A MATTER OF DESIGN

MAKING SOCIETY THROUGH SCIENCE AND TECHNOLOGY

PROCEEDINGS OF THE 5TH STS ITALIA CONFERENCE 2014

EDITED BY
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Proceedings of the 5th STS Italia Conference

Edited by Claudio Coletta, Sara Colombo, Paolo Magaudda, Alvise Mattozzi, Laura Lucia Parolin and Lucia Rampino

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From physical to digital. A new way of interaction with an Integrated System of smart appliances

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Politecnico di Milano

As ICT is invading the realm of everyday objects, many products are becoming always more interactive and smart. This trend makes product designers wonder about the meaning and potentialities of this new man-machine interaction. While a first phase of products' digitalisation has seen the arising of 'smart' concepts, that were not successful (such as the refrigerator that sends you a message because your milk is spoiled), today we are witnessing the development of promising concepts of interaction between digital interfaces and industrial products. In this article the authors present, as an example, a prototype of interface developed and tested within the Research Programme 'Sviluppo di un sistema integrato di nuovi elettrodomestici a ridotto consumo energetico', cofunded by the Italian Ministry of Production. The aim of the Design researchers was to transfer part of the physical interaction, that typically occurs within domestic appliances, to a digital interface able to control the whole Integrated System of Appliances. The assumption was that it could lead to an advantage, in terms of energy optimisation, by making users aware of their consumption. The challenge was to make this interaction both pleasurable and functional. The research brought about some crucial issues, that will be discussed in this paper.

***Keywords**: Product interaction; data visualisation; smart products*

Introduction

In the late 80's the debate about the dematerialisation of practices and media, deeply concerned who deals with product design matters.

At the beginning of that debate, the general though was that many physical products would be eventually substituted by immaterial contents

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(Manzini, 1990; Negroponte, 1995; Destrouzos, 2001). But if we go back at reading such essays, we will find that predictions were at the same time right and wrong. They were right because the switch from physical to digital matter really took place (just think of the changeover from mail to email).

They were wrong because this switch did not mean a dematerialisation of our world. One example over all: in the Nineties Negroponte (1995), just like many other IT experts, was suggesting that in the future printed books would be substituted by files. That is true, books printed on paper are slowly disappearing (even though maybe less slowly than predicted), while they are still edited in their digital form. However, they are not read on computers, they are read on tables or electronic book readers. These last ones in particular, are brand new physical products that did not reach a wide market until the need to read electronic books arose. Therefore, dematerialisation is a real phenomenon that is taking place, but it does not implies that less products are needed and manufactured. On the contrary, the management of this new and abundant 'digital matter boosts the development of new products (such as the e-book reader) and makes old products become 'smart' (by mean of sensors and interfaces that enhance their functions).

This trend is so in vogue that today technology-experts speak with enthusiasm of the 'Internet Of Things' (Stephenson, 2012; Brynjolfsson and McAfee, 2014) referring to a world where all things will be smart and connected in order to serve at best our needs and wishes.

In this perspective, the focus of this paper is on the trend of adding digital interfaces to existing products (more in details, to domestic appliances) in order to make them 'smart'. Such a trend makes product designers wonder which are the potentialities and the advantages from the user point of view and in which ways this new ICT content changes the way these products are perceived by users.

While a first phase of products' digitalisation has seen the arising of 'smart' concepts, that were not successful (such as the refrigerator that sends you a message because your milk is spoiled), today we are witnessing the development of promising concepts of interaction between digital interfaces and industrial products. We believe that this progress is reached when engineers and designer cooperate from the very beginning to the development of products that are not just technically feasible but also useful (Ferraris and Maiocchi, 2005). In other words, innovation should be driven by design and technology together, not by technology alone (Rampino, 2012). Indeed a first phase of products' digitalisation has seen

the arising of 'smart' concepts, that were technically feasible but were not successful on the market (the field of home automation is full of examples).

The effort today is to merge technical possibilities with users' needs and requirements. This is exactly the aim of the Project presented hereafter.

Designing the innovative interface of an 'Integrated System of Domestic Appliances'

The Research Programme 'Sviluppo di un sistema integrato di nuovi elettrodomestici a ridotto consumo energetico', ('Development of an Integrated System of new energy efficient Domestic Appliances') co-funded by the Italian Ministry of Economic Development, started in 2009 and is now coming to the end. The body in charge of the Research is Whirlpool Europe, global manufacturer of domestic appliances, while eleven companies and five research centres are partners, one of them being the Design Department of Politecnico di Milano and the others being Engineering Dept. of the same Athenaeum.

Programme aim

The Programme general objective was to design, prototype and test a smart system in which the following elements would be integrated: the smart appliances (that are traditional appliances able to connect to the System to optimise the energy consumption); the renewable energy sources (such as solar panels); and not-smart appliances that can be integrated through the use of smart plugs (i.e. an iron).

The enlarged project team was made up of mechanical, energy and computer engineers, ICT experts and designers. Among those, two companies (Whirlpool and Genius) and two research teams (the ICT experts of Cefriel and the Design team of Politecnico di Milano) were involved in the making of the prototype.

The final aim was to enable the user to interact with the prototype of the Integrated System so to test if it would help him/her to achieve an optimal overall management of his/her domestic energy consumption.

Specific design aims and process

The specific task of the Design Researchers (DR) was firstly to understand all the potentialities of the new Integrated System, in order to

design the interface of the Smart Display that would mediate the interaction between System and user.

In the original description of the Research Programme (that was written back in 2008), it was not defined how this interaction would take place. Actually the Programme was open to any kind of innovation. Then, during the development of the Programme (from 2009 to 2013), new devices - tablets and smart phones - reached the market and spread successfully all over the world: for instance, Nielsen, a leading US based global information company, in June 2012 provided market research reports that from May 2011 to May 2012 smartphone penetration has gone up 34 percent and tablet adoption is up 400 percent. This trend developed people's skill of using touch screens and software even embracing those who were not using computers jet. Thanks to this scenario, in February 2010, when the design of the user interface begun, it was considered very reasonable to use a tablet as a support. After taking this decision, the design process of the interface could start. It was made up of the following 3 steps:

- Analysis on the state of the art;
- Design phase;
- User test.

Through all these phases, the DR team interacted with the engineering partners of the Project involved in the making of the prototype. This collaboration was essential for designers to deeply understand the System potentialities and transfer them to the interface.

State of the Art

The idea of connecting domestic appliances in a system in order to save resources is widely explored nowadays, in particular from the point of view of electric energy in the field of research that goes under the name of 'Smart Grids'. A Smart Grid is an electrical grid that uses communications technology to gather consumption information and display them to the final user. The aim is to improve the efficiency, reliability and economics of the production and distribution of electricity. Not surprisingly, it is a research topic on which both local Governments and EU are making huge investments (www.smartgrids.eu).

In the first step of the design process, we surveyed the state of the art on this subject, with particular regard to the interface contents and elements.

The survey analysed 21 interfaces of smart-homes and services based on smart grids (i.e. Intelligy by Millennium Electronics, www.intelligy.com.au/system-components.php#intelligy-display; Chorus by Green Energy Options (GEO), www.greenenergyoptions.co.uk/support/chorus-support/choruspv/; SmartMonitoring by AlertMe, www.alertme.com/try_the_demo).

All the analysed interfaces have similar homepages: they display a set of basic data on consumption (i.e. daily average consumption of energy) and status of the system and its components (in smart homes the systems might also include other sub-system such as security systems, entertainments, etc.). Then, they display a set of icons that let the user access more specific data (i.e. records of historic data on energy costs and/or consumption). Some good examples were found for the representation of consumption data, but no one for the representation of the system of appliances.

After the analysis of the already developed Smart Grid interface, it emerged that three were the design challenges to face:

- how to represent the Integrated System, so that users would identify it, appreciate it and be intrigued to use it;
- select the contents (basic data and extra information) and interaction elements (icons, feedbacks, etc.) of the new digital interface;
- find the best way to transfer the typical physical interaction with home appliances (i.e. turning a knob of the washing machine) to a digital interface.

Design phase

Challenge 1: to represent the System

As already said, none of the analysed examples displayed a conceptual visualisation of the System. Therefore, the DR team decided to visualize the System for what it is: a group of single appliances connected together to create an extra entity. The connection makes the relationship; the relationship makes the system. For this reason the System is visualized through the icons of the smart domestic appliances graphically connected with a line to a bigger System Icon representing the home ‘Real time total consumption’.

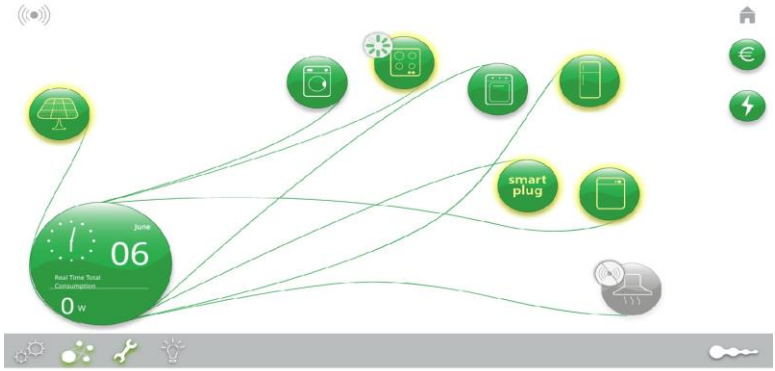

Figure 1 homepage

The homepage visualization (figure 1) aimed at simplicity. For this reason, very few data are present on it: date, time and 'Actual total estimated consumption'. Still, the homepage communicates much more information without the usage of words or numbers. The appliances icons can be in three status:

- grey means: 'the appliance is not connected to the System';
- dark green means: 'the appliance is connected but not in use'
- light and luminescent green means: 'the appliance is connected and in use'.

In case of appliances that have cycles of use (i.e. the washing machine), such cycles are represented by a small rotating wheel.

Other information are easily available through icons: the costs, the electric consumption and a set of functions that regards the interaction with the System (i.e. the historical data of consumption) and are placed in a grey task bar below. By these design choices, the DR team managed to get in a single view the 'idea' of an Integrated System of appliances and its status at the moment.

This design choice proved to be effective. Indeed, through the usability test (see paragraph 'User Test'), users immediately understood the meaning of the visualization and appreciated its simplicity.

Besides that, the DR team was aiming to give the user the feeling of interacting with an 'eco-efficient' System. As for the general aim of the Project, 'eco-efficient' was referring to the fact that users would be saving money and energy by optimizing the consumes, selecting the best timing of energy supply (concept at the base of any smart grid projects). Thus, the

interface should encourage consumers to use a smart approach to energy consumption.

In this perspective, the DR team chose to apply white and green colours as a basic tint for the interface. While green is a typical but extremely effective choice for any *sustainable looking* project, white colour refers both to the category of white domestic appliances and to the current trend of product design aesthetic started by Apple that expresses values of simplicity together with high quality.

Furthermore, the DR team designed the System with sinuous lines and a casual layout of the icons, so that it could resemble a biological body, with no direct reference to any specific vegetable or animal. The DR team thought that an abstract representation could transfer the feeling of 'eco-efficient' without using any naïve representation of trees, flowers, jellyfishes or any other living beings that had the kind of shape that was necessary to the project.

The result, as shown in figure 1, is a simple interface with a basic white canvas and green elements.

Challenge 2: to select the contents and interaction elements of the new digital interface

The main issue about selecting the contents of the System Interface was to pick the only ones interesting to a general user. Particular concern was about numbers and values that refers to energy consumption. Indeed, many users might not be familiar with data based on watt or kilowatt-hour, thus they might not be able to evaluate consumption performance of a single appliances or whole System, if expressed only by watts.

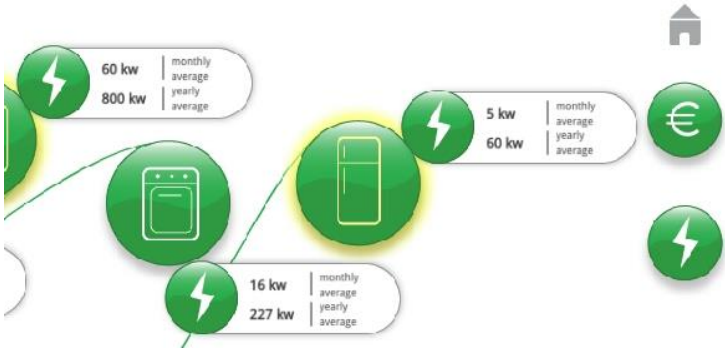

Figure 2 visualisation of energy consumption with data comparison.

To face this issue, the DR team decided that any single data about energy consumption would be shown by comparison to an average data. For instance, on the homepage the users can select the icon 'Energy' (a lightning) and they will get the monthly and yearly average consumption of any appliance (figure 2). The same approach was chosen to cost consumption data. This approach is applied in some case studies analysed during the state of the art of smart grid interfaces (among the previously mentioned examples see www.alertme.com). It was positively evaluated during the user test. In particular, the comparison of data was considered very interesting when reading the historical data, which were very appreciated by test users.

About the graphic elements of interface (such as icons), the DR team decided to use existing ones as much as possible, even copying those of Whirlpool's products. This choice was due to the necessity of making the interface intuitive and easy to use. The DR team knew that the main problem for the user would be to interact with a System that actually is an *immaterial entity* made of *physical products*, placed in different part of the house. Therefore the effort was to design an interface that at least had very common graphic elements of interaction. The only icon that has a brand new design is the 'historical data' icon (down right in the homepage, figure 1), because we could not find a largely recognised icon for this subject.

Challenge 3: to transfer the typical physical interaction with home appliances to a digital interface

This last challenge raised several design questions at the very beginning of the project. As part of the overall System, the DR team was asked to design the specific interface of the four appliances that would be part of the final prototype: fridge, oven, cooktop and washing machine. In the Project, four Whirlpool smart appliances were chosen because they were already developed at the level of prototypes. Therefore, the DR team had both the products (with their interfaces) and the instruction books to start from.

The first question was if the digital interface should or not be as much as possible similar to the product interface. This issue was a matter of discussion with the engineering partners. There were two main options to take. One option was to create a 'general' digital interface for each smart appliance so that it could work for any product that would be connected to the System in the future. That would allow Whirlpool to give, for instance, the same digital interface to different smart appliances. In this scenario, the user should learn only once how to use the digital interface to interact with

the smart appliances, and then buy and change smart appliances with no need to learn every time a new digital interface. On the other hand, the digital interface would not be similar to that of any specific product. Thus, for example, the generic digital interface of the fridge would differ from the physical product interface. This could mislead the user interaction. Indeed, even if the functions are very often the same (think about a typical washing machine knobs) they change from product to product in the way they are displayed or called or described by icons.

Therefore the DR team decided to make any effort possible to transfer the four product interfaces to the digital interface making them as similar as possible. This choice means that the digital interface has to change every time a smart appliance is substituted in the System. Plus, of course, any new smart appliance would require the implementation of its own digital interface too. This is economically not very smart, but perhaps it would make the manufacturer put more effort in the alignment of products interfaces.

To repeat the product interface onto the design of the digital interface was not easy at all. The four products represent very different problems to face.

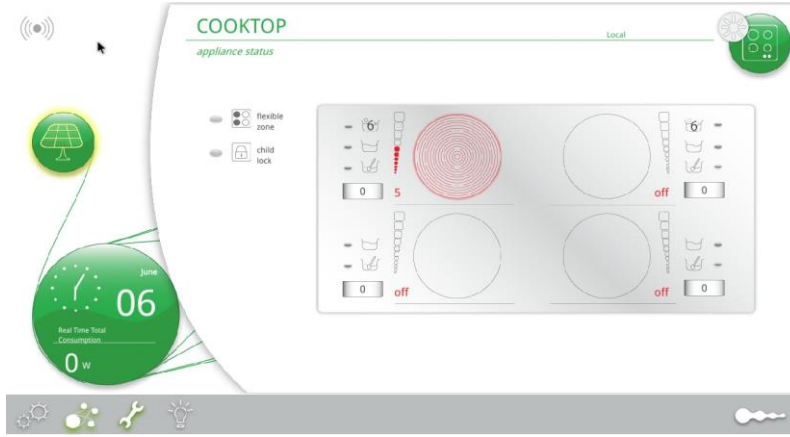

Figure 3 Cooktop digital interface.

The fridge and cooktop were the simplest. Indeed, the fridge has few functions to interact with and, the cooktop, for security reasons, cannot be activated by a remote control. Therefore the product digital interface has just an informative aim.

The DR team developed two interfaces that display a general layout of the product and the functional icons (designed exactly as the ones on the product). This way the users immediately recognizes the layout and functions. For instance, the cooktop digital interface (figure 3) shows which fire is on, its level of temperature and, if any, the cooking time set. Also it shows if the 'flexible' or 'child lock' functions are on.

Oven and washing machine were much more challenging. They can be operated by remote control and have a new function to display that was called 'green/comfort option' (it enables the user to let the System choose the best time to run a cycle and requires a time to end by; or it enables the user to set the mandatory starting time of the cycle). Choosing 'green' or 'comfort' might result in a different value of the 'estimated consumption' that appears down left in the digital interface, where the green option will result in a saving of money. This option was designed to reach the Project aim, that is to help the users prefer green options in the use of the System.

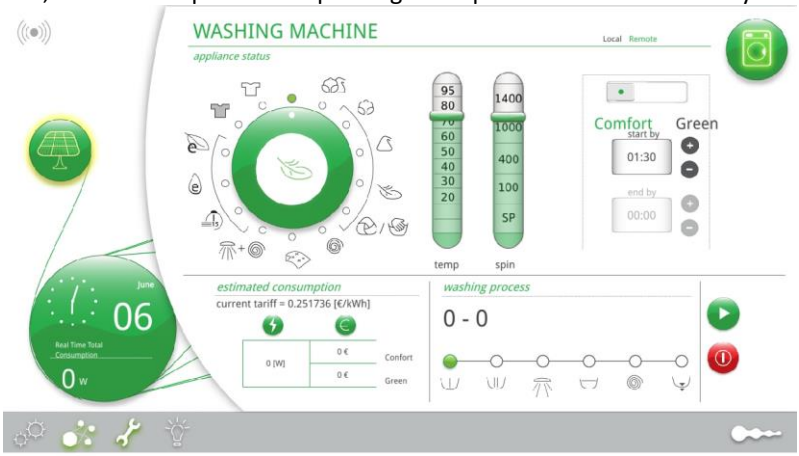

Figure 3 Washing machine digital interface

So, looking at the washing machine case, typically the user interacts with a physical knob, around which are displayed a number of icons, with a clear meaning of 'rotating to select' and a physical and sound feedback to the action. On the tablet, there would be no need of a wheel to select washing programs or temperatures. The selection could be achieved in a different way, for example by shifting a slide bar (option that requires less space on the screen area, for instance). In this case, the non-correspondence between the function and two different layouts should be fulfil by the user.

For this reason, this option was discarded. Indeed, it is exactly the opposite features that make interfaces easy and pleasurable to use: steadiness and constancy of references (Nielsen and Loranger, 2006) .

The resulting digital interface was very much a mix of functions similar to the product (washing cycle setting wheel, temperature and spin sliding bars and washing process line) and new functions (green/comfort option and estimated consumption). These functions were displayed so to follow the users process of interaction: first select the cycle, then the temperature, then the spin, the green/comfort option, then check the estimated consumption, in case change any option and click start. The 'washing process' is only an informative visualisation.

User Test

The last task of the Project was the test for assessing the usability of the interface prototype. The task was planned in two phases: a preliminary test (PT) and a laboratory test (LT).

Methodology

The PT was held at the Design Department of Politecnico di Milano. It aimed at checking the level of understanding and user-friendliness of the interface.

Ten test-users interacted with a tablet where the Smart Display was uploaded. The tablet was not connected to the Integrated System of smart appliances. So, in this phase, the testers tried the accessibility of functions and information, but not the feedbacks from the System. At the end of each session, the test-users filled out a questionnaire and gave free comments. The results were analysed to check if any major change was necessary to the Smart Display before the LT. The test was positive and resulted in a list of recommendations for the LT phase.

The LT was held at the Whirlpool headquarter (Cassinetta, VA, Italy) where the System prototype is set. It aimed at checking the ease of interaction with the System through the interface. Four test-users interacted with a tablet where the Smart Display was uploaded and connected to the System of smart appliances. So, in this phase, the testers tried both the accessibility of functions and information and the feedbacks from the System. At the end of each session, the test-users were interviewed by the Design researchers, who followed a questionnaire to collect comments.

Both tests were based on four phases of evaluation:

• 'at first sight': feedbacks on the soft values of the interface;
• 'trying to use the interface', identification and test of functions
• 'clarity of the interface', comments on communicative efficacy of graphics and navigation mode;
• 'utility of the system and interface', more general comments on the validity of the Project.

The results of the two test phases were integrated and analysed. Some major feedback regards the design issues.

Results

Regarding the representation of the System in the home page, the test users response to the question: 'is it clear what it represents?' was completely positive. Also the question about the understanding and accessibility on the interface *in general* was positive. Still, some feedbacks highlighted some improvements that are important to consider. The answer to the question: 'did you feel like you were interacting with an ecologic System?' was not completely positive Two options to solve this point could be: on one side, to add images that refer to nature (i.e. drawings of leaves) or, on the other, to enhance the perception of interacting with a green System by abstract means. This idea was not implemented in the prototype, but it could be in the future. Indeed the prototype displayed the icons in a static layout on the screen, but in the future development icons could be floating up and down in reference to the consumption of energy. Also the connecting lines could represent the passing of energy in a direction: from the System to the appliances or from the solar panels to the System. This way it would be highlighted the presence of green energy that comes from solar panels (or other green system of the house). The DR team believes that if these effects were implemented, the System would look more 'alive' and metaphorically representing what is going on. If the users thought the system to be constantly active, they might be more involved in interacting with it and trust its role in the optimization of home energy consumptions.

Of course, such an implementation would require a more complex software engineering to support it. That being said, the representation of the System of appliances proved to be effective.

Regarding the four appliances interfaces, the design decisions proved to be very positive during the user tests. The only comment to consider is that users were intrigued by the possibility of interacting with some functions (such as turning on a ring of fire of the cooktop) and felt sorry not to be able

to do it. This can be taken as a hint: users seemed interested by the opportunity of interacting with such products with a remote control, even if nowadays security regulations do not allow this interaction to take place.

On the washing machine, the user test gave two different feedbacks. As for the functions that are already known and similar to the product, the interaction was perfectly easy and intuitive. While the green/comfort option was considered a very interesting function that needed extra information to be understood at the first use. The advantage of a digital interface is, indeed, that adding extra information is possible and simple to do. This suggestions applies also to another note received by test users, that is to have information about the washing cycles (i.e. not all user are familiar with the icons, no matter how common they are already). Indeed this is one of the advantage of interacting with a tablet. The users can read the information about washing cycles, or any other hint and tip that the System suggests, sitting comfortably on a chair rather than leaning on the front of the washing machine where the interface usually stands. This means that users might spend more time interacting with their smart appliances.

Regarding the results on the choice of contents and interaction elements of the Smart Display, we can say that the icons and actions were clear when they were already know ones, while they need an explanation if they are new icons and functions. For instance regarding the 'historical data' icon, during the test, users had to try it to find out what it was at the first use. Then, they all agreed both on the clearness and usefulness of the historical data. Regarding the contents, all users commented that they would enjoy having even more information on the Smart Display, such as: details about usage of the their appliances, understating about how the System works, hints about washing machine cycles, or any other data they might found out about their domestic appliances and use of the System.

Conclusion

The development of the new interface for the interaction with a System of smart appliances let the Design Researchers achieve different levels of result.

Some of them are 'context specific', and regard the quality of the designed interface and the improvements that could be made to enhance it, as described in the paragraph on the results of the user test. These results could be useful to other design groups facing the challenge to design a similar interface, in the same way the interfaces we surveyed in our State of

the Art were useful to our design project. In particular, the recommendation to visualise the System is certainly very useful and applicable to many similar cases.

Others results are more general and refer to the way the interaction with the interface of the System changed the perception of the appliances by users. Indeed, beside the feedbacks on the interface quality, the DR team realised that users, who typically do not ever read appliances' instruction books, stated to be interested in deepening the knowledge of their domestic appliance functions and efficiency by interacting with the smart display. It seems that a digital interface could give to the appliances a conceptual identity that users did not perceive before. A new perception of the product would arise: it would not be just a 'machine that makes the job', but a entity to interact with it, besides the job itself. The DR team believes that this is a new value that is worth developing.

This could lead to a higher interest of users for smart appliances because they build a more personal and interactive relationship with them. This is certainly a field worth studying both for researchers and manufacturers.

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