

ウェアラブル・コンピュータ受容のための基本的要件 ---初対面の自己紹介機能を例として---

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Satisfying Fundamental Needs With Wearables: Focus on Face-To-Face Communication

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Abstract – ウェアラブルコンピュータを活用することで、利用者の生活の質を改善できると期待されているものの、まだ必ずしも一般に広く受け入れられるには至っていない。本論文ではその原因を解明するため、マズローによる人間の基本要素階層を応用することを試みる。本理論を活用することで、一般人に受容されるウェアラブルコンピュータの特性を解明できる、というのが筆者らの仮説である。そこから導かれるのは人間の基本的要求を満足するウェアラブルコンピュータのコンセプトであり、筆者らはそれをサイバークローズと呼ぶことにする。第一次のアンケート調査を行ない、このコンセプトにより基本要素階層のうち生理レベルと安全性レベルの要求を満たしうることを確認した。しかし社会的帰属レベルについては必ずしも明確な結果を得られなかった。この調査結果をより明確にし、かつ仮説の妥当性を検証するため、プロトタイプ機を製作し実験を行っている。特に初対面での自己紹介に応用する局面について、この実験を紹介した。

Keywords : ウェアラブル・コンピュータ、サイバークローズ、心理学、マズロー理論

1 Introduction

Although wearable computers can improve our quality of life, they have not been widely adopted yet. This situation might be due to an excessive focus on technical aspects, and to a lack of interest in social aspects. A source of inspiration to investigate this idea is the hierarchy of needs defined by Abraham Maslow. Its main version includes five types of needs : physiological, safety, belonging, esteem, and actualization. We think that, so far, wearables have not taken these needs enough into account. Therefore our working hypothesis is that focus on human fundamental needs can foster the adoption of wearables.

If our theory is confirmed, it will provide the community with a way to foster the adoption of wearables, and motivate additional research in the field. As a consequence, people will benefit from wearable computers fulfilling certain levels of human needs, thus improving their quality of life.

In order to check our idea, we need to answer several underlying questions. Because the range of fundamental needs is wide, we need to focus on specific aspects. Which fundamental needs should we consider to test our hypothesis? According to which criteria can we make this decision?

The ideal approach to confirm our theory would be to develop numerous wearable computers, and see if

people are more likely to adopt those based on Maslow's theory than those not based on it. Unfortunately, this is not a realistic method because it is too expensive and time-consuming. We can however test a small set of wearables focusing on a limited scope of fundamental needs, and see if they confirm or infirm our idea.

Covering three of the five types of needs would already make our results meaningful. Because of our limited resources, we chose an hybrid approach that combines social studies and tests with prototypes. First, we carried out social studies in France and Japan, collecting information from the general public using questionnaires. Results validated our theory for physiological and safety needs, but challenged it for belonging needs. Then, to understand and counter factors of rejection in the latter case, we developed a prototype and services accordingly, and prepared experiments.

Our paper is therefore organized as follows. In section 2 we present Maslow's theory, related works, and our concept of cyberclothes. Then we present the results of the social studies, including emerging guidelines. In section 4 we describe our prototype and experiments on belonging needs. Finally we conclude and present future works.

2 Wearables satisfying fundamental needs

So far, wearable computers dedicated to the general public are rare. One reason is that the research focus has been mainly technical. To place people at the locus of attention we took into account the fundamental needs of

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human beings, and tried to satisfy them.

With *cyberclothes*, we introduce wearables that fit this objective, as explained hereafter. Creating this concept clarifies our goals, proposes a starting point for the design of wearables dedicated to the general public, and provides a framework for adoption of wearables on a wide-scale.

2.1 Maslow's hierarchy of needs

Maslow considered an ordered set of needs [1] including deficit needs and being needs. The first ones must be met before the second ones become salient. The usual representation of this theory is a five-level pyramid (figure 1), displaying most fundamental needs at the bottom. Based on this theory, a wearable fulfilling a person's needs should sustain in priority physiological needs, safety needs, then belonging needs.

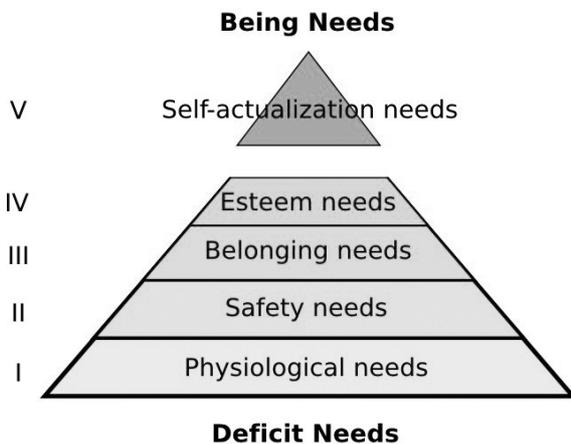


Fig. 1 Maslow's hierarchy of needs

Physiological needs (I) deal with homeostasis, and therefore with food, water, air, and sleep. Safety needs (II) are related to physical and psychological security : health, comfort, freedom from danger, and peace of mind. Belonging needs (III) include relationships and emotional involvement with people at large such as clubs, work groups, or family. Esteem needs (IV) are related to a person's self confidence, skills, and achievements. Actualization needs (V) are high level needs that are fulfilled by few people; they deal with achieving one's true nature.

The distinction between categories is not always clear-cut, for example relations with the family can fall into safety or belonging categories. For Maslow, categorization should be based on an individual's motivations.

2.2 Related works

Existing wearables can be classified using

Maslow's hierarchy of needs. The following classification considers the potential of devices rather than intended functions. Currently, we find wearables for levels I to IV. Designing wearables for level V is more difficult because it deals with the discovery and integration of one's nature.

On level I, wearables deal with physiological needs, and therefore basically with survival. Several models were designed for experts and specific uses; they help find and monitor the quality of vital resources and sustain good body conditions. Models developed for soldiers help find resources using a GPS, magnetic compass, and digital map [2]. Some provide ballistic and laser protection [2]. Others are under development to detect chemicals and biohazards [3]. For firefighters, the *LifeShirt* [4] monitors physiology as well as posture, and embarked sensors inform wearers and command centers [5] via wireless. Cheap sensors assess environments (temperature, oxygen, toxicity) as well as firefighter's location and health, which is vital for them and for people to rescue. Other models include a suit for survival in arctic environments [6] that regulates the wearer's temperature. These dedicated models are easily adopted because they can save their wearer's life.

Systems useful to the general public include a medical jacket [7] that prevents fatal heart problems, with electrodes to acquire ECG data, a CPU to compare it to a personalized profile, and a transdermal drug delivery component to inject nitroglycerin when required. There is also a watch [8] that monitors sleep and highlights anomalies revealing for example sleep apnea¹. Poor awareness about this vital issue certainly hampers the acquisition of such equipment.

On level II, wearables are dedicated to health, comfort, freedom from danger, and peace of mind. Several models of level I also support level II [10]. Novel features help navigate in urban spaces, and recognize persons encountered [11] for security purposes. By sending photos of scaring situations to acquaintances or to the police, the *StartleCam* [12] also improves physical safety. For health, we find systems that support exercise [13] and monitor diets [14].

On level III, wearables support emotional bonding. Standard functions satisfying belonging needs include e-mail and phone. A good example of novel application is the *galvactivator* [15], which emits light according to a wearer's stress. Other models tested in real environments include badges that display messages [16], inform people about

1 Sleep apnea syndrome is an health problem [9] that usually causes shallow sleep. It can lead to losses of consciousness during attention-requiring periods, which can be perilous, for example when driving.

relationships within their community, and help people know each other in more depth [17]. Garments that display graphics like *France Telecom's* tee-shirt [18] support communication and community belonging. Numerous fashion shows are organized in Japan, notably those prepared by *Team Tsukamoto* [19]. Fashion is also related to level III because it reflects belonging to communities, and establishes links between people.

On level IV, wearables support everyday and job tasks. Some of them are digital accessories including jewelry [20].

There are few studies on the perception and adoption of wearable computers. In 2001, a user study was planned to evaluate usability and acceptance of digital jewelry [20] but it has not been carried out yet². Studies of other devices, such as mobile phones, are of little use because their characteristics are so different: wearables can have any number and type of sensors, effectors, and can be used for a wide range of services.

2.3 Definition of cyberclothes

Based on Maslow's study of human needs, we define cyberclothes –in a nutshell– as garments that promote human growth and well-being. Such clothes:

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

This definition covers wide needs in order to describe cyberclothes that can be used in daily life. Well-being covers only physiological and safety needs. Awareness however deals with all needs because it helps feel secure, take good decisions, and increase control. Sociability is related to humans' safety needs and belonging needs. Using effectors, it is possible to use garments as a medium of communication. Normal garments already express a wearer's personality, feelings, or ideas. Enhanced garments can offer *mutability* : change their shape, modify graphics on their surface, produce smells, etc. Applications include the display of conversations' transcripts in real-time for a deaf person, translations for foreigners, or photos of common interests for strangers. Cyberclothes are not necessarily about wearers : garments may cooperate with other cyberclothes and smart artefacts to

produce a relaxing environment.

We considered the use of clothes because (1) people already wear normal garments in everyday life, (2) body contact offers possibilities such as monitoring of biosignals, and (3) garments provide a large surface for sensors and effectors. Many existing technologies can be used to create cyberclothes however there are still several challenges. Wires and soft components can be incorporated in garments. They can also benefit from flexible screens [18] but their resolution is still poor, and energy consumption is a persistent issue. Much research is still needed to incorporate other modalities (olfactory for example).

Like any garment, cyberclothes provide information about personality, and belonging to communities. With effectors and displays, such information can be dynamically modified or amplified. In addition to the social aspect, cyberclothes fulfill the functions of tools. For that, they should ideally evaluate physical and mental state of wearers, complement behaviors, support activities, and pass selected information to other entities. Besides, autonomy is important for cyberclothes to blend into people's life seamlessly. Results of social studies presented hereafter show however that it is a sensitive issue.

3 Social studies about wearables

These studies were designed to gather surface information about the general public's perception of wearables. Because people are unfamiliar with wearables, we focused on enhanced garments that respondents could easily imagine. In addition, we considered several aspects (hardware, intelligence, information, events), and everyday life situations.

Because physiological needs deal with survival, they are mostly fulfilled for average people. Therefore we focused on safety and belonging. Results validate the interest of the general public for enhanced garments that improve body condition, comfort, and safety, but indicate mixed feelings for belonging needs. The pattern is similar in France and Japan, but varies due to cultural and gender dimensions.

3.1 Method followed and scales

We 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 2 pages included seven series of closed-ended questions, and one open-ended question.

For closed-ended questions, participants rated assertions on a 5-point scale: 1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4-agree, and

² E-mail exchanges with Christopher S. Campbell, IBM Almaden Research Center, 02-May-2005.

5-strongly agree. The questionnaire was produced and checked by native speakers in French and Japanese. During analysis, we considered that a mean below 2.5 indicated a significant trend for rejection, and above 3.5 acceptance.

Due to cultural and ecological specificities, answers can vary between populations. Therefore, we 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. Questionnaire provided in electronic form were mainly distributed in universities, and via a PR 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.

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, but 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.

	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. French and Japanese respondents.

3.2 Perception of wearables in France & Japan

French and Japanese respondents show similar patterns of perceptions regarding wearable computers. However, some elements highlight a cultural and gender dimension. [21] introduced French results but not Japanese ones. Check our web site for a copy of our data [22].

Level I and II. 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 (heart beats, movements) to adapt my environment to my needs (temperature, light, music)*.

Figure 2 and 3 show that most accepted items improve body condition, comfort, or safety. The French and Japanese give high ratings to garments that adapt their temperature to the environment or analyze the air. Besides, physiological monitoring is considered positively to adapt the environment to users' needs, evaluate sportive performances, and inform emergency services. Because of the limited randomness of our samples, the *means* we calculated may be biased. Using the *t*-distribution, we confirmed intervals for our means, with a confidence of 95% (table 3.2).

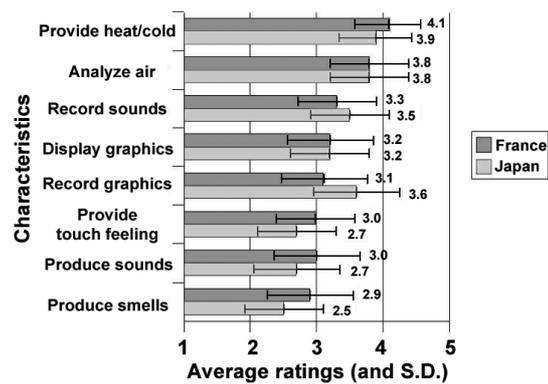


Fig. 2 Accept perceptual sensing and stimulations.

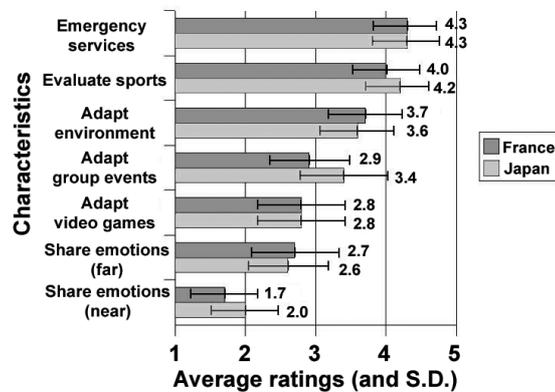


Fig. 3 Accept physiological monitoring

	French	Japanese
Emergency monitoring	4.2-4.5	4.0-4.6
Evaluate sports	3.9-4.2	4.0-4.5
Provide heat & 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. T-distribution (95%) for level I & II.

Level III. 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 (heart beats, movements) to reveal my emotions to surrounding people.*

Figure 3 and 4 show a good acceptance for wearables that help communicate in disrupted settings (during trips or with disabled people). However, several applications are considered neutrally : at a party, conference, when meeting new people, or to adapt events to the group. Finally, emotional displays are rejected.

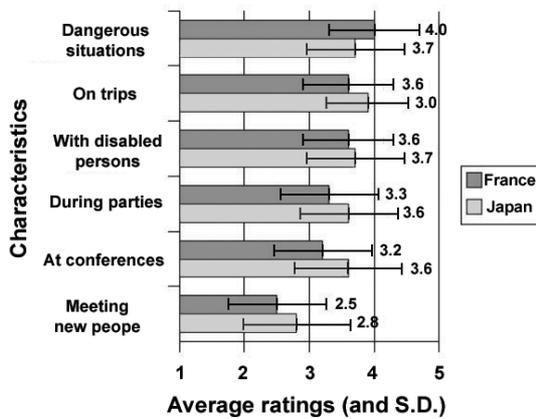


Fig. 4 Accept selected usages.

Using the *t*-distribution, we conclude that both Japanese and French respondents have mixed feelings about wearables for belonging needs (table 3.3). The intensity of acceptance can be very low (share emotions nearby), neutral (adapt group events), or very high (on a trip). All results are provided with a confidence of 95%. Note that two items indicate a significant cultural effect.

	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 (far)	2.5-2.9	2.3-2.9
Meeting new people	2.4-2.7	2.5-3.1
Share emotions (near)*	1.6-1.8	1.8-2.3

* significant cultural effect, $p < 0.05$

Table 3.3. Confidence of results for level III.

Miscellaneous features. As shown by the results of questions on *perceptual functions* and *physiological monitoring*, items unrelated to fundamental needs receive neutral ratings. These include the ability to produce smells or touch feelings, to display graphics, and adapt video games with biosignals.

The autonomy of wearables (figure 5) appears as an important factor. 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.* The Japanese prefer to use limited artificial intelligence whereas the French prefer full user-control. In both cultures, full control by an artificial agent gets the worst results; open comments from respondents state a fear that wearables with AI would harm them physically or socially.

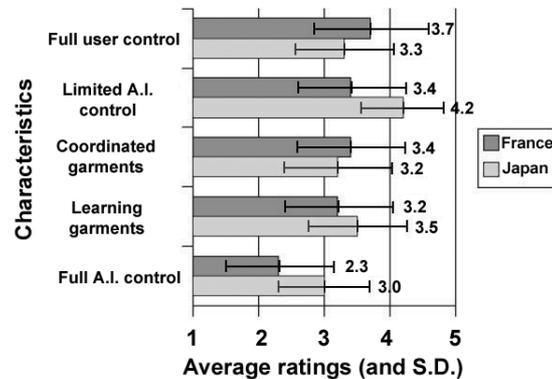


Fig. 5 Accept autonomy.

Cultural effect. Although French and Japanese respondents have a similar pattern of answers, there are occasional differences (2 items for level III in table 3.3). To avoid bias in future experiments (see section 4) and to improve the design of our wearables, we identified cultural factors of acceptance. To do so, we analyzed our data using *t*-test for unpaired samples (table 3.4). *p* defines the critical region.

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

Table 3.4. T-test analysis for cultural effect.

This *t*-test for unpaired samples (2-tailed) shows that French and Japanese have significant differences ($p < 0.05$) for the acceptance of some items. We reach a 99% certainty for enhanced garments that record videos, are under full or limited control of an AI. We reach a 98% certainty for enhanced garments that monitor physiology to produce group effects during artistic or sportive events, or to reveal the wearer's emotions to surrounding people. Finally we reach a 96% certainty for the use of enhanced garments for professional purposes. For level I and II, there is no cultural effect. However two items of level III indicate a cultural effect.

Gender effect. To complement the investigation of cultural effects, we considered the case of gender. Some answers suggest a gender effect; for example the acceptance of garments that vibrate or provide a feeling of touch is medium for males but low for females. Therefore, we analyzed our data using *t*-test for unpaired samples (table 3.5).

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

Table 3.5. *T*-test analysis for gender effect.

This *t*-test for unpaired samples (2-tailed) shows that males and females have significant differences for the acceptance of some items. We reach a 99% certainty for enhanced garments that record sounds, analyze the air, provide a feeling of touch, or monitor physiology to adapt video games. We reach a 98% certainty for enhanced garments used for professional purposes, or under full-user control. Finally we reach a 96% certainty for enhanced garments under full control of an AI. Only one of these items was directly linked to fundamental needs: analysis of the air.

3.3 Conclusions and guidelines for wearables

Our results for wearables on level 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 level III should be investigated further. Respondents are interested in wearables that help in exceptional situations (e.g. on trip or with disabled people) but not much in standard settings. Of particular interest is the rejection of wearables that help share emotions. We suspect that this rejection is due to a sense of vulnerability because people do not normally show their feelings to everybody. If we are right then the sharing of emotion was rejected because it went counter to safety needs. This would match Maslow's theory, that states a prepotency of lower needs over higher needs (e.g. safety has priority on belonging).

We established that the French and the Japanese show a similar pattern for level I and II, although there is a slight cultural and gender effect. Most differences are for items unrelated to fundamental needs (table 3.4 & 3.5). Because these two cultures are very different, these trends point to a certain universality of our results. Therefore we propose the following guidelines for the design of wearables :

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

Guideline A is related to level I and II of Maslow's needs. Because they increase peace of mind, guidelines B and C deal with level II. Guideline C deals with this level because the rejection of full AI is motivated by a worry for physical and social safety. Guideline B is also related to level III. Guideline D is loosely connected to all needs, reflecting that some elements are a bit more important than others depending on wearers' gender and culture. Besides, gender impacts on physiology, which is important for, for example, physiological monitoring (potential services for levels I to III). Guideline E is more technical and expresses a will to fully exploit cyberclothes' potential, for example being able to use surrounding sensors and effectors to make wearers' environments safer and more comfortable.

One way to validate further these 5 important guidelines is to carry out experiments with prototypes and services that partly or completely match the guidelines. Then wearers' satisfaction would be compared to the degree of respect of the guidelines. According to our theory these should be positively correlated.

4 Experiments for belonging needs

Questionnaires are a good way to collect superficial information about the general public's perception of wearables. However, experiments are more appropriate to compare settings and understand how to counteract the rejection of a feature; they enable us to get a deeper understanding of our results. Finally, experiments can clarify the validity of our design guidelines.

The results of the social study presented in the previous section indicate interest for wearables supporting physiological and safety needs. However it shows mixed feelings for belonging needs, making it a good target for additional investigations. Accordingly, we developed a prototype and services. The first one deals with the support of face-to-face first contacts, and the second deals with emotional displays. For practical reasons we chose to begin our experiments with the former one; experiments on the latter will be carried out later.

4.1 Scenario in everyday life

Face-to-face first contact (see figure 6). 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 armbands appear on your clothes and on a man close to you. Your badges adapt to each-other 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 cards and information gathered during the talk.



Fig. 6 Conceptual picture.

4.2 Prototype to support face-to-face contacts

We developed a prototype to improve sociability and provide emotional information. We based our design on scenarios described in [23]. The prototype (figure 7) consists of a jacket that can process data, communicate over a wireless network, render sounds, display graphics, and acquire physiological data (heartbeats, skin conductivity) from the wearer. A device with 3 buttons provides control to the user.

The first screen is a badge-size display placed on the chest, and the second is a laptop screen (26cm of diagonal) placed in the back. The intended role of the small screen is to display basic content such as name, and languages spoken, as well as photos or videos to support the wearer's ongoing conversations. It can also be used to display emotional information, for example with colors or smiley. The intended role of the big screen is to display multimedia content to attract the attention of passersby and to inform them about the wearer.



Fig. 7 Prototype for face-to-face support.

Although this prototype lacks features for use in everyday life (e.g. weight, softness), it is well-suited to study functional aspects. We can use it to study the acceptance of wearables that support face-to-face communication or provide emotional information. We can also study interactions in disrupted settings: between wearers from different cultural backgrounds, or with disabled persons. We can also use it to validate further our guidelines, for example regarding the acceptance of different levels of autonomy.

The prototype uses a computer with an Intel Pentium 1.6 Ghz processor, 500 Mb of RAM, and uses standard wireless (IEEE 802.11). The operating system is Windows XP with Service Pack 2. The connection of the small screen is done via a PCMCIA card, and the physiological data is acquired via a USB port. The prototype can be operated continuously for several hours.

4.3 Application: meeting new people

Face-to-face first contacts include meeting a person, conversing, and keeping in touch. Wearables can be used to support the whole process but we consider here only the first phase.

Successful first contacts require to catch the attention of interesting persons. As a solution, we considered the use of displays placed in the wearer's back. Although we can not usually see the front side of people engaged in conversations, we can easily see their back. Therefore, it is an appropriate area to display information, and to catch strangers' attention. Besides, viewers can easily walk away from an uninteresting-back-display without embarrassing the wearer; this would not be the case with a front display.

In our system (see figure 8), the garments of the wearer (called *displayer*) communicate with the computer (PDA, cyberclothes, or other wearables) of a passerby (called *viewer*). When a connection is established, the viewer's computer sends a list of keywords or HTML documents that describe the viewer's centers of interests. The displayer's garments compare the information received and stored. If common topics are found, photos belonging to the displayer are extracted accordingly, and a personalized slideshow is generated for the viewer.

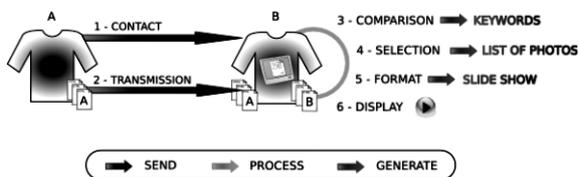


Fig. 8 Common interests displayed on garments.

We plan to check how interesting is an automatic system for the viewers, and how displayers reacts to people seeing slideshows about them in their back. Because the system is asymmetric, viewers get information about displayers, but the contrary is not true; displayers may not even be aware that somebody is seeing information about them.

To evaluate reactions (such as interest or frustration) of viewers and displayers, and to improve the system, we will investigate the following settings: (1) without feedback to the displayer, (2) with an LED indicating activity to the displayer, (3) with semi-transparent glasses providing to the displayer a copy of the content displayed on his or her back.

Besides, we want to estimate the impact of the system on the easiness to meet interesting people, and on information acquisition from a qualitative and quantitative point of view.

4.4 Framework for the service

Previously, we proposed a service based on dynamic content acquisition and delivery. Generating and displaying personalized slideshows is not the only service that cyberclothes can provide. Services can be diverse and follow various security and privacy policies. As a consequence, pulling together a demonstration application involves many aspects. The overall process includes the detection of services, their step by step management, and seamless manipulation of resources transferred or rendered (such as photos or videos).

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 mainly targets Internet applications, it is not directly applicable to face-to-face services, especially low latency for processing based on location-awareness.

Our own framework takes advantage of technologies involved in the semantic web. First, we use ontologies to share a common vocabulary to describe resources and capabilities of services. Second, we use XML to describe services and to annotate resources.

We describe services with XML because of its strength regarding interoperability. The following example (figure 9) includes inputs required from the service requester, outputs provided by the service provider, the function of the service, and information about privacy policies.

To be efficient, the ontology describing services needs to be semantically clear and rich. By efficient, we mean easy understanding of the service by humans as well as software agents, and achievement of complex tasks in dynamic environments involving numerous entities.

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.

In order to take advantage of existing resources, we considered HTML files as input of our service. XML annotations can be added to HTML files easily without compromising the files' integrity for other applications. This way, the same files can be used for cyberclothes' services as well as for the user's homepage. During the service, we process the files with a SAX (*Simple API for XML*) parser rather than a DOM (*Document Object Model*) parser, because

its event-driven model is more appropriate for the limited resources of wearable computers. Figure 10 is an example of photo annotation embedded in an HTML file, validated with a DTD.

```
<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>
```

Fig. 9 XML describing a service.

```
<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>
```

Fig. 10 XML describing a photo resource.

To enable manipulation of resources and facilitate maintenance, annotations need to 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 *concepts* required is huge, difficult to manipulate.

To alleviate the burden placed on users, the process should be automated as much as possible. Cameras can associate information related to time, and in some cases to position (GPS). Additional context data can be extracted from the computer's calendar, and identity of acquaintances appearing on photos can be inferred from recognition algorithms, using photos in the address book as a basis.

Therefore we propose to combine two ontologies. 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 would 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 annotations, 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.

4.5 User studies

Our main objective is to clarify the acceptance of wearables that support belonging needs. Thus we want to understand why emotional displays were rejected, and why several social uses of wearables are seen in a neutral way. Our second objective is to validate further our guidelines. Taking into account the main objective and our current resources, this leads us to focus on design guidelines B and D.

As explained previously, we created a first prototype and developed a service to support face-to-face first contacts and emotional displays. Using this service, we evaluate three settings: (1) in a disrupted setting, (2) at a party, and (3) when meeting new people. According to our social study, they respectively have high, medium, and low acceptance. For setting 1, we place a subject in a room for 15min and ask her to communicate with three persons that do not speak the same language; everybody wears a prototype. In setting 2, we ask a subject to wear a prototype and participate to a cocktail party for 30min; other attendees do not wear the system. For setting 3, two subjects wear the system and introduce themselves for 15min. All participants can train with the system 15 minutes.

Each setting is evaluated with two conditions: with and without an emotional display. The emotional display is synchronized with data extracted in real-time from bio-sensors (heartbeat and skin conductivity). The output is a patch that varies from blue (calm, slow heartbeats, low SCL) to red (excited, fast heartbeats, high SCL). This is a simple evaluation of emotional states, and interlocutors still have to guess if excitation is positive (happiness) or negative (anger).

The evaluation of the results is qualitative and quantitative. It takes into account the amount of information exchanged during the experiments as well as feelings expressed by subjects during a post-experiment interview. Final results will be checked against those of a control group.

We have begun our evaluation of the system with a pilot group of students in computer science. Our first tests indicate that the system works well. However it needs to be refined with users to improve the rules used to match common interests and photos. Besides, these tests raised issues regarding

the language in which annotations are written, for example comparison between Japanese and English annotations are problematic. Finally, we are currently refining our experimental protocol to investigate the impact of the system for *natural* face-to-face contacts with limited levels of artificiality. Results will help us confirm or infirm our hypothesis concerning Maslow's theory.

5 Conclusions and future works

In this paper we presented the first elements of an investigation about the possible contribution to wearable computers of Maslow's theories. We introduced the concept of cyberclothes, based on human fundamental needs. To check if we can foster the adoption of wearables by focusing on these needs, we considered an hybrid approach combining social studies and tests with prototypes.

The results of our social study in two dissimilar cultures confirmed the interest by the general public of wearables improving the two first levels of Maslow's needs. However, results for the third level were not conclusive. Consequently we developed a prototype to explore support for face-to-face communication. This prototype reacts to the presence of passersby and provides cues for communication. Besides, the prototype can evaluate the emotional state of the wearer using bio-sensors, and display it to support mutual understanding.

Our next step is to validate our hypothesis for higher needs (level III & IV). The prototype will be used for user studies. Qualitative and quantitative data will help identify factors of acceptance of wearables supporting belonging needs, and clarify the validity of related guidelines. Later we will consider in more depth gender and cultural issues.

Acknowledgments

The authors would like to thank Ryo Yoshinaka (University of Tokyo) and Takeshi Ozawa (University of Tokyo) for translating the questionnaire into Japanese, and Valérie Moreau (Laval Mayen-ne Technopole) for helping disseminate the French one.

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(2005年7月21日受付)

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