Human Universality in Ubiquitous Computing: Maslow, Where Are You?

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Abstract

Too narrow, the productivity-oriented vision guiding ubiquitous computing should be replaced or enriched with humanistic aspects. We discuss the role of Maslow's hierarchy of needs in the creation and adoption of smart spaces, robots and wearable computers worldwide to provide elements for alternative visions of ubiquity. We show that current ubiquitous systems are stratified at the lowest levels of the hierarchy. Based on interviews, questionnaires and experiments, we highlight a positive correlation between the hierarchy of needs and the general public's perception and possible adoption of services. Finally, we discuss implications of these results, and notably the importance of creating humanistic frameworks, services and environments.

1. Introduction

Human needs should be at the heart of ubiquitous computing as they are at the heart of our lives because emerging technologies permeate our physical and social worlds in the form of smart spaces, robots and wearable computers, with little considerations for national borders. Scholars, inventors and artists should cooperate to provide humanistic frameworks, services and environments worldwide on the long-term to ensure the pertinence of their works beyond technical potentials and commercial interests.

However human aspects are usually neglected as can be seen from the core vision of ubiquity and from the nature of systems designed. Mark Weiser's dated vision [23] deeply influences ongoing research in ubiquity and maintains an agenda marked by a search for efficiency and productivity. Alternative visions of the future are missing although insightful analyses by Genevieve Bell [4][5] and a few others suggest changes are under way. We believe that a humanistic perspective will benefit the general public worldwide on the short-term by providing new visions and by promoting the creation of more useful and more appropriate systems.

Here, we highlight and investigate aspects of human universality in ubiquity because we do not know of any such works at the moment whereas human diversity benefits from some efforts (e.g. age [7][9], culture [4][5], spirituality [5]). We consider *needs* (aka basic, essential, natural needs) and not *wants* (aka pressing needs) [20] to provide a clear and realistic scope of research: needs are limited whereas wants are unlimited, and needs are not based on choice although their satisfaction allows choice. As a starting point, we consider Maslow's hierarchy of needs.

Hereafter, we introduce Maslow's theory then consider existing ubiquitous system from his perspective. We then describe our investigations of the public's perception of ubiquity, notably checking the match between the hierarchy of needs and people's requests and fears. Finally, we discuss the potential impact and role of Maslow's theories on ubiquity and conclude.

2. Maslow's theory as model of universal needs

Abraham Maslow, the psychologist at the origin of the humanistic movement, established the existence of a hierarchy of needs that motivates human behaviors [16]. He identified the following five fundamental needs, listed by order of decreasing potency (Figure 1): physiological, safety, belonging, esteem, and self-actualization needs.

Maslow hinted at the universality of his hierarchy of needs, and his successors strengthened his position, highlighting that the *essence* of the needs seems universal although their *expression* varies from person to person and from group to group due to e.g. personal history, culture and environment. Finally, he added that some behaviors are unmotivated, corresponding to the expressions of one's personality and past rather than to a need.

Thus Maslow's theories establish a clear and strong basis to identify and prioritize services and designs worldwide from a human point of view, though with a focus on usefulness that ignores dimensions of art and entertainment.

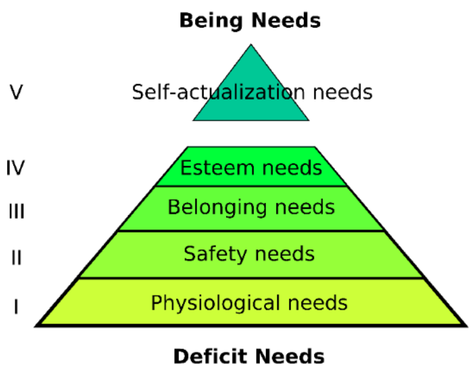

Figure 1. Maslow's hierarchy of needs.

Physiological needs target homeostasis (food, sleep, air, heat). Safety needs target physical (no illness or war) and mental (freedom, stability) security. Belonging needs deal with relationships (family, coworkers, etc.). Esteem needs include respect (from others) and self-esteem (achievements, skills). Self-actualization needs are the highest; they incite us to fulfill our potential.

Lower needs have priority over higher ones; when a need is satisfied, higher needs become salient. However full satisfaction of a need is not required before the emergence of higher needs: priorities evolve gradually. Alternatively, lower needs can come back into focus: when facing a crisis (job loss, divorce, etc.), one can drop to a lower level that reflects needs of what was 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.

3. Current ubiquitous systems in Maslow's hierarchy

Ubiquitous computing is exceptional because its services are available to users in most places, most of the time, and can exploit body- or context-related features (e.g. physiological monitoring, presence of acquaintances) in real-time. Ubiquity is thus particularly well-suited to assist humans in everyday life worldwide on both short- and long-term.

So far, ubiquitous systems have been designed mainly for artificial needs and for lower basic needs but not for higher basic needs (self-esteem and self-actualization). Most services appear at the bottom of the hierarchy of needs, and are perceived as most useful, which is logical because they deal with survival. Services gratifying higher needs are missing because their design is more difficult and because it implies the discovery and integration of one's nature and motivations.

For lack of place, we present hereafter only examples of wearable computers and let intelligent environments and robots aside.

3.1. Level I: Physiological needs

Several wearables dealing with physiological needs were designed for experts and specific uses; they help find vital resources such as water in deserts, monitor their quality e.g. through tests for their composition, and sustain good body conditions. The *Twenty First Century Land Warrior* models were developed to help soldiers find resources with Global Positioning Systems, magnetic compasses and digital maps [24], and to provide partial ballistic and laser protection [24]. Others were created to cool soldiers in deserts or detect and protect against chemicals and biohazards. Similarly, equipment for firefighters is under development such as the *LifeShirt* by Vivometrics, which continuously monitors physiological states as well as posture, or other prototypes combining embarked sensors with wireless to inform on-site members and command centers [14]. Cheap sensors assess environments (temperature, oxygen, toxicity) as well as the location and health status of firefighters, which is vital for them and for endangered people. Other models include suits for survival in arctic spaces [18], which notably support thermoregulation of the wearer's body; the main problem being energy. These dedicated models are easily adopted because they can reduce injury and risks of death for the wearers.

For the general public, we find a medical jacket [13] that monitors cardiovascular activity, using electrodes to acquire data and a unit to compare it to a personalized profile, and that may prevent fatal heart problems thanks to a component that can inject drugs when required. Such vests are potentially useful to a non-negligible number of citizens suffering from heart problems due to obesity, genetic expressions or ageing. Similarly, the *SmartShirt* by Sensatex exploits various sensors to monitor and help the wearer.

Systems beneficial to the general public include watches that monitor sleep [2] and highlight anomalies revealing e.g. sleep apnea. Poor awareness about this vital issue hampers the diffusion of such equipment, leading to reduced productivity and quality of life, and to premature death. Another device is the *GlucoWatch* [22], which monitors blood content and was designed for diabetics. *Lifewatcher* [1] tracks food intakes, medicine use and activities, with services on mobile devices. To maintain health with appropriate diets and exercise, sensor-based (movements, temperature, ultraviolet or heartbeats) support systems can be used (e.g. [15]).

Although related to physiology and safety, wearables dedicated to environmental or ecological issues are scarce.

3.2. Level II: Safety needs

Diverse wearables are dedicated to health, comfort, freedom from danger and peace of mind, providing features such as the recognition of bystanders and alerts in case of earthquake or imminent tsunami. Surveillance systems for the army [19] can be adapted for the general public for either practical or critical applications, e.g. to help people suffering from Alzheimer's disease. Systems possibly useful for rare events include the *StartleCam* [12], which transmits photos of the environment when e.g. fear is detected. Technologies available in Japan and embedded in cell-phones offer 3D information to find escape ways in case of natural disasters such as earthquakes. Children are also considered, with wearables that inform kids and parents about dangers on the way back home [21]. Creative ideas include garments that produce smells to relax wearers [3] and fight against depression.

3.3. Level III: Belonging needs

Standard services satisfying belonging needs include phone calls, e-mail and social network support. Services dedicated to wearables include the disclosure of emotions e.g. with the *Galvactivator* [17], which emits light according to evaluated arousal. Other devices include badges that display messages [11], inform people about relationships within their community and help people know each other in more depth [6]. Garments displaying graphics may also support communication and community belonging.

3.4. Level IV: Esteem needs

Esteem needs do not benefit from notable wearable services as we ignore how to increase respect and how to guide towards meaningful achievements.

4. Social studies on ubiquitous computing

We gathered surface information about the world general public's current perception of ubiquity because this lacking information should guide the creation of systems. We focused on easy-to-imagine smart clothes because existing data mainly relates to small devices and smart spaces and because people are unfamiliar with ubiquity. For useful results, we considered hardware, functions, autonomy, and everyday life.

Due to costs of and required technologies for ubiquity, users' physiological needs should be mostly fulfilled. We thus focused on safety and belonging. Results are mixed for belonging but validate interest in smart clothes that enhance body condition, comfort and safety. A pattern appears in France and Japan, with variations due to culture and gender.

4.1. Method followed and scales

We interviewed 26 computer scientists and psychologists to design a questionnaire for the public. From feedback by a pilot group, we rewrote questions and added an introduction. The 2 pages included 7 series of assertions and an open-ended question; natives checked the French and Japanese versions. Assertions were rated with 1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4-agree, and 5-strongly agree. We considered that means below 2.5 signify rejection, and above 3.5 acceptance. French and Japanese citizens (Table 1) allowed interesting comparisons because of their cultural and ecological differences.

Table 1. French and Japanese respondents.

	Male (FR)	Female (FR)	Male (JP)	Female (JP)
Number	115	59	61	54
Age Range	14 - 67	14 - 58	19 - 54	14 - 45
Age Mean	26	25	29	30

We distributed questionnaires in public places (coffee shops, bars, train stations) on weekdays and week-ends and by e-mail in universities and via a public-relations department, which provided large samples with moderate randomness. Respondents included artists, designers, librarians, reporters, students, teachers, researchers, engineers, secretaries, salesmen, managers, housewives, retirees, medical staff, soldiers, and preachers.

Respondents answered without time limit, usually in 15 minutes in public places. No photo or video of systems was shown but a short text introduced the study as research on new technologies: clothes possessing particular features, capacities, and some intelligence. The text also indicated that Japan, France, and America were designing prototypes.

Finally, we carried out experiments with fourteen Algerian, French, German and Japanese people aged 21-32 y.o., including two females. The experiments consisted of 10-minutes discussions between a participant wearing an enhanced jacket (Figure 2) and two interlocutors simulating an encounter at a professional seminar.

Figure 2. Wearable system created for the experiments.

The jacket supported conversations with a front screen and evaluated the wearer's arousal with sensors for heartbeats and skin conductivity. Personal data was uploaded wirelessly, and users could act by touching the screen or manipulating a multi-button device. The equipment, interface and JAVA-based framework are detailed in [8].

4.2. Physiological and safety needs

Our investigations show that the French and Japanese general public want smart clothes that satisfy physiological and safety needs (Figure 3). According to discussions and free comments, this attraction reflects unfulfilled needs and the acceptability of technological solutions.

The public could reject physiological monitoring because it is novel, potentially invasive, and carries a *cyborg* connotation but, unexpectedly, services based on it are significantly accepted. Marked interest for emergencies, sports, temperature maintenance, and air quality suggests services to develop in priority. Edmison's study [10] about the perception of medical wearables complements and validates further these results.

Besides, negative reactions to autonomy for smart clothes show that the non-respect of safety needs can lead to rejection (Figure 4). According to respondents, their rejection of full control by artificial intelligence (A.I.) lies in fears of physical and social harm resulting from agents' actions. For example, an agent could cause sickness by setting temperature too low, or embarrassment by showing inappropriate photos to one's boss or wife. In such cases, both real and perceived dangers matter.

Figure 3. Acceptance of services for physiological and safety needs.

Reactions towards emotional displays also demonstrate the influence of safety needs. Garments revealing the wearer's emotions are rejected, especially if disclosure is local (e.g. to interlocutors during face-to-face discussions). Our experiments indicated that apparent uselessness and dangerousness cause rejection (Figure 6). Besides, rejection varies with the social distance to potential viewers.

Because the concerns about autonomy and emotional displays are not based on personal experience, they might be reduced by contact with such features, especially if introduced progressively. Familial settings seem most promising for emotional displays because they are perceived as safest and most useful. However, safety concerns may rise due to a higher awareness of e.g. privacy issues, which are well-known for cell-phones, laptops and online medical services.

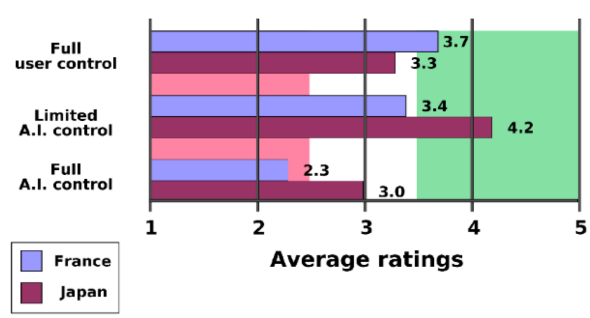

Figure 4. Acceptance of A.I. control based on danger perception.

4.3. Belonging needs

Respondents show much interest in communication support for disrupted settings (Figure 5), namely during trips and with people having a disability. However the analysis is inconclusive for several items, and concludes to the rejection of physiological monitoring to share emotions, and of support for first encounters. To clarify these results, we designed a wearable system focusing on emotional displays and on support for first encounters (Figure 2).

Figure 5. Acceptance of services for belonging needs.

During experiments, participants communicated while wearing an enhanced jacket that analyzed data to identify common interests and displayed slideshows of related photos. Comparing answers to questionnaires before and after experiments showed a shift in perception attributable to experience with an actual system. The marked rise in acceptance of the service (+1 point on a 5-points scale) demonstrates that the negative perception of support for first encounters can be quickly overcome. However, short personal experiences do not suffice to promote emotional displays. Feedback from participants shows that perceived danger and uselessness cause rejection (Figure 6); finding appropriate solutions requires complementary investigations.

To conclude, the results highlight the importance of physiological, safety and belonging needs in ubiquity. Besides, the experiments confirm the priority of lower needs over higher needs (e.g. safety over belonging).

4.4. Cultural and gender effects

Although French and Japanese respondents answer similarly, occasional differences appear. To avoid bias in evaluations and to improve designs, cultural factors of acceptance should be identified. As a first step, we identified several design elements significantly influenced by demographic dimensions, using t-tests for unpaired samples (Figure 7 for culture and Figure 8 for gender).

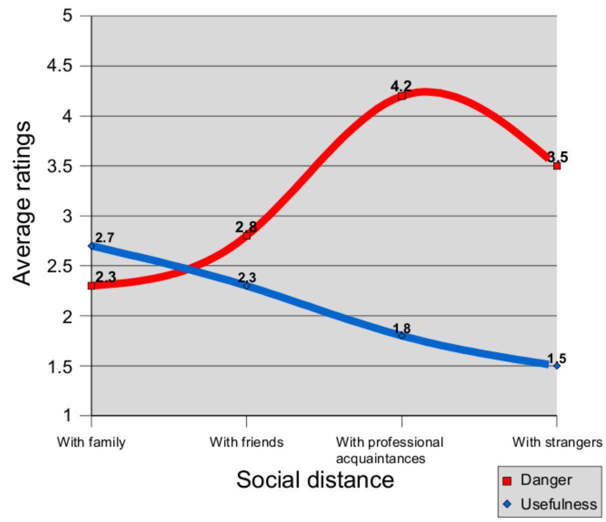

Figure 6. Perceived danger and usefulness of emotional displays.

If we consider only *significant* cultural differences, the Japanese globally accept smart clothes more than the French. The latter score higher only for *professional uses*.

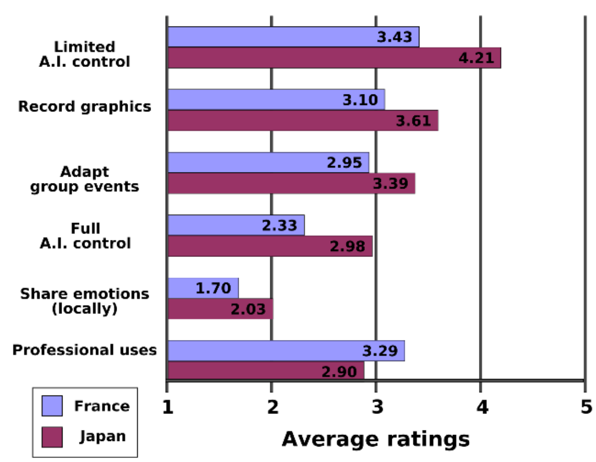

Figure 7. Items indicating a significant cultural difference, p$<$0.04

If we consider only *significant* gender differences, males systematically accept smart clothes more than females, which is consistent with the established literature on technology. Females score higher than males only for *full user control*, which is the only feature clearly restricting technology.

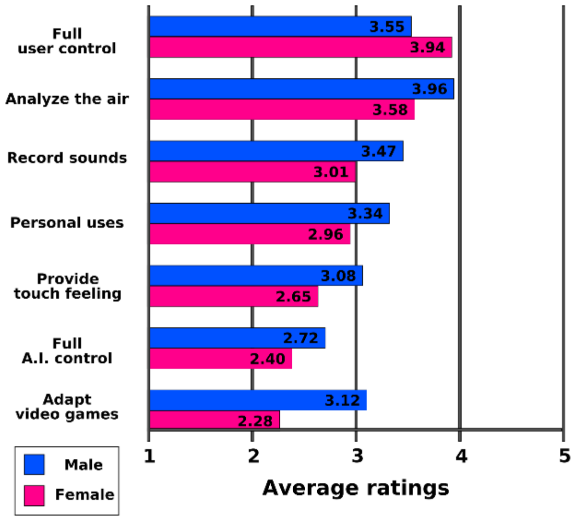

Figure 8. Items indicating a significant gender difference, p<0.04

The roots of these cultural and gender differences are unclear. Possible candidates include: religion (A.I. control), current acceptance of other technologies (A.I. control, share emotions, video games), risk perception (A.I. control, provide touch feeling), communication stratification (share emotions), individuality and harmony (group events).

5. Discussion

Although requiring additional validations, our results should apply to all forms of ubiquity (intelligent environments, robots, wearable computers) worldwide and at any moment because Maslow's theories are independent of the technologies concerned.

So far, the community has selected the concepts of ubiquitous systems worth investigating based on Mark Weiser's vision of the twenty-first century, with an auto-catalytic effect that led to the neglect of basic needs even among young researchers. The titles and abstracts of publications in the main dedicated conferences and journals (*Ubicomp*, *Percom*, *Personal and Ubiquitous Computing*) illustrate the current focus on efficiency and productivity. In these scientific papers, words like "quality of life" are almost non-existent, and the word "needs" usually refers to artificial needs or to a mix of artificial and basic needs. The multiplication of prototypes and use-cases did not solve the problem because the community's agenda hinders the coverage of potential application domains and the emergence of diverse pluridisciplinary groups. Systems exist for some physiological and safety needs but few–if any–satisfy self-esteem or self-actualization needs although it would greatly benefit individuals and societies.

Besides restricting purposes, Weiser's vision restricts features: design tools are clustered around the concepts of context-awareness and invisibility. But where is the modelling of user's needs, not the list of tasks to do at a place or another, but real needs? If it has been done then it lacks a visible status. Such a modelling requires the consideration of both the *essence* of needs and their *expression* because human needs are quite universal but preferred gratification means notably depend on personal tastes and culture. Besides, we can wonder about the significance of context-awareness and invisibility. Context-awareness is a dead-end if it is disguised artificial intelligence, which itself failed decades ago. As for invisibility, it may in fact be a feature to avoid because it rises feelings of insecurity: how can one feel safe while wondering if some device records speech or if some movement will trigger an unknown action? This is true for houses as well as for offices or public places.

Efforts towards the modelling of human needs may be very valuable as they would provide a strong basis for ubiquity and as they would benefit the world population in other contexts. Culture-dependent aspects would require most efforts and collaborations with humanities specialists but would inform much about useful and appropriate services and interfaces for individuals and groups in varied settings. Because ubiquity suggests travels and contacts with other physical or social contexts, this modelling could also be used to facilitate understanding and communication between travellers in the real world or in digital worlds.

In the same sense that we support modelling human needs rather than pursuing context-awareness, we support visibility rather than invisibility. For example, visions of forests reacting to the presence of humans appear to us creepy and may remind of fairy tales that thrilled or frightened us during our childhood. Invisibility is good when it does not directly concern users. Invisibility is bad when one does not know whether something is happening, whether data is being or may become recorded, whether a useful or critical service is available, whether our orders are being carried out properly or not. Safety needs are second only to survival, and the feeling of insecurity is tantamount to insecurity because it stresses and influences our behaviors in the same way. The potential feeling (or even real) insecurity raised by excessive control by machines or by invisibility should therefore not be neglected, both at the infrastructure and service levels.

As a conclusion, Maslow is absent in the "ubicomp" research community's vision of ubiquitous computing and is only slightly perceptible in prototypes and products although he is fully present in the wishes and fears of the general public. Because one of the specialists' stated goals is to bring ubiquity to the masses, the community should strive to bridge the gap between laboratories and the real world based on Maslow's findings.

6. Perspectives

We investigated the potential role of Maslow's hierarchy of needs in the creation and adoption of ubiquitous systems worldwide to provide elements for alternative visions of ubiquity. While current research mainly follows Mark Weiser's vision, we argue that the community should focus on human universality and diversity to fulfill the potential of ubiquity.

Since no study had been done on the influence of human universality on the research, development, and adoption of ubiquitous computers, we considered altogether the visions in ubiquitous computing, existing prototypes, and the general public's perception of ubiquity. Our analysis confirms that universal needs are ignored in the main vision of the field, that prototypes do not cover their full scope, but that laymen's wishes and fears are related to Maslow's hierarchy of needs. We accordingly suggest to establish humanistic ubiquitous frameworks, services and environments.

We are currently considering perspectives from other major psychologists and sociologists to see how they complement or contradict Maslow's theories. Besides, the current work indicates that the research community should investigate systems to satisfy self-esteem and self-actualization needs as such prototypes are missing and as we do not know yet how to create them. Finally, one challenge will be to integrate findings concerning human universality and human diversity in ubiquitous computing.

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