific one. I chose garments for two reasons. First, they look familiar to the general public, and enhanced versions are easy to imagine. Second, they provide body contact and a large surface for components, which is a plus for applications relying on biosensors, and for multi-purpose designs.

For social studies and experiments, it is easy to control parameters such as age, gender, profession and nationality of respondents. Because this research concerns the general public, and because results should have a certain universality, I left aside the age and profession factors, and varied my samples to limit their influence. However, considering the role of gender in technology perception and adoption [30][88], I decided to study it in depth. This parameter is easy to control and requires little selection from the pool of participants. The only common feature among the targeted population was its lack of experience with wearable computers.

Sharing an international environment, I was aware of culture's impact. As shown by the hiring of ethnographers by companies such as Intel [14], this issue acquired some consideration. Because my work relies on Maslow's theory, seemingly universal, I was curious about results' convergence and divergence across cultures or countries. The research's scope would be too wide if numerous cultures were covered but with two very different ones it appears feasible. Such comparisons ensure that results do not mirror a single society but can be generalized to a certain extent.

1.3 Process overview

Maslow's theory points out five types of needs. Investigating all of them would be very time-consuming. However, covering the three first ones (physiological, safety, belonging) is feasible and already makes results meaningful. The process consisted of two main parts: social investigations and experiments. First I collected information from the general public France and Japan with interviews and questionnaires. Results validated the hypothesis for physiological and safety needs, but challenged it for belonging needs. Then, to clarify these results and validate further the theory, I accordingly developed a prototype and services. The experiments provided insights in proper designs, explained the initial rejection of emotional displays, and helped overcome that of support for face-to-face first contacts.

1.3.1 Social investigations

In order to investigate the general public's perception of wearables satisfying fundamental needs, I gathered data with informal interviews and self-completion questionnaires. These two tools were used in France and Japan. The objective was to gather general information, and check intuitions regarding the impact of culture and gender.

First I interviewed students and researchers in computer science and psychology to know their feelings about wearables and interest for enhanced garments compared to other devices. These interviews showed that there was a place for cyberclothes, complementing existing devices like PDA and laptops, and not replacing them. On one hand, Japanese interviewees expressed their interest for garments that can–notably–display graphics on their surface to communicate or for fun. On the other hand, French interviewees were more interested in health aspects but more sceptical about visual communication. Besides, the garment form-factor looked less attractive to the French. Therefore these informal interviews confirmed an interest for wearables supporting well-being and communication, and hinted at a cultural effect.

Second, I carried out an exploratory study among in Japan and France to gather surface information about the general public's perception of wearable computers. Because respondents had never used wearables previously, the questionnaire focused on a form-factor easy to imagine (garments), and on everyday situations. It covered lower needs and several technical aspects. The answers were coded with a 5-points Likert scale. Besides, open comments were checked for insights about the motivations of respondents in their ratings. Analyses using *t*-distributions confirmed the theory for

physiological and safety needs with high levels of confidence. However results for belonging needs were mixed. Additional analyses using *t*-tests demonstrated a gender and cultural effect with high levels of confidence.

The results of the interviews and questionnaires were used to establish first design guidelines for wearables. Then belonging needs were explored in more depth with experiments on face-to-face communication and emotional displays.

1.3.2 Experiments with prototypes

Experiments with prototypes aimed at a second validation of the theory and to a clarification of previous results about belonging needs. I developed a prototype and framework to improve sociability and provide emotional information. The user study investigates the system's efficiency and the participants' feelings regarding cyberclothes before and after experiments.

The prototype is a jacket that processes data, communicates over a wireless network, renders sounds, displays graphics, and acquires physiological data from the wearer. Users control it with a small multi-button device. A small screen placed on the chest, and a larger one in the back display formal or emotional content to interlocutors and passersby. The prototype lacks features for use in everyday life but is well-suited for the user studies. The framework that controls the equipment is based on a JAVA engine with XML data management. Developed services exploit it to automatically generate slide-shows based on events, wearers' common interests, or on their mental states. These mental states can be evaluated using heartbeats and skin conductivity.

With this prototype and service, I evaluate the participants' perception of cyberclothes when manipulating a real wearable dedicated to the support for face-to-face first contacts, and emotional display. A first questionnaire is provided before and after the experiment to estimate shifts in the perception of cyberclothes. A second questionnaire is also provided after the experiment to get feedback dedicated to the system worn. Finally, a qualitative evaluation of the service is carried out. These experiments clarified previous results, validated the theory for belonging needs, and enabled incremental ameliorations of the prototype.

1.4 Summary and conclusion

Wearables can improve our quality of life but little work was done in that direction. Using Maslow's hierarchy of needs, I extend the scope of wearable computing, clarify the influence of fundamental needs for the general public, and expect the creation of a virtuous cycle. I propose the concept of *cyberclothes* and select an hybrid investigation method focusing on gender and cultural factors. Social investigations provide an overview of the general public's perception of wearables and confirm physiological and safety needs' influence. Experiments then clarify results and validate the theory for belonging needs. The originality of this approach is its rooting in psychology.

This document is organized as follows. After the introduction, chapter 2 presents wearables satisfying human needs, beginning with Maslow's theories, a state of the art, and a definition of cyberclothes. Then chapter 3 introduces the social studies based on interviews and questionnaires, and provides guidelines for wearables. Chapter 4 describes experiments that focus on belonging needs, the prototype and services. Then chapter 5 discusses the results. Finally, chapter 6 concludes, summarizes the results, broadens the perspective and raises new questions.

ウェアラブル・コンピュータは我々の生活の質を向上させる可能性を持っているにも関わらず、そうした使われ方をしている物は殆ど無い。マズローの欲求段階説を適用する事で、我々はウェアラブル・コンピューティングの範疇を拡張し、人々の基本欲求による影響を明らかにする。それにより人間とウェアラブル機器の間に好循環が生まれるのを期待するのである。我々は「サイバークローズ」の概念を提案し、異なる性別や文化の被験者に対して社会調査と実験を行う。調査においては、一般の人々によるウェアラブル機器に対する認識を概観し、生理欲求及び安全欲求の影響を確認する。次に実験により、社会調査の結果を明確にし、親和欲求に対する仮説を裏付ける。心理学の観点からこの分野にアプローチするという点が、我々の研究の新規性を示している。本論文は以下のように構成される。導入の後、第 2 章ではマズローの理論、現在の動向、サイバークローズの定義を述べ、基本欲求を満たすウェアラブル・コンピュータについて説明する。第 3 章で面接とアンケートに基づく調査について述べ、ウェアラブルの設計指針を導く。第 4 章で親和欲求に焦点を当てた実験、プロトタイプ、サービスについて述べる。第 5 章において結果を議論する。最後に第 6 章で結論づけ、結果の総括を行い、今後の展望と問題を述べる。

Chapter 2. Wearables satisfying human needs

Wearable computers are currently mainly used for technical purposes, however they can also be used for humanistic purposes, improving the quality of life of both wearers and surrounding persons. For this, Maslow's theory of motivation and hierarchy of needs are interesting starting points. Considering both deficit and being needs, actual salient needs determine the behavior of people. Wearable devices that partially satisfy these needs have been researched and developed independently, with a focus on technical rather than humanistic issues. This prevented a systematic study of human needs in the field. To lay the basis of a new direction, I propose the concept of *cyberclothes*, focusing on fundamental needs, and describe humanistic and technical requirements. Three scenarios are then introduced to facilitate understanding.

現在、ウェアラブル・コンピュータは工学的な目的に使用されているが、人文社会科学的な目的においても有用である。すなわち、着用者やその周りの人々の生活を豊かにする為にも使用されうる。この事にマズローの欲求段階説を適用することは興味深いことである。欲求段階説においては deficit needs と being needs を考慮して actual salient needs が人間の行動を決定するとされる。此れ迄は、人文社会的な問題よりも工学的な問題に焦点が当てられてきた為、個々の欲求を別々に実現するウェアラブル・デバイスが独立に研究、開発されてきた。此れにより、ウェアラブル・デバイスの領域では人間の欲求について体系的に研究がなされてこなかった。本章では新たな体系の基礎を築く為、基本欲求に焦点を当てた「サイバークローズ」という概念を提案し、人文社会科学及び工学上の前提条件を述べる。また、理解の補助の為に三つの状況を導入する。

2.1 Maslow's theory

Theories about human behavior in psychology belong to four movements, or forces: Freudian, Behaviorist, Humanistic, and Transpersonal. The psychologist Abraham Maslow was instrumental in the formation of the *humanistic movement*. While his colleagues focused on pathology, he focused on exceptionally healthy people and on human growth. His primary contribution was his *theory of motivation* [54], with his *hierarchy of needs* as primary tool. It is often represented as a 5-story pyramid, with prepotency of lower levels over higher ones. The first version of the theory classified physiological, safety, love and esteem needs as *deficit needs*, while self-actualization was the only *being need*. Latter extensions and refinements added upper levels within being needs. Maslow's theory does not claim universality but it shows a high unity beyond cultures. Because fundamental needs impact on people's behavior, actions and choices, this theory has numerous practical applications. Maslow used it and validated it in American companies, notably improving their management system. His influence grew over decades with the development of the humanistic movement. One can argue that Maslow's theory is superior to others' because it focuses on growth and well-being instead of pathologies.

2.1.1 Deficit and Being needs

Fundamental needs are hierarchically ordered, the emergence and satisfaction of higher needs depending on the satisfaction of lower needs. Maslow identified five basic needs and put them in two categories: deficit needs (or D-needs) and being needs (or B-needs). Deficit needs are physiological, safety, belonging and esteem needs. Initially being needs only included self-actualization. The difference between these two types of needs is that deficit needs can be seen as necessary for survival, at least to maintain a good health, whereas being needs are not. Besides, deficit needs can be satisfied whereas being needs tend to grow while they are fulfilled. I present thereafter the needs by order of priority for the organism, and illustrate them with the usual 5-story pyramid (illustration 2.1).

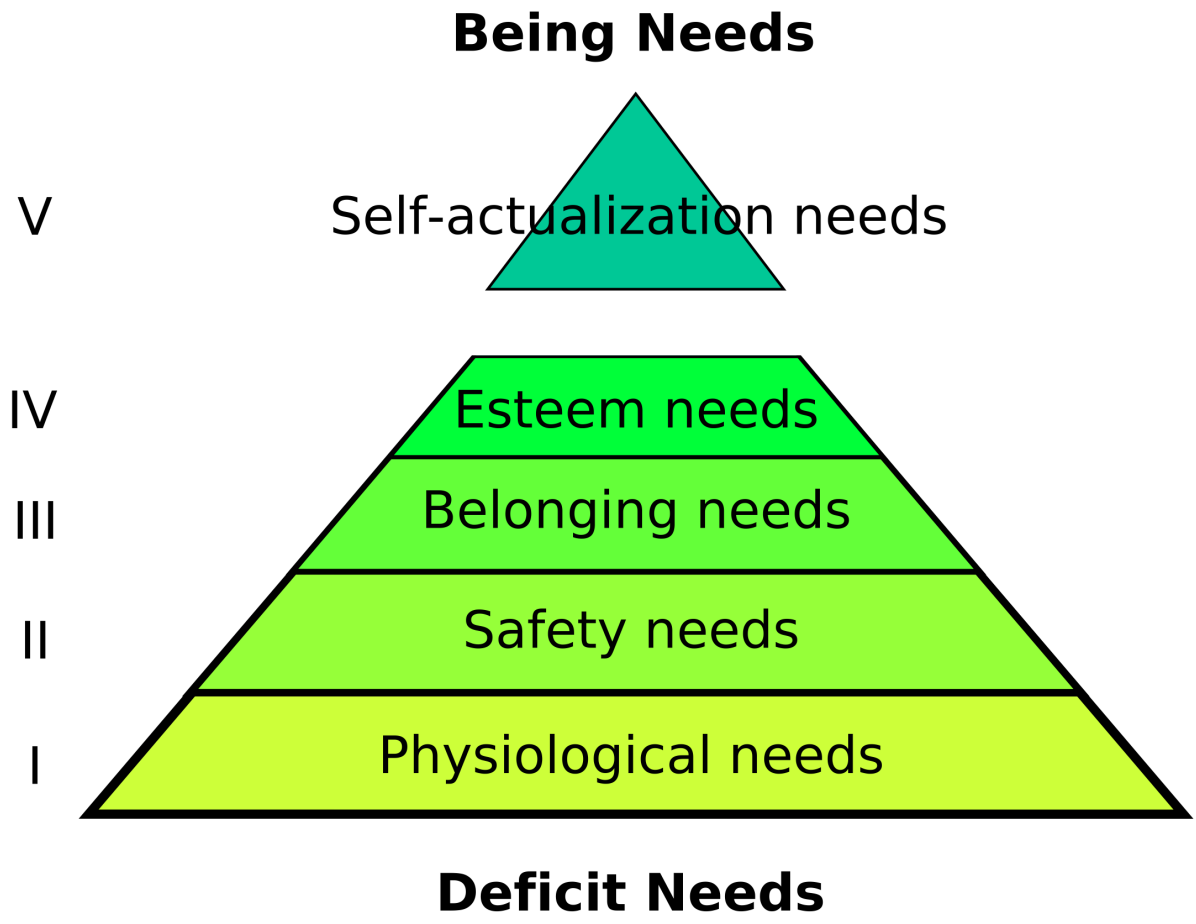

Illustration 2.1: Maslow's theory – Standard representation of the hierarchy of needs.

The most basic needs are *physiological needs*. They target homeostasis, and regulate our internal environment to maintain a stable state, within tolerable limits, of–notably–the temperature and blood composition. These needs evolve, in the same way as appetites change depending on the actual lacks in the body [95]. Basically homeostasis is sustained by consumption of air, food and drinks, by good sleep, by an appropriate temperature, *etc.* Effects of unfulfilled physiological needs include pain, illness, discomfort and death. When a person has physiological needs all her resources, senses and intelligence become *e.g.* hunger-oriented until relief.

After the gratification of physiological needs, *safety needs* emerge. They are concerned with physical and psychological security: health, comfort, freedom, peace of mind, stability and consistency. Physical assaults, divorces, experiences with sickness, death, wars and natural disasters increase safety needs. Even simple unfamiliar situations can arouse them; for example a child can become terrified just because she got lost.

Once physiological needs and safety needs are relatively-well gratified, *belonging needs* become salient. They are concerned with all emotional relationships: love, affection and belongingness. This covers relationships with the family, community, work groups and clubs. Love needs, here, exclude sexual needs because sex can be studied as a purely physiological need. However sexual behaviors are a good example of behaviors depending on multiple motivations such as sexual release (physiological), security of affection (belonging) and proof of femininity/masculinity (esteem). Without love or a feeling to be needed, belonging needs are not fulfilled, which can elicit loneliness and social anxieties.

After the satisfaction of belonging needs, *esteem needs* emerge. These needs have an external and internal component: *respect* and *self-esteem*. Respect is related to status, presence and reputation. Self-esteem is related to concrete achievement, confidence, competence, independence and freedom. Negative aspects of these needs include a sense of inferiority and helplessness.

Finally, after the satisfaction of esteem needs, *self-actualization needs* become salient. These are not deficit-needs but being-needs. One particularity of these needs is that they get stronger while being fulfilled. Self-actualization reflects a need to fulfill one's potential. Its nature varies greatly from one person to another. For one, it may be to become a great mother, for another a great athlete or artist. Because deficit needs must be fulfilled before reaching self-actualization, people who reach this stage are rare. The literature about self-actualization is extensive but details are of limited interest for this study. To conclude, we can sum up the definition of self-actualization by:

> "What a man *can* be, he *must* be." (emphases in original)
>
> Maslow, 1943 [54].

In later works Maslow's hierarchy of needs was extended beyond these five levels, including a level for spiritual needs.

2.1.2 Evolution of salient needs

As explained previously lower needs have priority over higher ones. When a need is satisfied, it becomes unimportant in the current dynamics of the individual, and higher needs then become salient. However the full satisfaction of a need is not required before the emergence of higher needs; priorities evolve gradually. Besides, lower needs can ulteriorly come back into focus: when one faces a crisis (job loss, divorce, etc.), she can regress to a lower level that reflects needs of what has been lost. Salient needs impact on our current perception of the environment and future, which

can lead to a crisis due to the underestimation of lower–currently satisfied–needs.

Under special conditions the hierarchy might need adaptations. In some cases the order of needs just seems changed, for example when one seeks a good reputation (apparently esteem needs) as a means to get affection (in reality belonging needs). In other cases needs can be suppressed or weakened, *e.g.* long unemployment can lead to a long-lasting satisfaction just with simple food and a roof. A trauma can cause a permanent deficit; in the pyramid it can be represented as a well (illustration 2.2). For example people suffering from war, illnesses, or being alone as a kid might crave for the same things all their life while higher needs are being fulfilled. Psychotics, on their side, loose needs for belongingness. The opposite case is people who have higher values and can go beyond their basic needs; for example martyrs.

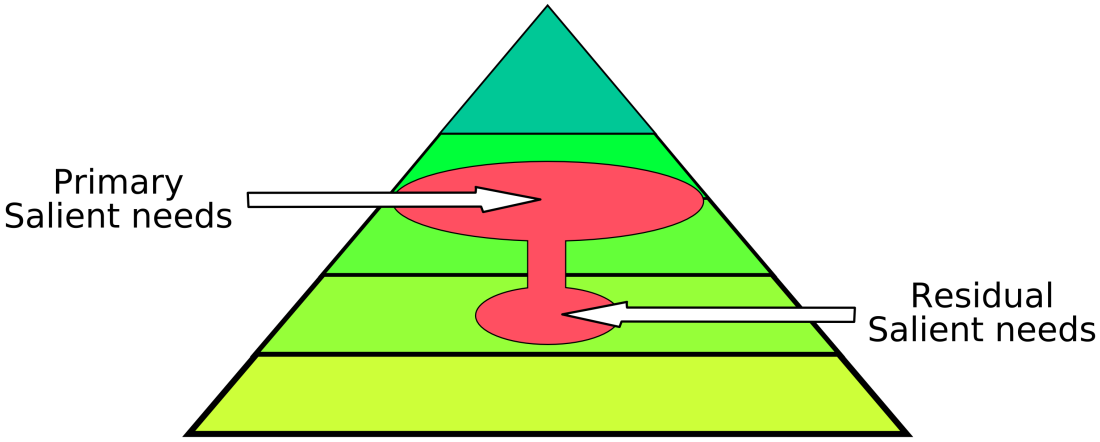

Illustration 2.2: Maslow's theory – Impact of traumas on the hierarchy of needs.

Because of their low level, physiological and safety needs can be almost exclusive organizers of behaviors, using all available resources for their gratification. However normally functioning peaceful societies provide basic security, with physiological and safety needs well-gratified for average, healthy citizens. As a consequence salient needs are often identified to belonging and esteem needs. Maslow highlighted that in our modern societies, physiological and safety needs are mainly fulfilled whereas love and affection are disregarded. He therefore considered that many psychological problems resulted from belonging needs.

> "In our society the thwarting of [belonging] needs is the most commonly found core in cases of maladjustment and more severe psychopathology."
>
> Maslow, 1943 [54].

2.1.3 Unmotivated behavior

Maslow also considered [55] that some behaviors are unmotivated. Accordingly he opposed behaviors emerging from coping (instrumental, functional) with those from expression (non-instrumental). Coping deals with context: environment and culture. Expression is more related to the organism itself. Characteristics of coping and expressive behaviors are presented in table 2.1, adapted from [55] (pages 62-64) .

	Coping	***Expressive***
Purposive or unpurposive	Purposive	Unpurposive
Paradox of trying not to try	Effortful	Effortless
Determinants	External: environment, culture	Internal: state of organism
Learned or unlearned	Learned	Unlearned, released, disinhibited
Possibility of control	Controlled	Uncontrolled, uncontrollable
Affecting the environment	Designed to change environment	Not designed to do anything
Means and ends	Means (towards need gratification)	Ends
Conscious or unconscious	Conscious	Not conscious

Table 2.1.: Maslow's theory – Coping versus expressive behaviors.

As a conclusion human behaviors arise from five fundamental needs and from the specificities of one's organism. Expressive behaviors are more individual and display much variations. On the contrary, except in case of trauma, coping behaviors are prioritized in a way that is common across cultures, with survival as utmost priority. This makes fundamental needs more critical and more accessible for technological support.

2.2 State of the art

Compared to standard computers, wearables are exceptional because they follow their user in most places and can exploit body-related features. They are therefore particularly well-suited to assist humans in their everyday life. Existing wearables can be classified using Maslow's hierarchy of needs. The following classification considers the potential of devices rather than their intended objectives. Currently, we find wearables that deal with deficit needs but none for being needs. Designing wearables for being needs is more difficult because it deals with discovering and integrating one's own nature and motivations. In any case, due to the prepotency of deficit needs [54], wearables supporting being needs would only be useful to a tiny part of the population.

2.2.1 From physiological needs to esteem needs

Most devices appear on lower levels of the following classification, which mirrors Maslow's hierarchy of needs. Results of my social investigations suggest that the reasons are their perception as most useful, and their easy acceptation, which is logical because they deal with survival. As far as I know, this is the first attempt to formally classify wearables based on human needs.

Level I: Physiological needs

On level I, wearables deal with physiological needs, and therefore basically with survival. Several models were designed for experts and very specific uses; they help find and monitor the quality of vital resources and sustain good body conditions. The *Twenty First Century Land Warrior* models developed for soldiers can help them find resources using GPS, a magnetic compass and digital maps [96], and provide a partial ballistic and laser protection [96]. Others are under development to cool soldiers in the desert [85] or detect and protect against chemicals and biohazards [70]. In the army acceptance of such equipment is high. Equipment for firefighters is also under development such as the *LifeShirt* by VivoMetrics [87] that continuously monitors physiological data as well as posture, or other prototypes combining embarked sensors with wireless networks to inform on-site firefighters and command centers [39]. Cheap sensors assess the environment (temperature, oxygen, toxicity) as well as the location and health status of firefighters, which is vital for them and for people to rescue. Other models include a suit for survival in arctic environments [68], which notably supports thermoregulation of the wearer's body. These dedicated models are easily adopted because they can reduce injuries and death of wearers.

For uses by both professionals and the general public, we find a medical jacket [38] that prevents fatal heart problems, with electrodes to acquire ECG data, a processing unit comparing data to a personalized profile, and a trans-dermal drug delivery component to inject nytroglycerin in the wearer's body if her condition requires it. Such a vest can be used by people moving in hazardous environments, as well as a non-negligible part of the population suffering from heart problems. Sensatex's *SmartShirt* [4] also takes advantage of various sensors.

Systems useful to the general public include a sleep watch [5] that monitors sleep and highlights anomalies revealing for example sleep apnea[25]. Poor awareness about this vital issue certainly hampers the acquisition of such equipment. Sleep disorders have societal and personal costs; they reduce productivity, require medical care and decrease quality of life. Another device is the *GlucoWatch* [3][80], designed for diabetics. Also useful to–but not only–diabetics, *Lifewatcher* [60] tracks food intakes, medicine use and activities, with services on cell-phones or other mobile devices. To maintain good health it is sometimes necessary to go with a particular diet and appropriate exercise; we can therefore use wearable exercise support systems [43] equipped with sensors for temperature, ultraviolet, heartbeats and movements. In order to preserve health wearable computers can also monitor diets and provide advice for it. One explored method is to evaluate eating and drinking habits using sensors placed on arms [10].

Although related to both physiological and safety needs, none of the wearables is dedicated to environmental or ecological issues. The closest work would be that of Kaur et al. [42], who combined an ultrafine particle detector with a video camcorder to measure and visualize exposure to pollutants in transport microenvironments. The equipment used is portable but not yet wearable.

Level II: Safety needs

On level II, wearables are dedicated to health, comfort, freedom from danger and peace of mind. Several models of level I also provide support for level II [49]. Diverse wearables were developed, providing novel features such as help for navigation in urban spaces and recognition of persons encountered. For example the *Digital Military Policeman* was developed to enhance security at the entrance of military sites [69]. Such functions increase users' peace of mind, and similar systems can be adapted for the general public; special services can thus be investigated for people suffering from Alzheimer's disease. By sending photos of scaring situations to acquaintances or to the police, the *StartleCam* [34] can support more physical safety. Technology embedded in cellphones and other mobile terminals provide 3D information to find escape ways in case of natural disasters such

25 Sleep apnea is a spread disease that can be fatal, resulting in strokes [22].

as earthquakes [8]. Kids are also taken into account with wearables that detect dangerous situations on the way back home then appropriately inform both children and parents [79]. Creative devices include clothes that produce smells to relax their wearer [6][81], which helps fight against depression[26].

The evaluation of prototypes led to the definition of metrics and guidelines to maintain comfort of wearable computers compared to normal garments [17][32][45] but not to enhance comfort. Besides, studies regarding the perception of wearables supporting safety needs are rare [25].

Level III: Belonging needs

On level III, wearables support emotional bonding. Standard functions satisfying belonging needs include e-mail and phone. For novel applications a good example is the *galvactivator* [66], which emits light according to its wearer's arousal and therefore hinting at stress levels. Other models tested in real environments include badges that display messages [26], inform people about relationships within their community and help people know each other in more depth [19]. Devices that exchange digital cards when shaking hands facilitate interactions and help keep in touch [41]. Garments that display graphics, like *France Telecom*'s tee-shirt, support communication and community belonging [2]; this is a rare example of model dedicated to the general public from the beginning. Finally fashion is related to belonging because it reflects belonging to communities and establishes links between people. Several fashion shows were organized in Japan, for example by *Team Tsukamoto* [7].

Level IV: Esteem needs

On level IV, we find wearables that support everyday and work tasks. Some of them are digital accessories including jewelry [59].

26 Depression is widespread and raising in both developed and developing countries [92]. The interest of such research is therefore not negligible.

2.2.2 Design and fashion in wearable computing

The aesthetics of wearable computers impacts on acceptance, on the evolution of users' feelings over time, and on social interactions. People who overcome a disability with a wearable might not want to make it obvious, with the risk to be ostracized. Others however might want to make it visible to impress surrounding people. Sometimes it is necessary to make the wearable very discreet (e.g. for social studies, security) or very visible (e.g. for communication support) for functional reasons.

There are cases when style results more from choices than requirements. This happens when information can be rendered in several ways: remotely controlled jewelry that changes its colors depending on contexts [37][44], illuminating dresses that display time in a coded format [29], pants or skirts whose shape changes according to users' will [15] or to the proximity of passersby [29][37], or decorative flowers that bloom [15]. Another original creation is an emotional wardrobe [77]: undergarments with biosensors (heart rate) and extensions to environmental sensors (temperature) help estimate the wearer's emotions then the outer layer provides feedback on electroluminescent panels.

In other cases, style results from function. This happens when components are hidden in the textile [27] or when garments are designed to evaluate body-centric issues: contact with flesh [91] and play with the body [91]. Beside clothes, intermediate shapes like the *Parasitic Humanoid* [52] examine wearers' behavior; the shape of this exoskeleton depends on its ability to anticipate walking behaviors.

Innovative models of enhanced garments are frequently presented at dedicated fashion shows. Cube-f's *Media fashion show 2003* (Tokyo, Japan) [1] introduced garments displaying graphics and producing smells. *Team Tsukamoto* [7] presented some works at *Active Media Technologies 2005* (Takamatsu, Japan) as shown on illustration 2.3 and at *International Symposium on Wearable Computers 2005* (Osaka, Japan). Models included garments that display blinking lights or texts, change their lighting patterns (fiber optics) depending on external data, and produce music played using an integrated flexible keyboard. These models focused more on style than function, acknowledging the importance of looks in wearable computing.

Illustration 2.3: Fashion show – Active Media Technologies 2005, by Team Tsukamoto.

The design of garments is not only about aesthetics. For example the properties of materials are important to establish a micro-climate that allows thermal and moisture regulation, and to ensure that the wearer is feeling good, moves easily and perceives well her environment [57]. Other matters of concern are the nature of activities performed with the clothes and of eventual extreme conditions to sustain. Culture (in a broad sense: age, nationality...) also imposes dress codes [72]. In any case, fashion is an important element as a part of wearers' expressive behaviors.

Finally we are used to combine garments and to change them depending on our moods or needs. Some enhanced garments integrate this dimension of personal creativity, with the coordination of layers and elements of clothes based on a digital synthesizer model: *wearable synthesis* [89].

2.3 Definition of cyberclothes

We define cyberclothes–in a nutshell–as garments that satisfy human fundamental needs. As a consequence they:

- promote well-being,
- promote awareness,
- promote sociability,
- have special features for use as social markers,
- have special features for use as tools,
- possess some autonomy.

Cyberclothes are first of all clothes, not just computers concealed in fabrics. They extend the normal functions of garments, which are either practical or social. The practical aspects are to ensure comfort and safety (*e.g.* against cold, rain, sunburns), and to provide containers (pockets and inner compartments). Social aspects include the revelation of belonging to specific groups (such as businessmen, sportsmen), and self-expression (*i.e.* beliefs and personality).

As a basis Maslow's theory provides a strong scientific grounding with a focus on healthy rather than pathologic individuals. It is therefore well-suited for uses in everyday life by the general public. After justifying the choice of a garment form-factor, I introduce below cyberclothes from both humanistic and technical perspectives.

2.3.1 Why (cyber-)clothes?

Historically, clothes were designed to support some fundamental needs [21]. They have two important dimensions: functionality (protection, object container) and aesthetics. The functional aspect deals with physiological processes, comfort, belonging needs and esteem needs. Aesthetics is directly related to belonging and esteem needs. Therefore usual clothes provide a frame for the gratification of fundamental needs. Because people wear them on a daily basis, garments are familiar objects, and enhanced versions should be more easily adopted than new devices [23]. Finally the prefix “cyber” reflects the integration of technology while “clothes” reminds the familiar nature of cyberclothes.

Garments support our physiological processes because they participate in homeostasis. One of their role is to stabilize our temperature and protect us from the elements. Reinforced materials also provide a limited protection against injuries from spikes, animals or even other humans. All this contributes to the amelioration of comfort. Another source of comfort is the direct feeling of some materials such as silk. From a social standpoint, wearing a uniform or clothes similar to other people's highlights belonging to specific groups [72]. This reinforces feelings with insiders and creates a gap with outsiders; for example police uniforms can inspire respect or disdain to members of other groups. Besides, the apparent cost of an attire impacts the reputation of its owner.

For thousands of years most people have been wearing clothes; it is therefore a natural interface between people and the world, from newborns to seniors. As a consequence garments are a good basis for the adoption of wearables. However visibility is an issue. For example, elders supported by wearables in their efforts [73] might want to remove external signs of the presence and function of a supporting device. Embedding novel features in garments is appropriate but, as can be seen with this example, requires particular care about the user's situation. Besides, the garment form-factor has a great potential for the inclusion of technology: clothes offer a large surface for sensors and effectors, and body contact allows the continuous acquisition of physiological data.

Envisioned cyberclothes have the main characteristics of normal garments, protecting the body from aggressions (dirt, cold, rain) and enabling normal activities (moving, eating, sitting). To project the appropriate image of their wearer they should exist in different styles [72]: tee-shirts, business suits, kimonos, etc. Differences between cyberclothes and normal clothes are found in maintenance (washability, etc.), functionalities and ergonomics.

The traditional role of clothes regarding deficit needs, their ubiquity and features make them an interesting basis for a deeper support of fundamental needs, from both humanistic and technical perspectives.

2.3.2 Humanistic perspective

The humanistic perspective stresses the ultimate goal of cyberclothes: the satisfaction of fundamental needs. To be useful in everyday life, cyberclothes cover wide aspects: well-being, awareness and sociability. They can target the wearer, surrounding or distant people; cyberclothes may even cooperate with each other or with smart artefacts to produce relaxing environments.

Cyberclothes improve well-being

Well-being encompasses physiological and safety needs. This can be achieved with garments that monitor physiology and contact emergency services, provide guidance, adapt to the environment or adapt the environment to users (temperature, light). Cyberclothes can also maintain peace of mind by conveying comforting news about one's kids or lover. Examples of concrete applications include support for exercise with a system that evaluates movements, devices that track food intake for diets, or patches that monitor ultraviolet exposition.

Cyberclothes improve awareness

Awareness helps take good decisions, increases control, and helps be and feel more secure. It is therefore linked to all deficit needs, and can be used to react to a current state or on emerging conditions such as an increase of pollution in the neighborhood or a reduction of physical activity. Using various sensors and wireless networks, cyberclothes can inform about the user herself (self-awareness: movements, physiological data, activities), other people (availability of co-workers) or the environment (weather forecasts, pollution level).

Cyberclothes improve sociability

Sociability mainly supports belonging and esteem needs; it facilitates contacts, enables better emotional connections, and helps achieve objectives. Using effectors, it is possible to use garments as a medium of communication thus improving sociability. Normal garments are already used to express a wearer's personality, feelings, or ideas.

> "Clothing does indeed communicate, but not in the manner of speech or writing; what it communicates has mostly to do with the self, chiefly our social identity as this is framed by cultural values bearing on gender, sexuality, social status, age, etc."
>
> Davis, 1992 [21] p191.

Enhanced garments can offer *mutability*: change their shape [15], modify graphics on their surface [2], produce smells [81], etc. Social applications include the display of conversations' transcripts in real-time for deaf persons, of translations for foreigners and of photos identifying common interests for strangers.

2.3.3 Technical perspective

Technical aspects partly reflect the nature of cyberclothes. They provide elements of understanding about their scope, potential and requirements. Existing technologies enable us to create cyberclothes but there are still challenges. We can incorporate wires and soft components in garments [51], and embed flexible screens [2] (though energy consumption is a problem). However research is still needed to incorporate other modalities (e.g. olfactory). Technical aspects include the existence of special features for use as social markers or as tools, and of some kind of autonomy.

Special features for use as social markers

Like standard garments [72] cyberclothes provide social marking. However, their unique features enable them to dynamically modify or amplify it.

Because cyberclothes are garments, their aspect provides information about the personality of their wearer and about her belonging to communities. Styles deemed acceptable vary with fashion, culture, time and place [72]. However design should allow cyberclothes to blend in their wearer's life. This is a critical difference between cyberclothes and exoskeletons: cyberclothes look more natural. Besides, because people are used to combine different pieces of standard garments depending on occasions or moods, cyberclothes should be modular. To accept cyberclothes, wearers may request the same feature as normal clothes.

Finally wearable technologies can enhance social marking. Using displays [2] and effectors [15] one can modify the image she projects on the environment (metaphorically and literally). Depending on their design, cyberclothes may allow their colors, patterns, texts, shapes, smells or sounds to change. Such clothes dynamically modify or amplify sensory information produced.

Special features for use as tools

Clothes come in different shapes/sizes, can cover the whole body, and offer a big surface due to twists of the fabric. Body contact offers possibilities such as the monitoring of physiological signals. Besides garments provide a large surface for sensors and effectors. Together these features enable services such as local health monitoring.

In addition to the social aspect, cyberclothes fulfill the functions of tools. To do so, they should ideally evaluate the physical and mental state of wearers, complement behaviors, support activities and pass selected information to other entities (illustration 2.4). These entities can be humans, cyberclothes and other computer systems:

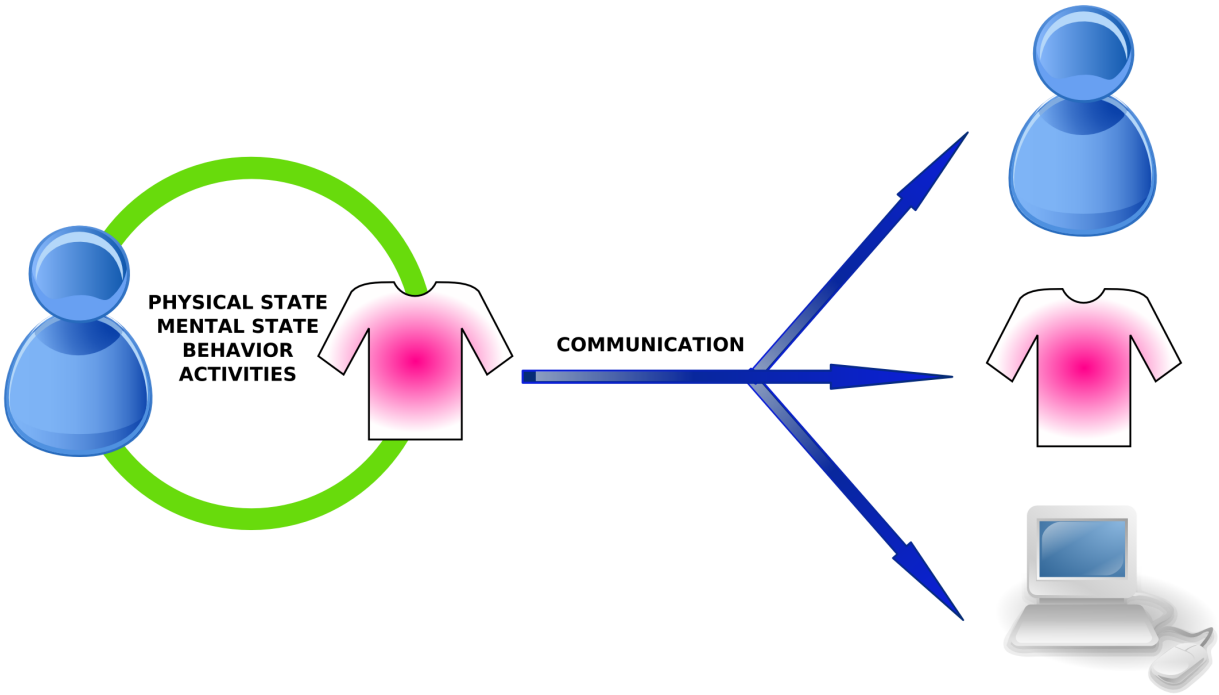

Illustration 2.4: Cyberclothes – Special features for uses as tools.

The dyad human-cyberclothes can act as a closed or open system. In the first case, the wearer feeds her garment with information about her, and the garment provides feedback to her. In the second case, it acquires and transmits information from and to the environment.

Sensors can help evaluate wearers' state. For example stretch sensors incorporated in textiles can deduce body position and current activity [27]. Biosignals (like skin-conductivity and heartbeat) hint at the user's mental state [66].

Cyberclothes provide sensory stimulations to wearers or bystanders. OLED or optical fibers can provide visual stimulations, display various colors, graphics and texts [2]. Small motors can provide tactile sensations by vibrating, applying pressure, or changing the shape of a linked material [15]. Small speakers can render speech, sound and music [56]. Finally, perfume capsules can produce appropriate scents if precisely controlled [81]. The sense of taste is a bit apart as no technology is available yet to stimulate it (illustration 2.5):

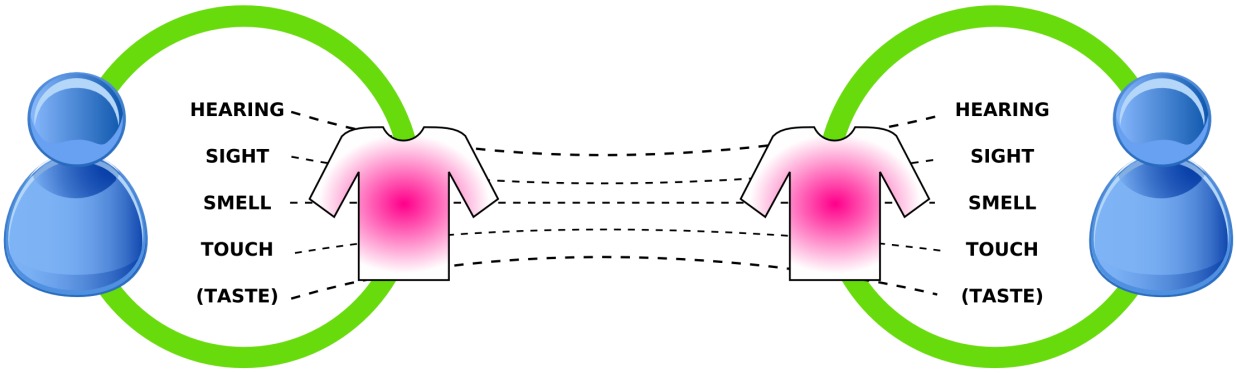

Illustration 2.5: Cyberclothes – Sensory stimulations mediated between wearers.

Autonomy

Autonomy is important for cyberclothes to blend into people's life seamlessly. If enhanced garments are not autonomous, their control becomes difficult, error prone, and *de facto* limits the number of embedded functions. Results of social studies presented later show however that it is a sensitive issue for the general public.

2.3.4 Scenarios in everyday life

Face-to-face first contact

> At a seminar, attendants display on their garments photos of their latest project. Vibrations in your shoulders notify you of an interesting profile nearby, and discreet armlets appear on your clothes and on a man close to you. Your badges adapt to each-other's language while you talk. You introduce your laboratory, showing videos on your chest. Your clothes reveal your common interests. Finally a photo of your interlocutor is stored with an electronic business card and information gathered during the talk.

This scenario is depicted by illustration 2.6:

Illustration 2.6: Scenario – Concept image for face-to-face first contacts.

Accident in mountains

While you hike in the mountains on a sunny day, your garments monitor the temperature, your heartbeats and respiration. Based on their evolution, the cyberclothes beep to recommend you to take breaks. In case of accident, your position is sent to emergency services; your clothes provide appropriate warmth and relax you with music. When the rescue team arrives, it accesses your medical file and a summary of your latest physiological data.

Combination of technologies

You are invited at the house of a blind friend. At your arrival your garments communicate with the intelligent house, which turns on the light for you. While talking, you notice a faint odor of rose. Your friend explains that her clothes produce specified smells reflecting her husband's emotions. On his side, he gets feedback about hers in a discreet visual way, more adapted to his work activities...

2.4 Summary and conclusion

In this section I presented Maslow's theory, the state of the art in wearable computing, and the new concept of cyberclothes. Maslow's hierarchy of needs stresses the role of physiological, safety, belonging, esteem, and self-actualization needs. Because the state of the art in wearable computing indicates that the humanistic dimension is neglected, I introduce the concept of cyberclothes. Taking their roots in Maslow's study, cyberclothes focus on the promotion of human growth and well-being. From a social and technical point of view, garments appear as the best form-factor to achieve such goals. The main features of cyberclothes are that they improve well-being, awareness, and sociability; they have special features for use as social markers and tools, and possess some autonomy. In order to clarify the proposal, I described a few scenarios related to face-to-face first contacts, accident in mountains, and the combination of technologies. The concept of cyberclothes is theoretically interesting because it integrates psychological findings into wearable computing. However we now have to prove it is meaningful for the general public. Accordingly, the next chapter presents a social study that investigates the perception of cyberclothes by the general public, and its associated expectations and worries.

本章では、マズローの理論、最先端のウェアラブル・コンピューティング、サイバークローズの概念を述べた。マズローの欲求段階説は生理的欲求、安全欲求、親和欲求、自我欲求、自己実現欲求の役割を強調している。最先端のウェアラブル・コンピューティングに目をむけると、人文科学的視点は問題にされていない為、我々はサイバークローズの概念を導入する。マズローの研究の根元的概念を採り入れることで、サイバークローズは人間の成長とより良い生活を促すことに焦点を当てる。社会的、技術的な視点から、その様な目的を成し遂げる最良の枠組として衣類があげられる。良く生き、よく知り、社会性を持つことを支援することがサイバークローズの主な特徴である。また、社会的な目印や道具としての機能を持ち、自立性を獲得する事も特徴としてあげられる。サイバークローズの理解を助ける為に、出会いの支援、山岳事故、技術の組合せといったシナリオを述べた。ウェアラブル・コンピューティングの領域に、心理学的知見を組み入れるという意味において、サイバークローズは理論的に興味深い。しかし、一般の人々にとってもこの概念が意義深い物であることを証明しなければならない。そこで次章では一般の人々がサイバークローズについていだく認識を調査したアンケートを分析し、サイバークローズに対する人々の期待や不安について述べる。

Chapter 3. Social studies: physiological, safety and belonging needs

In order to investigate the general public's perception of wearables satisfying fundamental needs, I gathered data with informal interviews and self-completion questionnaires. Both tools were used for two distant cultures, in France and Japan, so as to allow some generalization of the results. Until now, no equivalent work has been carried out in wearable computing. Far from being exhaustive, this exploratory study aims at providing guides for research and hints for adoption of the technology. Insights gained are valuable from theoretical and practical points of view: creation of prototypes, evaluation among diverse populations, design of the intelligence of systems, etc. The main objectives were to gather surface information, and to check intuitions regarding the influence of culture and gender.

基本欲求を満たすウェアラブル・コンピュータに対する一般の人々の認識を調査する為、略式的な面接、およびアンケートによる結果を集計した。どちらの手法も日本とフランスという二つの異なる文化圏でおこなわれており、結果を一定程度一般化することが可能である。今日まで、ウェアラブル・コンピューティングの領域では同様の調査は行われていない。包括的とはいえないが、この開拓的調査は研究への指針と同技術を採り入れる為のヒントを提供することを目的としている。この調査で得られた洞察は、例えばプロトタイプの作成、多様な集団における評価、知的なシステムの設計などの理論的、実際的な観点から大きな価値を持つ。調査は表層的な情報を集め、文化や性別の影響を調べることを主な目的として行った。

3.1 Informal interviews

The first step was to interview students and researchers in computer science and psychology. These specialists were chosen for their ability to rise technological and human issues related to wearable computers. The goal was to know their feelings about wearables and interest for enhanced garments compared to other devices.

3.1.1 Followed method

I interviewed 14 Japanese and 12 French students and researchers in computer science and psychology. The interviewees were between 20 and 37 years old, and all of them had a previous contact with wearable computing. Only one possessed a PDA but all possessed a cellphone as well as a personal computer. The duration of individual sessions was 15-30 minutes, with a focus on content rather than duration. To provide more reliable replies, the concept of cyberclothes was briefly introduced before asking questions. Interviewees expressed their feelings about wearables and about the interest of the *garment* form-factor. Then they discussed a selected aspect: the display of graphics on clothes. I chose this service because it easily stimulates imagination, corresponds to personal interests and can be designed for experiments.

3.1.2 Interest for cyberclothes

Interviewees had mixed feelings about wearables. Most of them considered such devices poor alternatives to replace laptops. However they considered that cellphones should provide more functionalities, different from their laptops'. Besides they easily imagined dedicated services for which laptops or cell-phones would not be optimal, such as in the case of the medical monitoring of people with heart problems.

Although knowledgeable in computer science, interviewees were not specialists in wearable computing and considered the integration of electronics in garments a surprising idea. The Japanese interviewees were enthusiastic about the concept whereas the French ones were skeptical of the improvement it would bring into their life. In addition, the Japanese considered that the technology could be available sooner. When asked if they would use cyberclothes and PDAs, interviewees indicated their preference for PDAs. However several students explained that the devices were complementary: PDAs to achieve complex tasks in calm environments, alone or with one partner;

garments to benefit from specialized hardware or to interact with larger groups in public dynamic spaces.

Asked about the ability to display graphics on clothes, the Japanese interviewees showed high interest in the technology. The French ones confirmed their previous stance by questioning the interest of such a feature. However they suggested that other elements would be interesting, such as physiological sensors for health services. Most of the Japanese said they would wear garments able to display graphics, a few would even agree to use them to advertise their favorite companies or products. The French all rejected the idea of displaying advertisements on their clothes.

The interviews indicated that enhanced garments complement existing devices, and that there is an interest for *graphics display* in Japan and *well-being* in France. Besides, the trends of replies suggested a cultural difference. I used these pieces of information as a basis for the design of questionnaires targeting a larger group from the general public.

3.2 Self-completion questionnaires

The questionnaires were designed to gather surface information about the general public's perception of wearables. Because people are unfamiliar with wearables I focused on enhanced garments, which respondents could easily imagine. Besides I considered four aspects (hardware, intelligence, information, events) and everyday life situations. Finally I targeted the French and Japanese general publics.

Because physiological needs deal with survival they are mostly fulfilled for average people. Therefore I focused my investigations on safety and belonging. Results show a similar pattern in France and Japan, with variations due to cultural and gender dimensions. This emerging pattern concerns the needs, wishes and fears of the general public. The analysis validates the hypothesis for physiological and safety needs. However there are mixed results for belonging needs.

3.2.1 Followed method and scales

I designed a questionnaire and improved it using comments from a pilot group of respondents: rephrasing questions, removing technical terms and adding a short introduction. The two pages included seven series of closed-ended questions and, at the end, one open-ended question.

For closed-ended questions, participants rated assertions on a 5-point Likert scale: 1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4-agree, and 5-strongly agree. The questionnaire was produced and checked by native speakers in French and Japanese. During the analysis I considered that a mean below 2.5 indicated a significant trend for rejection, and above 3.5 acceptance (illustration 3.1).

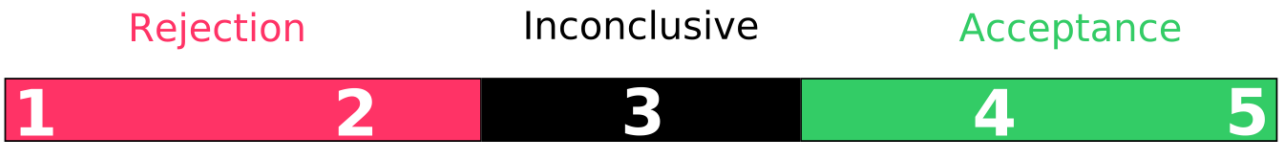

Illustration 3.1: Questionnaire – Interpretation of the rating scale.

There was no time limit to answer but questionnaires were usually filled in 15 minutes in public places. No photos or videos of wearables were shown to respondents. However a short text included in the questionnaire succinctly introduced the study as research on new technologies: clothes possessing particular features, capacities and some kind of intelligence. It also indicated that

prototypes are currently being designed in Japan, France and America.

Due to cultural and ecological specificities, answers can vary between populations. Therefore I focused on two nationalities (French and Japanese) corresponding to dissimilar cultures. Details about respondents are available in table 3.1. The questionnaires were provided in 2005 in public places (cafés, bars, train stations) on weekdays and week-ends. The questionnaires provided in electronic form were mainly distributed in universities and via a public relations department. This provided large samples with moderate randomness. Respondents included artists, designers, librarians, reporters, students, teachers, researchers, engineers, secretaries, salesmen, managers, housewives, retirees, medical staff, soldiers, preachers, etc.

	French male	***French female***	***Japanese male***	***Japanese female***
Number	115	59	61	54
Age range	14-67	14-58	19-54	14-45
Age mean	26	25	29	30

Table 3.1.: Questionnaire – Information about French and Japanese respondents.

With 174 French and 115 Japanese, the number of respondents is appropriate for an exploratory social study. One may note that computer science studies on human factors usually have less respondents and less variety (usually limited to university students and researchers in computer science). I was careful about this to avoid issues related to the validity and reliability of the results, in particular to allow a certain generalization of the results. The questionnaires and data can be found in Appendixes A and B.

3.2.2 Perception of wearables in France and Japan

The French and Japanese respondents showed similar patterns of perception regarding wearable computers. However some elements highlight cultural and gender dimensions.

Level I and II: Physiological and Safety needs

The results of questions on perceptual functions and physiological monitoring indicate that wearables related to level I and II are perceived positively. Examples of assertions to rate were: “It would be acceptable for me to wear clothes that analyze the air (smells, pollution, temperature)” and “I would agree to use garments that monitor my condition (heartbeats, movements) to adapt my environment to my needs (temperature, light, music)”.

Illustrations 3.2 and 3.3 show that most accepted items improve body condition, comfort or safety. The French and the Japanese give high ratings to garments that adapt their temperature to the environment (4.1/3.9)[27] or analyze the air (3.8/3.8). Besides, physiological monitoring is considered positively to adapt the environment to users' needs (3.7/3.6), evaluate sportive performances (4.0/4.2), and inform emergency services (4.3/4.3). Because of the limited randomness of the samples, the means calculated may be biased. Using the *t*-distribution confirmed intervals for the means with a confidence of 95% (table 3.2).

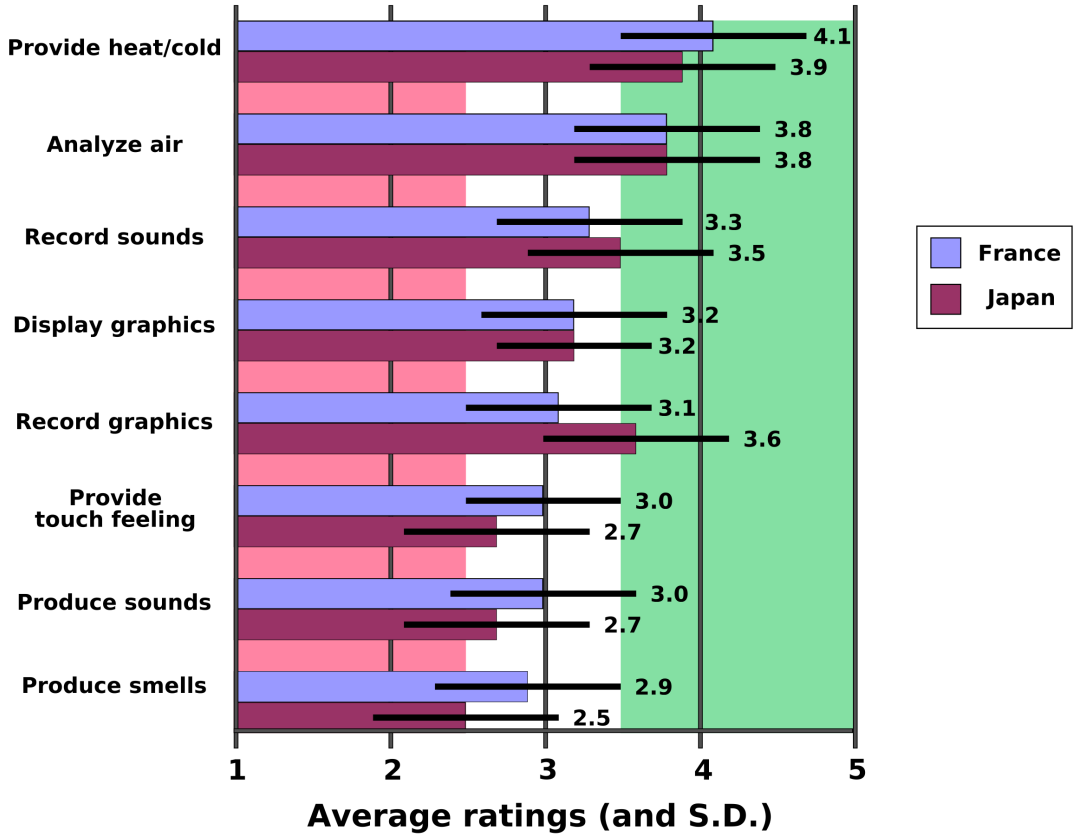

Illustration 3.2: Questionnaire – Acceptance of perceptual sensing and stimulations.

27 From now on, the average ratings will be presented French first and Japanese second. Therefore (4.1/3.9) means 4.1 for the French and 3.9 for the Japanese.

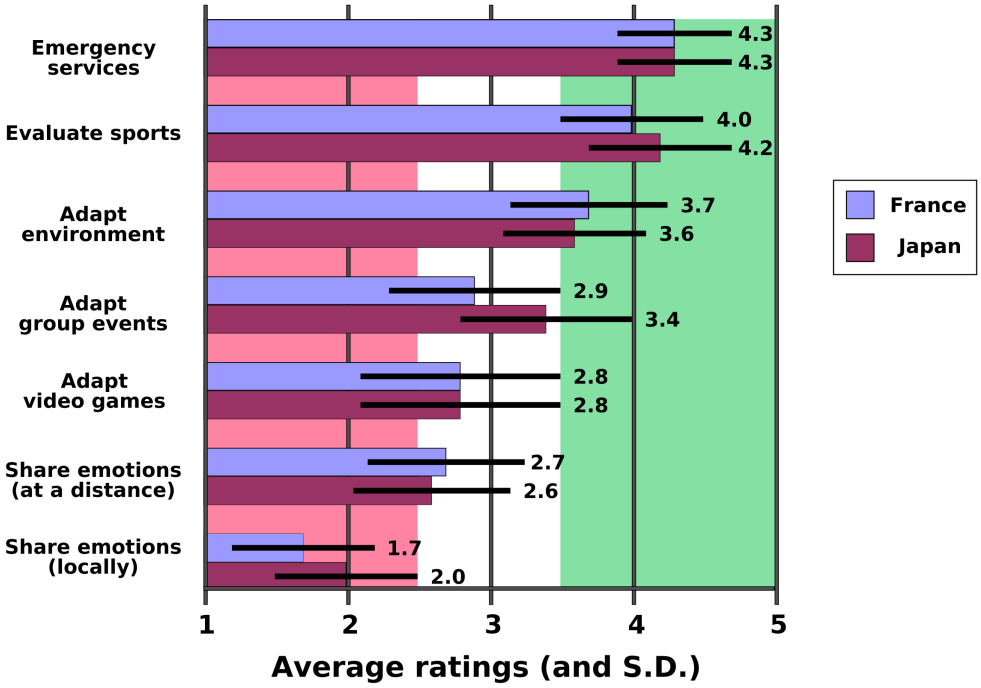

Illustration 3.3: Questionnaire – Acceptance of physiological monitoring.

	French	***Japanese***
Emergency monitoring	4.2-4.5	4.0-4.6
Evaluate sports	3.9-4.2	4.0-4.5
Provide heat and cold	3.9-4.2	3.6-4.2
Use in case of danger	3.8-4.1	3.5-4.1
Analyze the air	3.6-4.0	3.6-4.2
Adapt the environment	3.6-3.9	3.4-3.9

Table 3.2.: Questionnaire – Confidence of results for level I & II (T-distribution at 95%).

Level III: Belonging needs

The results of questions on physiological monitoring and selected usages indicate mixed feelings for wearables related to level III. Examples of assertions to rate were: “Enhanced clothes would be useful to communicate with disabled people” and “I would agree to use garments that monitor my condition (heartbeats, movements) to reveal my emotions to surrounding people”.

Illustration 3.4 shows a good acceptance for wearables that help communicate in disrupted settings (for trips or with disabled people from 3.6 to 3.9). However several applications are

considered neutrally: at a party (3.3/3.6), at a conference (3.2/3.6), or when meeting new people (2.5/2.8). Finally illustration 3.3 highlights the lack of interest for physiological monitoring to support communication and emotional bonding: adaptation of events to the group (2.9/3.4) is seen neutrally while emotional displays are rejected, especially for local disclosure (1.7/2.0).

Using the *t*-distribution shows that both Japanese and French respondents have mixed feelings about wearables for belonging needs (table 3.3). As described above, the intensity of acceptance can be very low (share emotions locally), neutral (adapt group events), or very high (on a trip). All results are provided with a statistical confidence of 95%. Finally the *t*-distribution indicates that two items are influenced by a cultural effect: physiological monitoring to adapt group events or to share emotions locally.

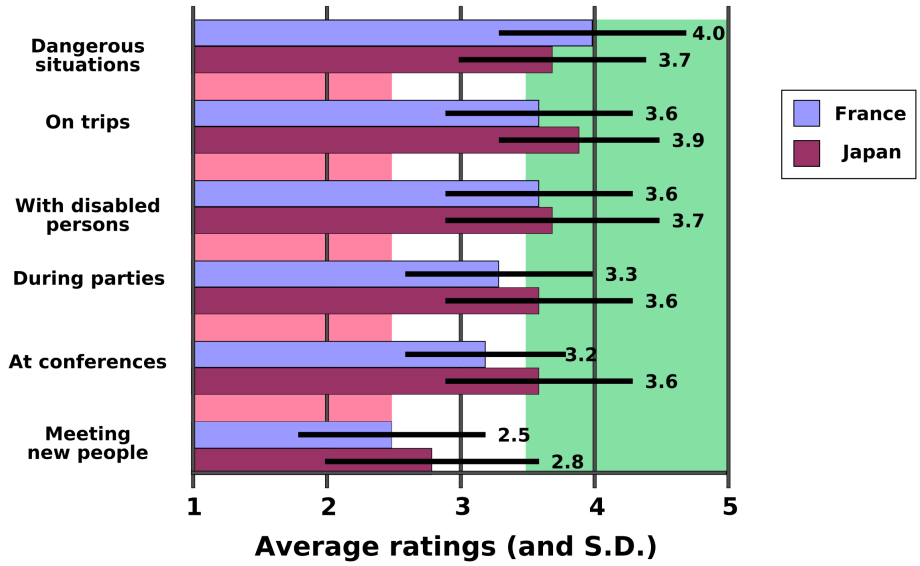

Illustration 3.4: Questionnaire – Acceptance of selected usages.

	French	***Japanese***
On a trip	3.4-3.7	3.6-4.1
With disabled people	3.5-3.8	3.3-4.0
During parties	3.2-3.5	3.3-3.9
Adapt group events*	2.8-3.1	3.1-3.7
Share emotions (at a distance)	2.5-2.9	2.3-2.9
Meeting new people	2.4-2.7	2.5-3.1
Share emotions (locally)*	1.6-1.8	1.8-2.3

* significant cultural effect, $p<0.05$

Table 3.3.: Questionnaire – Confidence of results for level III (T-distribution at 95%).

Miscellaneous features

As shown by the results of questions on perceptual functions (illustration 3.2) and physiological monitoring (illustration 3.3), items unrelated to fundamental needs receive neutral ratings. These include the ability to produce smells (2.9/2.5) or touch feelings (3.0/2.7), to display graphics (3.2/3.2) and adapt video games with biosignals (2.8/2.8).

The autonomy of wearables (illustration 3.5) appears as an important element. Examples of assertions to rate were: "If I had enhanced garments, I would like them to coordinate actions with other clothes" and "If I had enhanced garments, I would like them to be controlled by some form of artificial intelligence".

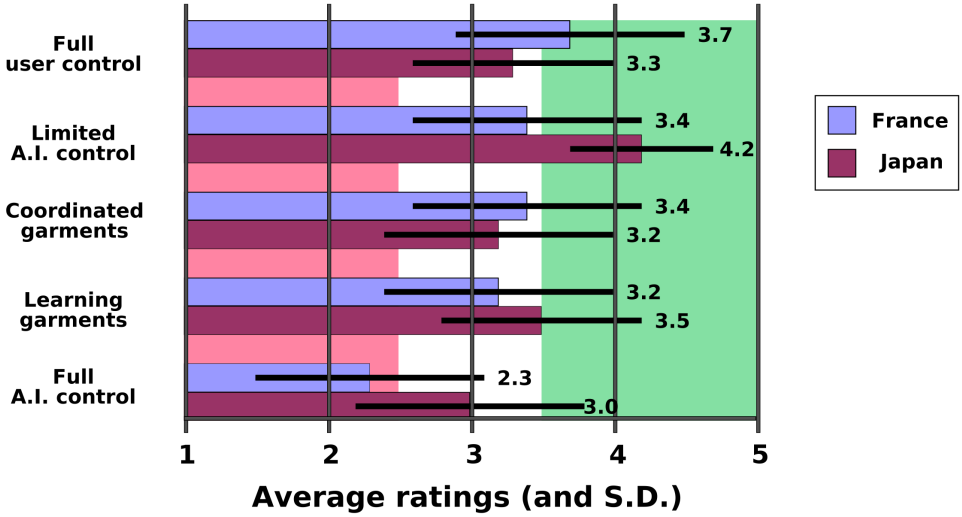

Illustration 3.5: Questionnaire – Wishes for the autonomy.

The Japanese prefer to use limited artificial intelligence (4.2) whereas the French prefer full user-control (3.7). In both cultures full control by an artificial agent gets the worst results (2.3/3.0); open comments from respondents indicate a fear that wearables with AI might physically or socially harm wearers.

Cultural effect

Although French and Japanese respondents have a similar pattern of answers, there are occasional differences (two items for level III in table 3.3). To avoid bias in later experiments (see chapter 4) and to improve the design of our wearables, cultural factors of acceptation needed to be identified. This was done with a data analysis based on a *t*-test for unpaired samples (table 3.4 and illustration 3.6), where p defines the critical region.

	p	*French Mean (SD)*	*Japanese Mean (SD)*
Limited A.I. control	0.01	3.43 (1.33)	4.21 (1.01)
Record videos	0.01	3.10 (1.27)	3.61 (1.25)
Full A.I. control	0.01	2.33 (1.26)	2.98 (1.08)
Adapt group events	0.02	2.95 (1.23)	3.39 (1.28)
Share emotions locally	0.02	1.70 (0.95)	2.03 (0.96)
Professional uses	0.04	3.29 (1.31)	2.90 (1.18)

Table 3.4.: Questionnaire – T-test analysis for cultural effect.

This *t*-test for unpaired samples (2-tailed) shows that the French and Japanese have significant differences ($p<0.05$) in the acceptation of a few items. The test establishes such differences with a 99% certainty for enhanced garments that record videos (3.10/3.61), or that are under full (2.33/2.98) or limited control (3.43/4.21) of an AI. There is a 98% certainty for enhanced garments that monitor physiology to produce group effects during artistic or sportive events (2.95/3.39), or reveal wearers' emotions to surrounding people (1.70/2.03). Finally there is a 96% certainty for the use of enhanced garments for professional purposes (3.29/2.90). For levels I and II, there is no cultural effect. However two items of level III indicate a cultural effect.

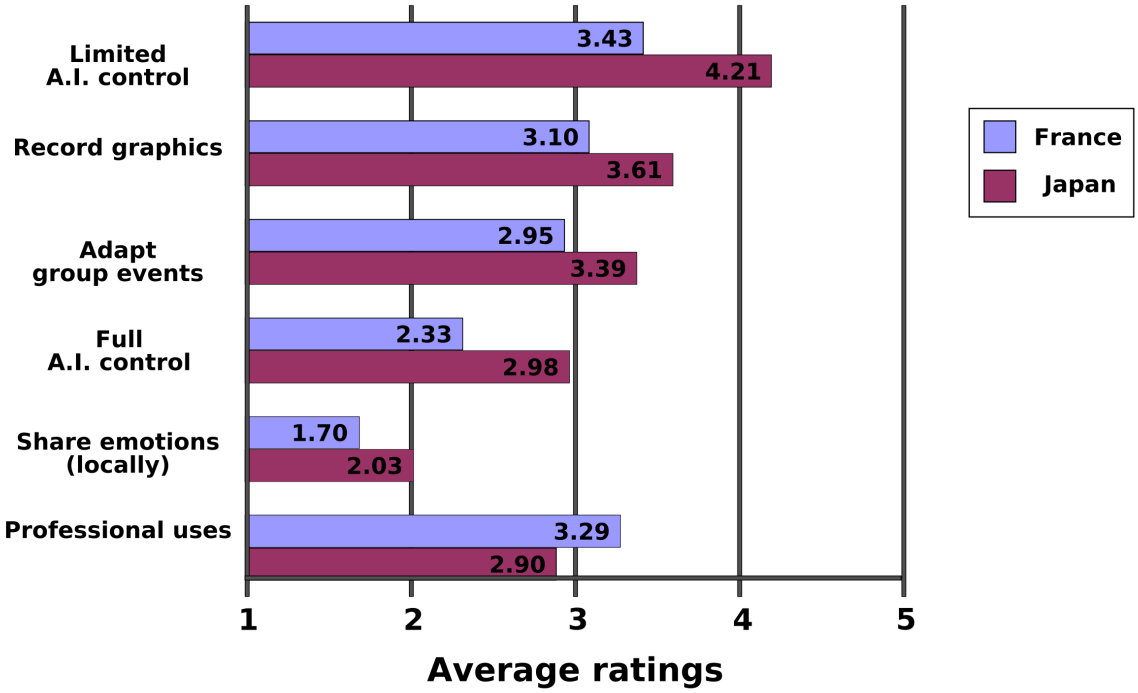

Illustration 3.6: Questionnaire – Items indicating a significant cultural difference.

Gender effect

The case of gender complements investigations on culture. Some answers suggest a gender effect; for example the acceptation of garments that provide touch feelings is medium for males but low for females. Therefore the data were analyzed with a *t*-test for unpaired samples (table 3.5 and illustration 3.7).

	p	***Male*** ***Mean (SD)***	***Female*** ***Mean (SD)***
Analyze the air	0.01	3.96 (1.10)	3.58 (1.28)
Record sounds	0.01	3.47 (1.20)	3.01 (1.29)
Adapt video games	0.01	3.12 (1.28)	2.28 (1.07)
Provide touch feelings	0.01	3.08 (1.23)	2.65 (1.15)
Full user control	0.02	3.55 (1.36)	3.94 (1.23)
Personal uses	0.02	3.34 (1.25)	2.96 (1.32)
Full A.I. control	0.04	2.72 (1.24)	2.40 (1.29)

Table 3.5.: Questionnaire – T-test analysis for gender effect.

This *t*-test for unpaired samples (2-tailed) shows that males and females have significant differences for the acceptation of some items. We reach a 99% certainty for enhanced garments that record sounds (3.47/3.01), analyze the air (3.96/3.58), provide a touch feeling (3.08/2.65), or monitor physiology to adapt video games (3.12/2.28). There is a 98% certainty for enhanced garments used for personal purposes (3.34/2.96), or under full-user control (3.55/3.94). Finally we reach a 96% certainty for enhanced garments under full control of an AI (2.72/2.40). Only one of these items was directly linked to fundamental needs: analysis of the air.

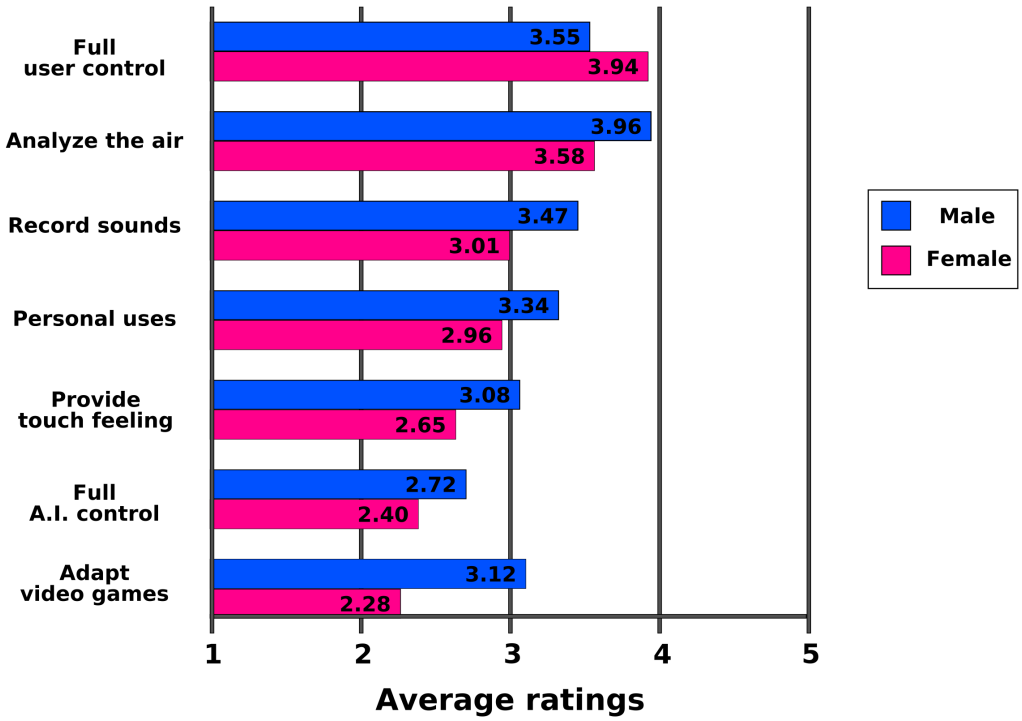

Illustration 3.7: Questionnaire – Items indicating a significant gender difference.

For significant differences, males have a better acceptance of the technology. The only score where females score higher is for a feature restricting the technology.

3.3 Discussion and guidelines for wearables

The results for wearables on levels I and II confirm that focusing on human fundamental needs is a good approach to foster the adoption of wearable computers. Laymen appear eager to get enhanced garments that improve body condition, comfort and safety. This result is consistent in France and Japan. Because respondents reject full control by an artificial intelligence due to their fear of physical/social harm, our results regarding AI also validate our hypothesis.

However according to these results, level III requires further investigations. Respondents are interested in wearables that help in non-standard situations (*e.g.* on trips or with disabled people) but not much in standard settings. Of particular interest is the rejection of wearables that help share emotions. Comments extracted from the open-ended question hint at a strong rejection due to safety needs: displaying emotions can induce a feeling of vulnerability that scare respondents.

The analyses established that the French and Japanese show similar patterns for levels I and II although there is a slight cultural and gender effect. The higher acceptance of cyberclothes by males may be due to what Wajcman calls “the constitution of male gender identity and the culture of technology” [88] and to what Durndell [24] demonstrated; it was therefore expected. Most differences are for items unrelated to fundamental needs (table 3.4 and 3.5). Because the French and Japanese cultures are very different, these trends point to a certain universality of the results. Therefore I propose the following guidelines for the design of wearables :

- Wearables should improve the body condition, comfort and safety of their wearer, and possibly of surrounding or distant people.
- Support for communication should focus on disrupted settings (*e.g.* with disabled persons, or on trips) rather than standard situations.
- Full control by artificial agents should be avoided.
- Design should be gender and culture oriented.
- Wearables should be able to communicate with other devices, and to suggest them a behavior based on knowledge about their wearer.

The first guideline is related to level I and II of Maslow's needs. Because they increase peace of mind, the second and third guidelines deal with level II. The third guideline also deals with this

level because the rejection of full AI is motivated by a worry for physical and social safety. The second guideline is also related to level III. The fourth guideline is loosely connected to all needs, reflecting that priorities are altered depending on the gender and culture of a wearer. Besides gender impacts on physiology, which is important for, for example, physiological monitoring (potential services for levels I to III). The fifth guideline is more technical and expresses a will to fully exploit the potential of cyberclothes, for example being able to use surrounding sensors and effectors to make wearers' environments safer and more comfortable.

One way to validate further these five important guidelines is to carry out experiments with prototypes and services that partly or completely match the guidelines. Then the satisfaction of wearers is compared to the degree of respect of the guidelines. According to my theory these should be positively correlated.

As a whole the results confirm the hypothesis for physiological and safety needs. However they show that more investigations are required for belonging needs, especially for the support of face-to-face communication and for emotional displays.

3.4 Summary and conclusion

In this section I described my social investigations regarding the general public's perception of wearable computers satisfying fundamental needs, carried out with informal interviews and self-completion questionnaires. The analyses show a similar pattern of answers for French and Japanese people. Both have a significant acceptance for garments that improve comfort and well-being, or that help communicate in disrupted settings. They also have common concerns and reject artificial intelligence as well as emotional displays and support to meet new people. This information provides insights in the proper design of wearables, and I accordingly propose five guidelines. There is however an important cultural divergence for the wishes on autonomy, which may be due to a difference of risk perception. The results validate my hypothesis for physiological and safety needs. However I obtain mixed results for belonging needs. As a consequence, I complement the social study in the next chapter with experiments related to the satisfaction of belonging needs, and in particular to the two highlighted difficulties: emotional displays and support for first meetings.

本章では、基本欲求を満たすウェアラブル・コンピュータに対する一般の人々の認識に関する社会的な調査を述べた。此れは略式的な面接とアンケートによって行われた。調査結果は日本とフランスの人々における類似したパターンを示している。どちらの人々も、生活を快適に、より良くしてくれたり、困難な状況での意志疎通を助けてくれる衣服に対する許容度は高い。共通の懸案事項も見られ、両者とも人工知能や感情表示機能、出会いを支援する機能は拒否している。この結果は、妥当なウェアラブル・コンピュータを設計する為の洞察を与えている。それにしたがって五つのガイドラインを提案する。しかしながら自律機能についてはある種の重要な文化的違いが見られた。これは両者の危険の認識の違いに依っているかと思われる。本章の調査結果は生理的欲求や安全欲求に対する私自身の仮説を裏付けている。しかし親和欲求については、決定的な結果が得られたとはいえない。そこで次章では、この結果を補うために親和欲求の満足に関連する実験を行う。その中でも特に、本章の調査で、問題となった感情表示と出会いの支援に焦点を当てる。

Chapter 4. Experiments: support for belonging needs

Although the hypothesis was validated for physiological and safety needs with social studies, investigations appeared necessary for belonging needs. In accordance with the selected hybrid approach, they were based on experiments with wearable computers. Considering the elements highlighted by the previous results, a wearable system and service were developed, focusing on emotional displays and on support for first encounters. I evaluated the shift of participants' perception regarding cyberclothes after experiments, examined the reaction to support for face-to-face first contacts and to emotional displays, and analyzed the performance of the system. The goal was three-fold: clarify previous results, check the validity of the hypothesis for belonging needs, and reveal design factors for cyberclothes.

社会調査により、生理的欲求や安全欲求に関する我々の仮説が裏付けられた。しかし親和欲求に関してはさらに検証が必要である。此れは、社会調査に加えてウェアラブル・コンピュータを用いた実験によって行う。前章の調査結果が強調した、感情の表示と出会いの支援に対する拒絶に焦点をあてたウェアラブル・システムとサービスを作成した。此れを用いて(1)サイバークローズに対する被験者の意識が装置導入前後でいかに変化するかを評価し、(2)出会いの支援と感情の表示に対する被験者の反応を調査し、(3)システムの性能を分析した。此れらを行ったのは次の三点の為である---(1)前章の調査結果を明らかにする、(2)親和の欲求に関する仮説の正当性を検証する、(3)サイバークローズの設計要素を洗い出す。

4.1 Wearable system

The wearable system was developed to investigate face-to-face first encounters and emotional displays. As a consequence the prototype targeted short interactions (less than 15 minutes), which imposed controls that are easy and intuitive to use. However this setting relaxed requirements on battery life, advanced functions and data management. Besides the concept of *cyberclothes* imposed a garment form-factor, and previous results suggested guidelines to apply. Finally a framework was developed to serve as a basis for the creation of services. It was designed to allow uses in real-world situations and to enable extensions to other services.

4.1.1 Interface issues

Because the wearable system targeted short interactions, it required easy and intuitive controls for testers. The advantages and disadvantages of multi-modal interfaces were evaluated, including those working on non-standard sensory channels. In order to avoid disrupting the natural flow of interactions between wearers and interlocutors, the equipment was limited to the minimum and to the least visible.

Choice of inputs

The following sensory channels were considered for input: hearing, sight, smell and touch. Movement and physiological sensors could complement the system in subtle ways, in the latter case with information usually unavailable to humans.

Microphones coupled with speech recognition can identify keywords in ongoing conversations or transmit direct orders to services. In the same way, cameras could acquire information [76] on both wearers and interlocutors, and interpret movements and gazes. There are however several caveats. According to the results of the social study (illustration 3.2), acceptation of video and sound recording is not granted. Besides the location and direction of microphones and cameras must be appropriate to the interaction to avoid occlusion and poor treatment of the data. Finally, in a real world system one would avoid energy-consuming devices such as cameras.

Smell was quickly eliminated as an input option. Although a device analyzing the air could provide contextual information, no such system was found. On the contrary several devices are based on touch, such as keyboards and mouses. Keyboards appear inappropriate for discussions because they distract users and require either space or training. Multi-button devices however can

easily provide limited control with discreet manipulations. The wearable device was therefore successively designed without touch input, with a touch panel, and with three buttons.

Finally, wearer's body can be used as direct input by monitoring movements or physiological activity. Movements were avoided because they might be difficult to do naturally while conversing or lead to unwanted actions, in particular for novices. The social study (illustration 3.3) highlighted a rejection of physiological monitoring for emotional displays but an acceptance for numerous other applications. To study this phenomenon in more depth, I therefore planned to embed physiological sensors, and selected those for skin conductivity and heartbeats because they are most adapted to evaluate mental states [65].

Choice of outputs

Because the projected usage of the system was face-to-face communication, the following sensory channels were considered for output: smell, touch, hearing and sight.

Smell was discarded because it requires training, conflicts with perfumes and proves unacceptable (illustration 3.2). Touch enables a system to communicate private information to a wearer (via located vibration [82] or heat). However, like smell, it requires training and it is limited in the precision of information that can be quickly and easily transmitted. For 15-minutes long uses or experiments, it looked inappropriate.

In the frame of face-to-face conversations, the use of sound is limited because it hampers the ability of interlocutors to hear each other, and because it can alienate surrounding people that would find users too noisy. Besides, making noise is prohibited in some places such as hospitals and trains. On the contrary, the display of information on garments' surface is convenient and *a priori* socially acceptable. In addition the understanding of information on screens can be straightforward, as in the case of photos or text. Sight therefore appeared as the most promising sense to stimulate.

As indicated previously, the system is notably designed to clarify the rejection of emotional displays (visuals or not) by the general public. One important question is whether the emotional display should provide straightforward or metaphorical information. Because touch is inconvenient it was discarded. Sounds and smells are well fitted for implicit but not for explicit information. Graphics on the contrary are versatile, being either fully explicit via text (“Happy”, “Sad”) or implicit via colors or drawings. Taking into account these elements and the higher appropriateness of graphics, the display was chosen to be visual. The choice for implicit or explicit information is left for the description of the service.

4.1.2 Framework for cyberclothes

The framework that controls the system was developed for cyberclothes, whose scope covers well-being in addition to social support. The framework was based on a decentralized architecture and on open standards to enable interoperability as well as an easy development of reusable and secure components. Coded in JAVA, two of its main features are the management of XML data and of physiological data. Services based on this framework can be consciously controlled by wearers with multi-button devices, and unconsciously via physiological sensors.

Based on non-standard premisses, wearable computers require special architectures that spare resources, can deal with changing configurations[28] and adapt to various contexts[29]. A modular architecture is therefore ideal. As shown on illustration 4.1, the framework accesses input/output devices and task-dependent databases. Data processing is shared by the framework components and by the services. The framework will normally manage output devices to update displays, produce sounds, etc. Because latency can have an impact on wearers and interaction partners, the framework is lightweight. As a consequence, the services and databases define most of the computational workload. Garbage collection is sometimes a problem for real-time activities with JAVA but improvements are expected with new versions.

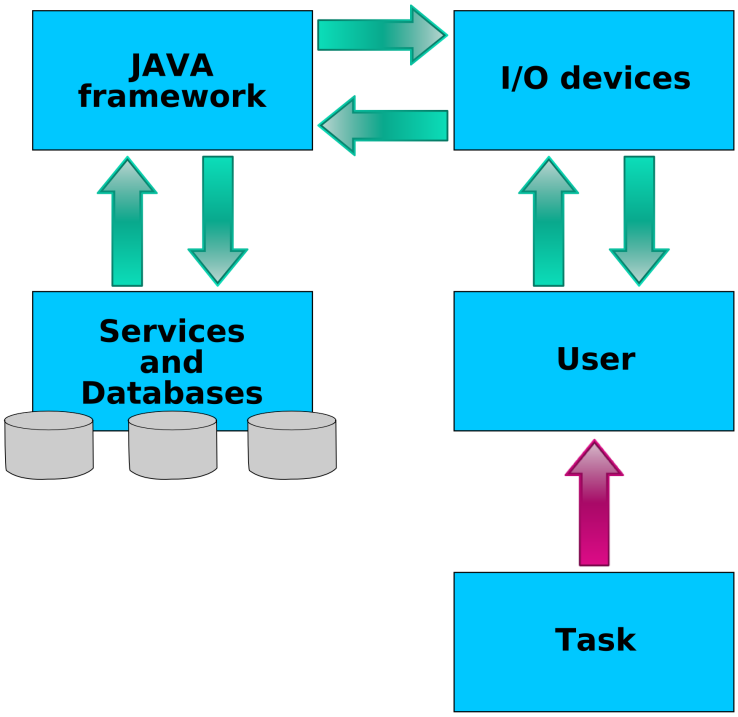

Illustration 4.1: Framework – External view.

28 Including operating systems, drivers, other pieces of software, and hardware.
29 Geographical, meteorological, social, etc.

The garments mediate the user's input into, and feedback from, the system. Interactions with other instances are possible in a peer-to-peer fashion in order to limit dependence on tiers, and to protect the privacy of users. To maintain this independence, the framework can manage concurrent inputs, from online sources or local sensors. With the appropriate equipment and drivers, one would for example be able to acquire contextual information online through weather forecasts or pollution alerts or locally with a camera and thermometer. To save energy, the framework can individually reduce the frequency of accesses to local peripherals and override them with other sources of information.

The framework is based on Sun JDK 1.5.0, and was developed without special extensions. For services to operate efficiently, the framework provides several handlers such as *GarmentHandler*, *WearerHandler* and *CommunityHandler*. The two first ones are used by default, the third one is optional. Main framework elements for social services are shown on illustration 4.2:

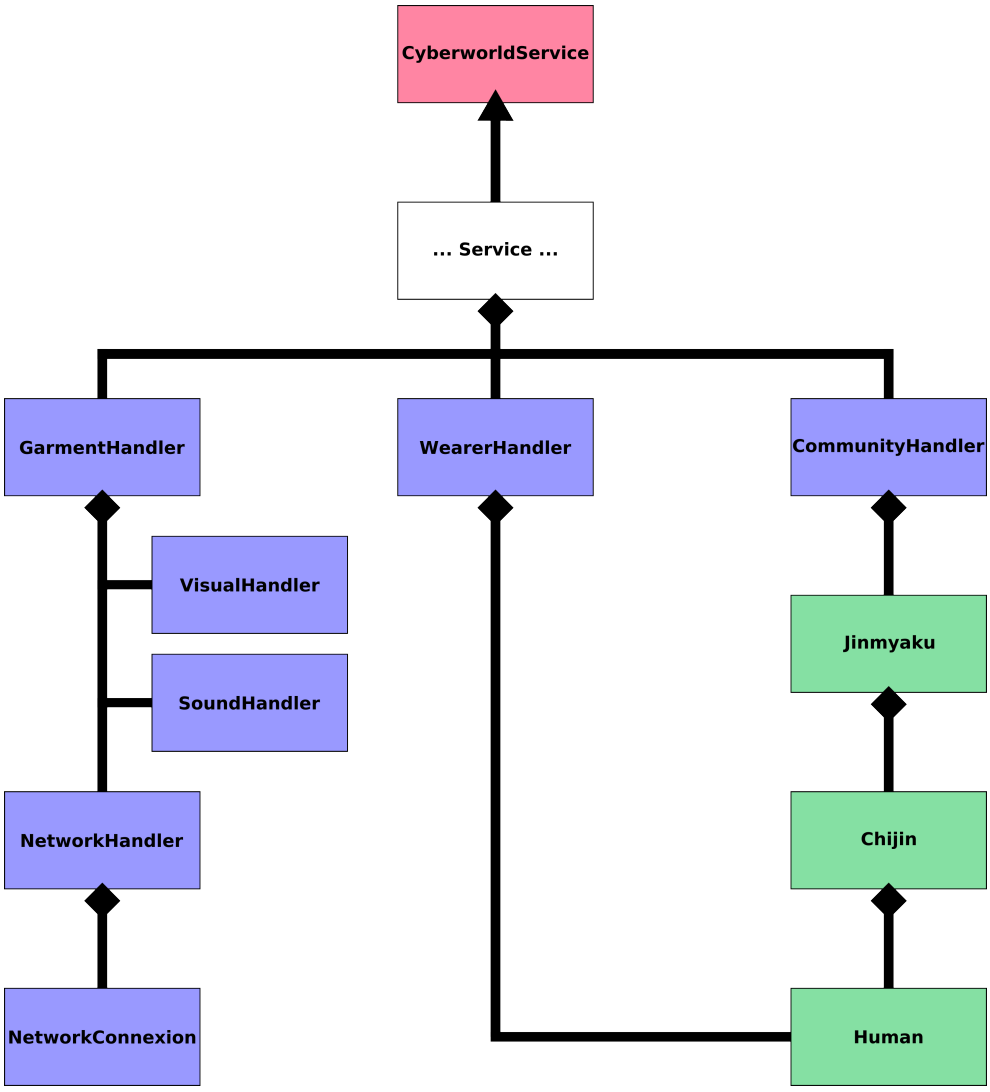

Illustration 4.2: Framework – Class diagram.

GarmentHandler manages the system's inputs and outputs. It keeps track of the nature, location, and number of devices used for inputs and outputs. A module allows the precise control of each device but it can be replaced by intelligent modules that select how services' requests are fulfilled depending on the context. Such a module can for example lower sound levels in theatres and hospitals. The *NetworkHandler* deals with digital communications between cyberclothes and with other devices. It creates objects to send, identifies them and checks the communication protocol. The *VisualHandler* controls the screens, associates visual data with the appropriate location (front and back screens for our prototype), and displays slideshows.

WearerHandler keeps information about the wearer, such as languages spoken, age, gender, or digital signature. This information can be used to adapt services provided by other cyberclothes or intelligent environments.

CommunityHandler can be activated for social services. It keeps a list of acquaintances based on unique identifiers. Depending on information received by the system, it can store practical data such as languages spoken, contact information such as e-mail addresses, and additional data such as hobbies. Extensions are under development to automatically update contact information and to evaluate human networks, allowing recommendations based on known relations between group members. *Jinmyaku*, *Chijin*, and *Human* respectively represent a human network, an acquaintance, and a human being.

Currently the framework mainly provides tools to manage a wearable's visual outputs, network connexions, wearers' profile, and information about communities. Although it is limited regarding privacy, security, and internationalization, it suffices to evaluate the potential of social applications dedicated to wearable systems. Additional handlers envisioned for the framework include a *ScentHandler* to provide relaxing scents to stressed wearers [6][81], a *TactileHandler* to communicate with the blind, and an *AirHandler* to analyze the air and evaluate pollution for health services.

Several aspects of data management were considered. First the storage, access, encoding and protocols of communication; UTF-8 encoding was used to properly manage internationalization. Besides some privacy aspects were taken into account. The framework clearly makes the difference between the user's data, versus data stored about other people; the permanent or semi-permanent (*e.g.* name, job, etc.) and the temporary (*e.g.* biosignals).

4.1.3 Overview

Taking into account functions and interface issues, the wearable system was developed as an enhanced jacket with processing abilities, access to wireless networks, a multi-button device, two embedded screens, and physiological sensors. Successive versions were tried, initially with sound but without sensors. The latest wearable would need several improvements for uses in everyday life however it was appropriate to clarify the results obtained with the social study.

In order to maintain the continuity of the study on cyberclothes, the form-factor selected for the wearable system was that of a garment. The choice of a jacket is justified by their common use in everyday life, by the good surface/volume available to embed components, and by their position in our field of view during face-to-face discussions. The chest and back provided a good surface to embed screens visible by either interlocutors or passersby, which could support conversations or attract passersby' attention. Considering the importance of eye contact in conversations, the front screen needed to be as close as possible of the wearer's face. This way gaze could easily move to and fro multimedia content. To avoid distracting interlocutors, very bright displays and animated content should be avoided. However these elements do not depend much on design, but more on use of the system by wearers. Illustration 4.3 shows the first wearable:

Illustration 4.3: Wearable system – First enhanced jacket.

The prototype features two screens, one in the front and one in the back. The front screen is intended to display information supporting wearers' conversations while the back screen attracts passersby' attention or provides public information. As can be seen on the photo of our first jacket, a front badge-size screen is insufficient to fulfill its purpose; it is too small, and photos and videos cannot be viewed from a standard interpersonal distance. Several sizes were tried and the latest version of the wearable includes a touch-sensitive front screen of 18 cm in diagonal. According to testers' feedback, it is still a bit small to view details of vertical photos but a zoom function can solve this problem in a satisfactory way. The back screen is 26 cm in diagonal, which is sufficient to see information from 3 to 5 meters away. Current technologies limited the quality, size and weight of affordable screens. With OLED or fiber optics, larger but lighter displays will be available, and improve rendering, comfort, and energy consumption.

As shown on illustration 4.4, one screen is connected to the video plug, and the other to a USB port via a VGA adapter. Other visible elements are the harnesses, the battery (top), wireless component (bottom center) and LightStone (bottom left) that acquires biosignals on the second USB port via three sensors.

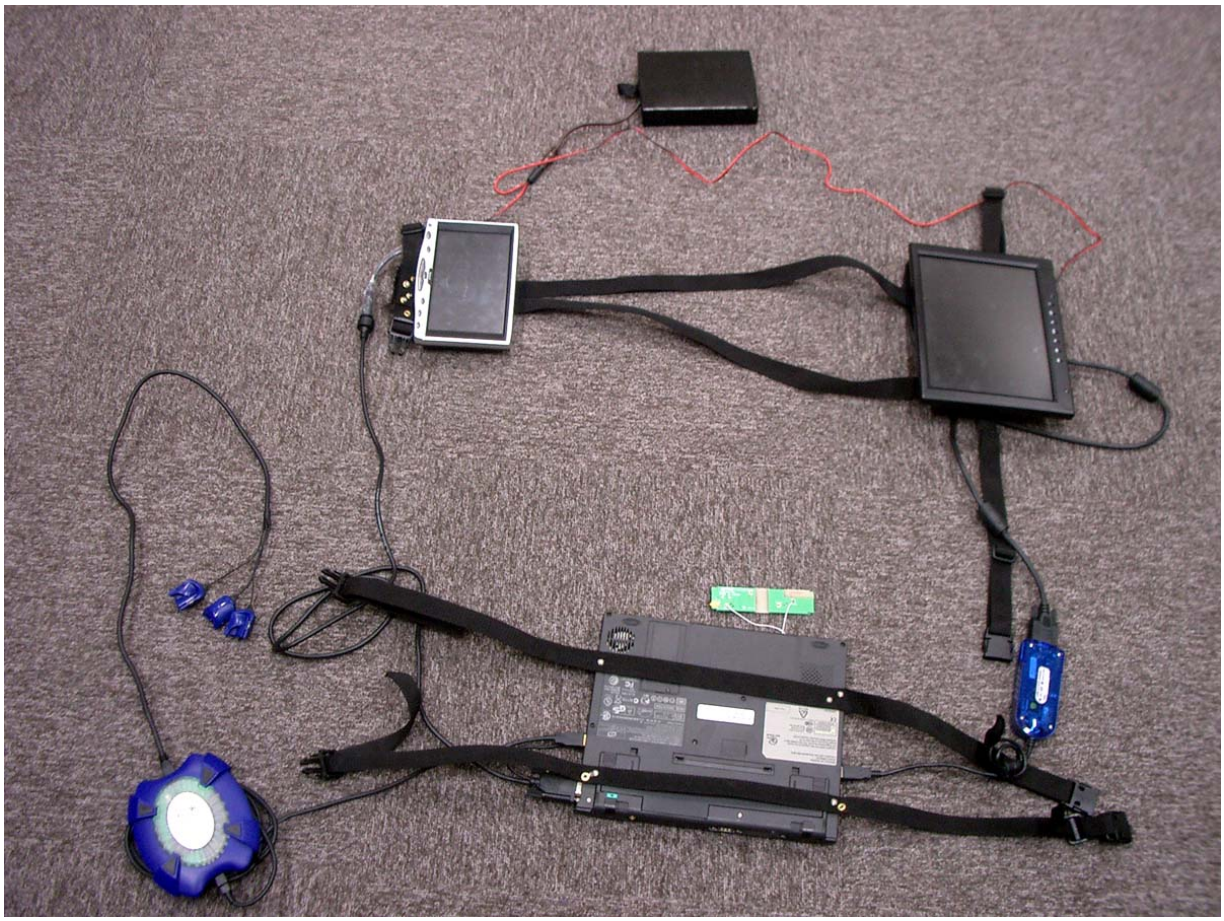

Illustration 4.4: Wearable system – Hardware components of the second enhanced jacket.

Considering the interface issues for both emotional displays and for the support of face-to-face first contacts, priority was given to visual output but the use of sound was also tested. Personal information can be uploaded through a wireless connexion, hints about emotion are obtained via the physiological sensors, and conscious actions can be carried out by wearers either by touching the screen or with a multi-button device. The motherboard was extracted from a Compaq Evo 410. Main components are a processor Intel Pentium III at 1.2 GHz, 512 Mb of RAM, and standard wireless (IEEE 802.11). The system runs with Windows XP Service Pack 2 but, with drivers for the physiological sensors, we could also use Linux.

When wearing the system, components are barely visible to interlocutors (illustration 4.5). The motherboard is fixed below the back screen, the battery in the left pocket, and the controller for the sensors in the right one. What is visible is the front and back screens, the harness that supports them horizontally, and three sensors that the wearer attaches to her fingers (two for skin conductivity, one for heartbeats). Control is discreet, which avoids disrupting the natural flow of interactions with interlocutors. However contact-less sensors would allow wearers to use their hands more naturally. The heat generated by the wearable did not affect the experiments because they lasted only ten minutes. However real-world uses would require dedicated motherboards and screens.

Illustration 4.5: Wearable system – Second enhanced jacket, with screens and biosensors.

4.2 Service for first encounters

The developed service supports first encounters with the enhanced jacket previously introduced. It allows prototypes to exchange information, accordingly display personalized photo slideshows and disclose wearers' arousal. These functions require the management of users' physiological data as well as the annotation of a set of selected photos.

4.2.1 Functions

To support first encounters, the system stores personal data about the wearer, processes information about context and interlocutors, displays photos and comments, and evaluates arousal with physiological sensors.

As shown on illustration 4.6, the process involves the recognition and acceptation of the service by a user (*a.k.a.* viewer) who sends personal data to the service provider (*a.k.a.* displayer). The provider stores the information, processes it to evaluate common interests, sends back the common keywords found, and displays a slideshow based on this result. The service is symmetric for the information on common interests so that one benefits from the disclosure of her personal data, which should have a positive influence on the perceived usefulness and attractiveness of the service.

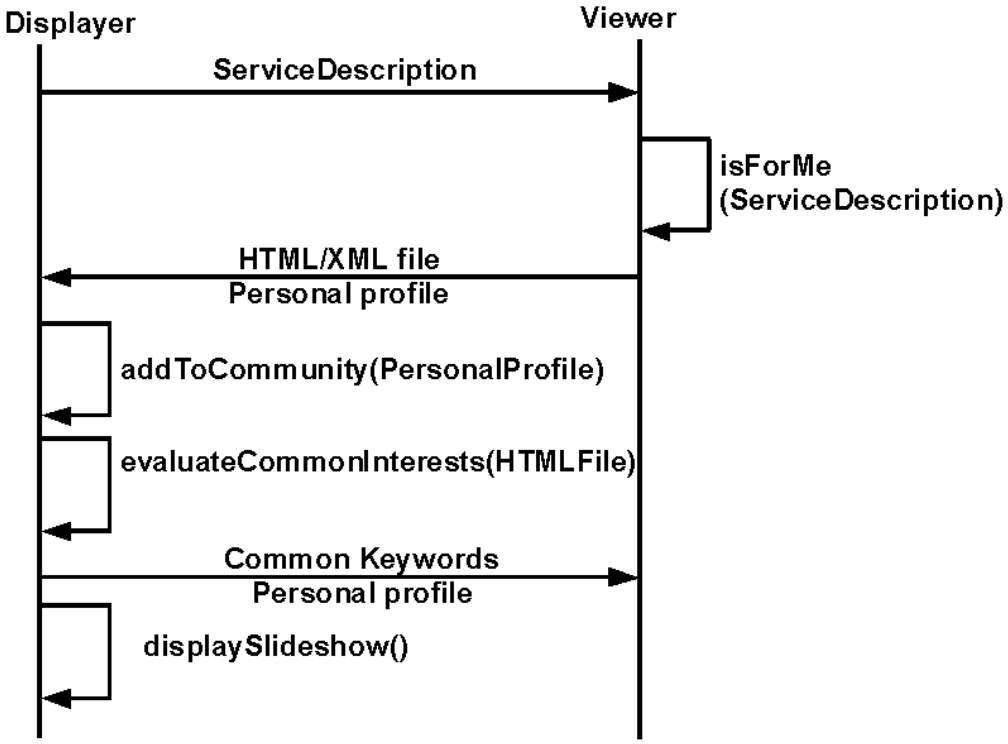

Illustration 4.6: Service – Flow of events with two wearers.

The viewer accepts or rejects a proposed service based on the service description it receives (see example on illustration 4.7) and on its configuration. Once the service has been accepted, the viewer provides a subset of her profile. It should contain her unique identifier for ulterior transactions, and information such as language spoken to accordingly adapt the service. If the viewer wants to remain anonymous, she can send a void profile, and the service will work with default values: English for the language, etc.

```
- <Service>
  - <Input>
    - <Resource min="1" max="3">
        <Type>HTML</Type>
        <Description>Requester interests</Description>
      </Resource>
    </Input>
  - <Output>
    - <Resource min="0" max="12">
        <Type>Keyword</Type>
        <Description>Common interest</Description>
      </Resource>
    </Output>
  - <Function>
    - <Display group_fusion="no">
        <Type>Slideshow</Type>
        <Description>Common profile</Description>
      </Display>
    </Function>
  - <Policy>
    - <Privacy>
        <Disclosure>None</Disclosure>
      </Privacy>
    </Policy>
  </Service>
```

Illustration 4.7: Service – Example of a service's description.

The description of a service is in four parts: *Input*, *Output*, *Function*, and *Policy*. *Input* indicates resources requested by the service from the wearable contacted. In the example it requests 1 to 3 HTML files that represent the user's interests (*e.g.* hobbies). *Output* indicates what information the user's wearable will receive in exchange. In the example it is a list of keywords corresponding to interests shared by the wearers (*e.g.* hiking, tea ceremony). *Function* describes the actions taken by the service, in this case the display of photos corresponding to common points of the wearers. Finally, *Policy* states the way the data can be used, for example whether it can be exchanged with or sold to third parties. *Output*, *Function* and *Policy* are not enforceable, but they establish a contract between providers and users of the service.

The service can process files in HTML or XML formats. This choice was motivated on one hand by a concern for interoperability, and on the other hand by the possibility to reuse existing materials available on home pages, blogs and wikis. HTML is a limited language, and the annotation of photos is only possible using the *alt* field. XML is a good complement because it is a standard, is easy to process and update, and can be inserted in HTML files with few negative side effects: memory and processing requirements are just slightly increased.

When two users get into contact, their wearables display a welcome message in the languages appropriate to the context (*e.g.* Japanese in Japan), and in the language of each user. Once common interests are calculated, photos corresponding to the associated keywords are extracted based on URLs indicated in the HTML/XML files. Then the system displays photos one by one, the user going forward or backward with the right and left buttons of the interface. Each photo is displayed with meta-data indicating why the photo was selected (usually common keywords).

Illustration 4.8 is an example of possible display for wearers who share a common interest in Japanese tea ceremony. The meta-data are either the relevant keywords extracted from the *alt* field of the HTML file, or data selected in XML. Only three meta-data are presented simultaneously to avoid overwhelming viewers: the display hints at a common interest but does not replace discussion.

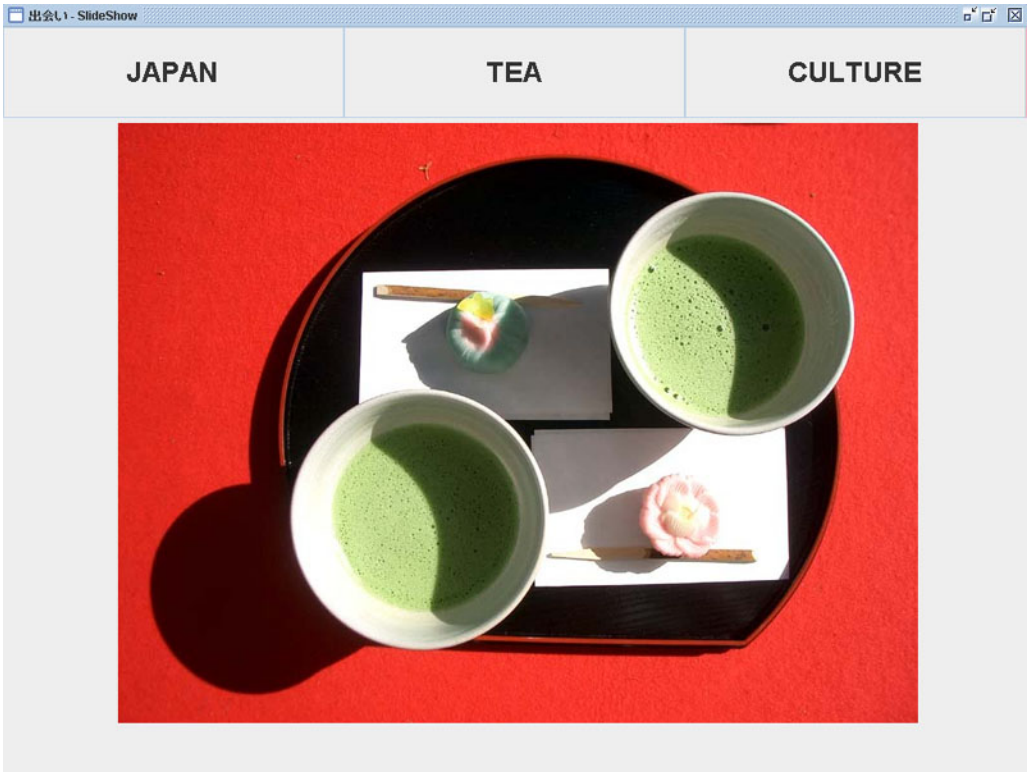

Illustration 4.8: Service – Example reflecting common interests in tea.

When there are no common keywords, or interlocutors do not possess a wearable, a slideshow is generated based on the wearer's schedule or other contextual information. For example, if the schedule indicates that the wearer should now be at a conference on computer science, the service will display a slideshow based on the words “conference” and “computer science”.

Displaying photos on a wearer's body is quite novel for services that exclude advertising. *Meme tags* [19] and *Bubblebadges* [26] display textual information stored by wearers (*e.g.* quotes), personalized for viewers (*e.g.* e-mail alert) or dedicated to communities. Although *GroupWear* [18] displays information about similarities between people, it only lights up LEDs corresponding to binary values on the top of badges, related to answers of predefined questions; it therefore lacks generality. *Moments of Interest* [16] takes photos but the goal is different.

While the slideshow is going on, wearers can concurrently activate their emotional mirror with a click on the device's middle button. Data streams from the physiological sensors are then processed in real-time to reflect the wearer's arousal. When skin conductivity is low, the wearer is considered calm, and when it is high the wearer is considered excited. In the current version of the service, the background color is modified along a linear gradient, from blue for calm to red for excited.

For emotional mirrors, I considered the use of smileys, colors and texts. A color gradient was preferred because it does not take visual space (it just fills unused spaces), can reflect skin conductivity values more flexibly than text, and is potentially less misleading than smileys. When research will provide better algorithms to evaluate emotions such as “happiness”, “anger” and “fear” [65], smileys will become more appropriate. Anyway, because the meaning of colors varies with cultures, color gradients are not silver bullets. Following the use of cold and warm colors, the background varies from blue (for calm) to red (for excited). This choice is appropriate in numerous Western countries but not in China, where red represents happiness. Misunderstandings can therefore arise because in our system red is used when wearers are happy but also when they are angry. This issue should be investigated in more depth.

4.2.2 Data management

The generation of a photo slideshow reflecting common interests, and the display of arousal require the management of photo and physiological data. As a consequence photos must be annotated (preferably automatically), and wearers' physiological profile must be stored and updated.

The Semantic Web provides a good framework to publish and share machine-understandable data, based on standard, non proprietary technologies. XML (*eXtensible Markup Language*) defines

a structure, RDF (*Resource Description Framework*) expresses meaning, and OWL (*Web Ontology Language*) provides common concepts. Because this framework targets Internet applications, it is not directly applicable to face-to-face services, especially due to low latency for processing based on location-awareness. The service takes advantage of technologies involved in the semantic web: XML describes services and resources, and ontologies are used to share a common vocabulary. XML is used because of its strength regarding interoperability.

To be efficient, the ontology describing services needs to be semantically clear and rich. By efficient, I mean easy understanding of the service by humans as well as software agents, and achievement of complex tasks in dynamic environments involving numerous entities. It could be used for context-based services. Requirements for ontologies describing multimedia resources are different because they deal with world descriptions instead of services' processes. Besides providers ought to publish data in a reusable form to incorporate them in various services and applications, hence again the choice of XML.

To manipulate resources and facilitate maintenance, annotations must be done extensively and consistently. Ontologies can provide a clean set of concepts available for annotations. A problem with real-world data is that the set of required concepts is huge, difficult to manipulate. To alleviate the burden placed on users, the process should be automated as much as possible. Partial automation is possible: cameras can mark time and location, schedules identify events, and video-processing identify acquaintances. Users just need to correct mistakes and manually complement keywords. This is not time-consuming if users only annotate photos destined for the service. Guided by a dedicated software, users easily produce XML annotations similar to those on illustration 4.9:

```
- <Resource id="2005_05_28_0084">
    <Type>Photo</Type>
    <Location gen="GPS">Tokyo</Location>
    <Event gen="schedule">Banquet</Event>
    <People gen="manual">Megumi</People>
    <People gen="manual">Paul</People>
    <People gen="recog_algo">Ryozuke</People>
    <Keyword gen="manual">Conference</Keyword>
    <Keyword gen="schedule">Party</Keyword>
    <Keyword gen="manual">Virtual Reality</Keyword>
    <Comment gen="manual">Great talks and sushis</Comment>
    <Copyright>...</Copyright>
  </Resource>
```

Illustration 4.9: Service – Example of photo annotation.

To efficiently compare users' annotations, common terms must be agreed on. Shared ontologies are a solution, with the possibility to combine a generic and a specialist one. The first would be shared with all users, and would cover a large set of situations with little depth. The second would be shared within a community (*e.g.* computer scientists) and therefore be narrow in scope. However it would be tailored to the content of a specific community and cover it in depth. This way, when the system compares annotated resources, it always provides a result, and particularly good ones with people from the same community, which should be the most interesting trade-off for wearers.

Another solution is to compare terms with a thesaurus. The main difficulty is to compare annotations from different languages. A pivot language allows comparisons between *e.g.* Japanese and French but ambiguous terms can generate surprising results. Once annotations are processed, sets of keywords are compared. The intersection indicates common interests. For more pertinent materials, the schedule's current event is used for an additional intersection (illustration 4.10):

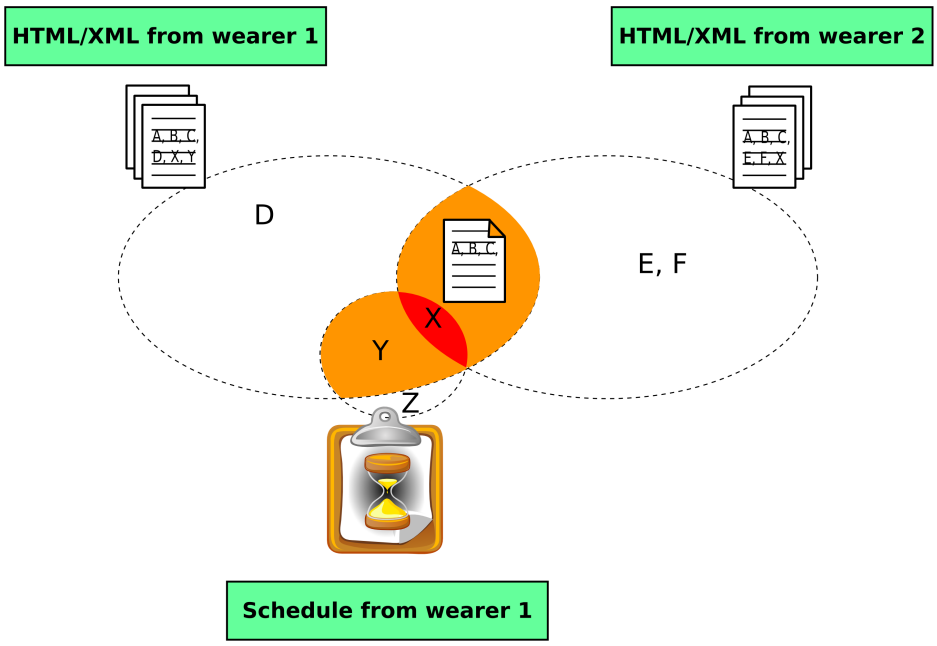

Illustration 4.10: Service – Matchmaking of two wearers' documents.

The system displays in priority the photos associated to the strongest (red) intersection, which corresponds to common interests related to the current event. Then the system shows photos associated to the weakest (orange) intersections, which are either related to common interests or to the event. This algorithm only works for a pair of wearers; a possible improvement is therefore to manage groups.

Globally the system involves more than the HTML/XML files discussed above. There are four main databases: context repositories, personal resources, physiological data and community data. Their role is depicted on illustration 4.11:

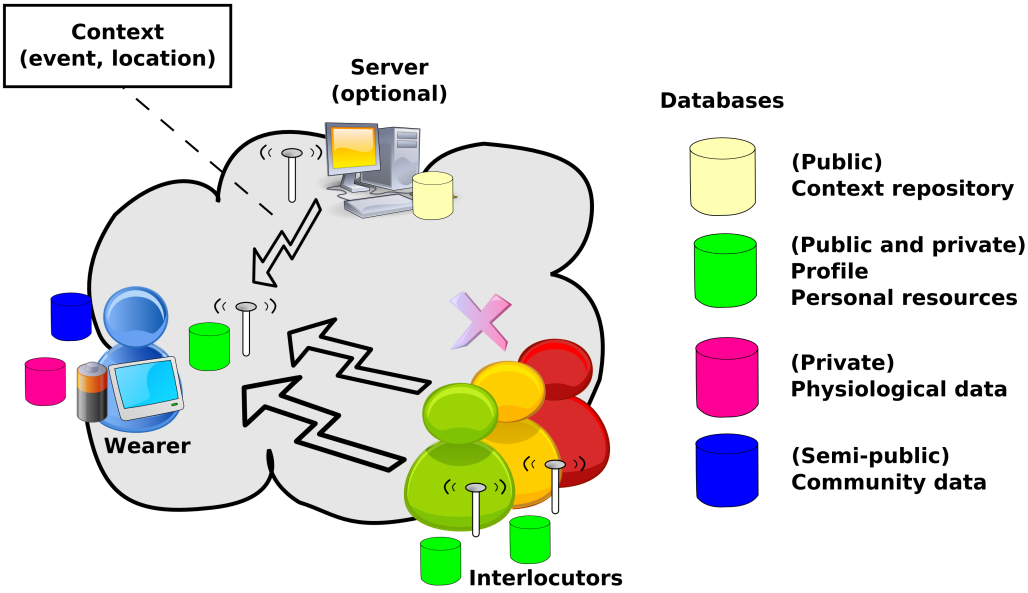

Illustration 4.11: Service – Databases in the system.

Context repositories are public but optional; they provide information related to the context. At a conference site or in the street, they can be accessed through a server that broadcasts information about ongoing events. Profile and personal resources gather information about the wearer, including shared HTML/XML files. This database is necessary for all service users; on figure 4.11 the third (red) interlocutor does not possess it and cannot therefore influence the generation of the slideshow. The physiological database stores usual values for heartbeats, skin conductivity, and can be used for medical, sportive or affective services; it must therefore be strictly private. Finally the community database stores information willingly released by and about people met, indexed by unique identifiers. It includes digital business cards, descriptions of first encounters, common interests, *etc.*

As a conclusion, the service reveals common interests of a pair of wearers from HTML/XML files that contain photo annotations. The algorithm prioritizes the slideshow using the internal schedule and optionally context information provided by external servers. The four databases that store the data are public, semi-public, or private depending on their role and on wearers' decisions regarding specific services. The main limitations of the system are related to the process of photo annotation, to internationalization, and to the generation of slideshows for groups. These issues are important for uses in everyday life but do not prevent first evaluations of the system.

4.3 User-studies

The user-studies cover the study of support for face-to-face first contacts, emotional displays, and perception of wearables after first uses. Because the wearable system displays photos, a pre-study focused on the disclosure of photos. The core study was then designed based on the gathered data and carried out with a small group of Japanese and Europeans. The qualitative and quantitative studies clarified previous results, validated the hypothesis for belonging needs and also enabled incremental ameliorations of the enhanced jacket and service.

4.3.1 Pre-study on the disclosure of photos

This pre-study was based on interviews about, and experiments with, photos. The results highlight an issue about relationships with the people to whom information is disclosed. Reluctance to show some types of graphics (photos, logos, texts) depends on the social distance expressed as the belonging to groups such as family, friends, co-workers or strangers. Although this is a social issue, technical solutions for displays on wearables are possible. For example, acquaintances can be classified in simple groups, wearables automatically using their memory to identify people and accordingly select sets of graphics to display.

Photos were shown to participants, and feedback was gathered about the kind of content they would be ready to show to various people. Additional information was acquired about the situations in which they would display dynamic graphics on their garments. Respondents' enthusiasm and the breadth of imagined situations were encouraging. The pre-study suggested differences between the Japanese and the French. On the contrary, there was no notable variation due to gender.

Setting and materials

The test consisted of the display of graphics, followed by a questionnaire with oral comments. Graphics comprised of 4 sets (A, B, C, D) of 12 pictures each. Set A included business cards and work-related photos. Set B included photos of friends and personal activities. Set C included graphics found on tee-shirts: brand logos, drawings, political and fun messages. Set D included four graphics of each previous set.

Participants were students and researchers of the National Institute of Informatics[30]. None had a previous experience with wearables. The five respondents were three males and two females aged

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between 24 and 36. Participants listed situations in which graphics display would be useful then indicated which sets they would show to professional contacts, family, friends, or strangers. Finally respondents described the level of control they would like for the displays.

Results of the selection of photos

Highlighted situations were big events (*e.g.* conferences, forums), parties, trips, and the meeting of new people. Table 4.1 summaries the replies. During the discussions, two items were added to reflect additional interesting situations for the display of graphics on garments: communication with disabled persons, and potentially dangerous situations. Less cited items included first dates (set A), interviews (set A), public places (set C), sports (set C), any situation (set B, D), and never (set D).

	Set A	***Set B***	***Set C***	***Set D***
At big events	60%	-	-	40%
During parties	60%	60%	60%	40%
On trips	-	60%	60%	40%
First encounters	80%	60%	-	40%

Table 4.1.: Pre-study – Most cited situations for the display of selected photos.

Participants considered they could show most photos to their family and friends, work-related photos to professionals, and everything except work-related photos to strangers (illustration 4.12). Participants explained their limited use (40%) of set D by the presence of work-related photos.

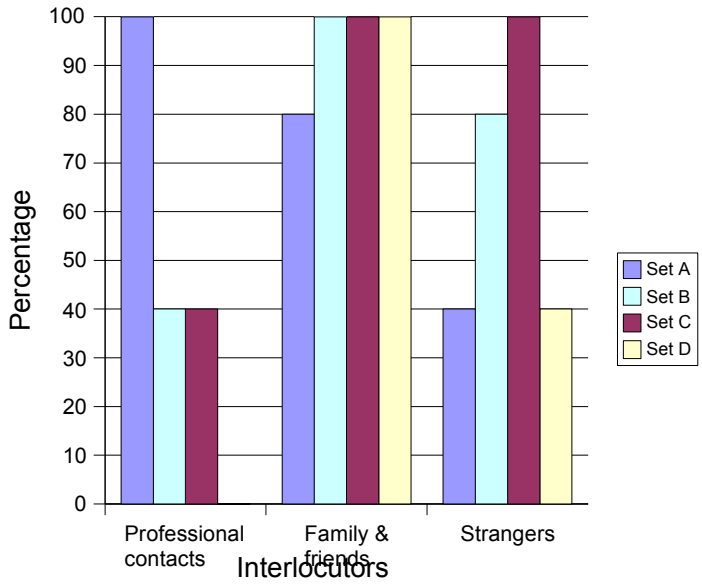

Illustration 4.12: Pre-study – Agreement to show graphics depending on interlocutors.

Regarding the autonomy of cyberclothes, 80% of respondents preferred to keep control at a category level (*e.g.* professional, personal). Control at an image level was judged too cumbersome (80%). All participants were anxious about giving full control to the machine and rejected that possibility. They explained that any mistake made by the system could embarrass or harm them.

4.3.2 Study on support for first encounters

The system was evaluated with quantitative and qualitative data. The goals were to verify the system's usability and efficiency, improve its design, check shifts in acceptance of social wearables after uses, and clarify the rejection of emotional displays.

Experimental Protocol

The system was evaluated with fourteen Algerian, French, German and Japanese. The age range was 21-32 (M=28, SD=3.1), with two females. The experiments consisted of 10-minutes discussions between a wearer and two interlocutors. Each user prepared 30 annotated photos. The simulated situation was an encounter at a professional seminar. The experiment was carried out in a room with limited lighting to ensure the visibility of the screen's content. Pilot groups tested the system in automatic mode (photos changed every 30 seconds) without manual control. The multi-button was provided at their demand, which greatly increased usability.

Before the experiment, testers filled a questionnaire about enhanced garments, using a 5-point Likert scale: 1–strongly disagree, 2–disagree, 3–neither agree nor disagree, 4–agree, and 5–strongly agree. After the experiment, they filled the same questionnaire, and replied to additional questions related to the system they had experienced. In addition, interlocutors had to list the interesting elements they had learnt about the wearer during the discussion. The questionnaires and data can be found in Appendixes C and D.

Design, usability and efficiency

Direct observation and feedback from participants indicated that usability and efficiency were good. Illustration 4.13 shows feedback based on the Likert scale. Testers think that the system improves both the wearer's (4.2) and interlocutors' (3.8) ability to communicate. According to oral feedback, the system is a good icebreaker because it provides starting points for the discussion as well as new topics when required. Participants also think the system helped them learn more things (4.3) and more interesting things (3.8) which is positive from quantitative and qualitative points of

view. Both wearers and interlocutors wonder (2.7) whether the system improves long-term relationships or not. Considering that the service was designed for short interactions, this result does not contradict the interest of the system. This evaluation might be improved by the explicit management of long-term data and transfer of a digital business card at the end of the discussion.

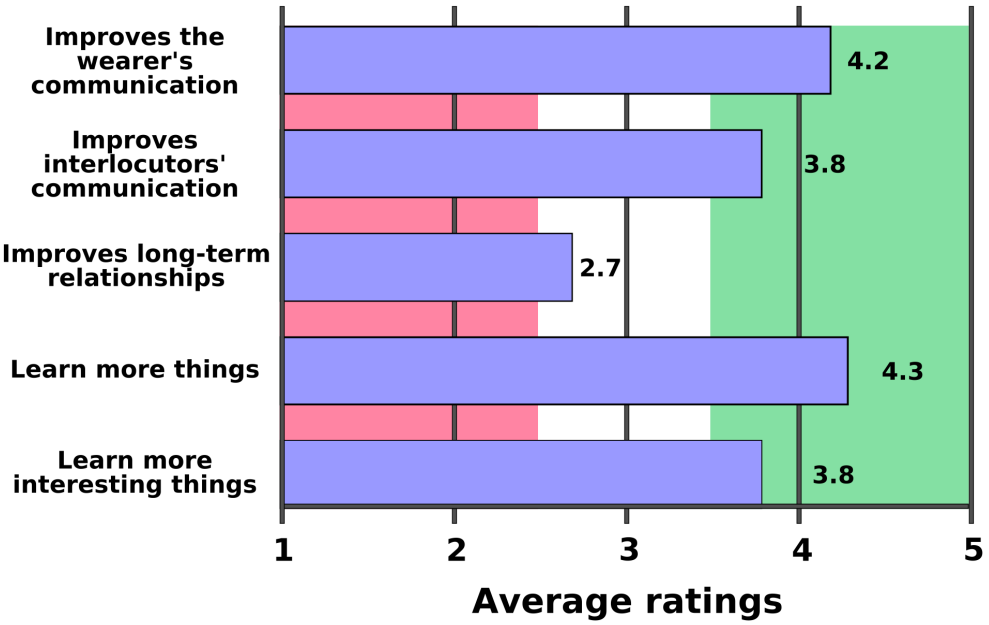

Illustration 4.13: User-study – Efficiency of the system.

Besides quantitative comparisons with a control group indicate that the system is efficient: interlocutors list 25% more items about a speaker when she uses the system than without it.

In all cases, participants think wearers should have more control. However the system would at the same be better if its intelligence was improved (illustration 4.14):

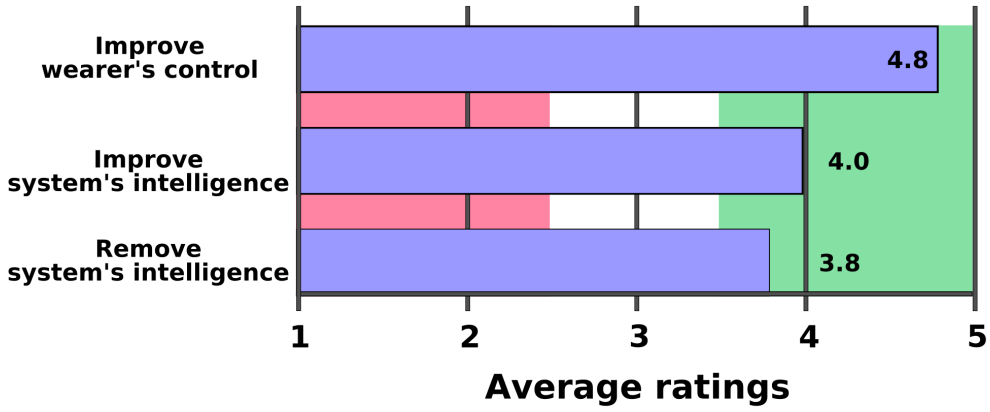

Illustration 4.14: User-study – Requests for the control of the system.

All participants think the system requires an additional display that the wearer can easily see to avoid looking down at its own front screen (illustration 4.15). Semi-transparent glasses (4.5) are preferred over screens on sleeves (4.3):

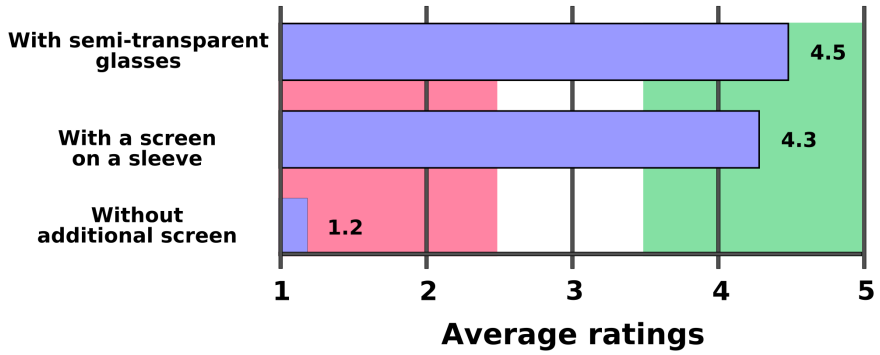

Illustration 4.15: User-study – Requests for additional displays.

Shift in acceptance of social wearables

A comparison of answers to the questionnaire before and after experiments indicates a shift in the perception of cyberclothes (illustration 4.16). Results are significant for the display of graphics on garments, for the disclosure of one's profile to her own community, and for the use of emotional displays. Besides, the acceptance of the service is very significant after the experiment.

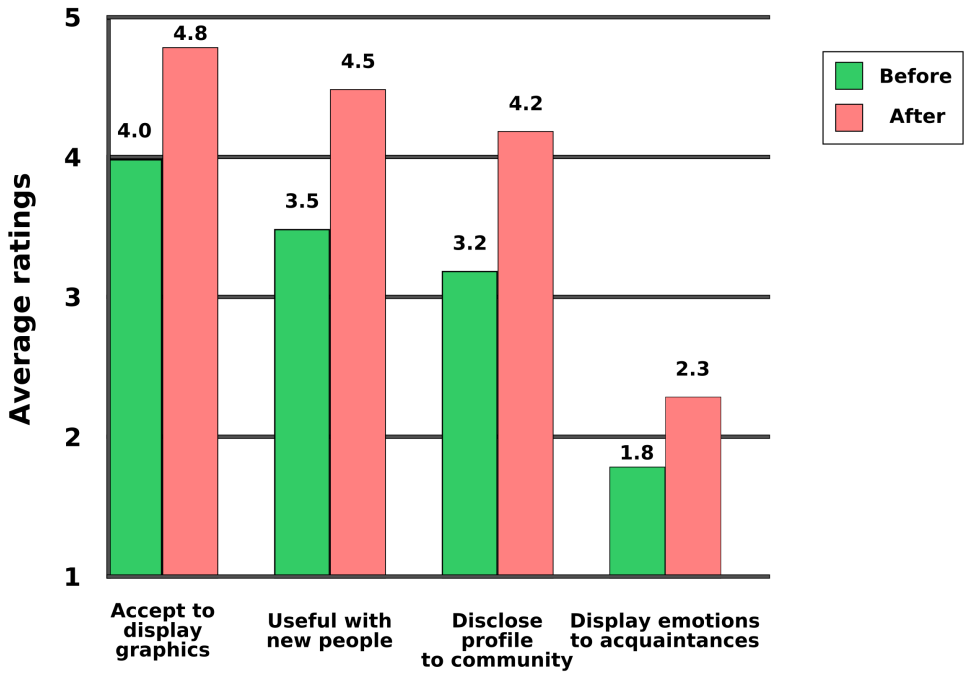

Illustration 4.16: User-study – Shifts in acceptance due to the experiments.

Rejection of emotional displays

Results clarify the rejection of emotional displays noted previously. Illustration 4.17 shows that emotional displays are considered useless and potentially harmful. This perception depends on the social distance with viewers of the display. Perceived usefulness is inversely proportional to social distance. Perceived danger follows a more complex pattern.

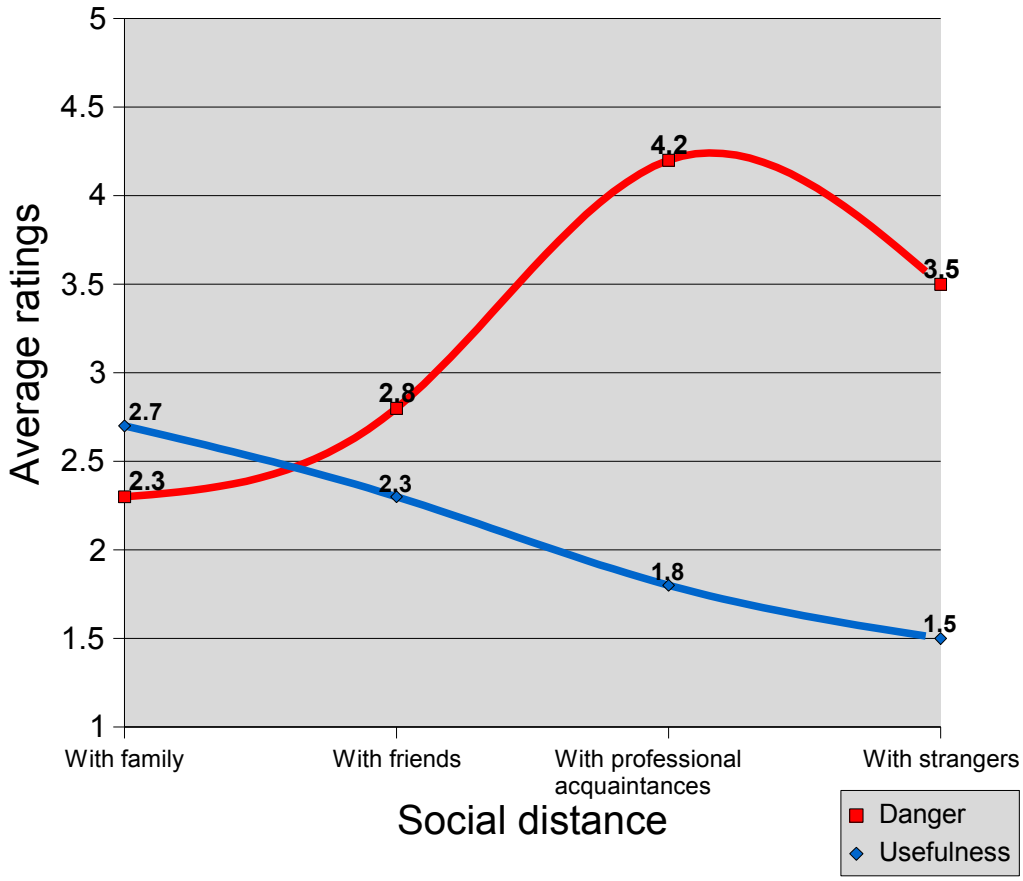

Illustration 4.17: User-study – Perception of emotional displays.

Perceived danger is the lowest with family and friends. It is high with strangers and the highest with professional acquaintances. Based on participants' comments, it is apparently because one usually tries to hide personal feelings to professional contacts and strangers. Emotional displays are seen as less harmful with strangers because strangers are easy to ignore if things go wrong, whereas it is difficult with co-workers that belong to our everyday life.

Finally participants think that biosensors enable very accurate evaluations of emotional states. All participants feel that the evaluation is at least reliable 60% of times; half of participants think it is reliable at least 90% of the time. This is beyond the capacities of current algorithms. Emotional displays therefore appear to the general public much more accurate and reliable than they really are.

4.4 Discussion

The results of the user-studies are very instructive. Firstly, they show an improvement of the perception of cyberclothes after first uses. Secondly, they indicate that the rejection of support for first encounters can easily be overcome. Finally, they identify two reasons for the rejection of emotional displays.

The results indicate that the perception of cyberclothes is improved when using the enhanced jacket and service for the first time. This is in accordance with what Durndell [24] showed for computers and Palen [64] for mobile phones: perception of a device can vary after acquisition and use. These variations were all positive but a different prototype might induce opposite effects; design remains crucial. The variations in perception that we note are not high: +0.3 for cyberclothes in general, +0.2 for profile disclosure, and + 0.3 for emotional disclosure. However it is consistently positive, which is a good sign for the results' reliability.

This improvement in perception is mainly related to exploited features: display of graphics on garments, usefulness when meeting new people, disclosure of one's profile to her community, and emotional displays. However at least one non-used feature also benefited from a better perception: the production of sounds/music/speech. This shows the existence of border effects: improving the perception of a feature (in this case certainly the display of graphics) can induce improvements for a closely related feature.

Besides the results of the social study indicated a rejection of support for first encounters. The user-studies show that it can be overcome. In the case of participants, the rating of such a service gained 1 point on a 5 point-scale after use. According to interviews, it is because the system is perceived as easy to use and as useful. Oral comments showed that participants initially thought that wearables supporting face-to-face communication might hamper the natural flow of interactions. However these comments changed after using the system to indicate that, although the system can be improved, it does not hamper much natural communication. According to the quantitative data too participants find the system useful, improving the ability to communicate whether one wears the system (4.2) or not (3.8), and enabling interlocutors to learn more things (4.3) and more interesting content (3.8).

The jacket's design can be improved in several ways. First steps have already been taken, for example increasing the size of the screen. Next steps would be to embed an additional display in a sleeve to help wearers quickly check what they show, then to compare its appropriateness with

semi-transparent glasses. I expect both settings to limit eye-contact, but recognize that it would be an improvement: wearers currently look at their chest (front screen) to know what they display.

Participants consider that the system does not help establish long-term relationships (2.7) but it is not considered as an obstacle to such relationships either. Because the system was designed for short interactions, long-term issues were not taken into consideration for the design. It could be done by managing digital business cards, storing information on interlocutors' interests, *etc.*

Finally the perception of emotional displays is improved after using the system (from 1.8 to 2.3) but remains low. Results on perceived usefulness and perceived potential harm explain this result. Independently of the context, emotional displays are seen as useless. This can be due to the system's novelty; a well-thought–novel–application might change this. In any case, the perceived usefulness of emotional displays decreases with social distance. It is highest with members of the family (2.7) then friends (2.3), and lowest with professional acquaintances (1.8) and strangers (1.5). Besides emotional displays are seen as potentially dangerous, especially with professional acquaintances (4.2) and strangers (3.5). Thus participants have two identified reasons to reject emotional displays. To solve this problem, first services using them should focus on interactions with the family: the familial setting is initially perceived as the most useful and least dangerous.

The results show that support for first encounters becomes accepted after using a prototype. They also show that the rejection of emotional displays is due to a perception of its danger, which corresponds to a problem with safety needs. Due to the prepotency of safety needs over belonging needs, the rejection of emotional displays caused by safety needs does not invalidate the hypothesis; *this* rejection confirms the hypothesis. Therefore the results obtained for the support of face-to-face first contacts and emotional displays validate the hypothesis for belonging needs.

4.5 Summary and conclusion

In this section I investigate support for belonging needs. I describe the enhanced jacket and service developed for the user studies, and the results obtained. The goals were to clarify the results of the social study, validate the hypothesis for belonging needs, and reveal design factors. The prototype is an enhanced jacket with two screens, and physiological sensors to evaluate emotions. It is controlled by a JAVA-based framework, exploited by a service that displays photos reflecting common interests of wearers and interlocutors. Personalization is possible thanks to data in HTML format, and annotations in XML based on an ontology. The system was tested with Japanese and Europeans, which showed that the rejection of support for face-to-face first contacts can easily be overcome. Besides the tests revealed that emotional displays are rejected because of their perceived uselessness and perceived dangerousness. Because the roots of this rejection lie in safety needs, the results validate the hypothesis for belonging needs.

本章では親和欲求に関する支援について検証した。実験に用いる高機能版のジャケットとサービス、そして実験結果について述べた。本章の目的は(1)前章の社会調査結果を明らかにし、(2)親和欲求についての仮説を裏付け、(3)設計要素を洗い出す事であった。プロトタイプ機器として、二つの画面と感情を測る生理センサーを備えた高機能版のジャケットを用いた。機器の制御はJAVAベースのフレームワークで行う。着用者とその対面相手の共通の興味を反映する写真を表示するサービスはこのフレームワークを利用している。HTML形式のデータとオントロジーを使ったXML形式の注釈を利用する事で機器のパーソナライズが可能になっている。日本人とヨーロッパ人を対象に、このシステムで実験を行ったところ、初めての面会を支援する機能に対する拒絶は容易に取り除かれうる事が示された。更に、感情の表示は、それが有用で無いとか危険かも知れないと考えられている事が理由で拒絶されている事も明らかになった。この拒絶感は安全欲求に起因するため、以上の結果は親和の欲求に関する仮説の妥当性を示している。

Chapter 5. General discussion

The goal of this research was to establish the influence of fundamental needs in the field of wearable computing. The social investigations and user studies complemented each other to show a convergence of results for physiological, safety and belonging needs. Besides they provided insights in hardware and software designs. Although the experimental system was not aesthetically attractive, it convinced testers of the potential interest of cyberclothes and of services supporting first encounters. Finally, a review of the concept of cyberclothes confirms its appropriateness and usefulness.

本研究の目的はウェアラブル・コンピューティングに、基本欲求の理論を取り入れた領域を打ち立てる事である。互いに補間し合う社会調査と実地の調査による結果は、生理的・安全・親和欲求の収束を示した。更に此れはハードウェアおよびソフトウェアの設計についての洞察をも齎した。外観上、魅力的とはいえないが、実験に用いたシステムは被験者にサイバークローズが潜在的に持つ興味深さや出会いを支援するサービスについて強く関心を持たせる事になった。最終的に、サイバークローズの概念を考察する事でその妥当性と有用性が確認された。

5.1 Physiological and safety needs

The hypothesis states that features or services related to physiological and safety needs would be accepted and requested by the general public. Self-completion questionnaires validated it, and the user studies further corroborated the importance of safety needs. The general public's reaction to artificial intelligence highlighted critical design elements. Finally, I propose four guidelines to create wearables that satisfy physiological and safety needs.

5.1.1 Convergence of results related to physiological and safety needs

Physiological and safety needs were broadly studied with questionnaires. Additional indirect evidence was provided by experiments that focused on belonging needs. As a consequence, two elements were studied in more depth: artificial intelligence and emotional displays. Although gender and cultural factors intervene, the results converged.

As previously explained physiological and safety needs deal with survival, health and well-being. This covers needs for air, food, drinks, sleep, appropriate temperature, as well as comfort, freedom and peace of mind. To avoid ambiguity when comparing results from different cultures, the questionnaires were designed with a focus on material needs and excluded philosophical elements such as freedom. Therefore, exhaustiveness would require additional–and careful–investigations for these latter elements. Focusing on former elements illustration 5.1 gathers results on physiological and safety needs from illustrations 3.2 and 3.3.

The analysis of the questionnaires indicated a high interest for all items related to physiological and safety needs. Unexpectedly, even services based on physiological monitoring are significantly accepted. Because such a feature is novel, potentially invasive, and carries a cyborg connotation, respondents could have been more reluctant. It would indeed be interesting to compare differences with respondents answering similar questions about in-body instead of in-garments technology. For physiological monitoring dedicated to emergencies or sports, and for garments that provide heat or cold, acceptance is particularly high in France and Japan. Although requiring additional validations, these results suggest services to develop and provide to the general public in priority. Edmison's recent study [25] on the perception of medical wearables complements and validates further these results.

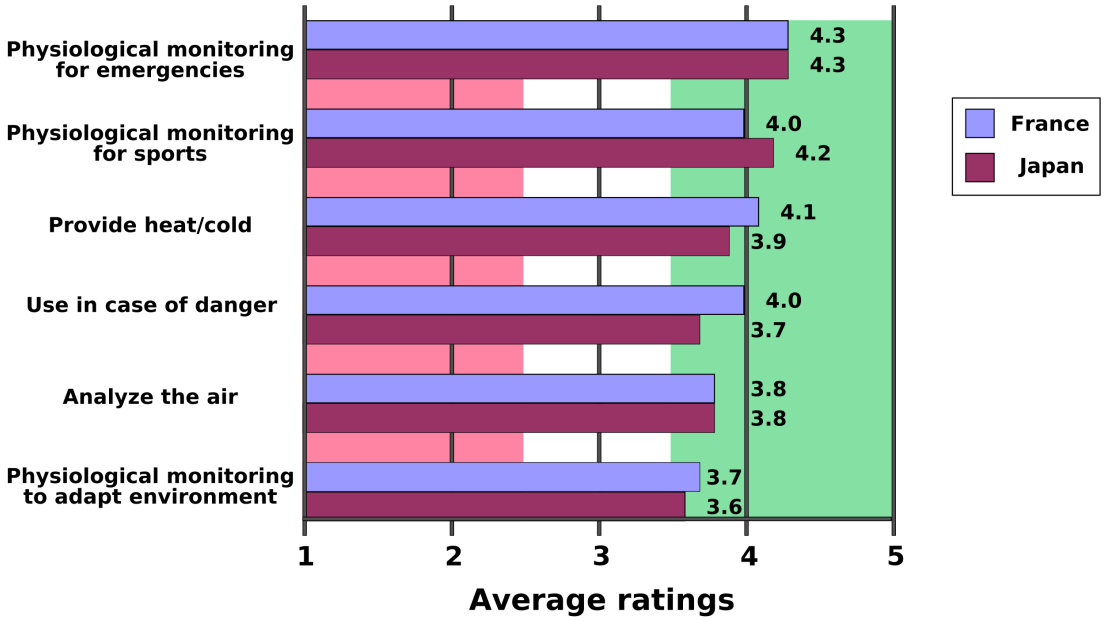

Illustration 5.1: Synthesis – Convergence of results for physiological and safety needs.

In addition, results about the desired autonomy for enhanced garments showed that the non-respect of safety needs can provoke rejection (illustration 5.2). According to respondents' comments, the rejection of full control by artificial intelligence lies in fears of physical and social harm that could result from agents' actions. Although the French and Japanese both reject full control by A.I., the former prefer full manual control whereas the latter prefer limited A.I. control.

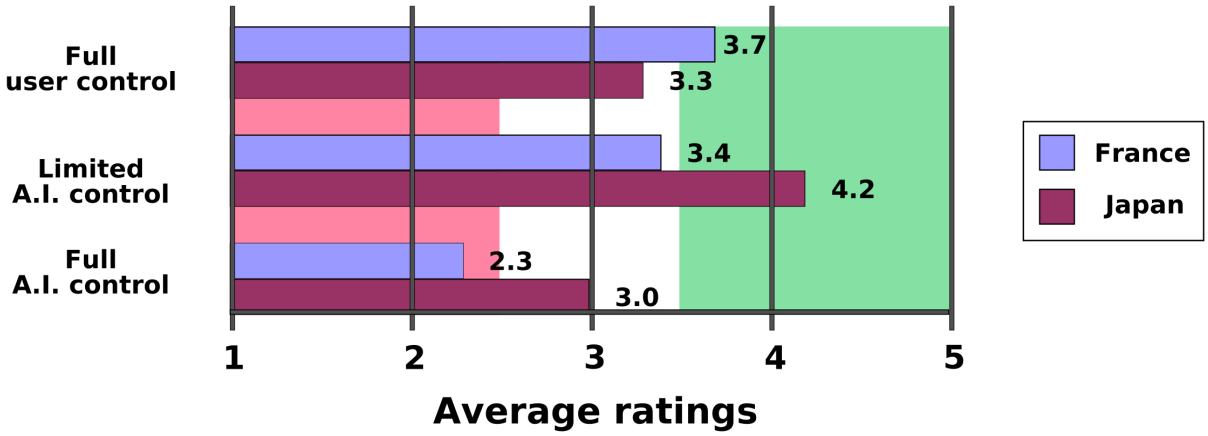

Illustration 5.2: Synthesis – Acceptance of A.I. based on the perception of benefits and danger.

The Japanese see more advantages to A.I. and drawbacks to full user control (*e.g.* usability hassles, need to activate functions and lower number of services); therefore they find a sweet spot

where artificial agents are both acceptable and profitable. Three–non-exclusive–explanations are possible. The first is related to habits regarding technology adoption: in Japan cellphones are frequently changed, and robots are found at some companies' reception desks [47]. The second is linked to the influence of tradition and religion, and was discussed for the adoption of robots: in Christian countries creating A.I. is seen negatively because it places humans at God's level but in Shintoist countries it is seen as a natural process. The third deals with the importance of individualism: the French prefer to take decision on their own whereas the Japanese are used to external suggestions [11][71]. Only the first explanation allows this cultural difference to quickly vanish.

Beside autonomy, emotional displays also demonstrate the influence of safety needs. Devices displaying emotional information about a wearer are rejected, especially if disclosed locally (1.7/2.0 locally, 2.6/2.7 remotely). The experiments indicated that rejection is due to apparent uselessness and dangerousness. Illustration 4.17 showed that the intensity of the respondents' feelings varies with the social distance to potential viewers. Based on the gathered feedback, I speculate that emotional displays are not considered harmful with the family because people already share much with other members of the family. The highest perceived risk is with professional acquaintances: such people are met every day, cannot be ignored, and do not usually share personal problems. Besides several participants worried about managers forcing subalterns to wear emotional displays, thus gaining an advantage in all interactions. Finally, showing emotions to strangers is less harmful than to professionals because one can walk away from a stranger and forget about her if things go wrong.

Because the general public's safety concerns regarding autonomy and emotional displays are neither based on sound knowledge nor on personal experience, they might be reduced by prolonged use of, or direct contact with, such features. Their progressive introduction might best overcome the current reluctance. However, if we consider most accepted services, we can expect a rise in safety concerns due to the emergence of–for example–privacy issues. Such issues are well-known for cell-phones, laptops and online medical services. Because privacy is critical, one can already find sets of tools and solutions to alleviate wearers' worries.

Finally I found marked cultural and gender differences. The cultural differences (table 5.1) regarding autonomy were discussed above, and those regarding emotional displays will be detailed in section 5.2.

	p	***French*** ***Mean (SD)***	***Japanese*** ***Mean (SD)***
Limited A.I. control	0.01	3.43 (1.33)	4.21 (1.01)
Full A.I. control	0.01	2.33 (1.26)	2.98 (1.08)
Share emotions locally	0.02	1.70 (0.95)	2.03 (0.96)

Table 5.1.: Synthesis – T-test analysis for cultural effects within physiological and safety needs.

The gender differences are introduced in table 5.2. Explanations for higher ratings of wearables that analyze the air (smells, pollution, temperature, *etc.*) by males require additional investigations. However the near rejection by female respondents of wearables that vibrate or provide a feeling of touch partially corresponds to a worry about the ability of–pervert–males to use the wearable to "touch" them remotely. This case is an instance of safety needs based on peace of mind rather than on bodily integrity. Finally, there are gender differences regarding the autonomy issue: females want more control over wearable systems. Overall, the higher acceptation by males of the technologies and services was expected because several studies previously showed such tendencies [24][88].

	p	***Male*** ***Mean (SD)***	***Female*** ***Mean (SD)***
Analyze the air	0.01	3.96 (1.10)	3.58 (1.28)
Provide touch feelings	0.01	3.08 (1.23)	2.65 (1.15)
Full user control	0.02	3.55 (1.36)	3.94 (1.23)
Full A.I. control	0.04	2.72 (1.24)	2.40 (1.29)

Table 5.2.: Synthesis – T-test analysis for gender effects within physiological and safety needs.

The investigations confirm that wearables satisfying physiological and safety needs are seen in a positive light, even when marked cultural and gender factors intervene. All features and services enhancing body condition, comfort, and well-being are very well accepted by the general public. Because wearables that implement artificial intelligence or emotional displays appear threatening, they are rejected, which confirms further the influence of safety needs. As a consequence, all results gathered validate the hypothesis for physiological and safety needs.

5.1.2 Influence on hardware and software

The high acceptance of wearables satisfying physiological and safety needs points to devices that the general public should acquire in priority. Because physiological monitoring is a basis for

several services, it must be carefully considered from the technological, bodily, and information perspectives. Besides, the rejection of artificial intelligence imposes requirements for interactions between the wearer and her wearable. Finally, external connexions and data storage are discussed.

Physiological monitoring can be exploited to monitor a wearer's health, adapt the environment to her needs, or even to evaluate her emotions. Existing technologies allow the acquisition of data on body temperature, sugar levels in the blood [3], heart activity [43], surface muscles activity [20], and skin conductivity [66]. Some devices acquire data from brain waves [9] but they are difficult to conceal in wearable outfits, and appear unnatural, which can have social consequences [83]. Using various sensors, medical [3][38] and sports [43][46][90] services were created. However, for uses in everyday life by the general public, sensors should be embedded in garments and should not require body contact, which Michahelles demonstrated for heart activity [58]. Besides the sensor's type, location is also important to ensure correct operation, and fluid movements of the wearer [32]. The case of effectors is even more complicated because requirements on position might be strict, such as in the case of drug injections [38].

Two advantages of physiological monitoring is that the data types are universal, and that the same data samples can be simultaneously used by very different services, locally or remotely. XML is a good format to store and manipulate physiological data. It is platform-independent, flexible, easy to implement and upgrade (for both elements and attributes), can be used to exchange data between systems, and can be used in conjunction with heterogeneous legacy systems, which is particularly appropriate for medical applications [35]. Besides, XML allows us to seamlessly combine information from different facets of our life: private, professional, health-related, *etc.* Convenient for personal health information management [67], it helps users to easily integrate and organize their activities. Practically, medical applications already use XML [28]. As a consequence, services satisfying physiological and safety needs should exchange information in XML format, and define the DTD with a close look to existing standards and to legacy systems with which information may be exchanged. Because wearables acquire data instead of doctors or trained staff, it would be sensible to embed meta-data such as a timestamp, the type and identifier of sensor(s) used to acquire the data, and the name of the module or algorithm(s) used to provide higher level information. This is even more important for cyberclothes because they can be exchanged, upgraded, updated or recombined with other cyberclothes or standard wearables on a daily basis.

The design of everyday wearables is considerably influenced by safety needs, as was shown by respondents' reactions to the integration of artificial intelligence and emotional displays. Wishes for limited or inexistent control by artificial agents has an impact on the number and types of functions

that a system can assume. Because agents can quickly process large data sets, they can help take more accurate decisions while limiting users' mental load. Because agents can communicate with each other at a speed humans cannot match, they enable faster decisions. Because agents are digital entities, they can do repetitive tasks without tiring. These three points illustrate what would be lost with a system solely based on direct human control. Besides, if a user has to do a task instead of the system, she can either not do the task, or take the time to do it. In the first case, the task is just dropped. In the second case, the user needs an interface to acquire data (output), and another one to enter commands (input). Manual operations therefore imply the inclusion of controls, hardware and software components.

Focusing first on outputs, screens and small speakers are the two most realistic options: they can provide complex information in a way that humans can understand without training, on the contrary to *e.g.* vibrating devices. However, the need to look at a screen or listen renders control difficult. How can one simultaneously look at a screen and at an important event? Listen to a computer's voice and converse at a party or meeting? Semi-transparent glasses provide a solution to the first question but such devices distract wearers, and might be considered socially unacceptable. A generic solution is to add a very simple control (*e.g.* multi-button device) that lets users select the output channel (vision, sound, touch) according to tasks or contexts. This nonetheless complicates the system. Besides, output interfaces rise their own problems and can be rejected, such as vibrating interfaces [40][50][82] by females.

Inputs have similar problems. Keyboards, trackballs, multi-button devices, or voice recognition with microphones are available. But how can one type on, move or press devices while doing other activities? How can one use voice-control at a meeting or in places where silence is requested (hospitals, churches, theaters...)? Discreet and/or “natural” interfaces were designed (EMG [20], gesture [76]) but the problem seems inextricable: diverse and/or complex orders cannot be easily and rapidly executed. Beyond a certain complexity threshold, “natural” control becomes error-prone without intensive training.

If full control by an artificial intelligence is unacceptable, and full control by a user impractical or useless, then a limited A.I. should control the system. This would not be a problem in Japan because limited A.I. is the Japanese's favorite choice. In France the situation is slightly different but limited A.I. is close to acceptance, which is a good sign. Finally, one should note that full control by an A.I. is rejected, not A.I. *per se*. Therefore agents may be fairly accepted if they provide suggestions to wearers, and wait for validation before acting. As a consequence, a recommended autonomous behavior is that of an advisor or “coach”. Individual tuning could still allow such

agents to automatically act for certain tasks, or in specific contexts (*e.g.* after accidents).

Finally, we have to consider external connexions and data storage. Several services may benefit from wireless connexions to acquire data from weather or transportation databases, or to send data to emergency services or to a medical doctor. In the latter cases, it would be important to ensure that a wearer is correctly identified: lending cyberclothes to a friend should not lead to a medical alert at some hospital. Correct identification is easily ensured with voice or fingerprint recognition. Biosensors in wearables could compare signals with the usual wearer's pattern. Besides, because private data is manipulated for numerous services, it should be encrypted, for both local storage and transfer to remote databases. An extensive literature on this issue is available. However, because wearers might change cyberclothes on a daily basis, there should be a way to easily transfer information (via physical components such as small cards?) from one cyberclothes to another. This component would contain identification data, user preferences for sensors and effectors activity, and also potentially the memory of the personal artificial agent.

As a conclusion, physiological sensors should be embedded, preferably based on non-contact technologies. Because physiological data is standard and because medical applications are involved, XML appears as a good substrate for the storage and transfer of information. To respect privacy, the wearer should be identified, and data encrypted. The absence of good interfaces to control complex processes in everyday life, and potential benefits of artificial intelligence suggest that A.I. should be used. Considering the general public's reluctance to leave control to artificial agents, I propose to implement the equivalent of advisers or coaches: agents that suggest but rarely act without explicit consent.

5.1.3 Guidelines A, A1, C and D

Based on the analysis of wearables for physiological and safety needs, I propose the following design guidelines:

A – Wearables should improve the body condition, comfort and safety of their wearer, and possibly of surrounding or distant people.

A1 – Full control by artificial agents should be avoided.

C – Design should be gender and culture oriented.

D – Communication with other entities, and suggestion of behaviors based on knowledge about wearers should be possible.

From the safety and comfort perspectives, the guideline A1 can be seen as a corollary of guideline A. Due to the importance of control in mobile devices and ubiquitous applications it must however be clearly stated and properly highlighted. The entities referred to in guideline D include intelligent environments, other cyberclothes, and ideally also humans.

5.2 Belonging needs

The hypothesis states that features or services related to belonging needs would be accepted and requested by the general public. Confirming this statement required experiments to clarify the results initially gathered with self-completion questionnaires. The user studies provided insights on emotional displays and support for face-to-face first contacts. These findings influence the architecture of related systems. Finally, I propose two additional guidelines to create wearables that respect belonging needs.

5.2.1 Convergence of results related to belonging needs

Belonging needs were studied with questionnaires and experiments that complemented each other. Two elements were studied in more details: first encounters and emotional displays. This led to convergent results consistent with the established literature.

As explained earlier belonging needs deal with emotional relationships, which covers family, community, work groups and clubs. According to the interviews and to the pre-study, the main interest of wearables lies in support to meet new people and to communicate in disrupted settings. Therefore I focused mainly on these two settings and left aside services directly related to the family and friends. However features such as the use of biosensors to share emotions indirectly cover them. Based on participants' reaction to emotional displays, the decision to exclude family settings should be reconsidered in future works: the general public considers emotional displays most useful with family then friends. Such investigations would be useful to the research community and provide information on settings rarely researched in the field. Focusing on settings studied so far, illustration 5.3 gathers results on belonging needs from illustrations 3.3 and 3.4.

As expected, the analysis of the self-completion questionnaires indicated a high interest for the support of communication in disrupted settings, namely during trips and with disabled people. However it was inconclusive for several items, and concluded to the rejection of physiological monitoring to share emotions, and of support for first encounters. Experiments on this latter application induced positive shifts in reactions after use of a prototype (+1 on the 5-point scale), sufficient to render the service extremely appreciated. This matches effects noted by Durndell [24] for computers and Palen [64] for mobile phones: perception of devices varies with acquisition and use. Except emotion sharing, all services were better rated than support for first encounters, they would therefore likely end up accepted too by respondents experiencing dedicated prototypes.

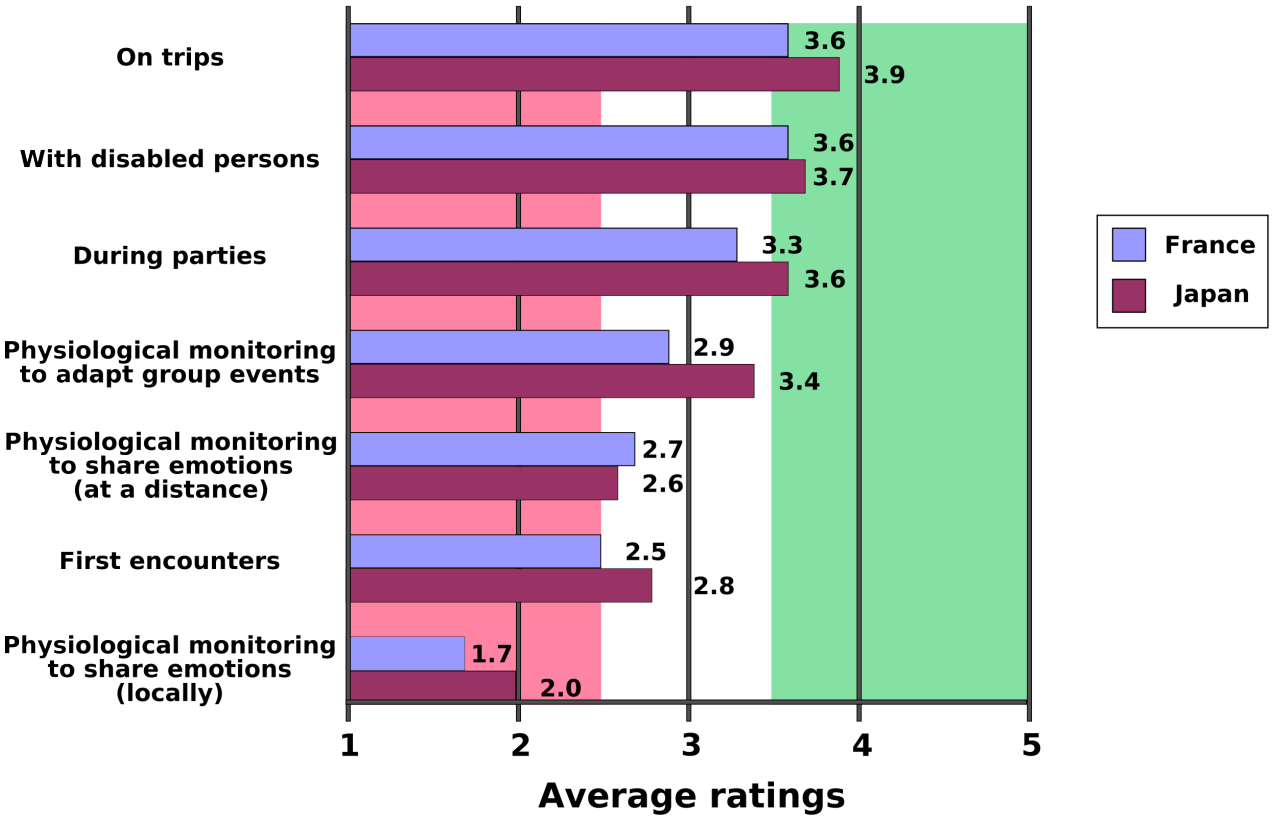

Illustration 5.3: Synthesis – Mixed results for belonging needs.

Physiological monitoring to share emotions was initially rejected. Because several services based on physiological monitoring were strongly accepted (*e.g.* adaptation of the environment to wearers' needs), this rejection could not be–uniquely–due to the use of biosensors. As shown on illustration 4.17, the experiments revealed two factors: a perceived risk and uselessness associated to emotional displays. The existence of a risk factor is consistent with a stronger rejection when emotions are revealed remotely rather than locally: distance hides the context in which the emotion arises (less risk to betray an important feeling), and disconnects emotions from seers (less risk to upset them). Besides, the perceived uselessness prevents the feature to be attractive at all. Therefore, although emotional displays can enhance communication and strengthen emotional bonding, it is unlikely they will be adopted any time soon. It will be necessary to provide a very interesting service while lessening perceived risks. The most promising services deal with family and friends because emotional displays are perceived as most useful and least harmful for services with these groups (illustration 4.17). Another way to lower risks is to render the information anonymous, which still has an interest for *e.g.* services reflecting the state of a group. This would for example provide a dynamic extension to Borovoy's community mirrors [19]. In any case, due to

the prepotency of lower needs over higher needs [55], the rejection of a service related to belonging needs (level III) because of safety concerns (level II) does not invalidate the hypothesis.

Finally the results indicate a lack of gender difference, and slight cultural differences (table 5.3). The Japanese appear much more attracted by physiological monitoring to adapt group events and to share emotions locally. The first difference was expected, due to the importance of the individual in the French society and the importance of the group in the Japanese society [11][71]. However the second difference is counter-intuitive considering that the Japanese have a higher tendency to hide their emotions [11][71] than the French. More detailed investigations are required to explain this result.

	p	***French*** ***Mean (SD)***	***Japanese*** ***Mean (SD)***
Physiological monitoring to adapt group events	0.02	2.95 (1.23)	3.39 (1.28)
Physiological monitoring to share emotions locally	0.02	1.70 (0.95)	2.03 (0.96)

Table 5.3.: Synthesis – T-test analysis for cultural effects within belonging needs.

The investigations confirm that wearables satisfying belonging needs are seen in a positive light, even when cultural factors intervene. Wearables that support first encounters may seem useless or intimidating at first, but users quickly accept them during trials. Physiological monitoring to share emotions is the only service that is negatively rated by the general public, even after experiencing it. Because this rejection is due to safety needs, all results still validate the hypothesis.

5.2.2 Influence on hardware and software

The study of wearables satisfying belonging needs highlights the interest of wearables for trips, communication with disabled persons and first encounters. Therefore design must particularly take into account internationalization, multi-modal interfaces and privacy. Besides, because of the reactions to emotional displays, the system should handle differently local and remote information disclosure. Finally, data should be managed in anonymous and group settings.

The issue of internationalization initially appears when we consider the use of wearables for trips. In this case, language, alphabet and cultural aspects[31] are better taken into account [13]. To enable this, location and culture sensitive data can be placed in external modules that are accessed depending on the actual context. Storing this data in XML format seems the best solution because it

31 For example color meanings vary with countries. Red means “danger” or “anger” in France but “happiness” in China.

is standard, and information can easily be gathered from various sources. Besides, existing tools ease the insertion, modification of elements and processing of information in XML files. However XML can only be advantageous with reusable DTD, which should be available because internationalization issues also appear in safety-related services (*e.g.* inform about accidents or natural disasters). One difficulty is to evaluate context: location, event, and surrounding people. Location can be identified outdoors with GPS and indoors with wireless connections. Events can be inferred from wearers' schedules and public databases that provide data depending on date or location. Finally information about surrounding persons can be acquired with technologies such as Bluetooth. JAVA is a good programming language candidate for internationalization because it is based on the Unicode character set, manages data with locales, provides various calendars, processes text based on locales, and supports character encoding conversion. Other languages, such as Python, can be used with appropriate libraries.

Besides internationalization, multi-modal interfaces can facilitate and enhance communication. This is particularly true when interacting with deaf or dumb people. For such situations inputs and outputs (I/O) must be embedded based on several sensory channels. Existing technologies already allow garments to include microphones, small speakers, cameras, and visual displays with fiber optics [2]. For disabled persons, the control of such wearables is possible by voice, touch, or hand movements. From an architecture point of view, it implies the decoupling of functions and I/O. In JAVA this is easily done with different objects implementing the same interface.

However, enabling communication is not sufficient because the services need to respect privacy concerns of users. There is already much research going on to ensure that transmitted information cannot be intercepted or decrypted. However there is another issue: even if information is not transmitted electronically there is a concern on the type of information disclosed, for example through photo displays. Illustration 5.4 summarizes this, based on data from the pre-study on photos, and user study on emotional displays. As a consequence I propose to base the classification and disclosure of data and people's profiles on social distances, either with groups such as “family”, “friends”, “professional acquaintances”, “strangers”, or with a numerical value. The latter solution would be more flexible but also more difficult to manage for users. Besides, services should progressively disclose information along this social distance axis, providing more personal information when wearers better know their interlocutors.

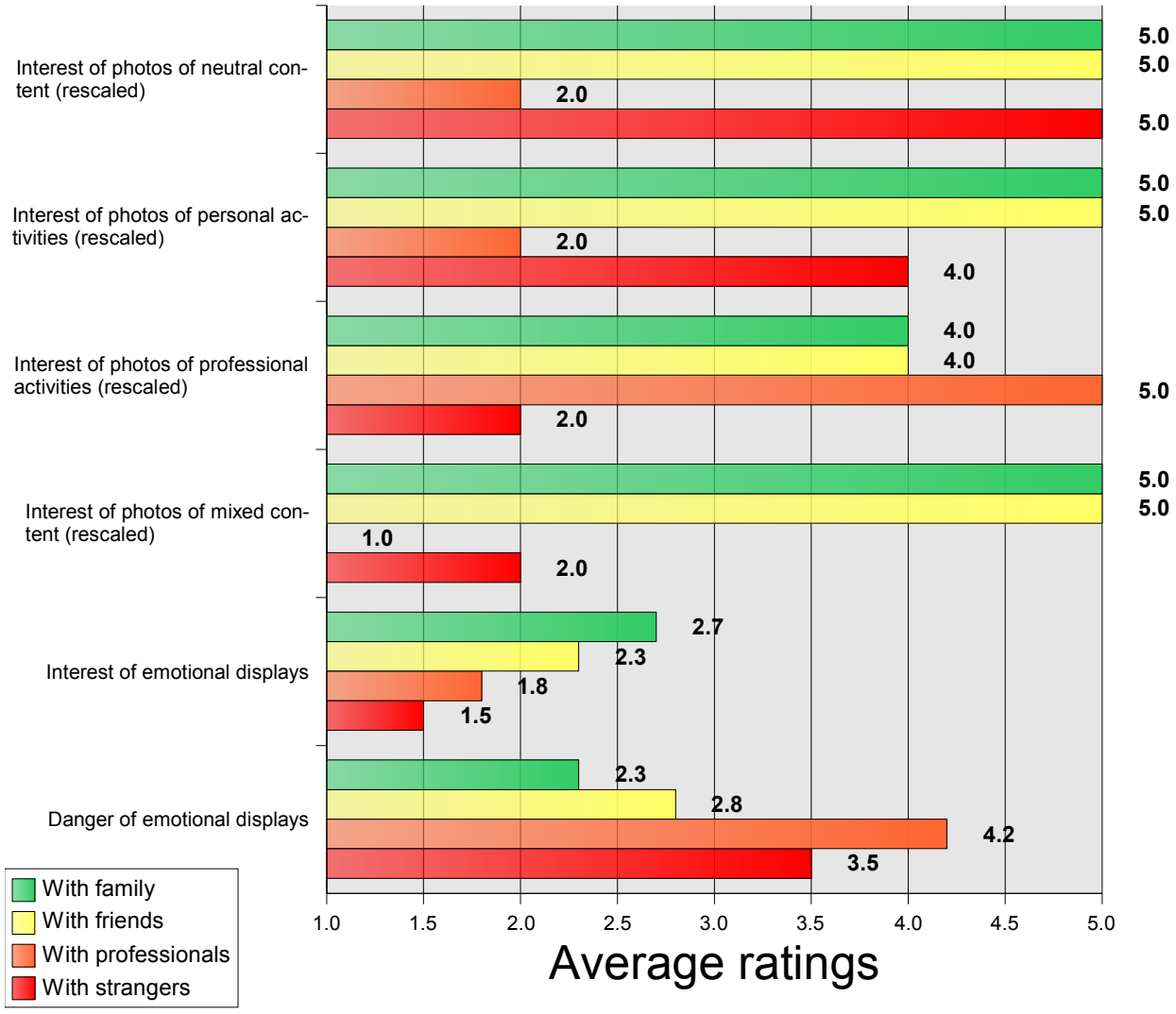

Illustration 5.4: Synthesis – Interest and danger of displays based on photos and emotions.

Because their perceived utility varies with social distance, emotional displays share similarities with photo displays. However their acceptance also depends on seers' physical location (illustration 4.17). Practically, physical distance changes the communication mode and the need for consistency. If seers are nearby, information can be transmitted visually (color, smiley) instead of electronically. When information is transmitted visually, everybody gets identical information, and the evaluation method of emotions is hidden. This case allows wearers to lock or modify the emotion displayed without others knowing it. When information is transmitted electronically, the originator can send data tailored to receivers' identity, and receivers can process data, store it and choose how to visualize it. To limit perceived risks, wearables should only provide high level information. For example, they should not indicate skin conductivity values but state information such as “Calm”, “Excited”, “Happy” or “Angry”. Besides, because perceived risks are lower for disclosure at a

distance, the system could transmit more accurate information to receivers in other geographical areas. Here accuracy can be more precise levels, or the removal of attenuating factors. Finally, wearers should have the possibility to turn on/off their emotional displays at will.

So far I only discussed interactions with “small groups” without a need for anonymity. However services based on anonymous information about a given group can be useful, such as community mirrors reflecting arousal within a community. A color patch at the end of a sleeve could reflect the state of friends, club members or co-workers. Users of such applications might not want to be directly identified as “happy” or “sad”, “calm” or “excited” therefore anonymity might be required. A good way to use such services is to rely on external servers that acquire information about the group, make it anonymous, and send synthesized content to users' wearables. A simple Internet connexion can be combined with control by biosensors or by manual updates of users' profile.

As a conclusion, JAVA is recommended to design services for belonging needs because it is an object oriented language, complements well XML, supports internationalization, and easily handles network connexions. The system should classify data and profiles based on social distances, deliver emotional information of varying accuracy or quality depending on physical distances, and rely on external servers for services requiring anonymity.

5.2.3 Guidelines A2 and B

Based on the analysis of wearables for belonging needs, I propose the two following design guidelines:

A2 – Emotional disclosure based on physiological data should be avoided, especially for non-anonymous public displays.

B – Support for communication should focus on disrupted settings (*e.g.* with disabled persons, or on trips) rather than on standard situations.

Guideline B should be universal. Because guideline A2 arises from safety concerns, it may be ignored if users consider emotion evaluation unreliable, allowing them to dismiss embarrassing displays as a system malfunction. Besides, guideline A2 may be unnecessary for targeted applications (*e.g.* family oriented), and might become deprecated if societies change enough to render emotional disclosure as natural as body language. Guideline A2 may also be discarded if satisfactory–from users' perspective–measures are integrated such as on/off manual controls.

5.3 Experimental system

The experimental system was mainly designed to clarify the questionnaire's results and to reveal design factors. As a consequence, it was only evaluated in a first encounter scenario during short sessions. The user study deepened the understanding of issues related to autonomy, and emotional displays. Besides it confirmed that design choices were appropriate, and that the service was useful to wearers. Finally, I propose two guidelines.

5.3.1 Potential and limitations of the evaluation

The user study complemented the social investigations based on interviews and questionnaires. Because it required the creation of prototypes, and on-site presence of participants, it could only be carried out with a small sample of potential wearers. This had an impact on the number of factors that could be controlled and analyzed. As a consequence, the study was limited to issues that concerned the validity of the hypothesis.

The main goal of the experiments was to clarify the rejection of support for first encounters, control by artificial agents, and emotional displays. Therefore the system was designed to meet new people, limited users' control over the output, and included a display reflecting the wearer's calmness and excitement. The system was designed to show photos mirroring common interests of the wearer and of her interlocutors. Because participants had to annotate the photos, and were likely to show them quite quickly, the experiments had to be short: longer experiments would have required too much investment from participants. This rendered testers' interactions simple, but was still sufficient to make the system appreciated. Besides, due to the duration of the experiments, the system had to be very intuitive. To do so, I automated functions as much as possible, left limited control to wearers, and reflected emotional states through a simple dynamic color patch. According to oral feedback from wearers, this system already looked overall interesting and powerful.

Therefore the main limitation of the user study did not lie in the prototype or service developed, but in the quantity and diversity of participants. Although the trends are clear enough to explain previous results and improve the system, the number was insufficient to enable cross-cultural and gender comparisons. In addition, it limited the number of social settings simulated, and therefore prevented the study of the impact of social distance, which appears quite important for face-to-face interactions (illustrations 4.17 and 5.4). As a consequence, the results should be checked with a larger and more diverse sample of the French and Japanese population.

In order to clarify the results of the questionnaires, I developed a system that focused on first encounters. The design was as simple as possible, exploited automatic functions and emotional displays. This allowed the study of feelings regarding A.I., emotional disclosure, and the validation of the interest of the service. However the size and nature of the sample prevented gender and cultural comparisons.

5.3.2 Design and guidelines

The study of physiological, safety and belonging needs led to the proposal of six guidelines. The system's design mainly focused on those related to artificial intelligence and emotional displays. The other guidelines were dismissed due to the goal and duration of the experiments. Overall, the system was improved in an iterative user-centered fashion.

Following guideline A1, the system was designed without artificial intelligence. When asked for the three features that should be improved in priority, many testers requested improved user control, however 29% of them still asked for more intelligence (illustration 5.5). Interestingly 14% of respondents asked for both more control and more intelligence. Therefore successive designs offered more control to wearers while also increasing the system's intelligence. Initially randomly displaying photos, the service then proposed personalized displays. The first improvement was to take into account the wearer's schedule to identify context-related content. The second improvement was to compare information about the wearer and interlocutors to identify common interests and display related photos.

Although the system still selects photos, the wearer is in control: she can quickly go to the next photo or come back to previous ones. As a result, the latest version has the best feedback from testers. One additional improvement would be to allow wearers to validate a photo before displaying it, which is possible with private displays such as semi-transparent glasses. With a simple validation by users before display, it would be equivalent to recommending an “advisor” design. For the small set of photos entered in the system for the experiments, this feature was not critical but it might become so when wearables are used in everyday life, containing numerous private and professional photos.

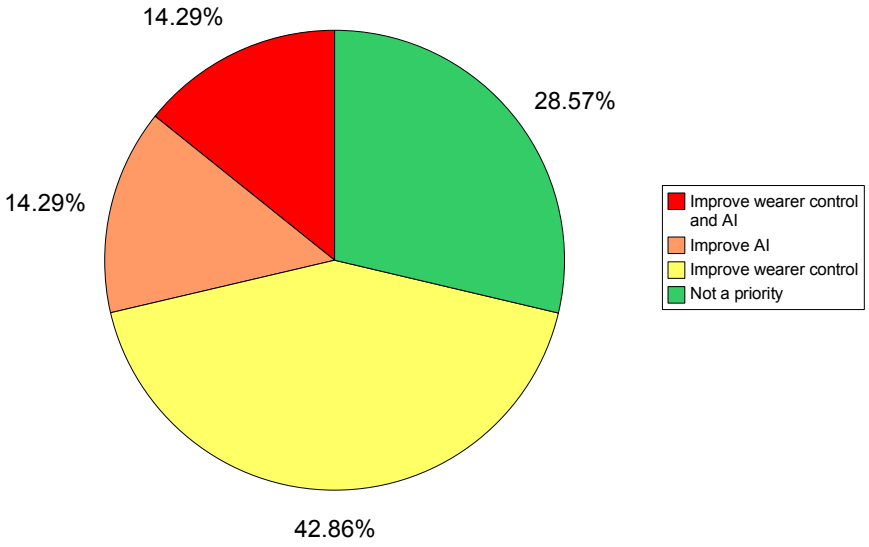

Illustration 5.5: Synthesis – Priority to improve the system's control.

Guideline A2 states that emotional disclosure based on physiological data should be avoided, especially for non-anonymous displays. This guideline was not followed so as to identify the roots of emotional displays' rejection. The prototype includes a set of three small sensors placed on three fingers of the wearer: one acquires heart data and the two other ones skin conductivity data. According to users, the presence of sensors neither bothered the wearer nor interlocutors. However if the system was used in everyday activities, they would be handicapping. The emotional information was displayed as a background color for the photo slideshow therefore it was visible but discreet. There were other ways to represent the information, for example with text or smileys. The limitations and advantages of each solution are presented in table 5.4. Considering that there is not yet any good model to precisely evaluate the emotions of a person with physiological data, the color patch was the best choice. None of the testers proposed to use text or smileys instead.

	Advantages	***Disadvantages***
Text	Clear meaning	Language dependent Fills space Requires a precise emotional model
Smiley	Clear meaning Language independent	Fills space Requires a precise emotional model
Color patch	Language independent Discreet Possible gradient Fills background Easy to map to any emotional model	Fuzzy meaning Interpretation is culture-dependent

Table 5.4.: Synthesis – Comparison of text, smileys and color patches for emotional displays.

All users clearly rejected the full time display of their emotions. Two options were proposed (illustration 5.6): adding an on/off button, or letting users select the emotion displayed (*de facto* allowing lies). In the case of the on/off button, half of the participants were satisfied, but the other half still rejects the system. Therefore the button clears up safety concerns for 50% of participants. For the possibility to choose emotions displayed, both acceptance and rejection drop, and half of participants become indecisive. Although choosing emotions displayed solves safety concerns, it annihilates the intrinsic interest of emotional displays. As a consequence, the latest version of the prototype included a button to turn on and off the emotional display. To protect privacy, [41] suggests a button to turn "off" functionalities but I use a button that turns functions "on". The difference is that turning a function off in front of interlocutors indicates unease or distrust, which negatively influences the relationship from the beginning. However if it is "off" by default, turning it "on" would show high trust. As a consequence, the system is designed to have emotional displays "off" by default, and to return to this state after a conversation.

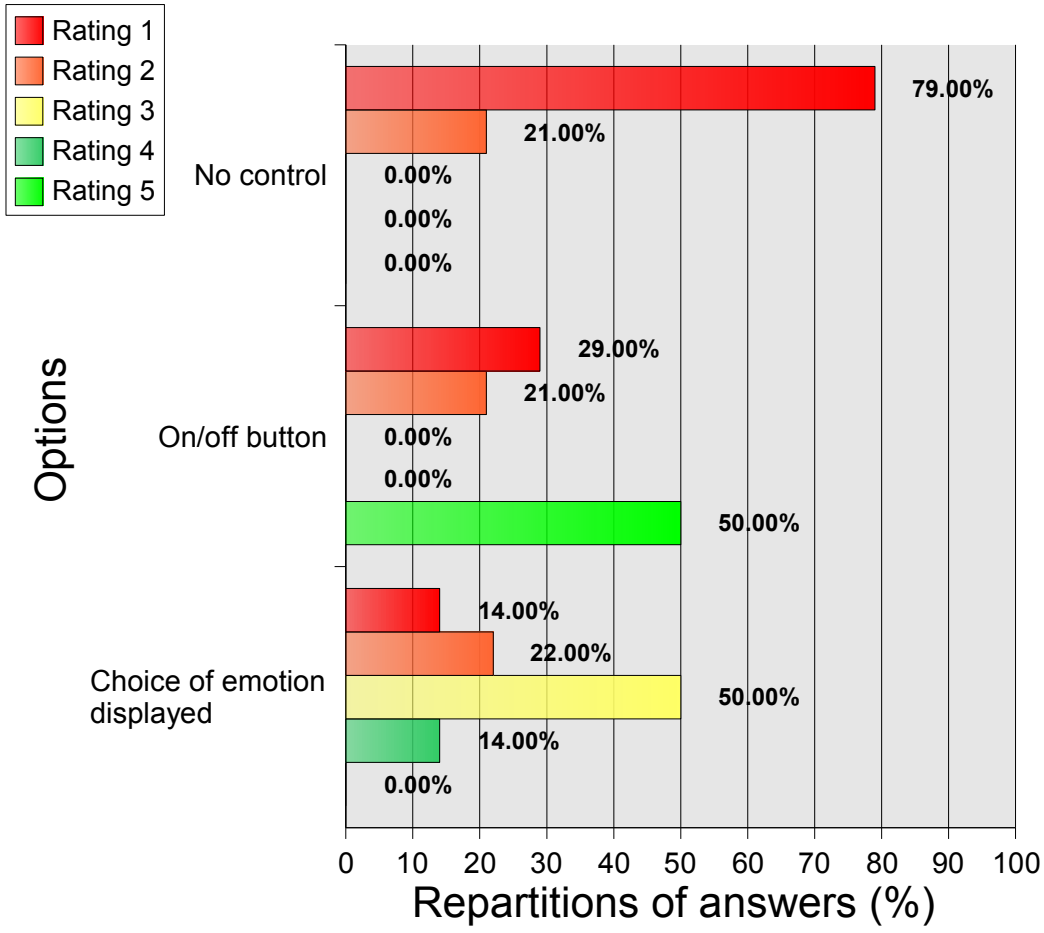

Illustration 5.6: Synthesis – Acceptance of emotional display depending on options.

Besides, guidelines A and B requested the creation of wearables that improve well-being, and communication in disrupted settings. These two guidelines were discarded to ensure that the evaluation would only deal with support for first encounters, artificial intelligence, and emotional displays. However, to avoid negative influences of a lack of well-being, the system was designed with comfort in mind. Accordingly, I followed some of Gemperle's guidelines for the design of wearables [32]. Components were placed at the rear, side, and front of the ribcage, as well as at the waist and hip levels. Attachments wrapped the body, and could be adjusted to tightly fit the wearer. Three of Gemperle's guidelines were violated : those dealing with aesthetics, weight and heat. The visible components are unattractive, the prototype is too heavy and the screens “warm” the wearer. Because of the short duration of the experiments, participants did not complain about heat. However half of them cited aesthetics or wearability as one of the three features to improve in priority. Toney's concept of social weight [83] also hints at possible improvements. For example, to improve social comfort, the screens should be replaced by flexible or woven materials. Although existing materials could solve this problem, their use is still difficult and life time limited. Such improvements will wait a few more years. Finally the guideline about gender and cultural design was unexploited due to the limited number of participants for the user-study.

As a conclusion, the guidelines and reactions of respondents led to the creation of consecutive versions of the prototype. During the iterative process, more user control and more intelligence was added to the system for the creation and control of the slideshow. Emotional displays were adapted to allow users to activate and deactivate them with a simple button, making it a more appreciated feature. Because inappropriate for our experimental setting, several guidelines were discarded. The main remaining problems of the prototype are related to aesthetics and comfort (weight, heat).

5.3.3 Usability and efficiency

Besides the problem related to aesthetics, heat and weight, the consecutive designs of the prototype highlighted related usability issues such as the audibility of sounds, and the visualization of data by the wearer herself. The latest version of the system is usable and fulfills its role properly.

The first version of the prototype included sounds in addition to the display of photos. It rapidly became obvious that the production of sounds was inappropriate: depending on the configuration, it covered voices, was inaudible or bothered bystanders. Besides, it interrupted the natural flow of interactions between wearers, as they were listening to the sounds or musics. Sound rendered the interactions less efficient. In addition to sound issues, the first prototype had a small screen, which

was replaced by a bigger one for the next version. Taking into account a personal space of approximately three meters, a screen of 18cm in diagonal provided a display big enough for a group of interlocutors. However, the wearer has a problem that interlocutors do not have: she cannot see what is displayed on her screen without looking down. All wearers repeatedly broke eye contact with interlocutors because of that. This is therefore both inconvenient, and ineffective from a social point of view.

Participants unanimously asked for an additional private display for the wearer's convenience (illustration 4.15). This is consistent with the results of works on the *Bubblebadge*, in which wearers indicated worries about what is displayed on their badge [26]. Using semi-transparent glasses is an attractive solution because it allows private visualization without changes of gaze direction. However it raises concerns about the evaluation of wearers' activities [75]. Such glasses have been shown to distract wearers, potentially making them miss important cues arising from body language. They can render interlocutors unease, missing eye contact, and wondering if the wearer is really involved in the discussion [75]. Screens on the tip of a sleeve are equally popular. However, there is a third possibility, which was not asked to participants: using a small projector to display information on a table, wall or ceiling instead of the chest. Recent studies recommend such equipment but the general public's feelings about personal projectors are unknown.

According to quantitative and qualitative data, the service was well accepted, and participants felt it improved their ability to communicate (illustration 4.13), with ratings between 3.8 and 4.2. This is confirmed by the objective data: the number of interesting elements remembered are 25% higher. The equipment was considered as an ice-breaker: the display showing photos gave a first thing to say to the wearer, to establish contact. This is consistent with results found by [41]. However on the contrary to their device, I think that if everybody wore the prototype it would not nullify its interest. The reason is that here people do not watch a succession of logos: they benefit from highly-personalized content. Besides photos change, maintaining the interest of interlocutors.

As a conclusion, the initial use of sound devices appeared inappropriate because it interrupted the natural flow of the conversation. The current prototype can be improved with the inclusion of a private display. However, it is already intuitive and efficient enough to enable wearers and interlocutors to learn more about each other.

5.3.4 Guidelines D1 and D2

Based on the analysis of the experimental prototype, I propose two additional design guidelines:

D1 – Wearers should receive feedback about their wearable's activities.

D2 – Surrounding persons should receive feedback about wearables' activities when they are concerned.

Guideline D1 includes the addition of private feedback to monitor displayed photos. Existing mobile devices illustrate well guideline D2: video camcorders turn a light on when they film and cellphones make noise when used to take a photo.

5.4 Review of cyberclothes definition

Cyberclothes were introduced as garments that satisfy fundamental needs. The investigations on physiological, safety and belonging needs confirmed the interest of this concept. Going back to this original definition, I discuss the choice of the form-factor then review the six underlying features that were proposed: promote (1) well-being, (2) awareness and (3) sociability, possess special features for use as (4) social markers or (5) tools, and (6) possess some autonomy. Finally I conclude on their appropriateness.

As stated earlier cyberclothes are first of all garments. During the investigations this form-factor was always highlighted, and the French and Japanese accepted it for services related to fundamental needs. Although a few other form-factors would also be accepted, they would not allow as many services. Physiological monitoring could be done with small wearables such as watches. However providing heat or cold depending on the weather and season is only possible when covering the body. Because exoskeletons are socially unacceptable for everyday life, garments provide a unique powerful and acceptable solution. However this form-factor induces four specific problems: embedding of components in textiles, washability[32], transfer of data between clothes when changing of attire, and simultaneous integration of gender/cultural technological preferences (guideline C) in addition to usual issues of garments design. The two first ones are being actively researched. On the contrary with the two latter ones we enter into virgin territories.

From a humanistic perspective, cyberclothes promote well-being, awareness, and sociability. Well-being, is in line with the satisfaction of physiological and safety needs. This feature appears the most promising considering the general public's requests for garments that monitor physical condition or the air, provide an appropriate temperature, and adapt the environment, especially in case of danger. It is a double-sided feature: it includes both providing elements that improve well-being, and avoiding elements that reduce well-being. Therefore, cyberclothes should be at least as comfortable as normal garments, look socially acceptable, and avoid features that make wearers anxious, such as full control by artificial agents or emotional displays that cannot be deactivated. This is reflected by guidelines A, A1 and A2.

Second, cyberclothes promote awareness. To satisfy physiological and safety needs, they should provide awareness about the wearer herself (self-awareness) and about the environment. Although it is possible to provide assistance based on introspection, this limits services to manual actions. Lack

32 Chemical washing and removal of water-sensitive components before cleaning are two solutions.

of awareness from cyberclothes would deny life-saving applications, such as the the detection of noxious–but odorless colorless–fumes, or access to emergency services when unconscious. It would also deny group services, such as the adaptation of an environment to the diverse needs of a group sharing the same space. Similarly, cyberclothes can satisfy belonging needs more efficiently if they gather information about other people to suggest behaviors (*e.g.* cultural cues) or to provide information (*e.g.* similar hobbies) that strengthen emotional bonds. One caveat concerns sensors used to acquire information and subsequent storage. If sensors are based on cameras or microphones, it might be sensible to let recorded people know they are being recorded, and ask their authorization. Besides, privacy and legal implications varying from country to country (or smaller geopolitical entities) must be taken into account. Although awareness does not appear in guidelines, it is an underlying requirement for the efficient satisfaction of fundamental needs and should be considered carefully.

Third, cyberclothes promote sociability. Support for disrupted settings is very attractive; other applications also appear interesting and useful after a try. It is unclear whether cyberclothes would be used for group services like community mirrors or not; other devices might be more appropriate. Finally, some technologies supporting sociability should be avoided or studied in depth before integration in cyberclothes. The rejection of emotional displays is a good example, but there may be other exceptions to uncover. These results are reflected by the guidelines A2 and B.

From a technical perspective, cyberclothes possess special features for use as social markers or tools. Because they are garments, cyberclothes ensure at least basic social marking: their style, colors and combinations provide information about their wearer's personality and belonging to communities. However they can go farther, transferring such information by electronic means or dynamically changing their sensory properties. The experiments demonstrated that support for first encounters can induce the acceptance of graphics display on garments. Such a feature allows adaptation to a wearer's environment, context or mood, making social marking dynamic and more multi-faceted. Other senses appear more difficult to exploit, and scents production is even rejected by the Japanese. Social conventions and requirements for groups and places explain the rejection of garments that produce sounds and smells. The investigations did not focus on social markers so there is only limited information about it. For example neither the questionnaire nor the experiments did investigate the acceptance and impact of shape-changing capabilities for social marking. It is unclear whether special features for use as social markers are a necessity, however there is a potential to exploit, at least for the visual aspect.

On the contrary to social marking, the use of cyberclothes as tools has been investigated, albeit

indirectly. Because investigations covered fundamental needs and not unmotivated behaviors, the services require tools. The case of physiological monitoring was *a priori* contentious. However the general public accepts it independently of the nature of the service, except for emotional displays. The widespread acceptance of physiological monitoring will allow better evaluations of wearers' physical and mental states, enabling the system to complement behaviors and support activities. People are indecisive for the use of most sensory sensors and effectors, except for graphics display (accepted), graphics and sound recording (accepted by the Japanese), scents production (rejected by the Japanese) and vibrating devices (rejected by females). Because cyberclothes are very looked after for communication during trips or with disabled persons, tools allowing channel translation might end up well accepted. In any case, the capacity to communicate (guidelines D, D1, D2) with the environment, other cyberclothes or directly with humans enables the maximum exploitation of cyberclothes' potential. To exchange or store data, XML appears appropriate, and provides an easy-to-analyze standard format. As for autonomy, wearers want to keep control over their tools.

Finally, although a high autonomy of cyberclothes would be powerful, artificial intelligence should be used parsimoniously (guideline A1). The main reason lies in the actual reaction of the general public to the presence of artificial agents in their garments. However, automatic behaviors and artificial intelligence can relieve wearers from the burden of complex or repetitive tasks. One middle way is to integrate an agent that proposes advice, and waits for the wearer to validate or discard it before taking appropriate actions. In any case, the integration and design of artificial agents should be based on gender and cultural premises.

As a conclusion, the definition of cyberclothes accurately reflects the needs and wishes of the general public, and its categorization with six features complements well the proposed guidelines.

5.5 Summary and conclusion

This section discussed the importance and influence of fundamental needs for the design of wearable computers. It confirmed that wearables satisfying physiological, safety and belonging needs are seen in a positive light, even when cultural and gender factors intervene. Technically, it concluded that physiological sensors should be embedded, and that A.I. should be limited to avoid thwarting wearers safety needs, for example using an advisor or coach model. However emotional displays should be avoided. A prototype was developed in an iterative fashion, and showed appreciation of support for first encounters as well as efficiency. JAVA and XML were good substrates for the prototype and their use is recommended for subsequent developments. Overall the results confirm the appropriateness of the definition of cyberclothes, and its usefulness.

本章ではウェアラブル・コンピュータの設計における基本欲求の理論の重要性および影響について論じた。その中で、利用者の文化や性別が様々であっても、彼らの生理的・安全・親和欲求を満足させるウェアラブル・コンピュータが受け入れられる事が確かめられた。技術的には、生理センサーを実装し、一方で人工知能は、例えばアドバイザーモデルやコーチモデルを利用する事で着用者の安全欲求を阻害しない程度にとどめておくべきである事が結論づけられた。ただ、感情表示の機能は、避けるべきである。プロトタイプは、効率的でありながら出会いを支援する機能を持つように改良を重ねながら作成した。JAVA および XML はプロトタイプを開発するのに良い枠組となったし、今後の開発にもそれらの枠組を使っていくべきであろう。総括すると本研究は、サイバークローズの定義について、その妥当性と有用性を証明する事となった。

Chapter 6. Conclusions

Taking roots in psychology with Maslow's research, I investigated the importance and influence of human needs in wearable computing. Focusing on physiological, safety and belonging needs, I identified and discussed characteristics that are critical for the creation of wearables dedicated to uses in everyday life by the general public. Informal interviews, self-completion questionnaires, and experiments with an enhanced jacket demonstrated that Maslow's hierarchy of needs is relevant in wearable computing and that garments supporting the three first levels of needs can be designed for and accepted by the French and Japanese general publics. To guide further research and the creation of practical devices, I proposed the concept of cyberclothes then provided eight related design guidelines. To complete this work, the community should extend studies on fundamental needs, create and evaluate various cyberclothes, and consider implications beyond this field.

我々は、マズローの心理学研究の基本概念を採り入れる事で、ウェアラブル・コンピューティングの分野における人間欲求の重要性、およびその影響について研究した。生理的欲求、安全欲求、親和欲求に焦点を当て、人々が日常生活で利用するウェアラブル・コンピュータを作り上げるのに欠かせない性質を見いだし、それについて議論した。略式的な面接、アンケート、高機能版ジャケットを使った実験によって、二つの事が明らかになった。すなわち（１）マズローの欲求段階がウェアラブル・コンピューティングにおいて重要な意味を持つ事、そして（２）最初の三つの欲求を支援する機器を、日本とフランスの一般の人々により受け入れられる様に設計可能であるという事である。今後の研究と実用機器の開発の方向性を示す為、我々はサイバークローズの概念を提案し、八つの設計指針を述べた。研究者はこの分野を完成させる為に、基本欲求についてより深く研究し、様々なサイバークローズの試作、評価を行い、他分野の動向にも注意を払っていくべきである。

6.1 Achievements of the study

This study casts some light on a new issue: humanistic factors in wearable computing. The social investigations and user-studies demonstrated the influence of fundamental human needs in wearable computing; they validated the possibility to simultaneously improve the quality of life of the general public and foster the adoption of wearables. Accordingly, the concept of *cyberclothes* was introduced, developed and enriched. Finally, these complementary steps led to the definition of eight design guidelines.

6.1.1 Validation of the hypothesis

The work hypothesis was that focusing on human fundamental needs in wearable computing can simultaneously improve the quality of life of the general public and foster the adoption of wearables.

The social investigation based on self-completion questionnaires showed that wearables are considered useful and acceptable when they gratify physiological and safety needs. To demonstrate the same point for belonging needs, it was necessary to complement the social investigations with experiments. The results were conclusive, demonstrating that actual prototypes can raise the general public's awareness of its needs and of ways to satisfy them. The analysis of reactions to emotional displays stressed the prepotency of safety needs over belonging needs, further confirming Maslow's theory, and providing elements of reflexion about potential inconsistencies–from a humanistic perspective–in the design of wearables.

Although participants' representativity was limited, the convergence of results for interviews, questionnaires, and experiments is a strong point for the reliability of the study. Besides the samples were much more heterogeneous than the usual samples of college students, permitting some generalization of the results. Besides, the hypothesis was tested in two populations reflecting very different cultures. The gathered results are therefore good hints of the universality of the importance of physiological, safety and belonging needs in wearable computing.

One limitation of this research is its focus on the 3 first types of needs from Maslow's hierarchy at the expense of the fourth (*esteem*) and fifth (*self-actualization*) ones. However it was appropriate due to inherent resource limitations and to the hypothesis' focus on the improvement of quality of life.

6.1.2 Creation of a new concept

To complement the usual technological perspective in wearable computing, the humanistic concept of *cyberclothes* was proposed and described. This concept focuses on the promotion of human growth and well-being. Although a few practical issues need to be dealt with, the favored *garments* form-factor can already be exploited by existing technologies. Based on psychology and targeting everyday applications, *cyberclothes* provide a useful guide for the field of wearable computing and open new horizons for ubiquitous computing.

Taking their roots in Maslow's theory of motivation, cyberclothes focus on the promotion of human growth and well-being. Their main features are that they improve well-being, awareness and sociability, have special features for use as social markers and tools, and possess some autonomy. They can target the wearer, surrounding or distant people, and may even cooperate with each other or with intelligent environments. The concept has been extended and refined during the whole process of investigations. It first reflected a lack in wearable computing, was then more faithful to its psychological roots, and was finally completed by technical elements. The combination of interviews, questionnaires and experiments proved that the concept was meaningful for the general public.

From a social and technical points of view, clothes appear as the best form-factor to achieve the roles enunciated above. Cyberclothes extend garments' traditional functions, ensuring comfort and safety, providing containers, revealing belonging to specific groups, and allowing self-expression. Because clothes are familiar objects, enhanced versions should be more easily adopted than new devices providing similar advantages. Finally this form-factor has a great potential for the inclusion of technology: there is a large surface to embed sensors and effectors, and body contact allows the continuous acquisition of physiological data.

Although time is needed before uses in everyday life by the general public, technologies are already available to create cyberclothes based on electronics and smart materials. Remaining issues concern battery life, washing, integration of components in more discreet ways with more flexible, energetically dedicated and environmental friendly components.

As a result, cyberclothes are appropriate for the general public, doable, and widely extend the scope of wearable computing. This can influence related fields such as ubiquitous computing and robotics in two ways. First, it can motivate the exploitation of the humanistic approach in these fields. Second, it can be directly used for symbioses between cyberclothes, intelligent environments and robots.

6.1.3 Insights about the proper design of wearables

The successive steps of the study led to the definition of eight design guidelines focusing on psycho-social and technological aspects. They mainly target cyberclothes but can also be applied to various wearable computers.

A – Wearables should improve the body condition, comfort and safety of their wearer, and possibly of surrounding or distant people.

A1 – Full control by artificial agents should be avoided.

A2 – Emotional disclosure based on physiological data should be avoided, especially for non-anonymous public displays.

B – Support for communication should focus on disrupted settings (*e.g.* with disabled persons, or on trips) rather than on standard situations.

C – Design should be gender and culture oriented.

D – Communication with other entities, and suggestion of behaviors based on knowledge about wearers should be possible.

D1 – Wearers should receive feedback about their wearable's activities.

D2 – Surrounding persons should receive feedback about wearables' activities when they are concerned.

The investigations showed that French and Japanese people show similar interests and worries, which points to a certain universality of the above-mentioned guidelines. Although several of them appear “obvious” or “common sense”, they are not applied to most existing devices. Guideline A appears for military, medical and sportive wearables. Guideline A1 is mostly respected due to the weakness of current A.I. systems however some systems lack controls for specific functions, and the risk to provide fully automated systems increases with technological improvements. Guideline A2 is usually ignored, as indicated by the extensive research in affective computing. Guideline B is rarely taken into account, mainly for specific services. Guideline C is–barely–visible in commercial products but more efforts should be done in the frame of research, prototypes and demonstrations. Guideline D is already applied to a few devices communicating with intelligent environments and smart artifacts. On the contrary guidelines D1 and D2 have not been much exploited, and proper ways to implement them need to be discovered.

6.2 Future works

The work presented previously is an important step for wearable computing. However it must be continued and applied to show all its potential. Initially, three tasks appear relevant and promising. The first is to extend studies on fundamental needs in the field. The second is to create and evaluate various cyberclothes, usable in real settings. The third is to consider implications beyond wearable computing, for example in intelligent environments and robotics.

6.2.1 Extension of studies on fundamental needs

Due to the limited resources available for the investigations, the samples from the general public for the questionnaires had a limited representativity; an additional study with random people, and a bigger sample would therefore be appreciable. In the same way, experiments with a larger group of testers would provide more data, notably allowing a gender comparison. Besides, extending the investigations to *esteem* needs would allow the creation of more useful and more appropriate devices for both personal and professional uses.

To validate further the questionnaires' results and to obtain additional information, a similar work could be done with larger, random samples. Because the questionnaires were provided in cafés and train stations, numerous professional categories were represented. However the results were biased by an over-representation of educated people and by an under-representation of people over 40 year old. This is acceptable for an exploratory study but may not accurately reflect the whole population. In the same way, the experiments allowed a clarification of several results but data on females is lacking; reactions and motivations may differ accordingly for this group of the general public. However, this the situation regarding experiments can easily be corrected when testing new versions of services and cyberclothes.

From a theoretical perspective, the definition of cyberclothes lacks some elements because it does not take into account *esteem* and *self-actualization* needs. Trying to cover the five fundamental needs in this study would have been unrealistic. The choice done is appropriate because *physiological*, *safety* and *belonging* needs must be satisfied in priority, and because they are the most related to quality of life. However it leaves for the future investigations of higher levels. Knowledge related to *esteem* needs could be beneficial, for example in the case of professional services. Being linked to realizations and self-confidence, these needs can be studied with services that support work, keep track of leisure information (*e.g.* stamp collections) or help organize daily activities (like a coach).

6.2.2 Creation and evaluation of cyberclothes

During the study, only one prototype was developed; it targeted social services and could only be used in a laboratory setting. Considering the results of the interviews, questionnaires and experiments, the most promising cyberclothes would target comfort and well-being. Cyberclothes for such services should therefore be developed as soon as possible. Besides, the prototype supporting face-to-face communication should be improved and tested in a real world setting, with groups of users. Testing these devices would deepen our understanding and help test the validity of the guidelines.

The enhanced jacket created for the experiments is based on a normal garment on which two screens have been attached, partially controlled by a multi-button device and by physiological sensors. Cumbersome, without flexible components, aesthetics, and presence of sensors on the hands render it unusable for everyday life; it was only appropriate to test the service during short sessions. It is now necessary to develop a new model solving most of these problems. A dedicated computer and a screen based on OLEDs or fiber optics are first improvements to try. Technologies being researched in other institutes or companies would prove very useful.

Wearables dedicated to health have already been created. Combining and embedding some of them would allow us to create garments improving comfort and well-being. These cyberclothes would be perfect to test the value and priority of the proposed design guidelines. Interestingly, although related to public health and daily life, wearables dedicated to environmental (ecological) issues have not been developed yet. The development of such wearables might be difficult but very influential as exemplified by Kaur:

> "This [visualization of exposure to pollutants] can potentially lead individuals to make incremental changes in lifestyle and daily choices [...]"
>
> Kaur, 2006 [42].

Finally, the guidelines have not been checked during this work, and they should be checked one by one to establish their influence. Work with companies that already designed commercial wearables could be very instructive for all stakeholders. As for gender and culture oriented-design, it does not need to be tested *per se* but local solutions must be identified for final products, maybe exploiting expertise from other fields.

In any case, evaluations cannot be considered from the sole perspective of fundamental needs: issues related to non-uptake and non-use of new technologies [74] as well as positive correlations between experience with computers and attitude towards them [24] must be taken into account.

6.2.3 Issues raised and implications beyond the field

Beyond the extension of research on humanistic aspects and beyond the development of cyberclothes, this study has implications for fields related to smart technologies for everyday life such as intelligent environments and robotics. Would the design guidelines apply after a few adaptations? Would artificial intelligence and emotional displays become big issues? And in the other way, what could these fields offer to cyberclothes?

Intelligent environments are environments (houses, offices, public spaces, or everyday objects such as cups [31], chairs [93] or cars) that automatically adapt to people to improve the quality of life in everyday settings. Because fundamental needs are universal, they should be at the core of the development of–most–intelligent environments[33]. We can imagine public places that monitor air quality, contact emergency services after incidents, adapt temperature, light, scents and music, to apparent moods and activities of the public. As shown with these examples, fundamental needs can be an important element for the design of any environment.

Whether focusing on fundamental needs or not, intelligent environments share common points with wearables. Ideally they are accessible and usable anywhere. They adapt their behavior depending on users and contexts, using sensors and knowledge databases. They process information and react using actuators or digital connections. Besides, they are both difficult to design due to the vast choices of sensors, actuators, control, interfaces and services. However, these similarities have their limits. Wearables are personal, move with their wearer and as such provide consistent functions as well as a high level of user control. On the contrary, intelligent environments are shared, localized, provide different services, and give control to their owner or to user groups rather than to a simple individual. As side-effects one may not necessary know what the environment can do, how to control it, how groups are managed and individual requests prioritized, *etc.* Robots can behave like a mix of wearable and intelligent environment.

As a consequence, findings about cyberclothes can be useful for adjacent fields but the weight of issues might be different (*e.g.* for artificial intelligence). Solutions might be mutually beneficial or complementary if cyberclothes, intelligent environments and robots can operate in symbiosis.

33 Fundamental needs need not be the focus of all intelligent environments. Artistic and expressive environments could let people express themselves instead of helping them cope with their activities and problems.

6.3 Final word

Satisfying fundamental needs in everyday life with wearable computers is possible in the limits of technology. The work presented here does not pretend to solve all human problems but aims at providing tools that significantly improve everyday life. Although enthusiastic about the potential benefits of the technologies at hand, I am conscious that designers will have a hard time finding solutions that are satisfactory on short, medium and long terms, from the perspective of both individuals and societies. As several participants rightly pointed out during investigations on belonging needs, devices can serve us well but can also render us dependent. I am confident that this work will rise awareness of humanistic requirements and hope it will contribute to improve our quality of life, whether by fostering the creation and adoption of cyberclothes or related technologies.

技術の範囲内で、ウェアラブル・コンピュータを使って日常生活における基本欲求を満たす事は可能である。本研究は人間の全問題を解決する為にあるのでは無く、日々の生活を有意に向上させる道具を提供する事を目的としている。この技術が近い将来に齎すであろう恩恵に興奮しているところではあるが、個々人と社会を視野に入れ、かつ短期、中期、長期的に納得出来る機器を設計する事の難しさについても考慮している。親和の欲求に関する社会調査において数人の被験者が指摘した様に、機器が様々な機能を提供する一方、利用者が依存的になるのを助長する可能性もある。我々は、この研究が人間を主体とした機器の要件に対する認識を高めるであろうと確信している。また将来実用化されるであろうサイバークローズ、或いは関連技術が生活の質の向上に貢献する事を望んでいる。

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Glossary

This section presents the main terms used in the thesis.

A.I.

Acronym standing for “Artificial Intelligence”.

Advisor

Digital entity whose role is to advise its owner, and not to act without his or her explicit consent.

B-needs

See *Being needs*.

Being needs

Needs related to the achievement of one's true nature. Initially being-needs only included *self-actualization needs*.

Belonging needs

Needs related to emotional relationships: love, affection and belongingness. Belonging needs cover relationships with the family, community, work groups and clubs. Love needs, here, exclude sexual needs because sex can be studied as a purely physiological need. Belonging needs are part of *deficit needs*.

Biosensor

See *physiological sensor*.

Community mirror

Public display reflecting the dynamics of a community. It can notably consist of bar charts reflecting “yes” or “no” opinions about a question or consist of a network graph representing relationships between community members.

Cyberclothes

Garments that promote human growth and well-being. Such clothes improve well-being, awareness and sociability; they have special features for use as social markers or tools, and possess some autonomy.

D-needs

See *Deficit needs*.

Deficit needs

Needs related to survival, physical and mental health. They include *physiological needs*, *safety needs*, *belonging needs*, and *esteem needs*.

E-garments

Stands for “electronic garments”. Used in wearable computing, its definition still needs to be agreed on. See *intelligent textiles* and *smart clothes* for related concepts.

E-textiles

Stands for “electronic textiles”. Used in wearable computing, its definition still needs to be agreed on. See *intelligent textiles* and *smart clothes* for related concepts.

ECG

Electrocardiogram. Record of the heart's activity.

EMG

Electromyogram. Record of muscles' activity.

Emotional display

Display that mirrors the emotions of one or several users. “Display” mainly refers, but is not limited to, visual displays. Tactile displays are a good example of displays adapted to specific users, such as the blind.

Esteem needs

Needs related to respect and self-esteem. Respect is an internal component linked to status, presence and reputation. Self-esteem is linked to concrete achievement, confidence, competence, independence and freedom. Negative aspects of these needs include a sense of inferiority and helplessness. Esteem needs are part of *deficit needs*.

Exoskeleton

External structure that provides protection or support to its wearer. For example the exoskeleton developed for the project HAL [73] is used to multiply its wearer's strength.

Form-factor

Aspect and shape of a device. It can be as wide as to be described like “watch” form-factor or as narrow as to describe details of the objects *e.g.* “curved to match biceps own shape”.

Fundamental needs

Needs that apply to human beings, impact motivation, and explain behaviors. Fundamental needs are composed of *deficit needs* and *being needs*.

GPS

Acronym standing for “Global Positioning System”. This system is used to know the position of objects or people. It is accurate enough to locate people in a street but usually not to locate an object inside a house.

Hierarchy of needs

Set of ordered needs defined by Abraham *Maslow*. It considers as the most important *physiological needs*, followed (in the order) by safety, belonging, esteem, and self-actualization needs.

Homeostasis

Tendency of an organisms to maintain its internal equilibrium through physiological processes.

HTML

Acronym standing for “Hyper Text Markup Language”. This language is a standard created to

write web pages and ensure they would be properly displayed by all web browsers.

Human growth

Inner development, liberation from hindrances and achievement of one's potential.

Intelligent environment

Environment that can react to events happening into it. Such environments cover *e.g.* intelligent houses, offices and cars. An intelligent house could for example automatically adapt temperature, light and music to people present in a room according to their needs and preferences.

Intelligent textiles

Textiles whose properties enables them to “naturally” adapt to different conditions. Examples include textiles whose heating properties change due to temperature and that can therefore warm much wearers in winter but less in spring or summer.

JAVA

Object oriented programming language developed by Sun.

Likert scale

Scale based on qualitative values. It usually comprises 5 to 7 values such as “I strongly agree”, “I agree”, “I neither agree nor disagree”, “I disagree”, or “I strongly disagree”.

Maslow, Abraham

American psychologist (1908-1970) who mainly worked on exceptionally healthy people and on human growth. He is mainly known for his *hierarchy of needs*. His work was continued after his death by psychologist from the humanistic movement.

Multi-modal interface

Interface involving several human senses.

OLED

Acronym standing for “Organic Electro-Luminescent Display”. Such flexible displays are being developed; their main disadvantage is currently their short life span.

OWL

Acronym standing for "Web Ontology Language". Used to share common concepts between users and/or applications; for example the vocabulary describing the hobbies of people using a matchmaking service.

PDA

Acronym standing for "Personal Digital Assistant".

Pervasive computing

See *ubiquitous computing*.

Physiological needs

Needs related to the balance of bodily conditions. They target homeostasis, and regulate our internal environment to maintain a stable state, within tolerable limits, of–notably–the temperature and content of our blood. Basically homeostasis is sustained by consumption of air, food and drinks, by good sleep, by an appropriate temperature*, etc.* Effects of unfulfilled physiological needs include pain, illness, discomfort and death. Physiological needs are part of *deficit needs*.

Physiological sensor

Device that acquires information about a person's physiology (*e.g.* body temperature, blood pressure, skin conductivity).

RDF

Acronym standing for "Resource Description Framework". Used to describe the meaning associated to a resource, for example the topic of a web page.

Safety needs

Needs related to physical and psychological security: health, comfort, freedom, peace of mind, stability, and consistency. Physical assaults, divorces, experiences with sickness, death, wars, and natural disasters increase safety needs. Even simple unfamiliar situations can lead to it; for example, a child can become terrified just because she got lost. Safety needs are part of *deficit needs*.

Salient need

Need that is currently the most important for an organism. According to the *hierarchy of needs*, once a type of need is satisfied, the next one becomes salient. For example, when safety needs are satisfied then belonging needs become salient.

Self-actualization needs

Needs that reflect a necessity to fulfill one's potential. Their nature varies greatly from one person to another: becoming a great mother, a great athlete or artist... Self-actualization needs are part of *being needs*.

Semantic Web

Vision of the Web were all information would be associated to data providing meaning about the information. This meaningful bits would be processed by the computers rather than humans. It could for example help identify if a story found on a web page is a news article or a piece of theater play.

Semi-transparent glasses

Glasses on which graphics (text, photos, *etc.*) can be displayed while the wearer still sees her surroundings.

Sleep apnea

Sleep apnea syndrome is an health problem that usually causes shallow sleep: one stops breathing for tens of seconds up to minutes during her sleep, wakes up and falls asleep again and again. Sleep apnea can lead to losses of consciousness during attention requiring periods, which can be perilous, for example when driving.

Smart clothes

Used in wearable computing, this concept has not been clearly defined. It mainly stresses technical aspects, with electronic components embedded in clothes.

Smart material

Material whose properties change depending on its environment. For example, textiles retaining warmth in winter but not in summer.

T-distribution

Statistical test providing some confidence about the existence of a difference between two populations, for a given parameter, based on a small sample of that population.

T-test

Statistical test providing some confidence about a parameter's mean value within a population, based on a small sample of that population.

Ubiquitous computing

Field of computer science that deals with computers available everywhere at any moment. The difference with “pervasive computing” is not clear. Ubiquitous computing is related to *wearable computers* as well as to *intelligent environments*.

Unmotivated behavior

Behavior that is not provoked by an organism's need. Such a behavior emerges from expression rather than coping. For example, the way one person walks (her gait) reflects her morphology and habits, not a particular need to walk that specific way.

Wearable computers

Small computers worn on a user's body, continuously available. Definitions vary, sometimes including simple cell-phones. Wearables can notably be embedded in garments or accessories.

Wearables

See *wearable computers*.

XML

Acronym standing for “eXtensible Markup Language”. Language used to store and organize

data in a standard human and machine readable form.

Appendix A: Questionnaires for the social investigation

Question 1	**It would be acceptable for me to wear clothes that:**
Q1.1	display images, photos, texts, or videos.
Q1.2	record my environment via photos or videos.
Q1.3	produce music, sounds, or speech.
Q1.4	record music, sounds, or speech around me.
Q1.5	produce selected smells.
Q1.6	analyze the air (smells, pollution, humidity, temperature).
Q1.7	provide a sensation of cold or heat in certain areas.
Q1.8	vibrate or provide a feeling of touch in certain areas.

Question 2	**Clothes with one or several capacities such as listed in question 1 would be useful:**
Q2.1	at big events like conferences or forums.
Q2.2	during parties.
Q2.3	on trips.
Q2.4	in potentially dangerous situations.
Q2.5	to communicate with disabled people.
Q2.6	when meeting new people.

Question 3	**If I had garments with one or several capacities such as in question 1, I would like them to:**
Q3.1	be able to coordinate actions with other clothes.
Q3.2	learn from my reactions to their actions.
Q3.3	be controlled by some form of build in artificial intelligence.
Q3.4	be controlled by guidelines but get back control whenever I want.
Q3.5	be under my full control at any moment.

Question 4	**I would agree to use garments that monitor my physical and mental state (heart beats, blood pressure, body temperature, movements, etc.) to:**
Q4.1	adapt my environment to my needs (temperature, light, music in the room, etc.).
Q4.2	adapt video games depending on my experiences.
Q4.3	evaluate my performances during sports trainings.
Q4.4	produce group effects during artistic or sportive events.
Q4.5	reveal my emotions to surrounding people.
Q4.6	share my feelings with selected persons (like husband/wife), even at a distance.
Q4.7	transmit information to emergency services.

Question 5	**During a gathering of people using special garments, I would like clothes to hint about:**
Q5.1	the wearer's personality.
Q5.2	the wearer's beliefs.
Q5.3	the wearer's mood.
Q5.4	the wearer's history.
Q5.5	the wearer's belonging to communities.
Q5.6	the group's harmony.
Q5.7	the group's common history.
Q5.8	the group's common centers of interest.
Q5.9	relationships between members of the group.
Q5.10	the topic of the gathering.

Question 6	**I would be ready to wear and use in my everyday life garments incorporating electronics:**
Q6.1	for personal uses.
Q6.2	for professional uses.

Question 7	**I would leave my profile (such as name, age, nationality, centers of interest) in free access:**
Q7.1	on Internet.
Q7.2	to people in the same room as me.
Q7.3	to people belonging to my community.
Q7.4	to people I met previously.

Question 8	**If you have any remarks or suggestion about the questionnaire or electronic garments, please write them below:**
Q8.0	

Appendix B: Raw data from social investigations

Age	Gender	Nationality	Occupation	Field	Q1.1	Q1.2	Q1.3	Q1.4	Q1.5	Q1.6	Q1.7	Q1.8	Q2.1	Q2.2	Q2.3	Q2.4	Q2.5	Q2.6	Q3.1	Q3.2	Q3.3	Q3.4	Q3.5
31	M	Algeria	Student	Informatics	1	1	3	3	4	4	5	3	5	5	3	5	5	3	3	3	5	3	5
24	F	Canada	Student	Multimedia	5	1	1	1	1	1	2	2	4	4	1	3	2	1	5	5	3	4	5
14	M	Finland	Student	-	1	2	1	3	2	1	3	1	1	3	1	1	1	2	1	2	1	1	5
25	M	France	Student	-	5	5	4	5	5	5	4	4	5	5	5	4	5	5	4	5	2	4	2
15	F	France	Student	-	2	4	2	4	3	4	4	2	2	3	5	5	2	4	4	4	5	4	5
15	F	France	Student	-	2	2	4	3	4	5	5	4	2	4	5	4	3	3	3	4	4	3	4
14	F	France	Student	-	4	2	4	5	2	3	4	3	3	3	2	5	4	3	4	3	4	3	5
15	M	France	Student	-	4	3	5	4	5	5	5	5	4	5	5	4	3	4	4	4	5	4	5
15	M	France	Student	-	5	5	5	5	5	4	5	5	5	4	3	5	2	3	5	3	5	4	3
15	F	France	Student	-	1	2	1	3	2	1	3	1	1	3	2	1	1	2	1	2	1	1	5
14	M	France	Student	Informatics	4	2	3	4	5	5	5	1	3	4	4	4	3	3	4	4	4	5	3
14	M	France	Student	-	3	4	3	4	2	5	5	4	2	4	5	5	4	2	3	4	2	5	4
15	M	France	Student	-	5	3	2	4	3	3	5	5	5	5	3	5	5	3	5	5	1	1	5
14	M	France	Student	-	4	5	5	5	5	5	5	5	4	4	5	3	3	3	5	5	5	4	3
15	M	France	Student	-	5	4	3	4	1	3	3	2	3	3	5	3	2	3	2	3	4	4	4
15	F	France	Student	-	1	3	1	3	4	3	3	1	3	1	2	4	2	2	1	2	1	3	5
15	F	France	Student	-	2	4	1	4	3	1	4	3	1	1	4	2	1	3	2	3	1	1	1
15	F	France	Student	-	3	4	5	5	4	2	5	3	3	1	4	3	5	1	1	2	1	4	5
14	M	France	Student	-	5	4	3	2	4	1	5	4	4	3	4	3	2	3	2	3	5	5	5
30	F	France	Researcher	Informatics	5	5	5	5	4	5	5	3	3	5	5	4	5	5	5	5	5	4	1
32	F	France	Researcher	Informatics	5	5	5	5	3	5	5	4	3	4	4	5	5	4	5	5	4	5	4
21	M	France	Student	Informatics	4	5	5	5	5	5	5	5	3	3	4	5	3	1	3	2	1	4	4
29	M	France	Engineer	Informatics	3	3	3	3	3	4	4	3	3	3	3	5	4	3	4	2	3	4	4
19	M	France	Student	Informatics	5	4	4	5	3	4	5	3	4	3	4	5	5	3	3	5	4	4	5
20	M	France	Student	Informatics	5	5	1	5	5	1	2	3	5	2	4	5	1	3	3	4	2	5	2
21	F	France	Student	Informatics	4	2	2	2	3	2	4	2	2	4	4	3	4	2	1	2	1	2	3
23	M	France	Student	Informatics	3	3	3	4	3	5	5	3	3	4	2	5	4	2	4	3	2	4	4
22	M	France	Student	Informatics	3	3	3	3	3	5	5	3	4	3	4	5	3	3	4	3	4	2	1
23	M	France	?	?	2	1	4	3	2	4	5	1	3	3	3	4	2	1	2	4	1	4	3
21	M	France	Student	Informatics	4	3	5	3	5	3	4	2	2	4	4	3	2	4	3	4	1	2	1
21	F	France	Student	Materials	3	4	2	4	4	4	5	4	3	4	3	4	1	1	1	1	1	1	5
21	F	France	Student	Law	4	4	3	2	2	5	5	4	4	4	5	5	5	4	3	4	3	5	5
54	F	France	Housewife	Banking	5	4	4	4	5	5	4	4	4	4	4	5	5	4	5	3	5	5	5
24	F	France	Student	Informatics	3	4	3	4	4	5	5	1	4	3	4	5	5	1	4	5	1	5	5
19	M	France	Student	Informatics	4	5	4	4	3	5	5	5	1	4	5	5	3	5	5	5	4	5	5
41	M	France	Researcher	Informatics	2	2	2	2	2	3	3	4	4	4	3	4	3	2	2	2	1	2	4
24	M	France	Student	Informatics	2	5	4	5	1	5	4	3	4	4	3	4	4	3	5	4	3	5	4
22	F	France	Student	Informatics	4	2	4	2	4	4	4	3	4	4	4	4	5	4	4	4	3	4	2
23	M	France	Student	Informatics	4	4	4	4	3	4	5	2	3	4	5	5	5	3	4	3	2	4	3
20	M	France	Student	Physics	5	4	2	3	2	3	5	3	2	4	4	5	4	1	3	4	4	3	3
21	M	France	Student	Informatics	4	5	1	4	1	1	5	1	5	4	5	1	1	1	1	3	1	2	1
21	M	France	Student	Informatics	2	2	4	2	5	3	5	4	2	5	4	2	2	2	3	3	1	4	4
31	F	France	Researcher	Informatics	4	3	2	2	3	4	4	2	1	3	3	1	3	1	3	5	5	5	5
24	M	France	Student	Informatics	3	4	1	4	1	5	4	2	4	3	2	5	4	2	3	4	2	4	5
21	F	France	Student	Informatics	4	2	4	3	3	5	5	4	2	3	4	4	4	2	4	2	2	3	4
21	F	France	Student	Informatics	3	3	4	3	3	4	5	2	4	3	3	3	3	1	2	2	1	2	5
22	M	France	Student	Informatics	1	3	1	3	1	5	1	1	3	2	2	5	5	1	1	1	1	1	1
26	F	France	Manager	Social	2	4	3	4	2	4	4	1	4	2	4	2	4	1	1	1	1	5	5
27	M	France	Student	Informatics	3	2	1	2	4	5	5	5	2	2	4	5	4	2	3	4	3	4	5
25	F	France	Teacher	Social	1	1	2	1	3	4	4	3	4	1	4	5	5	1	3	4	1	5	4
18	F	France	Hairdresser	Hairdresser	5	2	1	2	1	2	3	1	4	4	4	4	4	4	3	2	1	1	2
20	F	France	Student	Social	4	2	2	2	3	2	2	2	3	4	2	2	2	2	2	2	2	2	3
23	M	France	Mechanic	Mechanic	1	2	2	2	3	3	3	3	1	1	4	3	5	1	1	2	2	5	5
26	M	France	Driver	Driving	3	4	2	1	2	4	3	3	2	4	3	4	4	2	4	2	2	4	5
46	M	France	Teacher	Driving	2	2	2	2	2	2	5	2	2	2	2	5	5	2	2	2	2	2	2
67	M	France	Retired	?	1	1	4	4	1	4	4	4	3	3	3	3	3	3	3	3	3	4	4
56	M	France	Soldier	Military	5	1	4	5	5	5	5	5	5	5	5	5	5	5	5	2	1	5	5
26	F	France	Farmer	Agriculture	1	3	4	4	4	4	4	3	4	4	4	4	4	4	4	3	2	2	4
24	M	France	Student	Informatics	3	2	3	4	3	5	3	3	4	3	4	5	5	2	5	4	3	4	3
22	M	France	Student	Informatics	5	3	2	2	4	5	5	5	3	5	3	3	3	5	5	5	4	5	2
22	M	France	Student	Biochemistry	4	4	4	4	3	4	4	3	4	3	3	4	3	2	3	3	2	3	4
31	M	France	Consultant	New technologies	3	4	3	4	2	4	3	3	4	4	4	5	4	3	4	4	3	4	2
23	M	France	Student	Informatics	5	3	2	4	5	4	5	2	5	5	5	3	2	4	4	3	2	3	4
22	F	France	Student	Mechanics	4	2	2	2	2	2	4	2	2	4	1	4	3	1	2	2	2	2	4
29	M	Germany	Student	Informatics	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
39	M	Germany	Researcher	Japanology	3	3	2	3	1	4	4	3	4	4	4	4	5	4	2	3	2	4	4
29	F	Netherlands	Engineer	Psychology	2	2	2	2	2	2	2	2	4	2	4	4	4	2	4	4	2	4	5
24	F	Philippines	Librarian	Library	4	3	2	4	3	5	4	1	4	4	4	4	4	3	3	4	4	4	4
15	M	Spain	Student	-	4	5	5	5	3	4	5	5	3	3	3	3	3	3	5	5	4	1	5
16	F	United Kingdom	Student	Economics	5	2	4	4	5	4	4	5	1	3	3	1	2	2	4	3	4	1	5
32	F	Canada	Researcher	Informatics	3	3	3	3	3	4	4	4	4	4	4	4	4	3	3	4	4	3	4
23	M	France	Student	Informatics	2	2	1	4	1	4	5	2	4	4	4	5	5	2	2	4	3	4	5
18	F	France	Student	Physics	5	4	4	3	2	5	3	1	4	4	3	4	5	2	4	5	2	5	5
23	M	France	Student	Informatics	2	3	2	2	5	4	5	3	1	4	4	5	3	2	5	5	3	4	5
26	M	France	Engineer	Finance	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	3
22	M	France	Student	Informatics	2	5	4	5	1	5	3	1	5	2	4	1	4	1	4	4	3	3	5
55	F	France	Consultant	HR	1	1	1	1	1	2	4	3	3	2	2	3	3	1	1	1	1	1	5
42	M	France	Researcher	Informatics	4	4	4	4	4	4	4	4	5	5	5	4	4	4	5	5	5	5	5
22	M	France	Student	Informatics	1	1	1	1	2	3	4	4	1	1	1	2	2	2	3	3	1	3	5
20	F	France	Student	Physics	2	1	3	2	4	4	4	3	1	3	1	2	3	2	1	1	1	2	5
22	F	France	Student	Informatics	3	2	5	5	4	5	5	4	4	4	4	5	5	3	3	5	3	5	2
36	F	Japan	Researcher	Informatics	4	4	4	4	3	4	4	3	5	4	4	5	5	4	3	3	2	2	5
54	M	France	Manager	Informatics	3	5	4	4	4	5	5	3	4	4	4	5	5	2	5	4	4	5	4
35	M	Japan	Engineer	Informatics	5	5	5	5	3	3	4	4	5	4	5	3	5	2	5	5	5	5	3

Q4.1	Q4.2	Q4.3	Q4.4	Q4.5	Q4.6	Q4.7	Q5.1	Q5.2	Q5.3	Q5.4	Q5.5	Q5.6	Q5.7	Q5.8	Q5.9	Q5.10	Q6.1	Q6.2	Q7.1	Q7.2	Q7.3	Q7.4
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41	M	Japan	Engineer	Informatics	4	2	4	2	2	3	4	2	4	3	3	4	3	4	4	4	2	2	4
28	M	Japan	Engineer	Informatics	3	5	2	5	1	5	2	4	4	5	4	2	4	4	3	3	4	4	4
33	M	Japan	Engineer	Informatics	3	4	2	4	2	5	3	4	5	3	5	5	4	4	3	4	4	5	2
25	M	Germany	Student	Engineering	5	3	5	3	3	5	5	3	4	4	5	2	2	3	2	2	1	1	5
26	F	Japan	Engineer	Informatics	3	4	3	4	5	5	5	2	5	3	5	3	2	3	4	4	3	4	3
38	M	France	Consultant	Virtual Reality	3	3	3	3	3	4	3	3	3	3	4	4	3	3	3	3	3	3	3
56	M	France	Manager	Finance	5	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	4	5	3
24	F	America	Secretary	Finance	3	2	3	2	2	3	4	3	4	4	3	4	4	2	3	5	1	5	4
29	M	France	Student	Informatics	2	3	3	4	3	4	2	2	4	2	2	5	4	2	2	3	3	4	5
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19	M	France	Student	Informatics	4	4	4	4	4	4	5	5	3	5	5	5	4	2	5	5	1	1	5
26	F	Thailand	Student	Informatics	4	4	5	5	3	4	5	4	5	5	5	4	5	4	5	5	2	3	5
24	M	Japan	Student	Informatics	3	3	4	4	2	4	5	4	4	4	5	4	2	2	2	4	4	4	4
35	M	Argentina	CTO	Clothes manufacturing	4	3	3	3	3	5	4	2	3	3	4	5	3	3	4	4	4	4	4
21	F	France	Student	Informatics	4	4	5	5	3	3	5	2	3	4	5	5	4	3	3	5	2	5	3
33	M	France	Teacher	Biochemistry	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	F	France	Student	Publishing	1	1	1	1	1	4	4	2	3	3	4	4	3	3	1	1	1	4	5
19	M	France	Student	Informatics	2	5	2	5	2	5	5	5	4	5	5	5	3	3	5	5	2	4	5
22	M	France	Student	Informatics	2	3	2	4	1	4	2	2	4	2	2	5	2	1	4	4	2	2	5
26	F	America	Student	Volcanology	1	1	1	1	1	1	4	1	2	3	5	5	2	1	3	3	2	3	4
28	F	China	Student	Management	3	4	2	4	2	4	3	2	4	5	4	5	4	1	3	3	4	3	4
22	M	France	Student	Engineering	1	4	1	3	3	4	4	3	1	3	4	5	4	1	5	4	4	5	4
27	M	France	Student	Informatics	4	3	3	3	3	5	5	5	4	3	5	5	4	4	5	5	1	5	4
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22	F	France	Student	Engineering	4	4	4	4	5	5	4	4	4	4	5	4	3	3	3	2	3	4	4
22	F	France	Student	Finance	3	1	3	1	4	2	4	1	1	5	1	3	3	1	4	1	1	4	5
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30	M	Italy	Student	Virtual Reality	4	4	4	4	3	4	3	4	4	2	5	5	4	1	3	3	3	2	5
24	M	France	Student	Informatics	3	3	4	3	2	4	5	4	3	3	4	5	5	2	4	4	2	4	5
42	M	Canada	Researcher	Informatics	3	3	3	3	2	4	3	3	2	4	3	5	4	2	2	3	3	4	4
33	M	France	Engineer	Informatics	4	2	2	2	3	5	5	2	3	3	3	4	4	4	5	4	1	4	1
32	M	France	Manager	Dance	5	5	4	5	5	3	4	4	5	4	4	3	4	2	3	3	1	3	4
31	M	France	Salesman	Electronics	4	4	4	4	3	5	5	5	3	4	4	4	4	4	4	4	3	3	3
24	M	France	Student	Informatics	5	5	3	3	2	5	3	3	4	5	5	4	3	4	2	3	2	5	5
24	F	Germany	Student	Informatics-Cultures	3	4	4	4	4	4	2	2	4	4	4	4	4	4	5	4	4	5	5
22	F	France	Student	Law	1	1	3	1	1	5	5	1	1	1	5	1	3	1	1	1	1	5	5
24	F	France	Engineer	Physics	3	4	5	4	4	1	5	1	3	1	5	5	3	1	3	1	1	5	5
24	F	France	Student	Informatics	2	1	2	2	4	3	4	3	2	4	2	4	3	2	2	4	2	4	3
22	F	France	Student	Biology	5	5	5	5	5	5	5	5	5	4	5	5	5	4	4	4	2	5	4
41	M	France	Director	Virtual Reality	4	4	2	4	4	5	5	2	4	4	2	4	5	4	4	4	4	4	1
58	F	France	Animator	Religion	3	4	3	3	4	5	5	4	4	2	4	4	5	2	4	1	1	2	5
29	M	France	Technician	Informatics	3	3	3	3	3	4	5	3	3	3	3	3	3	3	3	3	3	3	5
28	F	France	Secretary	Environment	2	3	3	3	2	4	4	4	2	2	4	4	3	2	4	4	2	2	2
36	M	France	Director	Chemistry	3	4	4	4	2	5	2	4	4	4	4	5	5	3	4	4	4	5	5
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19	M	France	Student	Informatics	4	3	4	4	2	5	5	4	2	1	3	5	5	1	4	4	2	4	1
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22	M	Romania	Student	Informatics	4	2	1	2	4	4	2	4	2	4	2	2	2	2	4	3	3	4	4
28	F	France	Student	Tourism	3	4	4	3	3	4	4	4	4	3	4	4	4	3	4	3	3	4	5
33	M	China	Student	Physics	1	1	1	2	1	5	5	1	4	4	3	4	5	3	3	3	3	3	3
32	F	Japan	Researcher	Marketing	4	3	2	2	1	2	5	1	5	5	5	5	1	4	5	1	1	1	5
20	M	France	Student	Informatics	3	1	3	2	1	5	4	4	3	3	5	5	3	1	3	5	2	2	5
21	F	France	Student	Informatics	2	5	5	5	3	5	3	3	3	3	5	5	4	5	3	3	1	2	1
22	M	France	Student	Informatics	2	1	1	2	2	4	4	2	2	1	4	4	4	3	4	3	1	1	1
23	M	France	Student	Informatics	5	5	5	5	1	3	1	1	5	5	5	5	5	2	5	2	2	3	5
23	M	France	Student	Informatics	4	4	4	3	3	3	3	3	4	4	4	4	3	4	4	4	3	5	3
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36	F	France	Consultant	Administration	3	4	4	4	3	4	3	4	4	3	4	4	5	2	5	5	2	4	1
23	M	France	Engineer	Informatics	4	4	4	4	3	4	4	3	3	4	4	4	4	3	4	2	2	2	1
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24	F	Japan	Student	Physics	2	4	2	4	2	4	5	2	3	3	4	4	2	2	4	2	2	3	4
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40	M	France	Researcher	Virtual Reality	5	5	3	5	4	5	5	3	5	2	5	2	3	4	2	4	2	4	4
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21	M	France	Student	Informatics	4	4	4	5	3	4	2	2	3	5	5	5	4	3	5	4	2	2	4
19	M	France	Student	Informatics	4	2	2	3	1	2	3	2	4	4	2	4	4	2	3	1	1	2	1
23	M	France	Student	Architecture	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	2	3	5
29	M	France	Manager	Management	3	4	4	4	4	5	4	3	5	5	4	5	4	3	5	4	3	5	4
20	M	France	Student	Informatics	3	4	4	4	4	5	3	4	4	4	3	4	5	3	3	3	3	4	5
22	F	France	Student	Marketing	3	1	2	2	3	3	5	1	3	3	3	3	3	3	4	4	2	4	5
29	M	Greece	Student	Biology	5	5	2	1	1	4	1	1	1	1	1	5	1	1	1	1	1	1	5
23	M	Spain	Student	Informatics	2	2	4	3	3	4	5	2	3	2	2	3	2	2	2	3	3	5	5
23	M	Australia	Student	Engineering	2	3	4	5	1	5	3	2	3	2	4	5	3	2	2	1	2	3	5
21	M	France	Student	Informatics	3	2	2	2	2	3	4	3	4	4	2	4	4	3	4	4	3	5	2

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22	M	Venezuela	Student	Chemistry	4	4	1	1	1	5	5	1	4	4	4	5	3	1	2	1	2	3	1
22	M	Poland	Student	Control	1	1	1	1	1	1	1	1	1	4	2	1	2	3	1	4	2	4	5
24	F	China	Assistant	Clothes manufacturing	2	3	2	4	4	3	4	3	2	3	4	2	3	2	4	3	3	4	4
22	M	France	Student	Marketing	2	2	2	2	3	4	4	2	3	3	2	3	2	1	4	3	2	4	4
26	M	Iran	Student	Robotics	4	4	2	5	2	4	4	3	4	2	4	5	4	3	3	4	4	2	4
22	F	France	Student	Management	1	2	3	2	4	4	4	3	1	2	3	3	4	1	2	4	1	1	3
22	F	France	Student	Social	3	3	3	3	4	3	3	3	3	3	2	4	3	2	3	3	1	1	1
21	M	France	Student	Informatics	2	4	2	2	2	4	3	3	5	3	1	4	5	1	3	3	2	3	1
29	M	Thailand	Student	Informatics	2	4	4	3	3	5	5	4	3	4	3	1	4	3	5	5	5	5	5
23	F	Finland	Student	Management	3	4	2	2	2	1	4	2	5	3	4	5	3	4	2	2	3	5	3
41	M	France	Manager	Banking	5	2	4	2	1	5	5	3	5	5	3	5	3	1	4	5	3	5	3
27	M	France	Manager	Banking	5	3	1	1	3	3	5	3	4	5	4	3	3	1	5	1	2	4	3
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21	M	France	Student	Informatics	5	3	4	3	5	2	5	5	2	5	4	5	3	5	5	5	3	5	5
37	F	France	Manager	Marketing	1	1	1	1	1	2	4	3	3	2	3	3	5	2	4	4	3	5	5
37	M	France	Manager	Marketing	4	4	4	4	2	4	5	1	4	4	4	5	1	1	5	5	5	5	3
37	M	France	Manager	Marketing	3	3	3	3	4	3	5	3	2	4	5	5	3	3	4	4	4	5	5
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20	M	France	Student	Informatics	5	5	3	5	4	3	5	2	5	4	4	4	5	3	4	5	2	5	4
45	M	France	Manager	Banking	2	2	2	2	3	3	3	3	2	4	2	3	4	2	4	4	3	4	3
50	F	France	Nurse	Medicine	4	4	5	4	2	5	1	1	1	3	4	4	5	1	1	2	1	4	5
24	F	France	Student	Law	5	5	5	5	5	5	5	5	5	5	5	5	5	3	5	4	4	5	5
23	M	France	Student	Informatics	3	3	4	4	5	3	4	4	3	3	3	3	3	3	3	4	4	5	3
21	F	Germany	Student	Teaching	5	4	5	5	1	5	5	4	5	5	5	5	5	3	3	3	4	5	4
32	M	France	Researcher	Informatics	2	4	3	4	1	5	3	4	4	3	5	4	5	2	4	4	4	4	5
27	M	France	Engineer	Informatics	5	2	4	3	1	4	5	3	4	2	1	4	5	3	5	4	2	3	1
30	M	Ukraine	Student	Physics	4	4	3	4	4	4	5	2	3	4	5	4	4	3	4	4	3	4	5
30	F	France	Pediatric	Health	5	2	2	4	5	5	5	5	4	5	5	3	4	5	5	4	4	3	5
28	M	Japan	Student	Informatics	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	3	3	5	2
25	M	France	Student	Informatics	2	2	2	4	3	5	3	2	1	3	3	4	4	1	4	4	5	1	4
23	F	France	Student	Documentation	3	1	1	2	1	4	5	2	5	4	2	5	5	3	2	3	3	3	5
22	M	France	Student	Informatics	3	4	5	4	2	5	4	3	2	4	5	5	4	2	1	4	1	1	5
24	F	France	Student	Documentation	4	3	3	2	2	3	4	2	2	4	4	4	4	2	4	3	2	4	4
25	F	France	Student	Documentation	3	1	2	1	3	2	4	2	2	3	2	3	4	2	1	2	1	1	5
27	M	France	Reporter	Nature	2	4	2	4	1	2	4	3	3	3	3	3	4	3	4	4	4	4	3
25	F	France	Student	Documentation	4	1	2	2	2	3	4	3	2	3	2	4	4	2	3	2	2	3	3
23	M	France	Engineer	Environment	3	3	2	3	4	2	4	2	2	5	3	1	2	3	3	3	2	3	4
27	M	France	Soldier	Military	3	2	3	3	3	3	3	3	3	3	4	5	5	2	4	5	5	5	5
24	F	France	Student	Documentation	4	3	4	3	3	5	4	3	4	4	4	4	3	3	3	3	1	2	3
35	F	Australia	Engineer	Civil	4	3	3	4	3	4	3	3	4	4	4	4	4	4	3	4	4	4	4
18	M	France	Student	Informatics	3	4	3	4	1	4	5	1	1	3	2	4	5	1	5	5	1	4	1
23	M	France	Student	Acoustics	4	3	4	3	4	4	5	3	3	4	3	5	3	2	3	3	4	5	5
24	F	France	Librarian	Culture	4	4	1	1	1	1	1	1	1	1	4	3	4	1	3	1	1	1	1
25	F	France	Librarian	Books	4	2	1	4	2	2	5	5	4	4	4	5	4	1	2	3	1	3	5
23	M	France	Student	Informatics	3	3	3	3	3	3	3	3	4	4	4	4	5	3	2	2	2	2	1
27	M	France	Librarian	Books	3	4	2	4	2	3	4	3	3	4	4	4	4	2	4	2	1	2	4
22	F	France	Doctor	Health	4	2	3	2	4	3	4	4	4	2	4	3	4	2	4	3	2	4	4
25	F	America	Student	Veterinary	4	2	2	2	2	3	3	2	2	2	2	3	4	3	4	4	2	2	4
24	F	America	Student	Veterinary	1	3	3	4	3	4	5	3	3	3	5	5	5	3	4	5	5	4	5
28	F	Japan	Student	Chemistry	4	5	5	5	4	4	4	3	5	3	3	4	5	3	4	3	4	3	5
9	F	China	Student	-	4	4	3	4	4	4	4	4	4	5	5	5	5	4	4	3	4	4	3
36	F	China	Student	Informatics	2	2	3	2	4	5	5	4	4	4	4	4	4	3	4	4	3	4	2
35	M	China	Engineer	Informatics	2	2	4	4	3	4	4	3	4	5	5	5	5	4	4	3	4	4	4
26	M	Japan	Student	Informatics	2	4	4	5	2	4	3	3	5	3	3	5	5	4	2	3	4	5	5
23	F	France	Student	Literature	1	1	1	1	1	4	3	1	1	1	5	5	5	5	5	1	1	1	5
18	F	France	Student	Psychology	5	4	4	4	3	5	5	3	5	3	3	5	5	3	3	4	1	4	3
24	M	Japan	Student	Informatics	5	4	4	4	2	2	4	2	4	5	5	4	4	5	4	3	2	4	2
32	M	Nepal	Student	Informatics	3	4	4	4	4	4	5	5	5	4	5	5	5	4	4	5	4	4	4
21	F	Philippines	IT trainee	Informatics	5	5	5	5	3	3	3	3	5	5	5	3	5	5	3	4	4	5	3
29	M	Germany	Student	Informatics	4	4	4	4	4	4	4	4	5	5	4	5	4	4	4	4	4	3	3
15	F	Ivory Coast	Student	-	3	1	1	1	4	5	4	3	3	4	5	5	5	2	1	3	5	1	3
29	F	Japan	Staff	Education	1	3	4	1	1	1	4	1	1	1	5	5	5	1	3	5	1	5	3
54	M	Japan	Professor	HCI	3	3	2	4	3	2	4	4	2	4	2	2	4	4	3	2	3	4	3
25	M	Japan	Engineer	Informatics	4	4	5	4	3	3	4	3	3	4	5	2	5	3	4	5	4	5	4
28	M	Japan	Student	Informatics	4	5	1	4	2	4	5	5	5	5	4	3	2	1	3	3	3	4	2
51	M	Japan	Professor	Physics	5	5	5	5	3	5	5	1	1	5	5	3	5	1	1	5	1	5	5
23	M	Japan	Student	HCI	2	4	1	4	5	5	2	2	2	2	5	5	5	3	5	2	4	5	1
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29	F	Japan	Staff	Education	1	1	1	2	2	2	3	1	2	2	1	4	2	1	1	3	1	2	2
43	F	Japan	Staff	Education	4	4	2	4	2	4	4	4	4	3	3	5	5	1	3	3	2	5	5
27	M	Japan	Student	HCI	1	1	1	1	5	5	1	1	4	5	3	1	4	3	1	1	1	3	5
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29	F	Japan	Reporter	Physics	1	3	1	3	4	5	5	3	1	1	5	5	3	1	1	3	3	5	3
27	M	Japan	Engineer	Music	1	1	1	1	1	1	4	1	1	1	4	1	1	1	1	4	3	5	3
27	M	Japan	Engineer	Informatics	4	5	2	5	1	5	4	3	3	4	4	4	2	2	5	4	2	4	2
19	M	Japan	Student	Electronics	4	5	2	5	3	5	5	4	5	5	4	5	3	4	4	2	4	5	2
26	M	Japan	Student	Informatics	4	3	2	4	1	4	5	4	4	4	4	4	4	3	4	4	4	4	3
28	M	Japan	Student	Informatics	3	4	2	4	4	5	2	2	2	4	4	5	4	1	2	5	2	4	4
34	M	Japan	Engineer	Informatics	4	5	5	5	1	5	5	2	5	5	5	5	5	3	5	3	3	5	5
38	M	Japan	Researcher	Informatics	2	3	1	3	1	3	1	1	3	3	3	3	4	1	1	1	1	3	4
35	F	Japan	Housewife	-	4	3	4	3	3	4	4	3	4	4	3	3	4	3	4	3	3	4	3
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25	M	Japan	Engineer	Informatics	1	4	2	4	3	5	1	4	3	3	4	4	5	2	1	4	3	5	3
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34	F	Japan	Researcher	History of art	2	4	1	4	3	4	4	2	5	4	3	1	5	2	3	3	3	5	3
40	M	Japan	Consultant	Entertainment	1	5	2	5	1	5	5	5	1	1	1	5	5	1	5	5	5	1	1
27	F	Japan	Student	Informatics	4	4	4	2	3	4	4	2	5	5	3	4	4	2	5	5	3	4	5
14	F	Japan	Student	-	4	1	3	4	2	4	4	3	3	4	4	3	4	2	3	3	4	4	5
27	F	Japan	Staff	Sports	4	4	1	2	5	5	4	2	5	4	4	1	4	2	4	4	4	4	2
28	M	Japan	Researcher	Informatics	2	2	2	2	4	2	5	3	1	3	5	3	1	5	1	4	4	5	3
25	M	Japan	Student	Informatics	1	5	3	5	2	5	5	4	4	3	5	5	1	1	3	3	3	4	5
22	F	Japan	Teacher	-	3	2	2	2	4	1	4	2	4	5	2	5	4	2	3	3	2	5	4
27	M	Japan	Student	Informatics	5	5	3	5	2	5	5	4	5	4	3	1	5	3	4	5	2	5	3
33	M	Japan	Seller	Food	2	5	4	5	5	5	4	2	5	5	5	5	2	5	1	2	2	5	5
26	M	Japan	Student	Informatics	4	5	3	4	3	5	5	4	5	5	4	3	4	4	5	4	3	5	4
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15	M	Peru	Student	-	5	5	4	2	5	5	5	1	1	4	3	5	1	2	1	3	1	3	5
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Appendix C: Questionnaires for the user-studies

Two questionnaires were provided, one before and one after using the prototype. The second questionnaire contains the questions of the first one, and extends it.

Questionnaire 1 (before the experiment)

This questionnaire was designed for research on new technologies: clothes possessing particular features, capacities and some kind of intelligence. Prototypes are currently being designed in France, Japan, and USA. Your answers will be taken into account for a study that will be published in 2006; we therefore appreciate the time you will take to answer the following questions.

Answers will be kept in a database without association to your identity. Thank you for participating in this study.

Please provide the following information.

Age _____ **Gender** _____ **Nationality** _____

Occupation (student, engineer...) _____
Field (computer science, psychology...) _____

Using the scale below, please tell us how much you agree or disagree with the following statements by placing a number in the box provided.

Strongly disagree	*1*
Disagree	*2*
Neither agree nor disagree	*3*
Agree	*4*
Strongly agree	*5*

1 It would be acceptable for me to wear clothes that:

- display images, photos, texts, or videos. ☐
- record my environment via photos or videos. ☐
- produce music, sounds, or speech. ☐
- record music, sounds, or speeches around me. ☐
- produce selected smells. ☐
- analyze the air (smells, pollution, humidity, temperature). ☐
- provide a sensation of cold or heat in certain areas. ☐
- vibrate or provide a feeling of touch in certain areas. ☐

2 Clothes with one or several capacities such as listed in question 1 would be useful:

- at big events like conferences or forums. ☐
- during parties. ☐
- on trips. ☐
- in potentially dangerous situations. ☐
- to communicate with disabled people. ☐
- when meeting new people. ☐

3 I would agree to use garments that can monitor my emotional state (heart beats, blood pressure, body temperature, movements, etc.) to:

- adapt my environment to my needs (temperature, light, music in the room, etc.). ☐
- adapt video games depending on my experiences. ☐
- produce group effects during artistic or sportive events. ☐
- reveal my emotions to surrounding people. ☐
- share my feelings with selected persons (like husband/wife), even at a distance. ☐

4 I would leave my profile (such as name, age, nationality, centers of interest) visible:

- to people in the same room as me. ☐
- to people belonging to my community. ☐
- to people I met previously. ☐
- on Internet. ☐

5 I would leave information about by emotional state visible:

- to people in the same room as me. ☐
- to people belonging to my community. ☐
- to people I met previously. ☐
- on Internet. ☐

6 If you have any remarks or suggestion about the questionnaire or electronic garments, please write them below:

Questionnaire 2 (after the experiment)

Using the scale below, please tell us how much you agree or disagree with the following statements by placing a number in the box provided.

Strongly disagree *1*
Disagree *2*
Neither agree nor disagree *3*
Agree *4*
Strongly agree *5*

1 It would be acceptable for me to wear clothes that:

- display images, photos, texts, or videos. ☐
- record my environment via photos or videos. ☐
- produce music, sounds, or speech. ☐
- record music, sounds, or speeches around me. ☐
- produce selected smells. ☐
- analyze the air (smells, pollution, humidity, temperature). ☐
- provide a sensation of cold or heat in certain areas. ☐
- vibrate or provide a feeling of touch in certain areas. ☐

2 Clothes with one or several capacities such as listed in question 1 would be useful:

- at big events like conferences or forums. ☐
- during parties. ☐
- on trips. ☐
- in potentially dangerous situations. ☐
- to communicate with disabled people. ☐
- when meeting new people. ☐

3 I would agree to use garments that can monitor my emotional state (heart beats, blood pressure, body temperature, movements, etc.) to:

- adapt my environment to my needs (temperature, light, music in the room, etc.). ☐
- adapt video games depending on my experiences. ☐
- produce group effects during artistic or sportive events. ☐
- reveal my emotions to surrounding people. ☐
- share my feelings with selected persons (like husband/wife), even at a distance. ☐

4 I would leave my profile (such as name, age, nationality, centers of interest) visible:

- to people in the same room as me. ☐
- to people belonging to my community. ☐
- to people I met previously. ☐
- on Internet. ☐

5 I would leave information about by emotional state visible:

- to people in the same room as me. ☐
- to people belonging to my community. ☐
- to people I met previously. ☐
- on Internet. ☐

6 I feel that the system (prototype and service):

- improves the wearer's ability to communicate. ☐
- improves the interlocutor's ability to communicate. ☐
- improves their ability to establish a long-term relationship together. ☐

7 Compared to a normal meeting, I feel that I:

- learnt more things thanks to the system. ☐
- learnt more interesting things thanks to the system. ☐
- understood better the feelings of the wearer thanks to the system. ☐

8 I would prefer the system to:

- have no autonomy and let the wearer choose the photos (content & timing) by herself. ☐
- give the wearer more control (back, next, pause, timing) on photos displayed. ☐
- be more clever so it can choose and display by itself content at the right moment. ☐

9 I think that displaying emotions based on physiological sensors could be useful in the following situations:

- when I am with my family. ☐
- when I am with friends. ☐
- when I am with professional acquaintances. ☐
- when I am with strangers. ☐

10 I think that displaying emotions based on physiological sensors could be harmful in the following situations:

- when I am with my family. ☐
- when I am with friends. ☐
- when I am with professional acquaintances. ☐
- when I am with strangers. ☐

11 The system used physiological sensors to display an evaluation of the wearer's emotional state. In everyday life, I would like to:

- display my own emotions this way at all times. ☐
- display my own emotions this way from time to time, with a on/off button. ☐
- display my own emotions with a possibility to select myself the emotion displayed. ☐
- see a display of my interlocutor's emotions. ☐
- see a display of surrounding people's emotions. ☐

12 As a wearer, I would prefer:

- to use the system with dataglasses to know what I display. ☐
- to use the system with a small screen on the tip of my sleeve to know what I display. ☐
- to use the system without any additional screen. ☐

13 How reliable do you think physiological sensors are to evaluate emotional states? ☐ %

14 How should we improve the system (from most important to least important)?

-
-
-

Appendix D: Raw data from the user-studies

Below is the data corresponding to the main results. The scores in columns Ax.y correspond to answers to the questionnaire provided before the experiments, those in columns Bx.y after. "x" identifies the question, and "y" the element. For example "B12.1" points to "As a wearer, I would prefer:" for x, and "to use the system with dataglasses to know what I display" for y.

Identifier	Age	Gender	Nationality	A1.1	A2.6	A4.2	A5.3	B1.1	B2.6	B4.2	B5.3	B6.1	B6.2	B6.3	B7.1	B7.2	B8.1	B8.2	B8.3
Algeria_00	31	M	Algerian	1	1	1	1	4	3	3	1	4	4	1	3	3	4	4	1
France_00	26	M	French	4	3	4	2	5	5	5	4	5	3	2	5	5	2	5	5
France_01	27	M	French	5	5	4	1	5	5	5	1	3	4	2	5	3	4	5	4
France_02	28	M	French	2	4	1	1	5	5	2	4	5	4	3	4	4	4	5	4
France_03	32	F	French	5	4	4	1	5	4	4	2	5	5	4	5	4	3	5	5
Germany_00	30	M	German	5	5	4	5	5	5	4	5	3	3	3	3	3	5	5	5
Germany_01	29	M	German	4	3	2	1	5	5	4	1	5	4	4	5	5	5	5	4
Japan_01	21	M	Japanese	4	5	4	5	4	5	5	5	5	4	5	5	3	4	5	5
Japan_02	29	M	Japanese	5	5	5	1	5	5	5	1	4	3	3	4	5	4	5	5
Japan_03	31	M	Japanese	2	3	3	1	5	5	4	2	4	4	2	4	5	4	5	4
Japan_04	25	M	Japanese	5	3	4	1	5	5	5	1	5	4	4	3	3	4	5	4
Japan_05	24	M	Japanese	5	5	4	3	5	5	5	3	3	4	1	5	4	5	4	1
Japan_06	30	M	Japanese	4	2	1	1	5	3	3	1	4	3	3	4	3	3	4	4
Japan_07	29	F	Japanese	5	1	4	1	4	3	5	1	4	4	1	5	3	2	5	5

Identifier	B9.1	B9.2	B9.3	B9.4	B10.1	B10.2	B10.3	B10.4	B11.1	B11.2	B11.3	B12.1	B12.2	B12.3	B13
Algeria_00	1	1	1	1	3	3	3	3	1	1	1	4	3	1	60
France_00	4	4	4	4	2	1	5	1	2	5	4	5	5	1	80
France_01	3	2	1	1	3	5	5	4	1	5	3	5	5	1	100
France_02	2	1	1	1	3	4	5	4	2	1	4	4	4	1	85
France_03	2	2	1	1	1	1	5	5	1	2	2	4	4	1	60
Germany_00	5	4	2	1	1	2	4	5	1	5	3	5	5	1	99
Germany_01	1	1	2	1	4	5	3	3	1	1	3	4	4	2	90
Japan_01	5	3	3	3	2	2	4	3	1	5	2	5	2	1	85
Japan_02	3	3	1	1	1	3	4	3	1	5	1	5	5	2	60
Japan_03	2	2	1	1	2	2	5	4	1	1	3	4	3	1	95
Japan_04	2	2	2	2	2	1	4	5	1	2	3	5	5	1	95
Japan_05	4	3	2	2	4	4	5	3	2	5	3	4	5	2	70
Japan_06	2	2	2	1	1	2	3	2	1	2	3	5	5	1	75
Japan_07	2	2	2	1	3	4	4	4	1	5	2	4	5	1	70

Identifier	B14.1	B14.2	B14.3
Algeria_00	Display depending on context (auto)	Information exchange at a distance	-
France_00	Additional display	Improve control of display (manual)	Improve aesthetics of prototype
France_01	Bigger display	Make the system more wearable	Improve control of display (manual)
France_02	Improve aesthetics of prototype	Improve A.I.	Add more metadata to pictures
France_03	On/off emotions	Improve control of display (manual)	Display depending on context (auto)
Germany_00	Improve emotional feedback	Solve loss of eye-contact	Projector would be a better display
Germany_01	Improve control of display (manual)	Add more metadata to pictures	Make the system more wearable
Japan_01	Solve loss of eye-contact	Improve aesthetics of prototype	Bigger display
Japan_02	Improve A.I.	Solve loss of eye-contact	Improve control of display (manual)
Japan_03	Improve aesthetics of prototype	Solve loss of eye-contact	Improve long-term management
Japan_04	Improve control of display (manual)	Improve A.I.	Improve aesthetics of prototype
Japan_05	Bigger display	Improve control of display (manual)	Improve aesthetics of prototype
Japan_06	Improve aesthetics of prototype	Solve loss of eye-contact	Improve control of display (manual)
Japan_07	Improve A.I.	Improve aesthetics of prototype	-

Appendix E: Main code of the service

The framework is based on Sun JDK 1.5.0, and was developed without special extensions. The XML data management is based on a SAX parser. Corresponding packages are:

- org.xml.sax
- org.xml.sax.helpers

The control of the multi-button device is done using the *MouseListener* interface (java.awt.event package) applied to visual components (e.g. *Jframe*).

cyberclothes.services package

Main class

```
package cyberclothes.services;

import java.awt.*;
import java.io.*;
import java.net.InetAddress;
import java.util.*;

import javax.swing.*;

import jinmyaku.human.Chijin;

import cyberworld.activities.*;
import cyberworld.data.graphics.*;
import cyberworld.services.*;

/**
 * Implementation of an application supporting first contacts with a human.
 *
 * @author  Sebastien Duval
 * @version 0.04, 28/12/2005
 * @since   1.5
 */

public          class FirstContactExec
                extends CyberworldService
                implements      VisualResourceLoaderHandler,
                                LightstoneOwner,
                                ServiceIdentifierHandler
{
        /*
         * ------------------------------------------------------------------------
         * --------------------------- Standard data ----------------------------
         * ------------------------------------------------------------------------
         */

        // Mode identifiers used for callbacks.
        private final String strShowEverything = "Everything";
        private final String strShowMe = "Me";
        private final String strShowOther = "Other";
        private final String strShowOtherSeveral = "Many";
        private final String strShowSchedule = "Schedule";

        // Information about the IP.
        public String strServiceProviderIP;

        // Information about other wearers.
        public int iSurroundingWearers = 1;
```

```
public InetAddress iAddressOther;

// Location of the wearer's personal information file.
private final String strArchiveLocationMe = "first_contact_data_xml_tags.htm";

// Identifier of the last sample for skin conductivity.
public int latestSclSampleNumber = -1;

// Refresh rate, in milliseconds.
private int iSleepLightStone = 1000;

// Name of the file where the data about biosignals is extracted.
private final String strFileNameLightStone = "lsm-data.xml";

// Graphical elements containing test information.
public JFrame frameBio = new Jframe();
private JLabel sclLabel = new JLabel("SCL");

/*
 * -------------------------------------------------------------------------
 * -------------------------- Specialized data -----------------------------
 * -------------------------------------------------------------------------
 */

// Elements about physiological data used to evaluate arousal.
private boolean bioActive = true;

// Main framework handlers.
public final GarmentHandler myGarmentHandler = new GarmentHandler(this);
public final CommunityHandler theCommunity = new CommunityHandler();
public final WearerHandler theWearer = new WearerHandler();

// Schedule of the wearer.
public ArrayList<EventMaterial> collSchedule = null;

// Description of the photos describing the wearer's interests.
public ArrayList<VisualResource> collVisualsMe = null;

// Description of the photos describing another wearer's interests.
public ArrayList<VisualResource> collVisualsOther = null;

// Container for graphical elements. Accessed by GarmentHandler.
public VisualFrame myRenderer = new VisualFrame
                (
                        strServiceName, strTitleSeparator, "SlideShow",new Dimension(900,600)
                );

//  Processor for the physiological signals.
private final LightstoneController bcStream = new LightstoneController
        (
                this,
                iSleepLightStone,
                strFileNameLightStone
        );

// External module contacting other wearables and sending them the service's description.
```

```
DemoTest myDemo;

/*
 * ------------------------------------------------------------------------
 * ------------------------- Initial functions ----------------------------
 * ------------------------------------------------------------------------
 */

/**
 * Starts the service and acknowledges the execution of the application.
 *
 * @param args Parameters (not used).
 */
public static void main(String[] args)
{
	JFrame.setDefaultLookAndFeelDecorated(true);
	final FirstContactExec fcAppl = new FirstContactExec();
	fcAppl.acknowledgeExecution();
}

/**
 * Constructor. Initializes the data.
 */
public FirstContactExec()
{
	// Initializes framework variables.
	 myGarmentHandler.initialize();
	theWearer.initialize();

	// Demo information.
	strServiceName = "出会い";
	strTitleSeparator = " - ";

	// Graphical elements for physiological feedback (debug).
	sclLabel.setPreferredSize(new Dimension(70,30));
	frameBio.add(sclLabel);
	frameBio.pack();
	frameBio.setVisible(true);

	// Initializes the schedule.
	collSchedule = theWearer.getSchedule();

	// Port userd for networking.
	int iInitPort = 12111;

	// Initializes the network handler.
	myGarmentHandler.initializeNetwork(iInitPort);

	// Starts the demo manager, which establishes contacts with other wearables.
	myDemo = new DemoTest(this);

	// Executes the service.
	executeService();
}
```

```
/*
 * ------------------------------------------------------------------------
 * --------------------------- Core functions ---------------------------
 * ------------------------------------------------------------------------
 */

/**
 * Executes the service: updates the number of detected wearers, starts the physiological data
 * extraction, and launches the displays of photos.
 */
protected void executeService()
{
	// Updates the number of other wearers that accepted the service from DemoTest.
	iSurroundingWearers = myDemo.updateSurroundingWearers();

	// Launches the physiological data extraction (placed in an XML file).
	if(bioActive)
	{
		bcStream.start();
	}

	// Alternatives depending on number of other wearers.
	if (iSurroundingWearers == 1)
	{
		displayPicturesCommon(myDemo.getFileName());
	}
	else if (iSurroundingWearers == 2)
	{
		displayPicturesCommonSeveral(myDemo.getFilesName());
	}
	else
	{
		displayPicturesSchedule();
	}
}

/**
 * Displays all the wearer's photos.
 */
private void displayPicturesAll()
{
	extractPictures(strArchiveLocationMe,strShowEverything);
}

/**
 * Displays the photos that the wearer has in common with another wearer (only one).
 *
 * @param strArchiveLocationOther	String indicating the location and filename used to store the
 *					information about the other wearer's interests.
 */
private void displayPicturesCommon(String strArchiveLocationOther)
{
	extractPictures(strArchiveLocationMe,strShowMe);
	extractPictures(strArchiveLocationOther,strShowOther);
}
```

```
/**
 * Displays the photos that the wearer has in common with several other wearers.
 *
 * @param strArchiveLocationOther      Set of locations (and filenames) used to store the
 *                                     information about the other wearers' interests.
 */
private void displayPicturesCommonSeveral(String[] strArchiveLocationOther)
{
	extractPictures(strArchiveLocationMe,strShowMe);
	for (int i = 0; i < strArchiveLocationOther.length; i++)
	{
		extractPictures(strArchiveLocationOther[i],strShowOtherSeveral);
	}
}

/**
 * Displays the photos related to the wearer's current activitry based on her schedule.
 */
private void displayPicturesSchedule()
{
	extractPictures(strArchiveLocationMe,strShowSchedule);
}

/**
 * Exits from the service.
 *
 * @param strMessage Message displayed before termination.
 * @param intDelay      Time left to read the message, in seconds.
 */
protected void exit(final String strMessage, final int intDelay)
{
	CyberworldManagerExitFrame manExit = new CyberworldManagerExitFrame
		(
			strServiceName,
			strTitleSeparator,
			strMessage,
			intDelay
		);
	manExit.start();
}

/**
 * Extracts visual resources from an HTML page.
 *
 * @param rSource       Reader that handles the extraction.
 * @param vrsStorage  Destination for visual resources extracted.
 */
private void extractPictures
(
	String strArchiveLocation,
	String strHint
)
{
	VisualResourceLoader loader = new VisualResourceLoader(this,strArchiveLocation,strHint);
	loader.start();
```

```
}

/**
 * Processes visual resources depending on the number of surrounding wearers.
 *
 * @param collVisuals           Visual resources to process.
 * @param strCallbackHint       String describing the identity associated to the visual resources.
 */
public void processLoadedVisualResources
(
        ArrayList<VisualResource> collVisuals,
        String strCallbackHint
)
{
        if(strCallbackHint.equals(strShowEverything))
        {
                VisualController myShow = new VisualController(myRenderer,30000,collVisuals);
                myShow.start();
                return;
        }
        else if(strCallbackHint.equals(strShowMe))
        {
                 collVisualsMe = collVisuals;
                 visualizeUs();
        }
        else if(strCallbackHint.equals(strShowOther))
        {
                 collVisualsOther = collVisuals;
                 visualizeUs();
        }
        else if(strCallbackHint.equals(strShowOtherSeveral))
        {
                 collVisualsOther = myDemo.merge(collVisuals);
                 visualizeUs();
        }
        else if(strCallbackHint.equals(strShowSchedule))
        {
                collVisualsMe = collVisuals;
                visualizeSchedule();
        }
}

/**
 * Identifies and displays visuals related to common interests.
 *
 * @param collVisuals           Visual resources to process.
 * @param strCallbackHint       String describing the identity associated to the visual resources.
 */
public void visualizeUs()
{
        if((collVisualsMe != null) && (collVisualsOther != null))
        {
                ArrayList<VisualResource> theColl =
              VisualResourceManager.getCommonVisualsInSource(collVisualsMe,collVisualsOther);
                integrateSchedule(theColl);
```

```
                VisualController myShow = new VisualController(myRenderer,5000,theColl);
                myShow.start();
        }
}

/**
 * Identifies and displays visuals related to ongoing events found in the wearer's schedule.
 */
public void visualizeSchedule()
{
        collVisualsOther = new ArrayList<VisualResource>();
        ArrayList<String> collWordTmp = new ArrayList<String>();

        for(EventMaterial evtCurrent : collSchedule)
        {
                if (evtCurrent.isOngoing())
                {
                        collWordTmp.add(evtCurrent.getName());
                }
        }

        VisualResource visTmp = new VisualResource("NA");
        visTmp.setCollKeywords(collWordTmp);
        collVisualsOther.add(visTmp);

        ArrayList<VisualResource> theColl =
              VisualResourceManager.getCommonVisualsInSource(collVisualsMe,collVisualsOther);
        VisualController myShow = new VisualController(myRenderer,5000,theColl);
        myShow.start();
}

/**
 * Process physiological data provided by the sensors.
 *
 * @param  newSampleNumber          Sample number.
 * @param  newSampleTime            Sampling time.
 * @param  newScl                   Skin conductivity level.
 * @param  newHeartRaw              Heart activity.
 */
public void processSignals
(
        final int newSampleNumber,
        final String newSampleTime,
        final float newScl,
        final float newHeartRaw
)
{
        if(newSampleNumber>latestSclSampleNumber)
        {
                latestSclSampleNumber = newSampleNumber;
                float fNormalScl = scale(newScl);
                String strState = "";

                // Color used to reflect the emotional state based on skin conducitivity.
                int iRed = (int) Math.round(255*fNormalScl);
                int iGreen = 0;
```

```
                int iBlue = 255 - iRed;
                myRenderer.setColor(new Color(iRed,iGreen,iBlue));

                if (isCalm(fNormalScl))
                {
                        strState = "Calm";
                }
                else
                {
                        strState = "Excited";
                }
                sclLabel.setText(strState);
        }
}

/**
 * Sends data to another entity if networking is active. Sends an error
 * if networking is inactive.
 *
 * @param ndsTransmit       NetworkDataSet that describes the data to be sent  and to whom.
 * @param iPort             Port to use for the connection.
 */
public void transmitData(final NetworkDataSet ndsTransmit, final int iPort)
{
        myGarmentHandler.transmitData(ndsTransmit,iPort);
}

/**
 * Processes the data received from another wearer and reacts accordingly.
 *
 * @param ndsData       NetworkDataSet received.
 * @param iAddress      Sender's address.
 */
public void processDataReceived(final NetworkDataSet ndsData,InetAddress iAddress)
{
        String strArchiveOther = "";
        for (int i = 0; i < ndsData.getSize(); i++)
        {
                if(ndsData.getElement(i).getType().equals("Service"))
                {
                        strArchiveOther = ndsData.getElement(i).getContent();
                        isServiceForMe(strArchiveOther,iAddress);
                }

                else if(ndsData.getElement(i).getType().equals("InterestFile"))
                {
                        Chijin myAcquaintance = new Chijin();
                        myAcquaintance.setNameDisplay(ndsData.getElement(i).getSender());

                        EventMaterial myEvent = new EventMaterial();
                        Date now = new Date();
                        myEvent.setDateBegin(now);
                        myEvent.setDateEnd(now);
                        myEvent.setName("First contact");

                        myAcquaintance.addEventMaterial(myEvent);
```

```
                                theCommunity.add(myAcquaintance);

                                strArchiveOther = ndsData.getElement(i).getContent();
                                File outFile = new File("tmp_file.txt");

                                try
                                {
                                        StringReader in = new StringReader(strArchiveOther);
                                        FileWriter out = new FileWriter(outFile);
                                        int c;

                                        while ((c = in.read()) != -1)
                                        out.write(c);

                                        in.close();
                                        out.close();
                                }
                                catch(Exception e)
                                {
                                        System.out.println("ExtractString: Error - " + e);
                                }
                                myDemo.acknowledge("tmp_file.txt");
                        }
                        else if(ndsData.getElement(i).getType().equals("CommonKeywords"))
                        {
                                store(ndsData.getElement(i).getContent());
                        }
                }
        }

        /**
         * Checks if the service is of interest for the wearer.
         *
         * @param serviceDescription   XML description of the service.
         * @param iAddress             Address of the other wearer.
         */
        private void isServiceForMe(String serviceDescription, InetAddress iAddress)
        {
                ServiceIdentifier identifier = new ServiceIdentifier(this,serviceDescription, iAddress);
                identifier.start();
        }
}
```

LightstoneController class

```
package cyberclothes.services;

import java.io.*;

/**
 * Implementation of a controller that processes biosignals from an XML file.
 * It opens the file, reads the content line by line, and requests the
 * processing of each line. The data is then sent for specific processing by
 * the owner.
```

```
 *
 * The current version extracts: sample number, sample time, SCL, and raw heart
 * data.
 *
 * @author  Sebastien Duval
 * @version 0.11, 08/09/2005
 * @since   1.5
 */
public class LightstoneController extends Thread
{
	// Boolean defining whether the thread should continue its activity or not.
	boolean boolContinueActivity = true;

	// Inactivity after a successful cycle, in milliseconds.
	int iSleep = 0;

	// Name of the file where the data about biosignals is extracted.
	private final String fileName;

	// Entity requesting physiological data.
	private final LightstoneOwner biOwner;

	/**
	 * Constructor. Initializes the external references.
	 *
	 * @param initOwner		Entity requesting physiological data.
	 * @param initSleep		Inactivity after a successful cycle, in milliseconds.
	 * @param initFileNameName of the file where the biodata is extracted.
	 */
	public LightstoneController
	(
		final LightstoneOwner initOwner,
		final int initSleep,
		final String initFileName
	)
	{
		biOwner = initOwner;
		iSleep = initSleep;
		fileName = initFileName;
	}

	/**
	 * Returns the string comprised between the first and last occurence of
	 * the indicated character.
	 *
	 * @param originalString		String to process.
	 * @param charSep		Character delimiting bounds.
	 * @return			String between the first and last occurence of the indicated character.
	 */
	private String getInnerContent(final String originalString, final char charSep)
	{
		final String processedString =	originalString.substring
							(
```

```
        originalString.indexOf(charSep)+1,

        originalString.lastIndexOf(charSep)
                                                                                );
                return processedString;
        }

        /**
         * Checks the validity of a String as sample input for biosignals.
         *
         * A valid line contains "<sample number=" and "/>".
         *
         * <em>Note: this is a weak test.</em>
         *
         * @param strInputLine String to analyze
         * @return                          true if the line is valid, else false.
         */
        private boolean isValidSampleLine(final String strInputLine)
        {
                boolean isValidBeginLine = strInputLine.indexOf("<sample number=") != -1;
                boolean isValidEndLine = strInputLine.indexOf("/>") != -1;

                return(isValidBeginLine && isValidEndLine);
        }

        /**
         * Processes the signals' file once. It opens the file, reads the content line
         * by line, and requests the processing of each line. The data is then sent for
         * processing by the owner. If the whole file is read correctly, the thread
         * pauses for the indicated duration.
         *
         * @param iSleepDuration        Duration of inactivity requested after processing if
         *                                                      the cycle is carried out correctly, in
milliseconds.
         * @see processXmlSample.
         */
        public void processSignals(final int iSleepDuration)
        {
                // Resources.
                BufferedReader brInputFile = null;
                boolean boolExtractingOk = false;

                // Opens the file.
                try
                {
                        brInputFile = new BufferedReader(new FileReader(fileName));
                        boolExtractingOk = true;
                }
                catch(Exception e)
                {
                        System.out.println("Exception (Open file): " + e.getMessage());
                }

                // Checks if the extraction should continue.
                while(boolExtractingOk)
                {
```

```
                String inputLine = null;
                try
                {
                        inputLine = brInputFile.readLine();
                }
                catch(Exception e)
                {
                        System.out.println("Exception (Read buffer): " + e.getMessage());
                }

                // Checks of the end of file has been reached.
                if(inputLine == null)
                {
                        // Stops processing the data.
                        boolExtractingOk = false;
                }
                else
                {
                        // Checks if the line contains interesting content.
                        if(isValidSampleLine(inputLine))
                        {
                                processXmlSample(inputLine);
                        }
                }
        }

        if(brInputFile != null)
        {
                try
                {
                        brInputFile.close();
                }
                catch(Exception e)
                {
                        System.out.println("Exception (Close buffer): " + e.getMessage());
                }
                biOwner.updateMirrors();
                try
                {
                        sleep(iSleepDuration);
                }
                catch(Exception e)
                {
                        System.out.println("Exception (Sleep): " + e.getMessage());
                }
        }
}

/**
 * Processes the string provided and extracts the biosignals' data. The data
 * is then sent for processing by the owner.
 *
 * <em>The content is identified with the following markers: "number=",
 * "time=", "scl=", "heart=", and "/>".</em>
 *
 * @param inputLine String to process.
```

```
	 * @see processSignals.
	 */
	private void processXmlSample(String inputLine)
	{
		// Element for the analysis of the XML file.
		final char charSep = '"';

		// Position of the data sections for the current sample.
		final int posNumber = inputLine.indexOf("number=");
		final int posTime = inputLine.indexOf("time=");
		final int posScl = inputLine.indexOf("scl=");
		final int posHeart = inputLine.indexOf("heart=");
		final int posEnd = inputLine.indexOf("/>");

		// Extracts the sample number.
		String valNumber = inputLine.substring(posNumber, posTime);
		valNumber = getInnerContent(valNumber,charSep);

		// Extracts the sample time.
		String valTime = inputLine.substring(posTime, posScl);
		valTime = getInnerContent(valTime,charSep);

		// Extracts the SCL value of the sample.
		String valScl = inputLine.substring(posScl, posHeart);
		valScl = getInnerContent(valScl,charSep);

		// Extracts the raw heart value of the sample.
		String valHeart = inputLine.substring(posHeart, posEnd);
		valHeart = getInnerContent(valHeart,charSep);

		// Sends the data to the owner for processing of the values.
		biOwner.processSignals
		(
				Integer.valueOf(valNumber).intValue(),
				valTime,
				Float.valueOf(valScl).floatValue(),
				Float.valueOf(valHeart).floatValue()
		);
	}

	/**
	 * Runs and stops the data acquisition and processing. This includes the
	 * extraction from a XML file, its parsing, and the sending of samples to
	 * the entity owning the BioController.
	 *
	 * @see processSignals
	 */
	public void run()
	{
		while(boolContinueActivity)
		{
			processSignals(iSleep);
		}
	}
}
```

LightstoneOwner interface

```
package cyberclothes.services;

/**
 * Interface for upper-end entities processing biosignals.
 *
 * The current version extracts: sample number, sample time, SCL, and raw heart
 * data.
 *
 * @author  Sebastien Duval
 * @version 0.02, 08/09/2005
 * @since   1.5
 */
public interface LightstoneOwner
{
	/**
	 * Processes the data provided by a BioController.
	 *
	 * @param newSampleNumber		Number of the sample.
	 * @param newSampleTime		Time when the sample was acquired.
	 * @param newScl			SCL value of the sample.
	 * @param newHeartRaw		Raw heart data of the sample.
	 */
	public abstract void processSignals
	(
		final int newSampleNumber,
		final String newSampleTime,
		final float newScl,
		final float newHeartRaw
	);

	/**
	 * Updates the mirrors with the latest biodata stored in the BioProfile.
	 */
	public void updateMirrors();
}
```

NetworkConnexion class

```
package cyberclothes.services;

import java.io.ObjectInputStream;
import java.net.Socket;


/**
 * This class defines an individual network connection between
 * the garment and another networked entity (garment or not).
 *
 * @author Duval Sebastien
```

```
 * @version 0.21
 */
public class NetworkConnection extends Thread
{
	/**
	 * Socket used as an endpoint between the garment and the other entity.
	 */
	private final Socket socClient;

	/**
	 * Object that reads information coming to the garment from the other entity.
	 */
	private ObjectInputStream oisReceiver = null;

	/**
	 * Handler that owns the connection.
	 */
	private final NetworkHandler nhOwner;

	/**
	 * Initializes elements required to manage the connection. Closes the
	 * connection if an error occurs.
	 *
	 * @param	nhInitOwner NetworkHandler that owns the connection and to
	 *		which information will will sent back.
	 * @param	socInitClient Socket describing the connection with the other
	 *			entity.
	 */
	public NetworkConnection
	(
		final NetworkHandler nhInitOwner,
		final Socket socInitClient
	)
	{
		/*
	     * Initializes the connection data.
	     */
		nhOwner = nhInitOwner;
	   socClient = socInitClient;

	   /*
	    * Creates the object to manipulate received data.
	    */
	   try
		{
		oisReceiver = new ObjectInputStream(socClient.getInputStream());
	   }
	   catch(final Exception excRaised)
		{
		try
			{
			socClient.close();
			notifyException(excRaised);
		}
		catch(final Exception excRaised2)
```

```
                    {
                    notifyException(excRaised2);
        }
        return;
    }
    this.start();
}

/**
 * Notifies the owner of an exception that occured.
 *
 * @param excRaised Exception that needs to be notified.
 */
public void notifyException(final Exception excRaised)
{
        System.out.println(excRaised);
}

/**
 * Notifies the owner of an exception that occured.
 *
 * @param strMessage String that describes the activity.
 */
public void notifyError(String strMessage)
{
        System.out.println(strMessage);
}

/**
 * Connection activity. Receives data from the other entity, and
 * transmits the data to the NetworkConnection owner.
 *
 * This function assumes that the received data is a NetworkData object.
 * Sends an error message to the NetworkConnection if the data is in
 * another format.
 */
public void run()
{
        Object objReceived = null;

        try
        {
                // Acquires the sent object sent by the entity.
        objReceived = oisReceiver.readObject();

       // Closes connections.
       oisReceiver.close();
       socClient.close();
       System.out.println("Closed a connection with: " + socClient.getInetAddress());
        }
    catch(Exception excRaised)
        {
        notifyException(excRaised);
        }

        if (objReceived instanceof NetworkDataSet)
```

```
                {
                        NetworkDataSet ndsReceived = (NetworkDataSet) objReceived;
                         nhOwner.processDataReceived(ndsReceived,socClient.getInetAddress());
                }
                else
                {
                        notifyError("Unsupported data format received. Data ignored.");
                }
        }
}
```

NetworkHandler class

```
package cyberclothes.services;

import java.io.*;
import java.net.*;

/**
 * This class defines a handler for cyberclothes network operations.
 * It serves as both a server and client.
 *
 * @author Duval Sebastien
 * @version 0.1
 */
public class NetworkHandler extends Thread
{
        /**
         * Port used for connections. Default for the server.
         */
        private final int iServerPort;

        /**
         * Server used for the connection.
         */
        private ServerSocket ssServer;

        /**
         * Global handler that owns the NetworkHandler.
         */
        private final GarmentHandler ghOwner;

        /**
         * Initializes elements required to manage the connection. Activates a server
         * that waits for connections on the defined port.
         *
         * @param ghInitOwner           GarmentHandler that owns the connection, to which
         *                                                      information is sent, and that gives orders.
         * @param iInitServerPort       int that identifies the port used by the server.
         */
        public NetworkHandler(final GarmentHandler ghInitOwner, final int iInitServerPort)
        {
                /*
```

```
         * Initializes the connection data.
         */
                ghOwner = ghInitOwner;
                iServerPort = iInitServerPort;

                /*
                 * Activates the server that waits for connections.
                 */
                try
                {
                        ssServer = new ServerSocket(iServerPort);
                        this.start();
                }
                catch(final Exception excRaised)
                {
                        System.out.println(excRaised);
                }
        }

        /**
         * Requests the owner to process the specified data received on the
         * network.
         *
         * @param ndsData NetworkDataSet received from another entity.
         */
        public void processDataReceived(final NetworkDataSet ndsData,InetAddress iAddress)
        {
                ghOwner.processDataReceived(ndsData,iAddress);
        }

        /**
         * Server activity. Waits for a connection and generates a NetworkConnection
         * to manage data that is to be exchanged between the garment and the other
         * entity.
         *
         * The server is by default permanently active.
         */
        public void run()
        {
                while(true)
                {
                        try
                        {
                                System.out.println("Waiting for connections.");
                                final Socket socClient = ssServer.accept();
                                System.out.println("Accepted a connection from: " +
socClient.getInetAddress());
                                final NetworkConnection ncExchange = new NetworkConnection(this,
socClient);
                        }
                        catch(final Exception excRaised)
                        {
                                System.out.println(excRaised);
                        }
           }
        }
```

```
	/**
	 * Sends data to another entity. Sends an error message to the
	 * GarmentHandler if an error occurs.
	 *
	 * @param ndTransmit  NetworkData that describes the data to be sent
	 *                                                and how to send it.
	 * @param iPort                              int that indicates the port to use for the
	 *                                                connection.
	 */
	public void transmitData(final NetworkDataSet ndsTransmit, final int iPort)
	{
	   try
	         {
	         System.out.println("Server targeted for data transmission: " + ndsTransmit.getReceiver());

	         // Initializes the connection data.
	         final Socket socket = new Socket(ndsTransmit.getReceiver(), iPort);
	         final ObjectOutputStream oosSender = new ObjectOutputStream(socket.getOutputStream());

	      // Sends the data to the other entity
	      oosSender.writeObject(ndsTransmit);
	      oosSender.flush();

	      // Closes the connection.
	      oosSender.close();
	      System.out.println("Data received by server: " + ndsTransmit.getReceiver());
	   }
	   catch(final Exception excRaised)
	         {
	         System.out.println(excRaised);
	   }
	}
}
```

cyberworld.services package

CyberworldService abstract class

```
package cyberworld.services;

/**
 * Implementation of a service: demonstration or application.
 *
 * @author  Sebastien Duval
 * @version 0.11, 08/12/2005
 * @since   1.5
 */
public abstract class CyberworldService
{
	/*
	 * -------------------------------------------------------------------------
	 * ---------------------------- Standard data ----------------------------
	 * -------------------------------------------------------------------------
	 */

	/**
	 * Name of the service.
	 */
	protected String strServiceName = null;

	/**
	 * Separator for the titles of frames.
	 */
	protected String strTitleSeparator = null;

	/*
	 * -------------------------------------------------------------------------
	 * ---------------------------- Core functions ----------------------------
	 * -------------------------------------------------------------------------
	 */

	/**
	 * Indicates that a full cycle worked correctly.
	 */
	protected void acknowledgeExecution()
	{
		System.out.println("Service executed.");
	}

	/**
	 * Executes the service.
	 */
	protected abstract void executeService();

	/**
```

```
         * Exits from the service.
         *
         * @param strMessage  Message displayed before termination.
         * @param intDelay    Time left to read the message, in seconds.
         */
        protected abstract void exit(final String strMessage, final int intDelay);
}
```

jinmyaku.human package

Chijin class

```
package jinmyaku.human;

import java.util.*;

import jinmyaku.human.activities.*;
import jinmyaku.human.contact.*;

import cyberworld.activities.*;

/**
 * Implementation of an acquaintance.
 *
 * The current version manages associated events, notes, phone numbers,
 * recent contacts, personal tasks, a description of the first contact,
 * and a name used for display.
 *
 * @author  Sebastien Duval
 * @version 0.18, 07/01/2006
 * @since   1.5
 */
public class Chijin extends Human
{
	/*
	 * ---------------------------------------------------------------------
	 * ---------------------------- Standard data --------------------------
	 * ---------------------------------------------------------------------
	 */

	/**
	 * Name displayed to represent the acquaintance.
	 */
	private String strNameDisplay = null;

	/*
	 * ---------------------------------------------------------------------
	 * ------------------------- Specialized data --------------------------
	 * ---------------------------------------------------------------------
	 */

	/**
	 * Digital events related to the acquaintance.
	 */
	private ArrayList<EventDigital> collEventDigital = new ArrayList<EventDigital>();

	/**
	 * Material events related to the acquaintance.
```

```
 */
private ArrayList<EventMaterial> collEventMaterial = new ArrayList<EventMaterial>();

/**
 * Recent contacts with the acquaintance.
 */
private ArrayList<Contact> collRecentContact = new ArrayList<Contact>();

/**
 * Personal task with the acquaintance.
 */
private ArrayList<TaskPersonal> collTaskPersonal = new ArrayList<TaskPersonal>();

/**
 * Notes about the acquaintance.
 */
private ArrayList<Note> collNote = new ArrayList<Note>();

/**
 * Phone numbers of the acquaintance.
 */
private ArrayList<PhoneNumber> collPhone = new ArrayList<PhoneNumber>();

/**
 * Description of the first contact with the acquaintance.
 */
private FirstContact fcDescription = null;

/*
 * ---------------------------------------------------------------------------
 * -------------------------- Initial functions --------------------------
 * ---------------------------------------------------------------------------
 */

/**
 * Creates an acquaintance. Does not initialize any field.
 */
public Chijin()
{
	super();
}

/*
 * ---------------------------------------------------------------------------
 * -------------------------- Core functions --------------------------
 * ---------------------------------------------------------------------------
 */

/**
 * Adds a digital event related to the acquaintance.
 *
 * @param	eventNew	Event to add.
 */
public void addEventDigital(final EventDigital eventNew)
{
	collEventDigital.add(eventNew);
```

```
}

/**
 * Adds a material event related to the acquaintance.
 *
 * @param       eventNew        Event to add.
 */
public void addEventMaterial(final EventMaterial eventNew)
{
        collEventMaterial.add(eventNew);
}

/**
 * Adds a recent contact with the acquaintance.
 *
 * @param       contactNew      Contact to add.
 */
public void addRecentContact(final Contact contactNew)
{
        collRecentContact.add(contactNew);
}

/**
 * Adds a personal task with the acquaintance.
 *
 * @param       taskNew                 Task to add.
 */
public void addTaskPersonal(final TaskPersonal taskNew)
{
        collTaskPersonal.add(taskNew);
}

/**
 * Adds a note related to the acquaintance.
 *
 * @param       noteNew                 Note to add.
 */
public void addNote(final Note noteNew)
{
        collNote.add(noteNew);
}

/**
 * Adds a phone number related to the acquaintance.
 *
 * @param       phoneNew        Phone number to add.
 */
public void addPhone(final PhoneNumber phoneNew)
{
        collPhone.add(phoneNew);
}

/**
 * Returns the digital events related to the acquaintance.
 *
 * @return      Digital events related to the acquaintance.
```

```
 */
public ArrayList<EventDigital> getCollEventDigital()
{
	return collEventDigital;
}

/**
 * Returns the material events related to the acquaintance.
 *
 * @return	Material events related to the acquaintance.
 */
public ArrayList<EventMaterial> getCollEventMaterial()
{
	return collEventMaterial;
}

/**
 * Returns the notes about the acquaintance.
 *
 * @return	Notes about the acquaintance.
 */
public ArrayList<Note> getCollNote()
{
	return collNote;
}

/**
 * Returns the phone numbers of the acquaintance.
 *
 * @return	Phone numbers of the acquaintance.
 */
public ArrayList<PhoneNumber> getCollPhone()
{
	return collPhone;
}

/**
 * Returns the recent contacts with the acquaintance.
 *
 * @return	Recent contacts with the acquaintance.
 */
public ArrayList<Contact> getCollRecentContact()
{
	return collRecentContact;
}

/**
 * Returns the personal tasks with the acquaintance.
 *
 * @return	Personal tasks with the acquaintance.
 */
public ArrayList<TaskPersonal> getCollTaskPersonal()
{
	return collTaskPersonal;
}
```

```
/**
 * Returns the description of the first contact with the acquaintance.
 *
 * @return        Description of the first contact with the acquaintance.
 */
public FirstContact getFirstContact()
{
        return fcDescription;
}

/**
 * Returns the name displayed to represent the acquaintance.
 *
 * @return        Name displayed to represent the acquaintance.
 */
public String getNameDisplay()
{
        return strNameDisplay;
}

/**
 * Removes a digital event related to the acquaintance.
 *
 * @param        eventEnd        Digital event to remove.
 */
public void removeEventDigital(final EventDigital eventEnd)
{
        collEventDigital.remove(eventEnd);
}

/**
 * Removes a material event related to the acquaintance.
 *
 * @param        eventEnd        Material event to remove.
 */
public void removeEventMaterial(final EventMaterial eventEnd)
{
        collEventMaterial.remove(eventEnd);
}

/**
 * Removes a note related to the acquaintance.
 *
 * @param        noteEnd                Note to remove.
 */
public void removeNote(final Note noteEnd)
{
        collNote.remove(noteEnd);
}

/**
 * Removes a phone number related to the acquaintance.
 *
 * @param        phoneEnd        Phone number to remove.
 */
public void removePhone(final PhoneNumber phoneEnd)
```

```
{
        collPhone.remove(phoneEnd);
}

/**
 * Removes a recent contact related to the acquaintance.
 *
 * @param       contactEnd      Contact to remove.
 */
public void removeRecentContact(final Contact contactEnd)
{
        collRecentContact.remove(contactEnd);
}

/**
 * Removes a personal task with the acquaintance.
 *
 * @param       taskEnd                 Task to remove.
 */
public void removeTaskPersonal(final TaskPersonal taskEnd)
{
        collTaskPersonal.remove(taskEnd);
}

/**
 * Sets the digital events related to the acquaintance.
 *
 * @param       collEvent       New digital events related to the acquaintance.
 */
public void setCollEventDigital(final ArrayList<EventDigital> collNew)
{
        collEventDigital = collNew;
}

/**
 * Sets the material events related to the acquaintance.
 *
 * @param       collEvent       New material events related to the acquaintance.
 */
public void setCollEventMaterial(final ArrayList<EventMaterial> collNew)
{
        collEventMaterial = collNew;
}

/**
 * Sets the notes about the acquaintance.
 *
 * @param       collNew         New notes about the acquaintance.
 */
public void setCollNote(final ArrayList<Note> collNew)
{
        collNote = collNew;
}

/**
 * Sets the phone numbers of the acquaintance.
```

```
	 *
	 * @param	collNew		New phone numbers of the acquaintance.
	 */
	public void setCollPhone(final ArrayList<PhoneNumber> collNew)
	{
		collPhone = collNew;
	}

	/**
	 * Sets the recent contacts with the acquaintance.
	 *
	 * @param	collNew		New recent contacts with the acquaintance.
	 */
	public void setCollRecentContact(final ArrayList<Contact> collNew)
	{
		collRecentContact = collNew;
	}

	/**
	 * Sets the personal tasks with the acquaintance.
	 *
	 * @param	taskNew			New tasks with the acquaintance.
	 */
	public void setCollTaskPersonal(final ArrayList<TaskPersonal> taskNew)
	{
		collTaskPersonal = taskNew;
	}

	/**
	 * Sets the description of the first contact with the acquaintance.
	 *
	 * @param	fcNew		Description of the first contact with the acquaintance.
	 */
	public void setFirstContact(FirstContact fcNew)
	{
		fcDescription = fcNew;
	}

	/**
	 * Sets the name displayed to represent the acquaintance.
	 *
	 * @param	strNew		New name to display for the acquaintance.
	 */
	public void setNameDisplay(final String strNew)
	{
		strNameDisplay = strNew;
	}
}
```

Human class

```
package jinmyaku.human;

import java.util.*;
```

```
import jinmyaku.human.contact.*;

import cyberworld.universe.*;


/**
 * Implementation of a human.
 *
 * The current version manages a birthday, gender, unique identifier, usual
 * material location, a first name (international and national), a last name
 * (international and national), and a photo location.
 *
 * @author  Sebastien Duval
 * @version 0.15, 07/01/2006
 * @since   1.5
 */
public class Human
{
	/*
	 * ---------------------------------------------------------------------
	 * ---------------------------- Standard data --------------------------
	 * ---------------------------------------------------------------------
	 */

	/**
	 * Date of birthday.
	 */
	private Date dateBirthDay = null;

	/**
	 * First name in the international alphabet (e.g. roman).
	 */
	//private String strNameFirstInternational = null;

	/**
	 * First name in the national alphabet (e.g. Chinese, Korean).
	 */
	//private String strNameFirstNational = null;

	/**
	 * Last name in the international alphabet (e.g. roman).
	 */
	//private String strNameLastInternational = null;

	/**
	 * Last name in the national alphabet (e.g. Chinese, Korean).
	 */
	//private String strNameLastNational = null;

	/**
	 * Location of the photo of the human.
	 */
	private String strPhotoLocation = null;
```

```
/*
 * ------------------------------------------------------------------------
 * -------------------------- Specialized data ----------------------------
 * ------------------------------------------------------------------------
 */

private NamePack namPack = new NamePack();

/**
 * Gender of the human.
 */
private Gender genHuman = null;

/**
 * Unique identifier.
 */
private IdUnique idOwn = null;

/**
 * Usual material location.
 */
private LocationMaterial locmUsual = null;

/*
 * ------------------------------------------------------------------------
 * -------------------------- Initial functions ---------------------------
 * ------------------------------------------------------------------------
 */

/**
 * Creates a human. Does not initialize any field.
 */
public Human()
{
}

/*
 * ------------------------------------------------------------------------
 * --------------------------- Core functions -----------------------------
 * ------------------------------------------------------------------------
 */

/**
 * Changes the gender of the human. <tt>This name was chosen instead of
 * setGender to avoid incompatibilities when serializing as XML </tt>.
 *
 * @param       genNew          New gender of the human.
 * @see                         setGenderString
 */
public void changeGender(final Gender genNew)
{
        genHuman = genNew;
}

/**
 * Returns the date of birthday.
```

```
 *
 * @return        Date of birthday.
 */
public Date getBirthDay()
{
        return dateBirthDay;
}

/**
 * Returns the gender of the human.
 *
 * @return        Gender of the human
 * @see                   changeGender
 */
public Gender getGender()
{
        return genHuman;
}

/**
 * Returns a string representing the gender. Required for serialization.
 *
 * @return String representing the gender.
 */
public String getGenderString()
{
        if(genHuman == null)
        {
                return null;
        }
        else
        {
                return genHuman.name();
        }
}

/**
 * Returns the unique identifier that represents the human.
 *
 * @return        Unique identifier that represents the human.
 */
public IdUnique getIdUnique()
{
        return idOwn;
}

/**
 * Returns the usual material location.
 *
 * @return        Usual material location.
 */
public LocationMaterial getLocationMaterialUsual()
{
        return locmUsual;
}
```

```
/**
 * Returns the first name in the international alphabet (e.g. roman).
 *
 * @return        First name of the human.
 */
public String getNameFirstInternational()
{
        //return strNameFirstInternational;
        Name theNameTmp = namPack.getStandardNames().get("Current");
        String strBack = null;
        if(theNameTmp != null)
        {
                strBack = theNameTmp.getNameFirstInternational();
        }
        return strBack;
}

public NamePack getNamePack()
{
        return namPack;
}

/**
 * Returns the first name in the national alphabet (e.g. Chinese, Korean)
 *
 * @return        First name of the human.
 */
public String getNameFirstNational()
{
        Name theNameTmp = namPack.getStandardNames().get("Current");
        String strBack = null;
        if(theNameTmp != null)
        {
                strBack = theNameTmp.getNameFirstNational();
        }
        return strBack;
}

/**
 * Returns the last name in the international alphabet (e.g. roman).
 *
 * @return        Last name of the human.
 */
public String getNameLastInternational()
{

        Name theNameTmp = namPack.getStandardNames().get("Current");
        String strBack = null;
        if(theNameTmp != null)
        {
                strBack = theNameTmp.getNameLastInternational();
        }
        return strBack;
}

/**
```

```
 * Returns the last name in the national alphabet (e.g. Chinese, Korean).
 *
 * @return        Last name of the human.
 */
public String getNameLastNational()
{


        Name theNameTmp = namPack.getStandardNames().get("Current");
        String strBack = null;
        if(theNameTmp != null)
        {
                strBack = theNameTmp.getNameLastNational();
        }
        return strBack;
}

/**
 * Returns the location of the human's photo.
 *
 * @return        Location of the photo.
 */
public String getPhotoLocation()
{
        return strPhotoLocation;
}

/**
 * Sets the unique identifier that represents the human.
 *
 * @param        idNew   Unique identifier that represents the human.
 */
public void setIdUnique(final IdUnique idNew)
{
        idOwn = idNew;
}

/**
 * Sets the usual material location.
 *
 * @param locmNew     New usual material location.
 */
public void setLocationMaterialUsual(LocationMaterial locmNew)
{
        locmUsual = locmNew;
}

/**
 * Sets the first name in the international alphabet (e.g. roman).
 *
 * @param        strNew  First name of the human.
 */
public void setNameFirstInternational2(final String strNew)
{
        //strNameFirstInternational = strNew;
        Name theNameTmp = namPack.getStandardNames().get("Current");
```

```
		if(theNameTmp == null)
		{
			namPack.getStandardNames().put("Current",new Name());
		}
		else
		{
			theNameTmp.updateNameFirstInternational(strNew);
		}
}

public void setNamePack(final NamePack namNew)
{
		namPack = namNew;
}

/**
 * Sets the first name in the national alphabet (e.g. Chinese, Korean).
 *
 * @param	strNew	First name of the human.
 */
public void setNameFirstNational2(final String strNew)
{
		//strNameFirstNational = strNew;
		namPack.getStandardNames().get("Current").updateNameFirstNational(strNew);
}

/**
 * Sets the last name in the international alphabet (e.g. roman).
 *
 * @param	strNew	Last name of the human.
 */
public void setNameLastInternational2(final String strNew)
{
		//strNameLastInternational = strNew;
		namPack.getStandardNames().get("Current").updateNameLastInternational(strNew);
}

/**
 * Sets the last name in the national alphabet (e.g. Chinese, Korean).
 *
 * @param	strNew		Last name of the human.
 */
public void setNameLastNational2(final String strNew)
{
		//strNameLastNational = strNew;
		namPack.getStandardNames().get("Current").updateNameLastNational(strNew);
}

/**
 * Sets the date of birthday.
 *
 * @param	dateNew			Date of birthday.
 */
public void setBirthDay(final Date dateNew)
{
		dateBirthDay = dateNew;
```

```
        }

        /**
         * Sets the gender from a string. Required for serialization.
         *
         * @param       strNew  String from which the gender is identified.
         */
        public void setGenderString(String strNew)
        {
                genHuman = Gender.valueOf(strNew);
        }

        /**
         * Sets the location of the human's photo.
         *
         * @param       strNew              Location of the photo.
         */
        public void setPhotoLocation(final String strNew)
        {
                strPhotoLocation = strNew;
        }
}
```

InvalidChijinException exception

```
package jinmyaku.human;

/**
 * Implementation of an exception for invalid acquaintances.
 *
 * @author  Sebastien Duval
 * @version 0.10, 12/11/2005
 * @since   1.5
 */
public class InvalidChijinException extends Exception
{
        /**
         * Exception identifier.
         */
        private static final long serialVersionUID = -975176656922490024L;

        /**
         * Creates a new invalid chijin exception with <code>null</code> as its
        * detail message, and no cause.
         */
       public InvalidChijinException()
       {
         super();
       }

       /**
         * Creates a new invalid chijin exception with the specified detail message,
```

```
     * and no cause.
     *
     * @param        strMessage      Detail message.
     */
    public InvalidChijinException(final String strMessage)
    {
      super(strMessage);
    }

    /**
     * Creates a new invalid chijin exception with the specified detail message,
     * and cause.
     *
     * @param        strMessage      Detail message.
     * @param        throwCause      Cause of the exception.
     */
    public InvalidChijinException
    (
      final String strMessage,
      final Throwable throwCause
    )
    {
        super(strMessage, throwCause);
    }

    /**
     * Creates a new invalid chijin exception from a Throwable.
     *
     * @param        throwCause      Cause of the exception.
     */
    public InvalidChijinException(final Throwable throwCause)
    {
        super(throwCause);
    }
}
```

Jinmyaku class

```
package jinmyaku.human;

import java.util.*;

import jinmyaku.human.contact.*;


/**
 * Implementation of a human network.
 *
```

```
 * All operations ensure that representations of acquaintances are non-null,
 * and have a valid unique identifier.
 *
 * @author  Sebastien Duval
 * @version 0.13, 12/12/2005
 * @since   1.5
 */
public class Jinmyaku
{
	/*
	 * -------------------------------------------------------------------------
	 * ------------------------- Specialized data ------------------------------
	 * -------------------------------------------------------------------------
	 */

	/**
	 * Group of acquaintances (Chijin), associated to their unique identifier.
	 */
	private HashMap<String,Chijin> everybody = new HashMap<String,Chijin>();

	/*
	 * -------------------------------------------------------------------------
	 * ------------------------- Initial functions -----------------------------
	 * -------------------------------------------------------------------------
	 */

	/**
	 * Creates a human network. Does not initialize any field.
	 */
	public Jinmyaku()
	{
	}

	/*
	 * -------------------------------------------------------------------------
	 * ---------------------------- Core functions -----------------------------
	 * -------------------------------------------------------------------------
	 */

	/**
	 * Adds an acquaintance, indexed with its unique identifier.
	 *
	 * Throws an exception if the acquaintance or unique identifier's value
	 * is <tt>null</tt>.
	 *
	 * @param	chiNew		Acquaintance to add.
	 * @return	Whether the acquaintance was added or not.
	 * @throws	InvalidChijinException if the acquaintance to add is <tt>null</tt>.
	 * @throws	InvalidIdException if the identifier of the acquaintance is invalid.
	 */
	public void add(final Chijin chiNew)
	throws InvalidChijinException, InvalidIdException
	{
		String strKey = null;
```

```
		if(chiNew == null)
		{
			throw new InvalidChijinException("Chijin is NULL.");
		}

		try
		{
			strKey = chiNew.getIdUnique().getValue();
			if(strKey == null)
			{
				throw new InvalidIdException("IdUnique's value is NULL.");
			}
		}
		catch(NullPointerException excNull)
		{
			throw new InvalidIdException("IdUnique is NULL.",excNull);
		}

		everybody.put(strKey,chiNew);
	}

	/**
	 * Returns the acquaintance corresponding to the given key.
	 *
	 * @param	strKey		Key of the acquaintance (value of the unique identifier)
	 * @return	Acquaintance whose identifier matches, or <tt>null</tt> if there
	 *			is no mapping for this key.
	 */
	public Chijin get(final String strKey)
	{
		return everybody.get(strKey);
	}

	/**
	 * Returns the display names of members of the human network.
	 *
	 * @return	Display names of members of the human network.
	 * @throws	InvalidChijinException if an acquaintance is <tt>null</tt>, or if an
	 *			acquaintance's display name is <tt>null</tt>.
	 */
	public String[] getDisplayNames() throws InvalidChijinException
	{
		final Set<Map.Entry<String,Chijin>> setChijin = everybody.entrySet();
		final List<String> listDisplays = new ArrayList<String>();
		String[] strDisplays = null;

		for(Map.Entry meCurrent : setChijin)
		{
			Chijin chiCurrent = null;
			String strDisplay = null;

			try
			{
				chiCurrent = (Chijin) meCurrent.getValue();
			}
```

```
                catch(NullPointerException excNull)
                {
                        throw new InvalidChijinException("Chijin is NULL.",excNull);
                }

                try
                {
                        strDisplay = chiCurrent.getNameDisplay();
                }
                catch(NullPointerException excNull)
                {
                        throw new InvalidChijinException
                        (
                                "Chijin's display name is NULL.",
                                excNull
                        );
                }
                listDisplays.add(strDisplay);
        }
        Collections.sort(listDisplays);

        if(listDisplays.size() > 0)
        {
                strDisplays = new String[listDisplays.size()];

                int iCounter=0;
                for(String strNew : listDisplays)
                {
                        strDisplays[iCounter] = strNew;
                        iCounter++;
                }
        }

        return strDisplays;
}

/**
 * Returns the human network.
 *
 * @return Human network.
 */
public HashMap<String,Chijin> getEverybody()
{
        return everybody;
}

/**
 * Returns the unique identifiers of members of the human network.
 *
 * @return      Unique identifiers of members of the human network.
 * @throws      InvalidChijinException if an acquaintance is <tt>null</tt>.
 * @throws      InvalidIdException if the identifier of an acquaintance is invalid.
 */
public List<IdUnique> getIds() throws InvalidChijinException, InvalidIdException
{
        final Set<Map.Entry<String,Chijin>> setChijin = everybody.entrySet();
```

```
		final List<IdUnique> listId = new ArrayList<IdUnique>();

		for(Map.Entry meCurrent : setChijin)
		{
			Chijin chiCurrent = null;
			IdUnique idCurrent = null;

			try
			{
				chiCurrent = (Chijin) meCurrent.getValue();
			}
			catch(NullPointerException excNull)
			{
				throw new InvalidChijinException("Chijin is NULL.",excNull);
			}
			try
			{
				idCurrent = chiCurrent.getIdUnique();
			}
			catch(NullPointerException excNull)
			{
				throw new InvalidIdException("IdUnique is NULL.",excNull);
			}
			listId.add(idCurrent);
		}

		return listId;
	}

	/**
	 * Removes an acquaintance from the human network.
	 *
	 * @param chiEnd Acquaintance to remove.
	 */
	public void removeChijin(final Chijin chiEnd)
	{
		final String strKey = chiEnd.getIdUnique().getValue();
		everybody.remove(strKey);
	}

	/**
	 * Sets the human network.
	 *
	 * @param mapNew New human network.
	 */
	public void setEverybody(final HashMap<String,Chijin> mapNew)
	{
		everybody = mapNew;
	}
}
```