Analysis of Wearable Interface Factors for Appropriate Information Notification

Vlaho Kostov, Jun Ozawa, Satoshi Matsuura
Advanced Technology Research Laboratories
Panasonic - Matsushita Electric Industrial Co., Ltd., Kyoto, Japan
vlaho@ieee.org

Abstract

This paper explores the emotional and the functional aspects of a new type of wearable notification interface. Three wearable devices with different shape, color and size have been developed: tangible mascot, box-shaped notifier and PDA virtual agent. They have a common function: to assist the user in various situations in every-day life. Likert scale questionnaires have been used to analyze the users' attitudes and preferences towards the interfaces in two basic modes: passive by visual observation and active through use-case scenarios. A separate study was conducted to correlate the visual effect patterns with the notification-message context. The usability of the proposed interfaces was measured by SUS (System Usability Scale). The relevant factors for appropriate information notification of each wearable interface were obtained and analyzed. The mascot was shown to be a preferred interface suitable for developing a personal relation with the user, while the box-shaped interface was found to be most helpful and suitable for business use.

1. Introduction

With the ubiquitous network society vision becoming a reality, the traditional information terminals such as digital televisions, mobile phones and car navigation systems will eventually become integrated into every aspect of daily life and a sophisticated information network environment will evolve. Especially with the proliferation of broadband communication, people can now instantly access Internet information, use e-mail via portable devices and even pay bills electronically. We are thus entering the ubiquitous network society where networks are accessible at any time and from anywhere with the personal and wearable communication devices considered as one of its driving engines.

In this study, three different wearable interfaces were developed and evaluated. Section 2 gives an overview of the current research work regarding remind/alert systems and introduces our wearable notifier approach, its basic hardware configuration and our initial hypotheses. Section 3 elaborates in more detail the evaluation method, the experiment procedures and the twelve use-case scenarios that are divided into three situational groups and four notification categories. Section 4 covers the discussion and analysis. Finally, Section 5 summarizes the current findings and further research developments as conclusion.

2. Notifier

As the personal assistance in a mobile environment becomes more pervasive, many of the current wearable computing products have already included some sort of notification functions based on time, location or context. However, we must ensure that those systems work autonomously and do not require additional time. Therefore we focused on investigating the relevant factors that influence the user's perception of appropriate information notification using different wearable interfaces and defining the most appropriate type and mode of notification that will prevent the information overload and will guarantee the user's positive experience.

2.1. Conventional notifier

There are many Personal Information Management development efforts based on desktop, place, context or location metaphors [1]. As most notification events provide potentially valuable information at a cost of interruption, it is important to know the value and priority of each event. One of the approaches to allow timeliness and reliability without being intrusive utilizes Instant Messaging (IM) as an alert delivery channel with e-mail as a backup channel. All alerts that a user subscribes to are first delivered to a centralized delivery preference customization module that acts as a personal alert router to protect the privacy [2]. Such approaches are complementary to the systems that assess the criticality of the messages [3] and the systems that concentrate on the

Proceedings of the Eighth International Symposium on Wearable Computers (ISWC'04)
1530-0811/04 $ 20.00 IEEE

functional aspects of general inter-person communications [4]. Others have explored awareness application displaying event notification in a form of scrolling messages across a single-line window [5]. Some works try to establish framework where different autonomous agents can easily work together to deliver total benefit to the users [6]. The tangible interfaces approach not constrained to the virtual space of the digitally stored information has been introduced as well [7]. Finally, different scenarios have been developed around the concept of Ambient Intelligence, envisioning the future technologies for the Information Society. People will be surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and they will benefit from services and applications in an environment that is capable of recognizing and responding to the presence of different individuals in a seamless way [8].

2.2. Our approach

This paper explores the personality as well as the emotional and the functional aspects of a new type of wearable interface for information notification. Three wearable devices have been developed: mascot, box-shaped notifier and PDA virtual agent (Fig. 1).

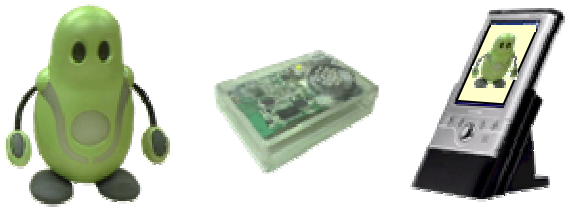

Figure 1. Wearable notification devices

Despite the significant difference in shape, color and size, they all have the same functionality in assisting the user or the owner in various situations in every-day life. The concept envisions a wearable device that evolves into a future partner and assistant that knows the owner's profile and context and accurately provides the desired information in a timely manner. Nowadays most of the needed technologies are available, thus the primary issue becomes the challenge to make an attractive and unobtrusive system that combines all the communication and information retrieval functionality (Fig. 2).

Our work addressed this issue by exploring which functionalities and factors of the interface contribute to positive user experience in using a wearable notification device. This is particularly important as the product differences in price, quality and specification diminish and other criteria such as technology experience emerge as a differentiate factor [9].

Figure 2. Ubiquitous future partner and assistant

2.3. Architecture

The wearable interfaces have been designed in order to explore the basis for providing the ability for people to relate in predictable ways to digital wearable artifacts. The common communication and interaction capabilities of the three interfaces are wearability, wireless communication capability, integrated Bluetooth module, programmable buttons, visual effects capability with variable frequency and colors (blue, green, cyan, red, purple, yellow, white) and audio effects capability (sounds, music, speech)

The mascot and the box-shaped notifier have the same hardware architecture with different embodiment, as shown in Fig. 3.

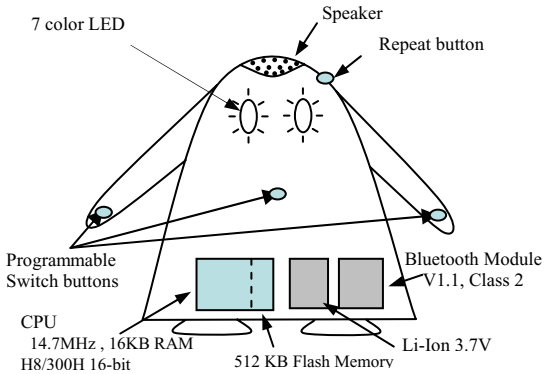

Figure 3. Configuration and hardware components

The virtual agent is composed of a software emulator that displays an agent image of the mascot. It is capable of generating exactly the same audio and visual effects as the other notifiers.

2.4. Our hypotheses

The development of an always-with-us wearable interface as an everyday life assistant is based on the following hypotheses which served as the basic principles for the design:

Hypothesis 1: When having two products with similar hardware specifications and functionality, the one with a

compelling embodiment and ability to personalize with the user will be preferred.

Hypothesis 2: The experimental evidence suggests that the relationships between colors are in many respects universal and relatively free from individual and cultural influences [10]. We assume that in cases such as when the message context is unknown or unclear: A) Red is associated with urgency, work and "shall be done", green is associated with private and non-urgent items and yellow and white are associated with low priority; B) The visual-effects blinking frequency is proportional to the priority of the message; C) Mixed colors indicate uncertainty.

Hypothesis 3: The passive (observation) and the active (interaction) perception of the same products or systems are different.

Hypothesis 4: It is possible by a statistical analysis to find out the particular functions and visual characteristics that the personal and wearable products should have for seamless HCI (Human Computer Interaction).

3. Evaluation

A four stage study was used to examine the validity of the hypotheses as shown in Fig. 4. It was conducted with 10 subjects, 9 male and 1 female, age span from 22 to 38 years old. Each subject experienced all 4 stages, taking approximately 25-30 min to complete the test.

Likert scale questionnaires have been used to analyze the users' attitude and preferences towards the interfaces in two modes: passive, by visual observation (Stage 1), and active, through use-case scenarios (Stage 3). Separate studies were used to correlate the visual effect patterns with the notification context (Stage 2) and to assess the usability of the interfaces (Stage 4).

As the emotions elicited by the appearance of wearable products are often difficult to express in words, especially across cultures, we wanted to avoid a purely verbal questionnaire. On the other hand, while the face emotional expressions were shown to be culturally independent [11], and in particular the cartoon faces suitable to be used as non-verbal attributes, its shortcoming is the time consuming development process. Therefore, in the questionnaires in Stage 1 and 3 we used a novel approach of a combination of traditional word-attributes and non-verbal cartoon face attributes.

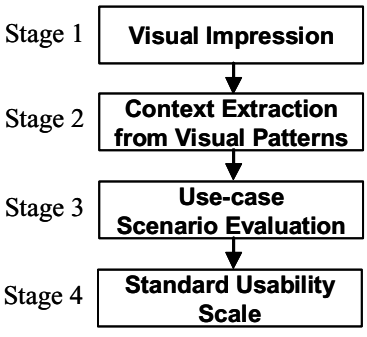

Figure 4. Evaluation flow

3.1. Visual impression study

In order to measure the user's emotional response to a wearable product appearance, the three interfaces were shown to the subjects for few minutes of visual inspection. Before the start of the experiment, the subject were told that they are going to see, experience and evaluate different types and shapes of wearable personal notifiers. A brief introduction of their capabilities and functionalities was given:

- Main purpose is to assist its user in various situations in everyday life, providing different information
- It is a device that always knows the owner's profile, situation, context and environment.

Then the subjects were asked to evaluate the 3 interfaces on a scale of 1 to 5 (strongly disagree to strongly agree) along 18 attributes. Six attributes were non-verbal cartoon faces taken from a previously developed cartoon vs. emotion set [12]. The remaining twelve attributes (desire, pleasant surprise, amusement, admiration, satisfaction, fascination, contempt, disgust, unpleasant surprise, dissatisfaction, disappointment, boredom) were chosen as a subset of the word attributes defined by Desmet [13]. The subjects were asked to express their feelings about the visual appearance of the interfaces by assigning their level of agreement with the expression of each cartoon face and the twelve word attributes.

3.2. Context extraction from visual patterns

This study was performed in order to correlate the visual notification patterns (blinking frequency, color, length) with the notification-message content. Nine notification messages - three variations each of three different general statements - were presented to each subject. Each notification message was composed of a visual color-blinking effect and an audio event made of synthesized speech utterance giving general and ambiguous information such as "you've got e-mail". All messages had the visual-audio-visual-audio-visual event sequence, whose details are given in Table 1 where, R=Red, G=Green, B=Blue, W=White and Y=Yellow color. After each notification, the subjects were asked to try to guess the content of the message by selecting a multiple choice item for each of the three categories as shown in Table 2.

Table 1. Notification messages sequence details of the context extraction study

	Visual effect	Audio event
1	$t_{1=100ms}$ R t_1 R t_1 R t_1 $3t_1$	You've got e-mail
2	$t_{1=50ms}$ R t_1 R t_1 G t_1 $3t_1$	You've got e-mail
3	$t_{1=100ms}$ R t_1 B t_1 W t_1 G t_1 $3t_1$	You've got e-mail
4	$t_{1=200ms}$ W t_1 W t_1 W t_1 W t_1	Today you have something important
5	$t_{1=100ms}$ R t_1 R t_1 R t_1 R $3t_1$	Today you have something important
6	$t_{1=200ms}$ G t_1 G t_1 G t_1 G t_1	Today you have something important
7	$t_{1=200ms}$ G t_1 R t_1 G t_1 R t_1 $3t_1$	Please check!
8	$t_{1=50ms}$ Y t_1 R t_1 Y $2t_1$ R t_1 Y $2t_1$ R t_1 $3t_1$	Please check!
9	$t_{1=200ms}$ Y t_1 Y t_1 Y t_1 Y t_1 $3t_1$	Please check!

3.3. Use-case scenario evaluation

The subjects evaluated the notifications events of twelve use-case scenarios, for both the mascot and the box-notifier, using fourteen attributes on a 1 to 5 scale. Four of the attributes were cartoon faces and ten were word attributes (interesting, contemporary, friendly, pleasant, funny, helpful, exciting, attractive, cool, natural). The scenarios were grouped in three situational groups: visual-silent mode (office / meeting / museum), audio non-intrusive mode (driving) and audio-video mode (home / private) and four notification types: e-mail, alarm / schedule reminder, Location Based Event (LBE) and telephone call, as shown in Table 3. A short explanation about each scenario was given before the actual notifications were played on both notifiers. After being presented 4 scenarios of the same situational group, the subjects evaluated each interface respectively. In case of the Audio group the subject filled out only one questionnaire as the notifications were played on an

Table 2. Message content study

From	Priority / Importance	Action needed
a) **Work** (Boss, Co-worker)	a) **Urgent**	a) **Yes**
b) **Private** (Friend-Hobby-Family)	b) **Normal**	b) **No**
c) **Unknown**	c) **Unknown**	c) **Unknown**

Table 3. Scenario overview

		Situational group		
		VISUAL - Silent mode Office/Meeting/Museum	AUDIO Driving	VISUAL + AUDIO Home / Private
Notification	E-mail notification	Scenario 01	Scenario 05	Scenario 09
	Alarm/Reminder/Schedule	Scenario 02	Scenario 06	Scenario 10
	Location Based Event	Scenario 03	Scenario 07	Scenario 11
	Tel. Call	Scenario 04	Scenario 08	Scenario 12

independent sound source and we assumed the visualization did not influence the audio evaluation (especially in use-case scenarios of driving). Thus the participants of this study filled out 5 questionnaires in total. Each use-case notification message consisted of a visual effect, an audio event or a combination of both. The following subsections give a detailed description of each scenario, where R=Red, G=Green, Y=Yellow and C=Cyan color.

3.3.1. Visual - silent mode.

Scenario 1: Bob is in his office. This week his colleague has an important deadline, and he is presenting him the final report document. During the presentation, he receives a non-urgent e-mail. The system senses Bob is busy and it is not an appropriate moment for e-mail, so it gives him a silent notification to check his e-mail later. Visual effect: G-G-G-Y-Y, repeated three times.

Scenario 2: It is 10:00am. Bob is at a managers meeting that will last until 11:00am. The system checks Bob's schedule and realizes that he has another meeting at

10:30am with a new customer. It knows that Bob is at a meeting and uses the silent mode to give him a discrete signal to check his schedule. Visual effect: R-R-R-Y-Y, repeated three times.

Scenario 3: Bob is visiting a ubiquitous network fair. He is particularly interested in home-networking technologies. The system knows his interests, so when he approaches the Future House exhibition, it gives him a friendly notification that the next hall contains items from Bob's preference list. Visual effect: Y-Y-Y-G, repeated three times.

Scenario 4: Bob is again in a meeting, and he receives a telephone call from his supervisor about an urgent problem. Visual effect: R-R-R, repeated three times.

3.3.2. Audio – driving.

Scenario 5: Bob is driving to his company HQ for a business meeting. While he concentrates on the bad traffic condition, he receives a business e-mail. The system is context sensitive and announces he has received a non-urgent e-mail that he can check later. Audio event: "Mail has arrived" synthesized voice preceded and followed by an artist designed ringing tone.

Scenario 6: It is 18:30h. Bob has just finished the report and is leaving the company parking, driving back to his home. The system knows he has left the office, checks his private schedule and reminds him of his wife's birthday so on the way home he should buy her flowers and a nice present. Audio event: "You have an important event today" synthesized voice preceded and followed by an artist designed ringing tone.

Scenario 7: Bob is in a hurry driving to an important meeting. He is approaching a big crossing giving a right signal. The system knows Bob's destination as well as the traffic condition (traffic congestion in the right turn street), so it suggests him an alternative route. Audio event: "There is always a traffic jam in that street" - synthesized voice preceded and followed by a ringing tone.

Scenario 8: It is almost lunch time; Bob is driving and wondering if he should eat in the city or in the company cafeteria. The phone rings, and it seems as a call from a good friend living nearby. Bob decides to accept the call and invite him for a lunch. The notifier gives an audio notification for an incoming telephone call. Audio event: Artist designed ringing effect.

3.3.3. Audio/Visual - home/private.

Scenario 9: Bob and his wife are spending a weekend at home watching a family photo album in their living room. The notifier is on the small coffee table next to them, and it tells them that an interesting/important e-mail has arrived. Visual effect: G-C-G-C, repeated twice; audio event: "Master I have mail for you" synthesized voice, preceded and followed by a tone effect.

Scenario 10: It is 8:15am, Wednesday morning and Bob is rushing to his office. When he goes out of the door, the notifier senses that it is the day of the non-burnable garbage collection, which Bob has not disposed yet. It reminds him to bring it out on his way to the parking lot. Visual effect: Y-R-Y-R-Y-R, repeated twice; audio event "Today is the garbage day" synthesized voice, preceded and followed by a tone effect.

Scenario 11: Bob discusses with his wife and his son where to spend the Sunday afternoon. They agree to go to a park nearby. The system understands the context of their conversation and tells them it is not a good idea because it is going to rain. Visual effect: Y-Y-Y-Y, repeated twice; audio event "It is going to rain" synthesized voice, preceded and followed by a tone effect.

Scenario 12: Bob is watching his favorite team playing soccer on a Sunday afternoon. It is a rainy day and his son is calling to tell him he will arrive at the train station in 10 min so he should pick him up by car. The notify-system knows it is a call from a family member and sends a visual and audio notification of the importance. Visual effect: C-C-G repeated twice; audio event: ringing tone effect.

3.4. System Usability Scale

In the context of usability of the proposed interfaces, System Usability Scale (SUS) was used. SUS is a reliable, low-cost usability scale that can be used for global assessments of systems usability [14]. Its objectives are to provide an easy test for subjects to complete (i.e. minimal number of questions), to be easy to score, and to allow cross-product comparisons. The SUS is a Likert scale 10-item questionnaire with overall value scores in a range of 1 to 100.

4. Analysis & discussion

In order to obtain a graphical representation of the results, a correspondence analysis was performed with two variables: Attributes (6+12 categories) and wearable interface type (3 categories). Correspondence analysis is a technique for describing the relations between two nominal variables in a correspondence table in a low-dimensional space, while simultaneously describing the relationships between the categories for each variable. For each variable, the distances between category points in a plot reflect the relationships between the categories with similar categories plotted close to each other. Unlike Factor analysis, Correspondence analysis assumes nominal variables and can describe the relationships between categories of each variable, as well as the relationship between the variables. In order to focus on how the variables are related to each other and to obtain the bi-plot, we use a symmetrical normalization. For each dimension,

the row scores are the weighted average of the column scores divided by the matching singular value, and the column scores are the weighted average of row scores divided by the matching singular value.

Figure 5 shows that the box-shaped notifier elicits mostly negative attributes; the mascot elicits amusement, fascination and admiration, while the PDA elicits a cluster of mixed attributes. Similarly, the positive cartoon faces were associated with the mascot, while the negative ones to the box. The normal face was closest to the PDA model. The analysis of the average Likert scale scores for each attribute was given in Table 4, which confirms the correspondence analysis plot and likely validates our first hypothesis.

Table 5 shows the results of the visual pattern vs. message context study as a percentage of the total subject's evaluation per each notification message. It shows that there are 3 distinct message patterns:

1. Work-Urgent-Yes: notification 1, 5 and 8
2: Private-Normal-No: notification 4, 6 and 9
3. Uncertain: notification 2, 3 and 7

Table 4. Visual evaluation average score

	Mascot	Box	PDA
	1.70	2.30	1.90
	3.80	2.50	3.60
	3.40	3.20	4.00
	2.20	2.30	2.60
	2.40	2.30	2.40
	3.90	2.20	3.10
Desire	3.30	2.20	3.30
Pleasant Surprise	3.30	2.20	3.20
Amusement	4.00	1.80	3.00
Admiration	3.80	2.70	2.70
Satisfaction	2.90	2.30	3.10
Fascination	4.00	2.30	2.80
Contempt	1.60	1.90	1.70
Disgust	1.90	1.70	2.00
Unpleasant Surprise	1.90	2.20	1.80
Dissatisfaction	2.30	2.60	2.30
Disappointment	1.70	2.30	1.90
Boredom	1.90	3.50	2.40

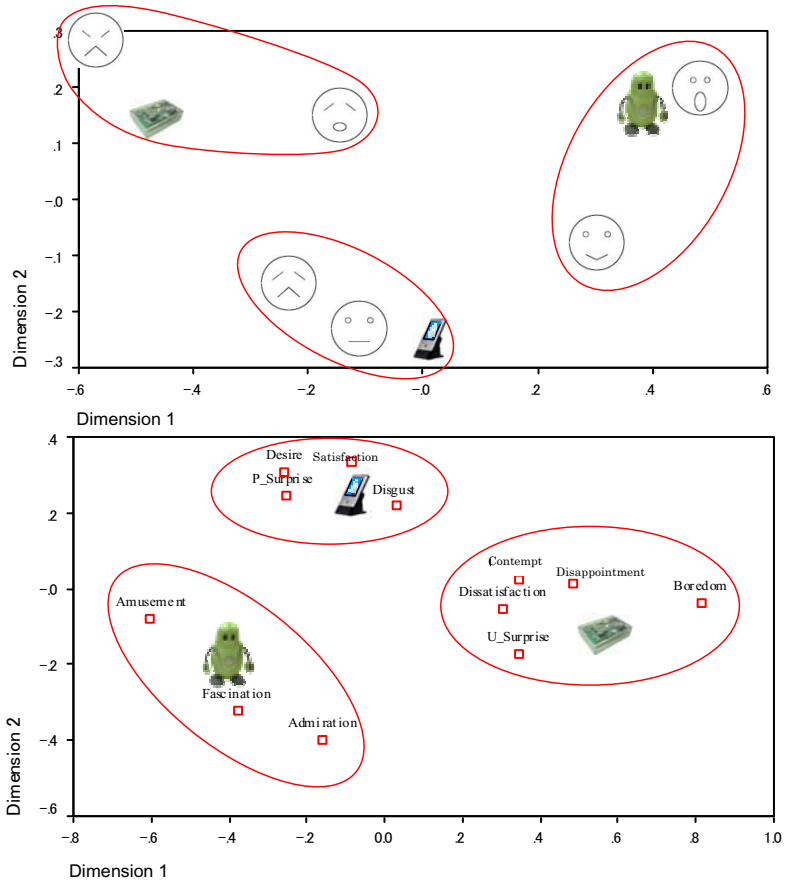

Figure 5. Correspondence Analysis

Table 5. Context evaluation by visual patterns

		From			Priority/Importance			Action needed		
		Work	Private	Unknown	Urgent	Normal	Unknown	Yes	No	Unknown
1	You've got e-mail	70%	10%	20%	70%	30%	0	70%	30%	0
2	You've got e-mail	30%	40%	30%	60%	10%	30%	80%	20%	0
3	You've got e-mail	20%	40%	40%	20%	60%	20%	20%	30%	50%
4	Today you have smth. important	20%	80%	0	0	100%	0	40%	60%	0
5	Today you have smth. important	80%	0	20%	80%	20%	0	80%	20%	0
6	Today you have smth. important	0	80%	20%	20%	70%	10%	20%	70%	10%
7	Please check	60%	10%	30%	30%	50%	20%	70%	0	30%
8	Please check	70%	10%	20%	100%	0	0	90%	0	10%
9	Please check	0	90%	10%	0	100%	0	20%	70%	10%

It is reasonable to expect that this validates our second hypothesis: work related and urgent messages (1, 5, 8) were always red colored and with the highest frequency; the private related non-urgent notifications (4, 6, 9) were white, yellow and green colored with a very low frequency. Although notification composed of mixture of urgent color (red) and non-urgent color (green, white) generally produces unclear context prediction, the presence of red color still gives impression of "urgent" and "action needed". Mixture of green, blue and white gives impression of normal priority, however it still remains unclear whether an action is needed and if it is work or private related. A mixed message of alternating red and green gives the impression of work related with unknown importance. It is interesting to note the co-occurrence of the "high priority" messages with "work related". In our future work, we will investigate the differences of the context extraction from visual patterns between different types of interfaces.

The scenario evaluation study results are shown in Table 6. It gives the average scores of the attribute evaluation for the mascot and the box in the three situational groups of use-case scenarios.

Table 6. Scenario evaluation

	Visual		Audio	A/V		Total	
	Mascot	Box		Mascot	Box	Mascot	Box
	3.8	2.8	4.30	4	3.4	4.03	3.50
	3.4	3.7	3.70	3.5	3.3	3.53	3.57
	2	2.3	2.10	2.1	2.2	2.07	2.20
	2.7	2.4	3.10	3.3	2.9	3.03	2.80
Interesting	4	2.2	3.60	3.7	3.4	3.77	3.07
Contemporary	3.7	2.9	3.40	3.7	3.5	3.60	3.27
Friendly	4	1.9	3.60	3.6	2.7	3.73	2.73
Pleasant	3.8	2.2	3.50	3.7	3	3.67	2.90
Funny	3.2	2.1	2.80	3	2.4	3.00	2.43
Helpful	3.8	3.8	4.40	4.1	4.5	4.10	4.23
Exiting	2.7	2.4	3.10	3.1	2.9	2.97	2.80
Attractive	3.1	2.1	3.00	2.7	2.8	2.93	2.63
Cool	3	2.8	3.00	3.1	3.1	3.03	2.97
Natural	3.2	2.3	3.30	2.8	2.6	3.10	2.73

In case of the visual scenarios, most of the positive scores were given to the mascot, very similar to the case of passive (visual evaluation) of the interfaces. The Box had a highest score for the Normal-cartoon face. As the audio capabilities of all the interfaces were the same, the audio scenarios were evaluated only once. The "audio" highest scores were given to Face-Happy and "Helpful" attribute. However, in case of the audio-visual scenarios, the advantage of the mascot is greatly decreased, i.e. the differences between the Box and the mascot across all attributes become significantly smaller. The "Helpful" attribute changed in favor of the Box, and both had similar scores for Cool, Contemporary and Attractive. It was shown that the implementation of the audio into the notification event brings significant positive evaluation effect in favor of the Box. This result suggests that during the initial passive impression evaluation at Stage 1, despite the given brief information about the functionalities of all the interfaces, the subjects could not imagine all the capabilities of the simple-shaped Box (such as speaking). Therefore, all of the positive attributes were given to the mascot, the artifact that has a certain shape and body implying that it has more human-like characteristics such as speaking. However, after the user-case evaluation, the voice addition overshadowed some of the mascot features and the evaluation becomes more identical. This is in accordance with the previous studies about multiple voices on computers [15]. Furthermore, the strong difference between the results of the passive evaluation (observation) and the active evaluation (user-scenario) shows the credibility of our third hypothesis.

Most of the attributes that reveal personalization (friendly, interesting, funny, etc) were associated with the mascot, while the functional ones such as helpful or contemporary were associated with the Box notifier. This suggests that both interfaces are appropriate for a wearable notification, however their further development should be in two different directions along their respective high score attributes. The Box interface should be targeted for a

business usage, while the mascot should target the private and family related activities. These findings support our fourth hypothesis.

The SUS study reveals that although the total SUS score across all subjects was only slightly better for the mascot than for the box (67.5 versus 66.0), 70% of the subjects had higher SUS for the mascot against 20% for the box and only 10% had equal SUS. It shows that while most of the subjects perceive the mascot as useful digital artifact, there are subjects that extremely like and extremely dislike the box interface as shown in Table 7.

Table 7. SUS results

	Mascot	Box
Preference	70%	20%
Total SUS	67.5	66

Further analysis of the individual items of the SUS, reveals that the box interface is considered as "easy and confident to use", the mascot is considered as "various functions are well integrated" and "people would learn to use it quickly", while both were considered as "would like to use frequently".

5. Conclusions

Our wearable interfaces have been designed to allow studies of novel system concepts, which today may still require a lot of equipment to realize, but they can be expected to become compact enough to disappear in the background in the near future.

With this study, the socio-cognitive problems in using wearable agent systems were identified. It was shown that the passive and the active perception of such interfaces for personal communication significantly differ. By analyzing the relevant factors for appropriate information notification of each wearable interface, the mascot was shown to be a preferred interface suitable for developing a personal relation between the users and their wearable agent-communicator, while the box-shaped interface was shown as most helpful and suitable for business use. It was also proved that when we have two products with similar hardware specifications and functionality, the one with compelling embodiment and ability to personalize with will be preferred.

In visual notification messages, it was shown that red color is associated with urgency and work related issues, while green color is associated with private and low urgency. Red and green color mixture produces uncertainty about the context. The visual effects blinking frequency is proportional to the priority of the message. It was possible to differentiate the particular functions that the personal and wearable products evoke against the users, which would enable us to develop agent interfaces and devices for seamless HCI.

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