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User Expectations in Intelligent Environments

Issues and Opportunities in the Interaction of Intelligent Users and Intelligent Environments

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Abstract The definition of Intelligent Environments [1] has always been focused around their *users*, aiming at helping them in a smart and transparent way, and avoiding bothering them or acting against their will. The complexity of IEs, whose technologies range from sensors to machine learning, from distributed architectures to tangible interfaces, from communication protocols to data analysis, challenges researchers from various fields to contribute innovative and effective solutions. In this quest for technical solutions to the myriad requirements of an intelligent environments, user expectations are often left behind, and while researchers tend to focus on niche technical aspects, they risk of losing the big picture of an IE "helping users in their daily life".
This paper analyzes the recent literature of the Intelligent Environments' research community, aiming at highlighting to which extent users are taken into account, or are involved, into the reported research works. Evidence shows that, while most papers refer to users in their description, only a small minority actually involve them in the design, testing or experimentation phases.

Keywords Usability · User Expectations · User Modeling · Interaction

Mathematics Subject Classification (2010) 68U35 · 68M14

1 Introduction

Every definition of Intelligent Environment (IE) [1], Ambient Intelligence (AmI) system [9], Smart Environment (SmE) [5], since the early inception of these disciplines and the key seminal works, puts a strong emphasis on the *users* living, working or otherwise exploiting the smart space. All researchers agree that the benefit for the users, the help that the system may provide them in their daily lives and activities, the usability of their interfaces, and the ability to serve, understand, and anticipate their needs and desires, should be the primary goal of every IE being designed, and its true *raison d'être*.

If this is the primary goal of our research area, we should question how well we, as a research community, are pursuing it, and how much we are investing in its direction. Even a cursory look at the literature on the relevant journals and conference proceedings reveals that a really limited number of works directly involve end users, or their needs, in research objectives or methods. The complexity of Intelligent Environments, in fact, requires significant advances in several research areas, including sensors, wireless communications, localization, power optimization, communication protocols, device-to-device interoperability, intelligent distributed platforms, big data storage and analysis, prediction and recommendation capabilities, just to name a few. There is no surprise, therefore, that the width of this interdisciplinary field attracts research from many different specialized disciplines, aiming at providing a useful contribution to the many issues raised by IE and AmI systems.

However, the lack of focus on user needs, user behaviors, and actual interaction of real end users (who are likely to be anthropologically different from researchers and engineers) is at the basis of many failures, both at the research level (where interesting results fail to

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be applied) and at the market level (where technically advanced products fail miserably[1]).

This paper, that stems from the interesting discussion around a keynote talk [6] at the Worskhop on Reliable Intelligent Environments in 2018, will analyze from the qualitative and quantitative points of view the contributions of past papers to the user involvement aspects. Section 2 analyzes the user expectations, i.e., what functionality and which features users expect from an Intelligent Environment; expectations are either induced by the promises coming from the research community and by market offerings, or appear spontaneously from users according to their daily routines and needs. Sections 3.1 and 3.2, on the other hand, analyze the research directions, i.e., aim at describing the effort of the research community towards end users; in particular, Section 3.1 describes the adopted analysis methodology, while Section 3.2 presents the results that have been found. A critical discussion over the collected results is presented in Section 3.3, and finally the paper is concluded in Section 4.

2 User Expectations

User Expectations can be defined as what users expect from a product, service or a digital asset, in particular concerning the consistency of their behavior and functionality. Users form their expectations from different sources: from the research agendas, especially when interpreted and popularized by mainstream media, from existing or announced products, and from their own experience.

2.1 Related work

Let us consider the definition of Ambient Intelligence (AmI) proposed by Cook *et al.* [5] (emphasis added):

> "An Ambient Intelligence system is a digital environment that proactively, but sensibly, *supports people in their daily lives.*"

or the definition of Intelligent Environment (IE) given by Augusto *et al.* [1] (emphasis added):

> "An Intelligent Environment is one in which the actions of numerous networked controllers [. . .] are orchestrated by self programming pre-emptive processes [. . .] in such a way *to create an interactive holistic functionality that enhances occupants experiences*".

In both cases, it is clear that the ultimate goal of any AmI/IE systems[2] should be to affect the users occupying the environment (for living, studying, working, healing, entertaining, etc.).

These definitions imply that the focus of most research works should acknowledge users as the ultimate goal, and explicitly consider their needs or involve them in the research. However, IE are complex systems, and to realize their potential they need to involve a large number of technologies and span several architectural layers. For example, an IE should generally include various kinds of sensors, sensor networks, wireless communications, outdoor and indoor localization, low-power devices, mobile and/or wearable user terminals and applications, image and object recognition, protocols for data publication and collection, decentralized (edge) or centralized (cloud) storage and processing nodes, semantic (big) data analysis, interoperability API, intelligent data analytics, actuator control, prediction and recommendation capabilities, etc. Each of these topics and technologies is complex and deserves the attention of the research community by itself; in the context of IEs, furthermore, they need to be integrated into one overall system. As a consequence, the literature on IE includes works covering all the mentioned areas (and more . . .), and the attention to end users is at risk of being forgotten, or at least sidetracked.

In the literature, we find several studies and recommendations that aim at pointing out user needs and expectations in IEs, and that help to put more technical research streams into the proper context.

Several works consider the issue of proper design methodologies for involving users and user needs in the design of IEs. Back in 2005, Rocker *et al.* [12] presented an empirical cross-cultural study conducted at six different sites in five European countries, where they elicited feedback from the target user population. The study results are presented as a set of 16 design guidelines, prioritized in 5 levels. More recently, some design guidelines for reliable intelligent environments were proposed in [7], where *user confidence* is considered as a necessary requisite for system reliability. On the same topic, Le Guilly *et al.* [11] describe some design methods that can be adopted to ensure user constraints are taken into consideration. Similarly, the work of Kaasinen *et al.* [10] advocates user-centered design methods for the IE and for its user interfaces, while Augusto [3] details the steps of a possible user-centric software development process suitable for IEs and tested in an health

[1] the interested reader will find many real-world examples on the `internetofshit` Twitter account

[2] For brevity, in the following of this paper, the terms Intelligent Environments (IE) will be used as a portmanteau term covering also Ambient Intelligence systems and other Smart Environments.

care setting. This last approach has been recently extended [2] for people with special needs, where users were involved in each step of the process, using suitable methodologies for each of the steps.

On the other hand, other works aim at directly analyzing the user point of view, by understanding which are the features most requested or wished by potential users of IEs. The work of Bonino and Corno in 2001 [4] started from one simple open-ended question: "What would you ask to your home, if it were intelligent?" The results were at the same time unsurprising and worrying: users expressed stronger demands over environment features that would allow them to relieve the burden of daily chores, such as managing security, comfort (lighting and temperature), cleaning, maintaining order, etc. Many needs expressed by users could be easily matched by current technologies, but there is no strong market offer or support for those (except some niche, non-integrated, products). Current 'intelligent' home devices, instead, tend to address "collateral" features (multimedia, entertainment, information, and remote control of non-essential devices), somewhat ignoring the latent user demand. Research topics, although set to a farther future than industrial products, tend to repeat the same mistake: addressing challenging technical problems, but not devoting enough energy to features most requested by current (and future) users.

A recent work by Coskun *et al.* [8], that focuses on the control of intelligent appliances (as opposed to an integrated IE), confirms the strong bias of users towards controlling in an easier way, even remotely, their appliances. However, users are worried about excessive automation, as they are afraid of losing control over their devices and of the risk of reducing social interactions in the house.

2.2 Impact on users

The results presented in the previous section may be better understood by trying to see and evaluate the IE from the point of view of the user, who is not interested in the underlying technologies or challenges, but rather focuses on the provided functionality, on the modality of interaction (and the associated usability), as well as the predictability of its behavior with respect to their (expressed or implicit) needs.

The reflection stemming from this analysis can be exemplified by analyzing the difference between an *enchanted* house (or enchanted castle) and a *haunted* one (see Figure 1). An enchanted mansion is autonomous in performing some actions (playing music, controlling doors and windows, providing food and entertainment, etc.). But also the haunted house shares the same features (slamming doors and ominous music are a constant in horror movies). We may conclude that the enchanted house and the haunted one could be powered by very similar intelligent systems, as they exhibit basically the same functionality.

Fig. 1 A comparison of an *enchanted* house (above) versus a *haunted* one (below)

The main difference between the two opposing words entirely lies in user perception: the actions of an enchanted house are *expected*, *desired* and *welcomed* by the user, who lives in a proactively friendly environment. On the other hand, the haunted space will execute actions *contrary* to the user will, who feels trapped (and tortured) by an hostile entity, that prevents them to perform their desired actions.

The inadequacy of current IEs for user expectations (the "haunted house" effect) may be attributed, among others, to two major issues: usability and IoT architectures.

Concerning usability, it is undeniable that web-based applications and mobile applications featured an incredible improvement over the last decade. Currently, everyone is able to fruitfully interact with a website or with an app, without any training, and by just relying on established conventions, exploration, and immediate feedback. The same virtuous path is not currently being taken in Intelligent Environments, especially those that are available to the general public. The pranks published on social networks exploiting flaws in command recognition by Amazon Alexa or Google Home, or the weekly discovery of vulnerabilities in smart consumer devices, are just two examples that highlight the *fragility* of current IE components, their *unpredictability* and, ultimately, their untrustworthiness. User interfaces of smart devices are either too complex, or too cryptic to operate by regular users.

Figure 2 shows a representative example taken from a real smart home (that shall remain undisclosed). The house has been designed to be fully automated (lights, doors, windows, appliances, etc.) in the effort of lowering any possible accessibility barrier. The designers decided that each house functionality should be directly controllable and, instead of relying on scenarios or control apps, decided to abound with physical wall-mounted buttons. The result, shown in the picture, is that besides each door of the apartment there were several buttons in a row, with no clear affordance to understand what each button did. The facts that buttons were grouped three by three (with no apparent logic), had a vertical orientation (as opposed to the normal horizontal one), and the plaques had different colors (with no relationship to their function), all contributed to a sense of confusion and misunderstanding (the opposite of usability) whenever you had to switch the light on, or open the door to go to the next room. After an initial period, some icons were added (shown in the picture, in white over red background) besides some of the buttons. Icons were small, difficult to read, difficult to associate to the button (they required a mental mapping from the icon position –left or right– and the direction to push the button), and their symbols were confusing. Ultimately, the householders' wisdom prevailed, and they taped some buttons with a "don't touch" label, to reduce the cognitive load and let the users focus on a smaller set of controls (and a smaller set of really-needed functions).

Currently users are also exposed to the "Internet of Things" (IoT) paradigm, that is a very evocative description that collects hundreds of different types of devices and systems. Thanks to the IoT, users expect to be able to interact with hundreds of devices, seamlessly, that could manage different aspects of their routine. Information coming from the media, from startups, from crowd-funding campaigns, and from several brands of 'visionaries', tend do reinforce this utopian vision.

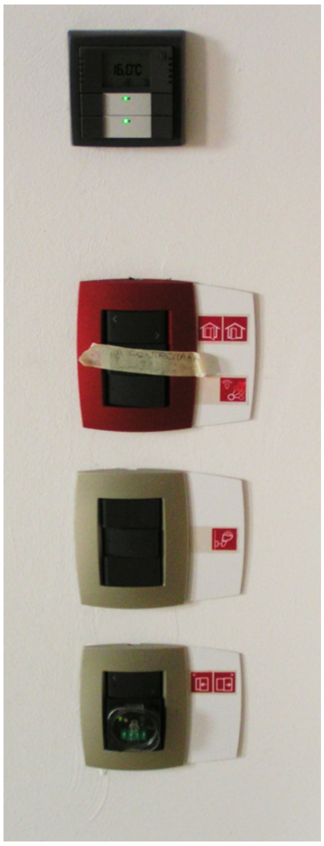

Fig. 2 An example of a bad user interface

By contrast, most currently deployed IoT systems have a much simpler, and much more limited architecture, like the one shown in Figure 3: data are collected from sensors (environmental or wearable), sent to and processed by some cloud platform, that ultimately allows users (or other stakeholders) to visualize some aggregated data. While we acknowledge the complexity of designing, implementing, and operating these system, especially at a large scale, we should notice that the benefits for the users are indirect (the availability of some information, later, on a different medium) or missing (when such information is exploited by other actors in the system). The immediate benefit of an intelligent environment (that could react, adapt, predict) is not implemented.

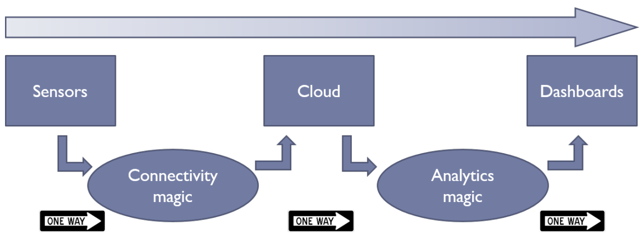

Fig. 3 Simplified architecture for many IoT systems

Users were promised (by the media and by the industry) user-centered systems; however researchers and industries delivered tons of technologies, mainly used to implement Sensor-to-Dashboard pipelines. And, even worse, these pipelines do not work together, by design (products from different vendors do not interoperate). Instead of an Internet of Thing, we delivered many Intranets of Silos of Things.

We may therefore conclude that the research community and the industry are delivering contrasting messages. On one hand, the message is of a total focus on the end user, to improve their daily activities. On the other hand, the complexity and immaturity of the technology leads to oversimplified and difficult to use systems, that fail to fulfill the promise.

3 Research Directions

Given the problem stated and analyzed in the previous section, i.e., that user expectations for IEs are not fulfilled by industry products nor by mainstream research agendas, this sections aims at better analyzing how is the problem tackled by the IE research community. In particular, we aim at investigating the following Research Questions:

RQ1: In the IE research community, how many papers consider users of IEs in their work?

RQ2: In the IE research community, how many papers involve users of IEs in the conception, design, experimentation, or testing or their proposed systems or technologies?

To address the research questions, we adopt a methodology based on the analysis of the recent literature, and in particular the meta-data of articles published in some relevant journals in the last 3–4 years. The analysis could be extended, in the future, to cover a wider time span, or a broader set of publications.

The literature analysis methodology is presented in Section 3.1, while the obtained results are shown in Section 3.2. The significance of the results and responses to the research questions are presented in the subsequent Discussion (Section 3.3).

3.1 Methodology

The analysis procedure followed in this paper is composed of 4 steps:

1. Define a literature corpus to analyze;
2. Extract metadata from each paper in the corpus;
3. Check paper metatada for “revealing” words;
4. Removal of false positives.

Each step is better detailed in the following sections.

3.1.1 Corpus Definition and Meta-data Extraction (steps 1 and 2)

The first step entails the definition of the corpus of papers to be analyzed. The choice should be a trade-off between representativity of the IE research community (by including the journals where most IE papers are published) and the breadth of the analysis, the recency of the results and the coverage of the research.

In this first analysis, three journals were selected (listed in Table 1): JAIHC, JAISE, and JoRIE. The analysis covered the papers published in the last 3 or 4 volumes (corresponding to the last 2.5–3.5 years, since the extraction was conducted in June 2018). For JAISE and JoRIE 4 volumes were considered (for JoRIE it amounts to the complete history), while for JAIHC only 3 volumes were analyzed, due to the much higher number of papers per issue, that would have biased the analysis results towards this publication.

From the above journals and volumes, 395 papers were identified in 47 different issues. For each paper, the most relevant metadata was extracted: title, abstract, and keywords. The extraction was a manual (copy and paste) process from the publishers’ websites. Whenever possible, the keywords were copied from user-provided ones. However, in some cases keywords were missing or machine-generated; in those cases, we accepted them.

Author names and affiliations were not considered nor collected, because we were interested in paper content, independently from the research groups. Of course, different researchers are active on different sets of topics, and some are more prolific than others, but these second-order effects do not affect the analysis of the research questions.

The full text of the paper was not considered, either. There are two motivations: *copyright* and *relevance*. Concerning copyright, automatic extraction and analysis of paper full text is not allowed by the license, and it would make the results less reproducible for researchers that do not have the necessary subscriptions. Regarding relevance, the main focus and the main approach of the paper should be clear and well-stated in the front page (title and abstract, mainly). The full text would be very long, contain a lot of supporting information, not directly linked to the work proposed by the authors.

It should be noted that many issues in the three considered journals are *special issues*, therefore the corresponding papers have a narrower and predefined scope. However, over 47 different issues, we may assume that the topic proposed in special issues are evenly distributed, at least for the purpose of this analysis.

The collected data was saved in a spreadsheet, that is available to any interested researcher.

The analysis could be extended, in the future, to cover a wider time span (but avoiding going too far, due to the fast pace of evolution of the underlying technologies), or a broader set of publications (but avoiding

Table 1 Reviewed Journals

Acronym	Journal name	ISSN	Vol.	Issues	Papers
JAIHC	Journal of Ambient Intelligence and Humanized Computing (Springer)	1868-5137	7–9	15	205
JAISE	Journal of Ambient Intelligence and Smart Environments (IOS Press)	1876-1364	7–10	21	144
JoRIE	Journal of Reliable Intelligent Environments (Springer)	2199-4668	1–4	11	46

Table 2 Revealing Words used in Step 3

Keyword	Examples
`adult*`	adult, adults
`child*`	child, children
`elderly`	
`HCI`	
`human*`	human, humans, humanized
`interact*`	interact, interaction, interacting
`people`	
`person*`	person, persons, personalize, personalized
`usab*`	usable, usability
`user*`	user, users

more specialized domains, where the focus on IE systems would be lost).

3.1.2 Revealing Keywords Identification (step 3)

The third step of the analysis methodology consists of identifying which papers consider, to any extent, users in their work, according to the statement of **RQ1**. We are interested in papers that mention users, in some form, in their metadata: the authors are aware that IEs must be user-facing and should mention that in their paper.

An approximate way of identifying user-aware papers, is to define some "revealing words", i.e., keywords that should appear in the title, abstract or keywords. The list of adopted revealing words is presented in Table 2: each paper title, abstract or keyword field was matched with all the listed keywords, and we recorded whether *at least* one keyword matched the field. Some keywords contain wildcards (`*`), and in those cases the next line shows some examples of possible recognized expansions. Matching was performed through SQL queries in a case-insensitive way.

The definition of these revealing words was done manually, after reading a sample of paper metadata.

We believe that the proposed keywords should have little or no false negatives (i.e., a paper that deals with users and mentions no one of these keywords). On the other hand, there will surely be numerous false positives, as detailed below.

3.1.3 Removal of False Positives (step 4)

The fourth step involves the identification and removal of false positives, i.e., papers that mention some revealing keywords, but do not really involve users in any phase of their work. In this step, we aim at identifying the papers that match the statement of **RQ2**.

There may be two types of false positives:

– *syntactic false positives*, where one of the revealing keywords is used with a meaning that is completely different from the expected one. A simple example is a network-oriented paper that described an implementation over the UDP protocol (user datagram protocol): in this case, the term 'user' has really no match with end-users of the IE system. The number of syntactic false positives was very low.
– *semantic false positives*, where the authors really refer to end-users in their description, but then the focus of the paper, its procedure, its results do not consider users anymore. An example is an indoor localization system, that is described as a system for localizing users, but the actual content is about radio beacons and network measurements: it is clear that the users will be the target of the work, but currently the work does not involve them in any way. This is the major source of false positives, as we will see below.

This step was conducted by reading the metadata of each paper, and determining whether it matched the following *selection criteria*. For each paper selected in step 3, at least one of the following conditions should hold:

– end-users were involved in the design phase;
– end-users or experimenters were involved in testing and/or evaluating the results;
– some form of user study (survey, trial, experiment, . . .) was conducted.

In particular, the following condition was *not* deemed sufficient, and many papers were excluded:

– using data-sets containing user-collected data or user recordings (audio, images, videos, . . .).

The rationale behind the selection criteria was to consider that, in user-centered design methodologies, users are involved (directly or indirectly) in *all* phases of the design. In our case, due to the specific nature of IEs and the complexity of the systems and technologies described by the authors, we adopted the principle that they should be involved in *at least* one phase.

3.2 Results

This section details the results obtained by the application of the methodology presented in Section 3.1 to the chosen literature corpus. Results are first presented in a qualitative way (Section 3.2.1), to have an idea of the dominant contents of the considered papers, and then in a quantitative way (Section 3.2.2), to ascertain the papers satisfying **RQ1** and **RQ2**.

3.2.1 Qualitative Overview

After steps 1 and 2, all metadata of the 395 papers is available. An effective visualization method for appreciating, with at bird's eye analysis, the most frequently used words is to plot them as a "Word Cloud", where each word is drawn with a font size proportional to its frequency in the corpus.

The whole set of extracted metadata (title, abstract, keywords) was concatenated in a single file per each of the 3 journals, and the corresponding word cloud was generated using the WordClouds on-line service[3]. Prior to plotting the clouds, some frequent by semantically neutral words (*stopwords*) were deleted, to avoid polluting the diagram with useless information (such as a huge word 'paper')[4].

The word cloud corresponding to JAIHC papers is in Figure 4, that for JAISE is in Figure 5, and finally JoRIE papers are represented in Figure 6.

Even a cursory look at the work clouds shows that JAIHC papers have a strong predominance of the word 'data', that is also present among the most used words in JAISE. On the other hand, JAISE has more references to the words 'user' and 'users', that are more dominant that in JAIHC. Other dominant words are 'result(s)', 'method(s)', 'smart'. For JAISE, also 'sensor(s)' has a significant presence. We could reflect whether these word clouds actually represent our understanding and perception of the IE research community.

The word cloud for JoRIE is significantly different. Possibly due to the smaller number of papers compared to the other two journals, there are no largely dominant words, but a more balanced set of terms. Curiously

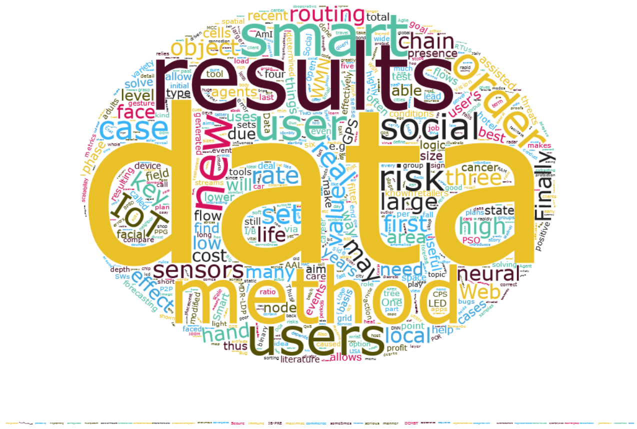

Fig. 4 Word cloud for JAIHC papers

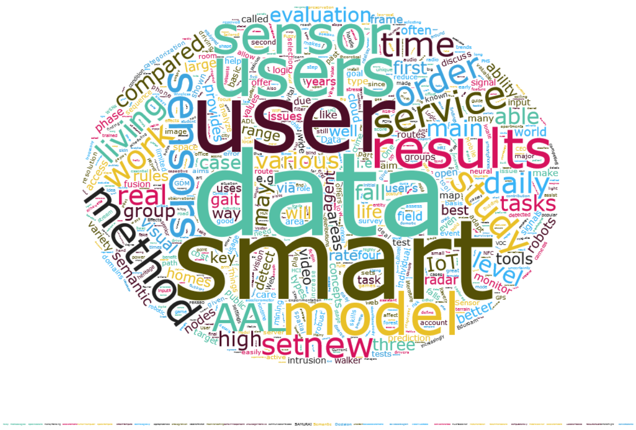

Fig. 5 Word cloud for JAISE papers

Fig. 6 Word cloud for JoRIE papers

[3] `https://www.wordclouds.com/`

[4] The deleted words (in addition to those already ignored by the WordClouds platform) were: also, approach, based, can, however, may, one, paper, proposed, show, two, use, used, using, well.

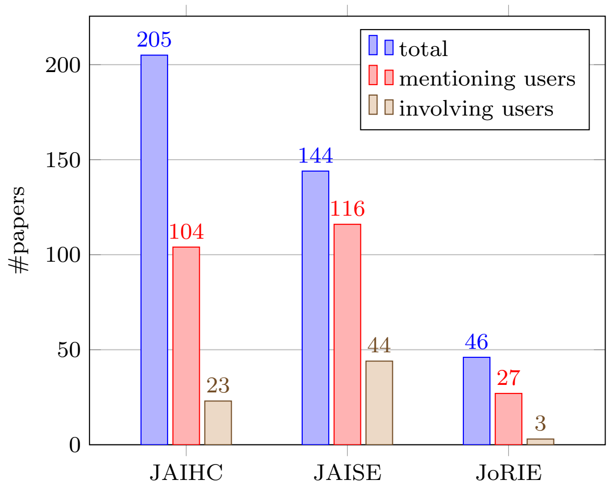

Fig. 7 Paper selection results

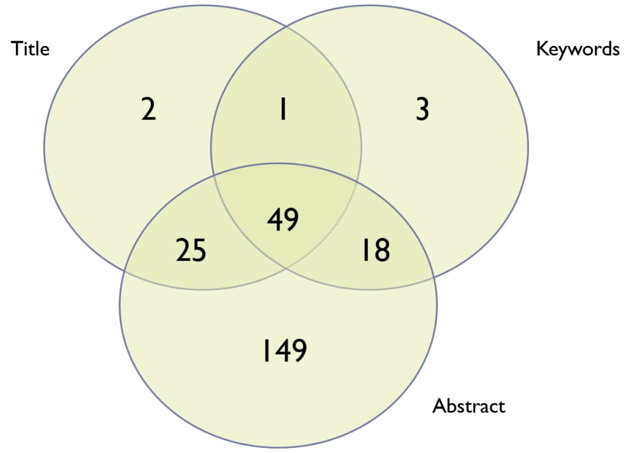

Fig. 8 Venn diagram of the papers according to matched metadata fields (mentioning users, after step 3)

Table 3 Paper selection results, with percentages

Papers	JAIHC		JAISE		JoRIE	
Total	205	—	144	—	46	—
Mention	104	50.7%	116	80.6%	27	58.7%
Involve	23	11.2%	44	30.6%	3	6.5%

enough, the term ‘user(s)’ is very small, and also ‘reliability’ is not that frequent. The journal seems more systems-oriented (see ‘system(s)’, ‘application(s)’, ‘environment(s)’) than data- or technology-oriented.

3.2.2 Quantitative Evaluation

The quantitative results after the application on steps 3 and 4 are presented in this section. The overall results are summarized in Figure 7: out of a total of 395 papers, 247 (62.5%) were identified as papers mentioning users (RQ1), and 70 (17.7%) as actually involving users (RQ2). The remaining 148 papers (37.5%) did not mention any user-related keyword at all.

Figure 7 also shows the breakdown across the different journals; the same data are also reported in Table 3, where they are additionally reported as percentages over the total number of papers. After step 3 (revealing words) nearly half of JAIHC papers, nearly 80% of JAISE papers and nearly 60% of JoRIE papers are selected. However, these percentages drop significantly when false positives are removed; the journal with a relevant number of papers involving users is JAISE (around 30%).

If we analyze the *location* where revealing words were matched (whether in the title, in the abstract, in the keywords, or in more than one field), we obtain the data reported in Table 4. The first three columns represent the three metadata fields, and an asterisk ($*$) indicates that at least one word was matched in that specific field. There are 8 rows, corresponding to the 2^3 possible combinations of fields. The first row represents papers where the revealing words are not matched by any field. The following 3 rows represent matches in one field, only. The next 3 rows represent matches in two fields (not necessarily of the same word), and finally the last row counts matches in all three fields. The central columns represent the number of papers that mention users (after step 3), and involve users (after step 4, respectively). The last columns report the overall data over the whole corpus, and are also reported in graphical form as Venn diagrams in Figure 8 (after step 3) and Figure 9 (after step 4).

From Figure 8 we may notice that the majority of the papers may be found by examining the abstract field, only: we can conclude that the matching of a revealing word in the abstract field is a good indicator for a paper mentioning users. The situation is completely changed in Figure 9, after removal of false positives: the only 11 papers out of the 149 where the revealing words were matched only in the abstracts did actually involve users: we can conclude that the majority of the mentions of revealing words in the abstract are just ‘passing’ mentions. No metadata field, alone, is able to represent the vast majority of papers involving users. However, we appreciate that in 57% of the cases (40 out of 70), revealing words appear in the paper title and/or keywords, thus outlining that the authors considered these features to be relevant and qualifying for their paper.

More in-depth analysis concerning each of the journals may be extracted from the central columns in Table 4, however the limited amount of papers makes it very difficult to draw significant conclusions.

Table 4 Location of revealing words

Title	Abstract	Keywords	JAIHC Mention	JAIHC Involve	JAISE Mention	JAISE Involve	JoRIE Mention	JoRIE Involve	**Overall** Mention	**Overall** Involve
			101	182	28	121	19	43	148	325
*			2	2					2	2
	*		67	6	61	12	21	1	149	19
		*	2				1		3	
*	*		10	5	14	7	1		25	12
	*	*	5	2	13	9			18	11
*		*					1		1	
*	*	*	18	8	28	16	3	2	49	26

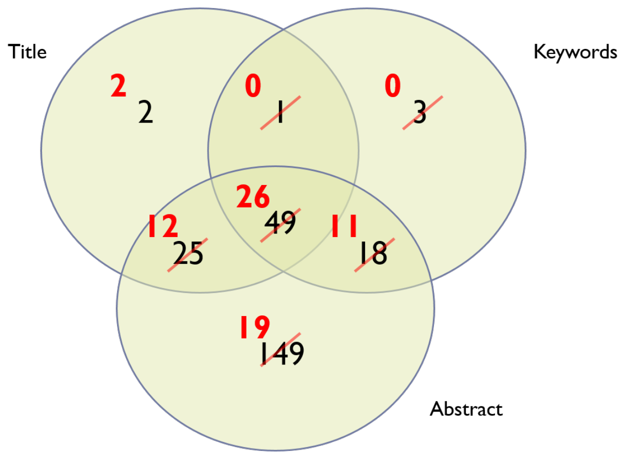

Fig. 9 Venn diagram of the papers according to matched metadata fields (involving users, after step 4): the effect of removing false positives is highlighted

3.2.3 Classification of False Positives

During the evaluation of false positives (step 4), it was interesting to analyze the reasons why authors mentioned user-related words in their paper, while the main contribution of their work was elsewhere. From the analysis of false positives, we discovered that they tend to fall in one of these categories:

– the authors are working on user-collected data (from other data-sets), as a basis for proposing new techniques (e.g., in machine learning); users are seen as merely data-producers, preferably if their data has already been collected in public data-sets.
– the authors propose a system (or algorithm, interface, optimization method, . . .) thought for user benefit, but without an actual user evaluation; in this case the quality of the work is only measured with 'technical' metrics, without a real assessment of user benefit or acceptance.
– the authors evaluate the possible user response by using historical data-sets (which is not entirely correct, since user behavior would be influenced by the system output).
– the authors propose a solution that *they think* the users would appreciate; this is one big mistake in user-centered processes, as the engineer should never try to guess the response of the end user.
– the author propose a solution, assuming that the users would use it in a particular way; this is also an issue, and has led to the failure of many commercial devices, for which users did not 'see' or 'use' the same features that developers intended.
– the authors offer a sentence equivalent[5] to "We found interesting results, that in the future can be extended to support the users"; this sort of wishful thinking is incompatible with user-centered system design, since user requirements should be analyzed upfront, not in future versions. But probably, in these cases, the authors do not really mean to extend it to real users.
– the authors offer a sentence equivalent to "Our theoretical results, in the lab, are positive. Therefore, the system is useful for real users"; quite obviously, this is never true in the real world.

3.3 Discussion

Every researcher in the IE field is aware that these systems should provide a benefit for the actual end users, and agrees on its importance. However, it seems that many research works (37.5%) do not mention users at all (**RQ1**), and the vast majority (82.3%) do not involve users in any phase of their work (**RQ2**).

This situation is partly motivated by the fact that designing an IE involves a large number of different technologies and devices, and requires solving several technical challenges. Therefore, it is not uncommon nor

[5] out of respect for the authors, these are not real sentences in any paper, and have been rephrased to look more provocative and explicit than the actual statements.

unexpected to find in IE-related journals some papers that are deeply focused on one technology, or aim at solving one specific challenge. However, research on IEs should transcend research over the single component technologies: we should work more at the system-level (as Figure 6 may suggest), and involve users as an integral part of the system. Editorial boards and reviewers should encourage works that take this holistic approach to IE system design.

The analysis of false positives (Section 3.2.3) supports the hypothesis that researchers are extremely focuses on their specific innovations, and do not consider the involvement of users as an added value for their work. This may be true for some kind of under-the-hood technologies or optimizations, but in these cases the main paper contributions are outside the specific domain of IEs (as the likely fall within some specific 'vertical' discipline).

Additionally, many research groups may see the involvement of users as an additional burden, or a task with high complexity or cost. However, as the HCI literature shows, it is often easy to obtain significant and valuable information (either in the design phase, or in final testing) even with small groups of volunteer users. The additional effort is often limited, but the potential benefits over the understanding of the research work and the additional research ideas that inevitably stem from these interactions, are much more valuable.

Working with users, of course, requires slightly different experimental methodologies and mind-sets; for example, an experiment with users are never really 100% repeatable (as a simulation or an optimization run would be). Insights and validations must always be considered in a statistical sense, by combining feedback and results from different users with the proper statistical methods. By the way, in many universities there are psychology, design, or interaction departments, that are usually very eager to collaborate on 'technical' topics, and they master the user analysis methods. Joining forces may open new possibilities, opportunities, and reduce the burden.

As researchers and designers of new technologies and solutions, we should always remember the primary needs of our users, that will be the ultimate judges of the success or failure of our results. This reminds me of a *motto* that is popular among the minorities; in Latin, it reads:

> *Nihil de nobis, sine nobis.*

that can be translated as

> Nothing About Us, Without Us.

This motto suggests that every proposal (of any kind: technology, law, event, tax, symbol, ...) that affects a given category of persons (characterized by any attribute, including being end-users of a potential IE system), should be designed, decided, and approved by a group that represents and includes people of that category.

4 Conclusions

Intelligent Environments and Ambient Intelligence systems are conceived as complex technological artifacts whose ultimate goal is improving the life of their users, by a combination of sensing, reasoning, and acting on the environment. Such systems are very complex, and entail solving technical challenges at every abstraction level and at every component boundary. The IE research community, therefore, lives a state of tension between finding adequate solutions to technical problems, and focusing on how potential users interact with the system.

This paper tried to analyze this tension, by describing some of the causes, mostly related to the different points of view of researchers versus users, and analyzing the recent literature to understand how the community, as a whole, is currently tacking the issue. Results from a literature analysis show that there is awareness of the user role in IEs (in over 60% of the papers), but there is much less involvement of users in the actual research (less than 20%).

From the system point of view, users should be included as part of the system design, they should close the loop of the intelligent algorithms, and they should get some appreciable benefit from system operation. From the user point of view, they must always feel connected and in control, otherwise thew would feel trapped and threatened.

In considering user needs and requirements, we should remember that more technology is not always the answer: research and industry should invest more in user involvement (even through collaborations with experts in the field), and take into account real user needs instead of creating new ephemeral ones.

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