Co-Creating Environmental Services Based on Pollution Citizen Sensing

Brigitte Trousse, Inria Sophia Antipolis - Méditerrannée, France,
Marc Pallot, University of Nottingham Business School, United Kingdom,
Caroline Tiffon, Inria Sophia Antipolis - Méditerrannée, France

Abstract

This paper describes an Open Innovation case study within the European project ELLIOT - Experiential Living Lab for Internet of Things (IoT). In this context, our lab aimed at co-creating green services with a set of stakeholders on air quality and noise measurement on Nice Côte d'Azur (NCA) territory via citizen sensing. Our objectives dedicated to Transport and Health scenarios are:

- Raising public awareness by involving citizens in collecting environmental data and creating a community of empowered citizens;
- Providing solutions that can reduce the environmental impact;
- Alerting the community in case of exceeding the thresholds recommended by the EU.

After introducing the context and the problem, we will first present the main related concepts and works before starting the ELLIOT project. Then, we present our approach for co-creating with citizen environmental IoT-based services, which is based on an eXperiential Design (XD) process, a new Ideation methodology dedicated to IoT and finally our User eXperience (UX) model and measurement methodology related to MyGreenServices portal we implemented. Before concluding about MyGreenServices in order to make it sustainable on the chosen Territory, we describe the main outcomes of this pilot, both issued from the XD process as well as the UX measurement.

Keywords

Citizen Sensing, User Experience, Experiential Design Process, Co-creation, Service Design, Internet of Things (IoT), Living Lab, Smart Cities, Green Services, Environment, Air Quality

Introduction

This paper describes an Open innovation case study managed by the AxIS team from Inria (http://www-sop.inria.fr/axis/) within the ICT Usage Lab (labelled by ENoLL in 2006 and located in the South-East of France) applied to the co-creation of IoT-based green services (in our green use case, air quality and/or noise) within the European FP7 ICT project named ELLIOT - Experiential Living Lab for Internet of Things (www.elliot2project.eu).

Context

Environmental issue is emerging as central in the coming years. The future of our cities, in Europe and around the world, are inevitably dependent on the way we will be able to reconcile economic, social and environmental sustainability.

Concerning environmental purposes, the strategy of Nice is supported by the "Eco-Cité" label given to 13 sites in France by the French Government to new friendly urban planning "Eco-Cité" of the future. The "Eco-Cité Nice Côte d'Azur (NCA)" project is a first step inserted into a larger project called "Eco-Vallée". Eco-Vallée is a "National Interest Operation" that covers around 10,000 ha. It is designed to become a laboratory for sustainable development. The innovation engine of the agglomeration can create a leverage effect on the entire territory. Main issues of this project are: High tech experiments, Well-being, Eco-buildings, Sustainable mobility, Energy management and Natural risks. The ambition of NCA is becoming eco-reference area in terms of sustainable urban development.

Problem

In this context, the French Institute for Research in Computer Science and Automation (Inria), as founding member of ICT Usage Lab, with the support of the French think-tank Fing and SME VULOG aimed at co-creating "green" services, i.e. IoT based services for air quality and noise measurement within the NCA territory of the Riviera Coast. NCA area is viewed as a lab/platform ecosystem for co-creating, exploring, prototyping and evaluating sustainable applications in partnership with citizens, education and research institutions as well as businesses. Let us remind the importance of the environment field in Nice area. Indeed, the City of Nice was one of 24 cities around the world to be awarded by IBM in the frame of "Smarter City Challenge" grant in 2011. This challenge aimed to contribute to the improvement of a sustainable growth. For more information about the assets of Nice area, see (Schaffers & al., 2011; FIREBALL 2012).

In the European ELLIOT project (Sept 2010 – June 2013), Inria for the living lab ICT Usage Lab coordinated the Green Services use case, motivated by the importance of this field in Nice. Our major goals were the following:

- Raising public awareness by involving them in the collection of environmental data and create a community of empowered citizens;
- Involving citizen and all stakeholders in the co-creation of green services based on IoT air quality and noise sensors;
- Focusing on the impact of environmental data on citizen behaviours for transportation and health/wellbeing routines.

Related concepts

This section presents the main relevant concepts or studies related to "designing user experience with living labs", to Service Design for IoT-based services and for Green Services, before deploying our Green Services pilot.

Designing User Experience within Living Labs

According to William Mitchell, professor at the MediaLab and School of Architecture and city planning at MIT, a Living Lab (LL) represents a user-centric research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts. He identified several noticeable impacts and benefits, such as the integration of the users into the development process for ensuring highly reliable market evaluation; the reduction of technology and business risks, as well as decreasing investment needs for SME, micro-organizations and start-ups, since they can share resources without mobilizing so much venture capital; and share access to a broader base of ideas, especially for large companies.

Since 2006, the LL approach was gradually applied within EU projects for involving all stakeholders, especially users and also policy-makers, at the earlier stage of R&D. A LL is often defined as a user-centred open innovation ecosystem integrating research and innovation within a Public-Private-People partnership through an iterative design process. Curley & Salmelin (2013) argue that Living-Labs engage users in open regional innovation ecosystems representing a quadruple

helix innovation mode beyond traditional technology driven testbeds.

A LL combines the UX quality in co-creating, exploring and experimenting with users a product/service with the capacity to capture previous design experiences (Arts & Marzano, 2003). It means that within LLs, UX covers the entire design process. For more definitions and concepts related to designing UX with living labs, see (Pallot, 2009; Pallot & Pawar, 2012).

Experiential Design (XD) Process

According to Erkinheimo-Mennander and Arjanne (2011), innovation failure has reached the rate of 86% due to the lack of user adoption and understanding of users' preferences.

While traditional industrial design process focuses mainly on product conformance with needs and requirements specified by developers, it rarely involves users, except in some cases as observed subjects, and simply ignores users' potential contribution in the value co-creation.

In contrast, the experiential design (XD) process, formalised during the ELLIOT project, shifts the priority from designing product features towards co-creating value with users in order to ensure a higher rate of service adoption. However, it requires all stakeholders, including users, to be engaged along the design process (see Take in Figure 1) for co-creating, exploring, experimenting and evaluating product/service scenarios (Pallot, 2012). These four activities are intended to better support the identification of value expected by users (e.g. usability, reliability, affordability, social interaction, empathy, fun) and supporting features that would convince a large community of users to adopt an innovative IoT-based product/service.

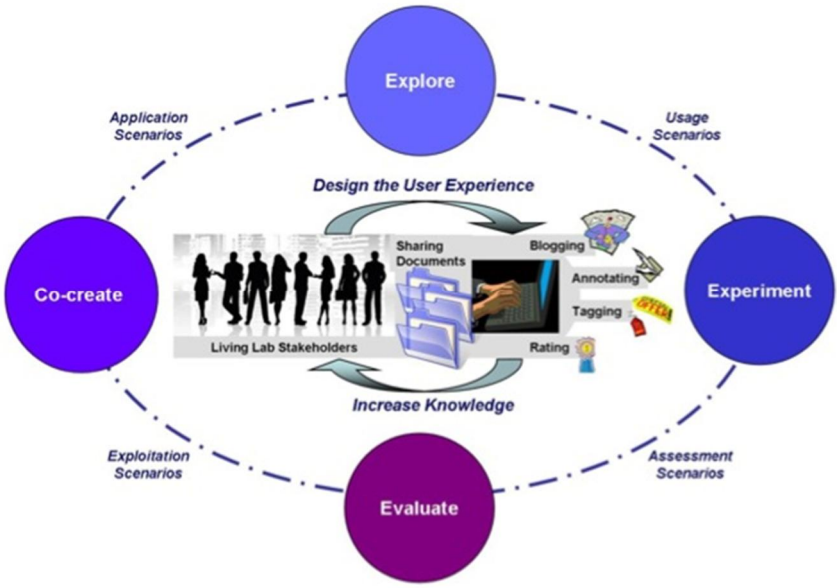

Figure 1. Iterative Design Process adapted from (Pallot 2009).

The XD process requires focusing on designing for value that is iteratively validated by experimentation and UX evaluation until it reaches the targeted score. Hence, exploring patterns of usage, capturing emerging people behaviour and evaluating the impact on service adoption become a corner stone in the design iterations and refinements. The intended goal is to raise the level of product/service adoption by a large community of users.

According to Pallot and colleagues (2013), the XD process is an iterative process (see Figure 2) that links together the four activities to be carried out whatever is the innovative scenario to be designed. It consists to: co-create ideas of new concepts, artefacts and/or innovative scenarios as sessions of collective creativity involving all concerned stakeholders and especially users; explore alternative scenarios in setting the scene through the use of different immersive techniques within a live environment; experiment alternative scenarios

in prototyping concrete application/services through the use of a technological platform within a real-life environment; evaluate alternative scenarios on the basis of metrics for measuring both the Quality of Service and the Quality of Experience that would allow assessing the degree of adoption by users.

The XD process is correlated to Mitchell's Living Lab user-centric process composed of research methodologies for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts (see Figure 2). In our view, "Sensing" leads to consider simultaneously the context, users, and the existing and emerging technologies (e.g. sensors, actuators) for co-creating and exploring innovative scenarios. "Prototyping" means to concretise alternatives that allow experimenting them with users in real life situations. "Validating" is the outcome of the evaluation of the experiments' results. Finally "Refining" leads to the identification and discussion with all stakeholders of potential refinements in order to prepare the next iteration until it reaches the proper level of user adoption. The main goal of the iterative XD process is to support the design for value that is continuously evaluated through the UX life cycle (Roto et al., 2011).

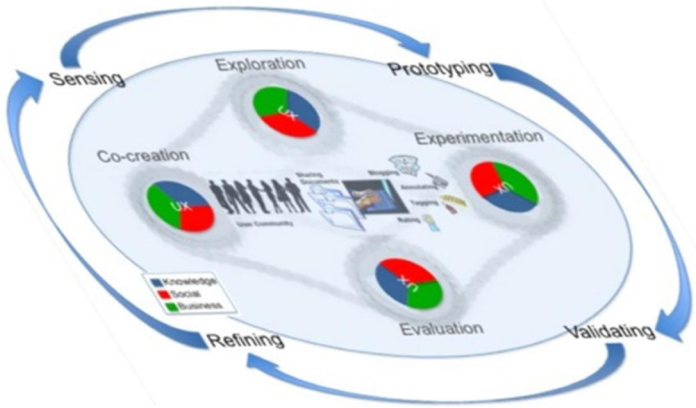

Figure 2. The Interactive Nature of the Experimental Design Process

A LL combines the UX quality in co-creating, exploring and experimenting with users a product/service with the capacity to capture previous design experiences (Aarts & Marzano, 2003). It means that within LLs, UX covers the entire design process. A recent survey among ENoLL Livings Labs (Pallot, Krawczyk & Kivilehto, 2013) reveals that User Co-creation and User Experience constitute the top two LL practices for engaging users in the R&D process.

User Experience and the UX Holistic Model

There is a considerable amount of publications dedicated to UX (Alben, 1996; Norman, 1999; Hassenzahl et al., 2000; Rubinoff 2004: Schrepp et al., 2006; Kankainen, 2002). There are many definitions of UX. For more details, see Scapin and al. (2012) and Pallot and Pawar (2012), as well as the standardised one from ISO 9241-210 (2009): "User Experience is a person's perceptions and responses that result from the use or anticipated use of a product, system or service". The ISO description presents UX as "all users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after the use of product, system or service". It also mentions that the type of product/system/service, user profile and the context of use are factors that influence UX. More recently, Scapin et al (2012) reported on the positive side that UX has become very popular but on the negative side UX has several meanings, with a varying and complex coverage of topics and issues, and according to Komulainen (2008) is very subjective and versatile by nature. Roto and his colleagues (Roto, 2008; Roto and al, 2011) introduce the notion of episodic, momentary and cumulative UX (as shown in Figure 8) related to the time spans of UX measures.

Based on a literature review and study on UX types, concepts, elements and their properties carried out during the ELLIOT project, a holistic model (Pallot & Pawar, 2012) has been created in order to provide a global UX model that could be instantiated

whatever is the use case domain. After instantiations and experimentations in various use cases within the ELLIOT project, the refined version of the UX model includes 10 experience types, 18 elements and 40 properties as shown in Figure 3. This model was used for analysing the user experience of MyGreenServices (see Take in Table 4.)

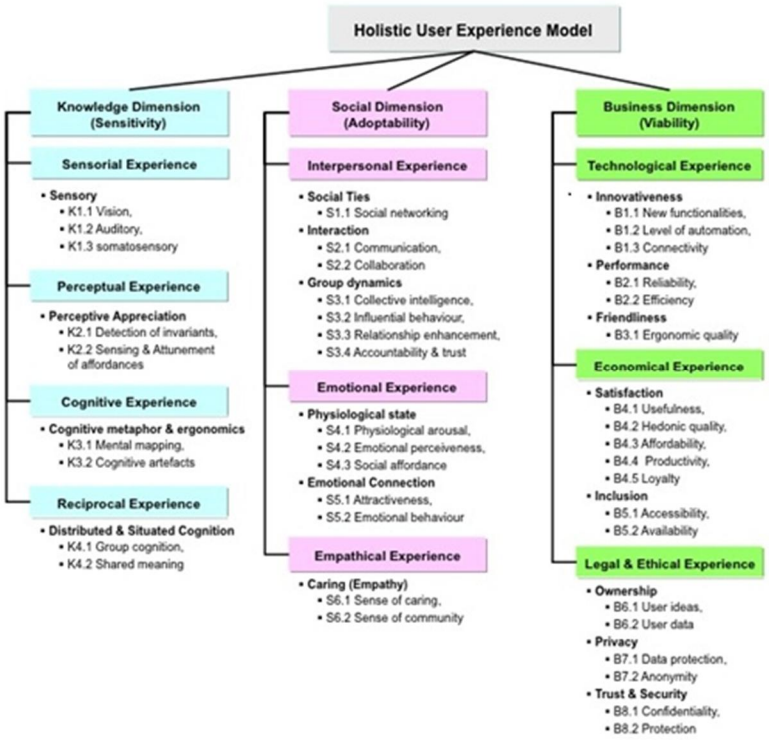

Figure 3. A Holistic View of User Experience Extracted from (Pallot & Pawar, 2012).

According to the three perspectives (Bifulco and Santoro, 2005), three categories of experience types were identified (Pallot & Pawar, 2012), namely: Knowledge (sensorial, perceptual, cognitive and reciprocal aspects), Social (interpersonal, empathical and emotional aspects), and Business (technological, economical, legal and ethical aspects). The names given to all experience types are voluntarily based on convenience for practical simplicity and understanding rather than deep scientific foundation.

IoT-based Service Design

Over the past decade, two well-known types of service design techniques for getting insight people' lives have become popular and efficient for co-creation with users: the generative techniques (say and make) and the bodystorming ones (do). Let us describe briefly these two types of techniques, issued from (Negri and al., 2012).

Cultural probes (or design probes) is a technique for idea generation, inspiration, values and dreams in a design process. It was initially developed by Gaver and colleagues (1999) and serves as a means of gathering inspirational data from people in a wide variety of projects. The idea of using probes or artefacts in the co-creation process is that this kind of technique enhances the communication between designers and users as well as it offers opportunities for further exploration. Kuznetsov and Paulos (2010) presented a research where various stakeholders (students, parents, homeless) were invited to place environmental sensor probes in the public space and to take pictures of the placement during one week. After the experiment, an interview was organized and the pictures were gathered by the researchers.

Bodystorming is not something new. It is an approach allowing the generation of unexpected ideas that might not be realized by a traditional brainstorming for example (talking or sketching). Bodystorming can be defined as a type of participatory method for demonstrating concepts

with a physical approach. Ideas are developed through acting. Thus, unlike brainstorming it is not just a written idea, and is often a technique that is used in the early stages of interactive design. In the service design domain both improvisation (incl. brainstorming) and role-playing have been used for fostering innovation and highlighting user needs since decades as highlighted by Medeler and Magerko (2010). It builds upon the notion of "bodystorming" coined by Simasarian (2003), whereby participants not only project themselves (at a rational and controlled level as they could do while reading a usage scenario) in an given role but do enact as the character they play, therefore live a deeper experiential learning and go through another cognitive process as well as group processes.

For ELLIOT purposes, ICT Usage Lab researchers developed two new Ideation methods (GenIoT and Aloha! (Negri and al., 2012) that have been tested in R&D context before being applied during the co-creation workshops (see Section Our Approach).

Citizen Sensing & Green Services

According to our goal of involving users in the co-creation and exploration steps of the XD process for green services, some previous work related to smart citizen environmental sensors and citizen sensing for environmental purposes were identified before starting the ELLIOT project in 2010 and reported below. Our objective is to build awareness through the act of monitoring and also to develop a user community.

Let us start with noise that is a serious problem in many cities and the research project NoiseTube started in 2008 at the Sony Computer Science Laboratory in Paris in collaboration with Vrije Universiteit Brussel (VUB). NoiseTube (www.noisetube.net) was created with the purpose of turning smartphones into mobile noise level meters. The application allows citizen to participate in the collective noise mapping of their city. NoiseTube has three features: measure noise, localize it and tag it. Tags include the level of annoyance and the source of sound, such as an airplane. The collected data is wirelessly sent to the NoiseTube server in real time. Once the data has been uploaded to NoiseTube's Web site, users can check their sound trajectory on Google Maps.

Concerning air quality and citizen sensing, let us cite three projects for illustrations. First Pre-emptive Media's AIR project (www.pm-air.net) which is a public, social experiment launched in 2006 and inviting people to use air monitoring devices in their urban environment, to collect data and see pollutant levels in their current locations and simultaneously view measurements from the other devices in the network. Secondly in 2009 the French think-tank Fing with its partners experimented in Paris a green watch with its City pulse platform. The Green Watch project was based on similar experiences carried out in London, New York and San Francisco: the watch communicated its measurement's data via the mobile phone of the user to a common platform either in real time or at night for synchronisation. Thirdly Patchube has launched a device called "the air quality egg" (cf. http://airqualityegg.wikispaces.com/AirQualityEgg) sensing nitrogen dioxide and carbon monoxide, which has built a community of interest around air quality and the construction of independent collective infrastructures. The Air Quality Egg community was born out of groups from the Internet of Things Meetups in New York City and Amsterdam. The Egg base station has the ability to convey information through a coloured light and also has a button for user feedback. The outdoor air quality data is sent in real-time to Patchube, an open data service, which both stores and provides free access to the data.

Various smart pollution devices have been proposed. Netatmo (www.netatmo.com) proposes smart connected weather and C02 citizen sensors and services on smartphones/tablets (with weather maps on the world). Azimut Monitoring (www.azimut-monitoring.com) specialist in air quality/noise urban monitoring proposes also smart citizen/city sensors (outdoor and indoor) and services. Students from Carnegie Mellon University have proposed low-cost giant air quality balloons (http://www.instructables.com/id/Air-quality-balloons/) which react to surrounding air quality: inside each balloon there are a tri-colored LED and an air quality sensor turning green, yellow or red based on low, average or high values.

Finally we can cite a recent European Research (ERC 2013-2017) project called "Citizen Sense" (www.citizensense.net), based on a crowdsourcing application which is a crowdsourcing which

proposes some cases under progress, such as urban sensing and air walk.

Even if some of these green services are based on citizen sensing and on manufacturing low cost sensors by citizens with a Do-It-Yourself approach, no work has been found at the beginning of the ELLIOT project related to the UX design and measurement of green IoT-based services within living labs.

Our Approach for Co-creating Green Services

In this section, we first present a) the XD process we have been followed for co-creating green services with citizen, b) the Ideation methodology we adopted for co-creating IoT-based green services and finally c) the UX model elaborated based on the holistic UX model and the methodology used for measuring UX of MyGreenServices and finally the citizen environmental data platform we implemented.

The XD Process

The XD process in the Green Services use case followed the four steps as presented in Figure 1 and illustrated in Figure 4 for our two scenarios conducted in an iterative way. We used a participative approach from the ideation to the test. Indicators of the Knowledge, Social and Business dimensions are computed for UX analysis and, more generally, for the service refinement.

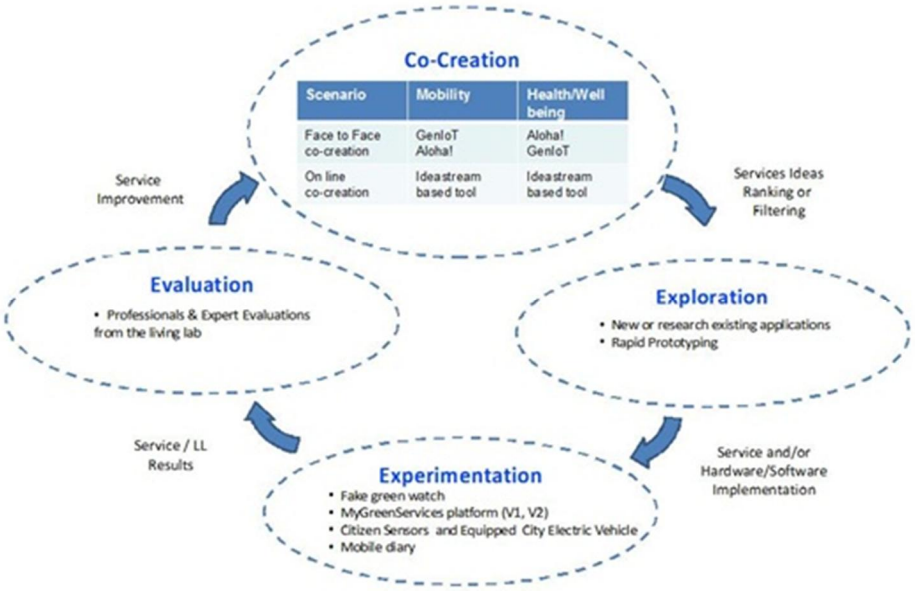

Figure 4. Experential Design Process Deployed for Green Services Use Case

Our use case is grounded on an original methodology combining participatory design methods for the whole process (face-to-face and online focus groups), diary studies for IoT experience analysis and a quantitative and qualitative approach for MyGreenServices UX measurement. This process has involved almost 50 active participants in the various workshops or experiments as shown in Table 1:

Table 1. Participants Involved

Co-creation / Exploration			Experimentation/Evaluation			
	Workshops Mobility	Workshops Health	Fake green watch	Experiment 1	Experiment 2	Total
Participants	13	8	6	13 (9 producers)	8 (6 producers)	48

For co-creation/exploration steps, we organised for each scenario (Mobility and Health/Well being) two workshops with the use of an IdeaStream-based tool for sharing ideas between each workshop. For each scenario, we applied our Ideation methodology elaborated within the ELLIOT project and described later.

For the experimentation/evaluation steps, due to important delays in manufacturing the second version of the green watch, we organised a fake green watch diary study with 8 citizens which was very fruitful about their contexts of use and their interests in terms of pollutants. In parallel based on the output of the previous steps, MyGreenServices platform has been developed, tested with citizens and improved via user feedbacks. The aim of the last experiments is to assess the UX and experiential learning related to MyGreeenServices; this includes experience related to the IoT devices, to the measures and services as well as air quality awareness and behaviour changes monitoring.

Two experiments have been carried out in February and in June 2013, with the aim to test the MyGreenServices platform by two types of user profiles (data consumers and data producers) and to measure UX. Data from pollution sensors were recovered and fuelled in the maps of MyGreenServices platform developed in the project. During the experiments participants were asked to fulfil various questionnaires in a longitudinal study to evaluate their awareness of air quality, their experience with the services provided by the platform (alerts, forum) and the user change behaviour on air quality. The involvement of users during the experiments was constant and the overall level of satisfaction was high.

Proposition of an Ideation Methodology

For supporting the co-creation/exploration steps, ICT Usage lab researchers proposed an Ideation methodology (Negri and al, 2012) elaborated during the ELLIOT project: it relies on the coupling of two Ideation methods (GenIoT, Aloha!) and the use of an open source collaborative idea management tool (IdeaStream from http://www.gi2mo.org/). This methodology has been applied for two scenarios Mobility and Health & Well Being, during workshops where participants were invited to imagine a green service.

With GenIoT, participants were invited to use probes during two weeks and think about the sensors position and they would therefore have access to the types of measures. They were supposed to place the probes and take a picture (see Figure 5). The second method called Aloha! is a role play with three steps (casting, meeting, playing), where participants after selecting a role (persona or object) met the others, built a scenario and played it. After an initial surprise effect caused by the playful aspect of the Aloha! method, participants tend to choose cards representing persona rather than those with intelligent objects (see Figure 6).

Figure 5. GenIoT Method – Fake Sensors with Indications of Wished Actions

Figure 6. AloHa! – Designers Enacting IoT Green Service Scenarios during the Health Workshop

In support, there was a customized IdeaStream-based platform (with gamification) dedicated to sharing ideas. The photos from GenIoT and the scenarios from Aloha! were put online in order to allow exchanges between the workshops and enhance the development of the ideas (see Figure 7).

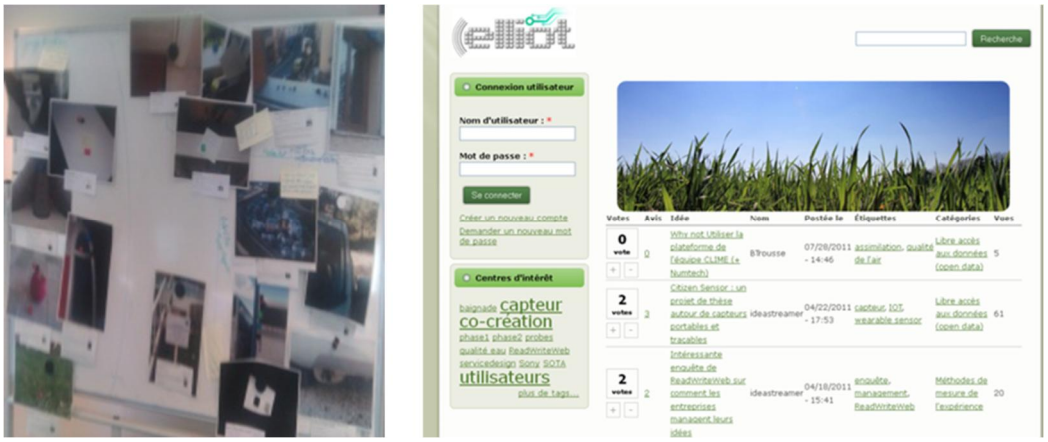

Figure 7. Sharing Ideas with a Gamified Ideastream-based Tool

The most reported benefit of our GenIoT method was that it increased the awareness about air quality and noise, in a permanent manner. It is very relevant since one of the aims of the use case was behaviour change and so on awareness about environmental issue. Some questions were raised permanently such as: "how can I put a sensor there?, how can I measure that?" In relation to this, there is the social aspect of the method. Indeed, their families or strangers asked participants about the signification of the cubes. Therefore, the awareness from individual became collective.

Aloha! is rooted in the bodystorming and its originality is that participants have the possibility to play not only persona but intelligent objects too. GenIoT allows participants to explore the say and make dimensions and its originality lies in the use of a diary and the collaborative platform dedicated to ideas sharing (a customized IdeaStream based platform). Finally the novelty on the approach developed here is in coupling two methods, maximizing with multiple supports and experiences the creativity of the group, but also in approaching the Internet of Things along the three experiential dimensions: say, make and do.

Our UX Measurement Methodology

In accordance with the overall objective of MyGreenServices, our UX measurement methodology focused on the level of awareness/experiential learning raised after usage of MyGreenServices (awareness pollution, awareness of citizen dissemination and change of behaviours), the ease of use and diffusion aspects (as being a tool provided to the citizen).Two objects of the learning were considered: IoT via MyGreenServices portal and Air quality. We used differential between a pre-profile and post-profile.

Our UX approach in the context of ELLIOT project (see Section 5 in Tiemann and al. 2013) relies on the following six steps:

Step 1: Select an UX model: in our context we instantiated the UX holistic model (see Figure 3) for our service i.e. we selected potential UX elements and properties. To address our overall objective according to the K, S and B dimensions, twelve UX properties have been selected to describe the user experience (see the first three columns of Table 4):

- **K** dimension: our main goals were to increase awareness on IoT paradigm and update knowledge on the impact of air quality in daily lives. Specifically the "cognitive" elements have been selected i.e. learning and understanding about behaviour change: Cognitive Artefacts and Sensing Affordances ;
- **S** dimension: our main goals were to foster user involvement in air quality measurement and encouraging information sharing. Specifically the "reciprocal" elements for the usage of the IoT based system as a persuasive and dissemination tool have been selected i.e. creating an interest about air quality and pollution in the community of users (collective intelligence);
- **B** dimension: our aim was mainly to provide robust, easy-to-use and engaging green services and to change citizen behaviour towards a more sustainable lifestyle. B elements for the technological functionality and ease of use have been selected, i.e. the solution should be user friendly (Ergonomic Quality) and providing reliable data (Reliability) taking care of personal data (Data protection).

Step 2: Clarify the types of UX and the time spans you choose for measuring UX properties and elements; indeed UX measures could either be cumulative, episodic or momentary as shown in Take in Figure 8.

Table 2. UX types and targets assessed via online questionnaires

	MyGreenServices	Alert	Forum	Maps/ Measures
Momentary UX				{Q3}
Episodic UX	Q1.1, Q1.2	Q1.2	Q2	Q2
Cumulative UX	Q1.2, Q4, interview	Q1.2, interview	interview	interview

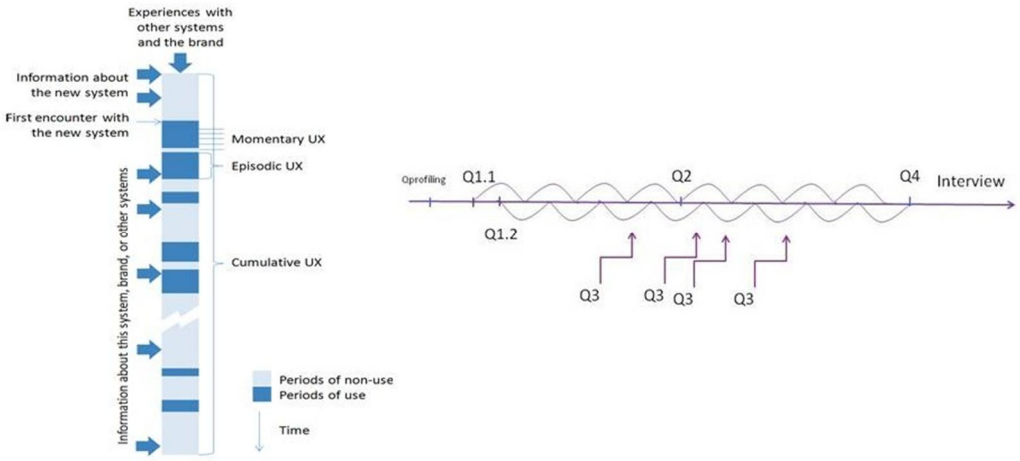

Figure 8. Time Spans: Types of UX (left) from (Roto et al 2011) – (right) from MyGreenServices

Step 3: Define relevant questions and/or data for indicator computation. Heterogeneous data have been selected:

- Five questionnaires have been used. User experience and behaviour changes were assessed via one user profile questionnaire and 4 types of online questionnaires:
  - The User Profiling questionnaire (Qprofiling) used to recruit our participants for the co-creation workshops has been used also for the experiments. It includes 65 questions about several themes: Lifestyle; Participants and Sustainable Development; Participants and ICT's; Participants and respiratory diseases; Green Services; Personal details.
  - One online contextual questionnaire (Q3) triggered at most twice a day and sent to the participant by SMS for an immediate answer. Such a questionnaire aims at gathering data on the participant experience of the air pollution.
  - Two online recurrent questionnaires (Q1.1 and Q1.2), triggered every 4 days in order to measure change in behaviour and opinion;
  - Two online one shot cumulative questionnaires at mid (Q2) and end (Q4) of the experiment (in order to gather the holistic UX and prepare the interview. Attitude changes were also assessed by measuring the pre/post experimentation delta;
- Logs: Logs of MyGreenServices, Logs from gamified forum, Contents of the forum, IoT data (more than 4 millions of measures);
- One individual Interview in order to debrief and qualify the data held at the end of the experimentation.

We summarize in Table 3 the various types of data used for each property.

Table 3. Types of Collected Data for our 12 UX Properties

Direct questions		Indirect questions	
Without log	With log	Without log	With log
S2.1	S1.1	K2.2	K3.2
B2.1	B6.	B4.2	S5.1
		B7.1	B3.1
			B4.1
			B4.5

To illustrate indicator computation, we choose Attractiveness (S5.1): to compute it, we use the user answers to two indirect questions (q7 and q9) from questionnaire Q4 and data from MyGreenServices logs.

- q7: Would you recommend the portal to your friends?
- q9: Have you recommended MyGreenServices to your friends / acquaintances?

Step 4: Define UX indicators and their weighting for each UX properties/elements computation (cf. Table 4) based on selected raw data. Each property of the holistic model was assessed by one or more dedicated questions and/or usage data (logs, data inputs in the forum, etc).

Table 4 reports the mapping between our instantiated UX model for MyGreenServices and the elaborated indicators for the mapping and the data used to compute them.

Step 5: Define the UX metrics for UX indicators and rules linking UX indicators and UX properties and elements. To address K dimension, we used Bloom's taxonomy (Bloom et al., 1973) for supporting us.

Below we illustrate with three examples of such rules for Green Services:

Cognitive artefact (K3.2) is evaluated by merging four questions and portal data log: the capacity of the user to remember the last value seen on the MyGreenServices portal, their perception of behaviour change, the comparison made between data provided by the MGS portal and other sources and the usage of the downloading functionality.

- If % users able to self-assess their environment are < 20% then Cognitive artefact is low;
- If % users able to self-assess their environment is > 20% and <40% then Cognitive artefact is medium;
- If % users able to self-assess their environment are > 40% then Cognitive artefact is high.

Social networking and openness (S1.1) is calculated merging one question and the data log: by measuring the activities i.e. the level of use and merging the usage log, the aim is to determine the utility of the forum for sharing information.

- If % users inactive > α then Social networking and openness is low;
- If % users proactive >= β the Social networking and openness is high;
- Medium for the rest.

Here α = 90% and β = 2% were chosen based on the common rule (http://en.wikipedia.org/wiki/1%25_rule).

Usefulness (B4.1) is calculated by aggregating the analysis of three questions related to *a change of behaviours during and/or after the experiment* in terms of: transportation, aeration, outgoing, sport, aeration or others. This is obtained with one method from FocusLab (2013) by clustering users based on their answers related to their behaviours of the diary study at every two days and analysing change in terms of clusters. Interviews help us to better understand the behaviour change.

- If % users declaring a change of behaviour > 5% then high
- If % users declaring a change of behaviour < 5% and > 1% then medium If % users declaring a change of behaviour < 1% then low

Step 6: Collect and pre-process experimental and log data for UX indicators computation inside the living lab. Pollution context for each participant is computed via advanced data stream mining methods from AxIS software of FocusLab platform (focuslab.inria.fr) as well as its usage of MyGreenServices in order to ponder some values of UX indicators and finally UX measures.

Table 4. Data – UX Indicators Mapping for the Experimentation

	Ref	UX Properties	Input	Indicators with weighting
			Knowledge	
Perceptual	K2.2	Sensing and attunement of affordances	Questionnaires	Air quality knowledge
Cognitive	K3.2	Cognitive artefact	Questionnaire, Log, Interview	Environment evaluation, Change in activity, IoT Data comparison
			Social	
Social Ties	S1.1	Social Networking and openness	Questionnaire, Log	Level of activity, Frequency of connections, Forum statistics
Interaction	S2.1	Communication	Interview	Number of MGS demonstrations
Emotional Connection	S5.1	Attractiveness	Questionnaire, Log	Number of intended recommendations, Number of effective recommendations, Frequency of connections after experiments
			Business	
Performance	B2.1	Reliability	Questionnaire, Log	Perceived data reliability, Frequency of connections
Friendliness	B3.1	Ergonomic quality	Questionnaires, Log	General findability Forum findability, Alert service opinion, Intuitivity of alert service
	B4.1	Usefulness	Questionnaire, Log, Interview	Alert programmation, Change in habits, Alert logs
Satisfaction	B4.2	Hedonic quality	Questionnaires	MGS opinion , Reaction to alert service, Forum opinion
	B4.5	Loyalty	Questionnaires, Log	Intention of use, Frequence of connections (perceived)+ data logs connections and users sessions
Ownership	B6.1	User ideas	Interview, Log	Number of new services, Forum statistics
Privacy	B7.1	Data protection	Questionnaire	Data protection (perceived)

The originality of our UX measurement methodology is based on the use of heterogeneous data, on the identification of relevant indicators as aggregated/computed variables based on advanced data mining methods (FocusLab, 2013) and finally the definition of UX rules linking UX properties and UX indicators.

Results

In this section we describe the three main results obtained during our Green Services use case.

Exploration – Co-creation

In order to introduce the process, several presentations were done concerning either IoT and noise/pollution or IoT and health/well being solutions. Then a few exploratory sessions were organized (Air Paca, Green Watch v1, Nice Air mock-up) using think aloud and verbal analysis.

In order to improve the analysis all the workshops were video recorded allowing the LL researchers to analyse the workshops using both video transcripts (verbal analysis and restitution of participants' ideas) and video analysis (body language).

The attitude of participants towards the two Ideation methods was globally positive even if unexpected – especially in the case of well-being professionals. For more details on the used methods, see (Negri and al., 2012).

After a run of both Aloha! and GenIoT methods the ideas were listed and participants have to vote for their favourite one, in order to work on the development of a usage scenario. At the end of the mobility workshop a list of four ideas of green services based on IoT emerged, but the elaboration of the usage scenario fails because of a lack of collective implication. However, in the health workshop only two ideas of green services based on IoT have been developed, but in the last workshop participants went further in the co-creation process. Indeed, the transcripts of de first workshop allowed the LL researchers to establish a usage scenario using a dedicated tool as illustrated in the Figure 9 below.

Figure 9. Part of the Usage Scenario in Health (people with respiratory problems).

In the last meeting, after reading the usage scenario, participants went further prototyping an intelligent object as shown in the Take in Figure 10.

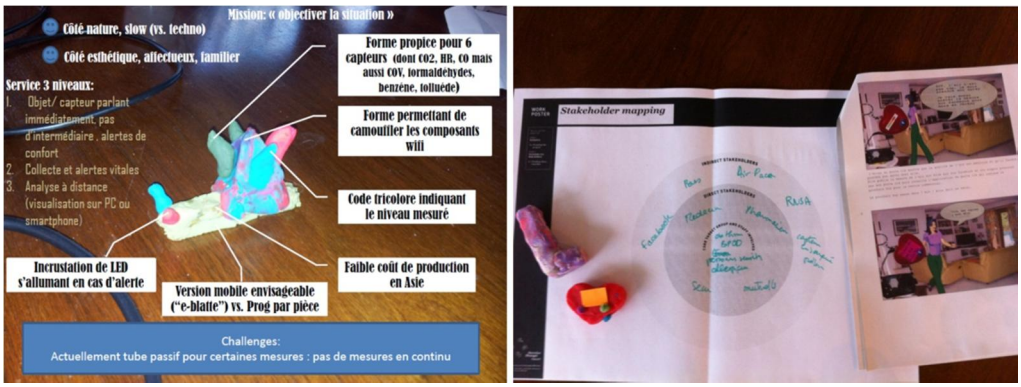

Figure 10. Face-to-face Workshop Productions (smart indoor air quality object, smart key holder)

MyGreenServices, a Pollution Citizen Data Platform

ICT Usage Lab researchers based on the citizen/professionals productions during the co-creation/exploration steps implemented an environmental data platform called MyGreenServices (MGS) and based on citizen sensing in order to raise public awareness and to create a community of empowered citizens. Let us note that in ELLIOT project proposal, our use case should involve outdoor environmental sensors (ozone, nitrogen dioxide, micro-particles) and two scenarios mobility and health/well being. So, even if within the different workshops, monitoring indoor air quality seems to be more for participants than outdoor air quality and also other pollutants such as pollen in our Nice region seems to be requested, we maintain, due to some ELLIOT constraints (proposal content, budget), to address outdoor air quality monitoring by citizen sensing.

MyGreenServices (mygreenservices.inria.fr) offers various green services such as the visualization of environmental data collected by citizen, the alert services, the ability to download data, the forum for sharing ideas and best practices in terms of eco-responsible behaviours. A pollution-alert service has been created considering two points of view: the first one consists of localising a person and indicating via email or text message the passage through a polluted area. The second one allows the user to define an area to follow and the user will be advised of pollution alerts for the area by email or text message. Privacy protection inside MyGreenServices has been taken into account with various features such as user authentication with CAPTCHA and email validations, SSL certificate, two separate data bases for sensors and for users and portal logs, and a loan agreement for sensors.

The IoT set up includes both citizen mobile & fixed sensors and one equipped MIA city electric vehicle related to pollution measures. The collected IoT data and green services are accessible to citizen/professionals on a community open data portal (see Figure 12) called MyGreenServices (mygreenservices.inria.fr with free registration). Two types of users are managed: data consumers and data providers (those who got an environmental sensor for data collection).

Two types of citizen sensors (see Figure 11) are used:

- Mobile sensor with user documentation and information on the pollutants (ozone 03, nitrogen dioxide NO2, noise) could be used on bikes, cars, or weighted by pedestrians;
- Fixed sensors with user documentation and information on the pollutants (dust or micro-particles PM10): these sensors should be used on balconies being well exposed to the sun.

Figure 11. Fixed and Mobile Citizen Air Quality/ Noise Sensors

Figure 12. MyGreenServices "Citizen Measures" Page.

A first added value of Citizen Production is the user feedback on the first version of MyGreenServices and on each user guide elaborated of our three types of citizen sensors. User feedback helped us to improve the service and to create new services in the second version: more access to all sensors, pollution synthesis by quarter/time-period, improvement of mobile sensors tracks inside MyGreenServices maps, etc. The second experiment confirms UX results obtained during the first experiment and most of UX indicators values are better with the second version of MyGreenServices improved with user feedback (see Figure 15).

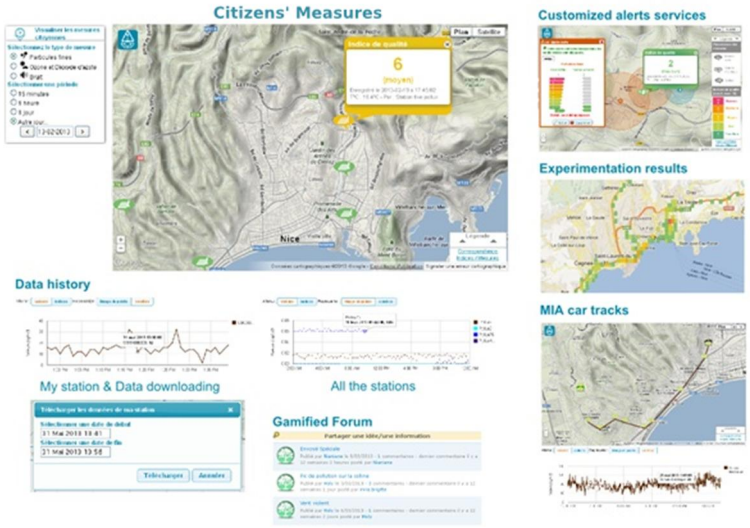

Figure 13. MyGreenServices Dashboard

Producers had an IoT device (fixed for PM10: Pollux – and AxISBox (based on Arduino) in the second experimentation – or mobile for O3 and NO2: Azimut) and their task was to charge the device regularly to ensure proper operation of the device and fill out questionnaires as part of a longitudinal study. Consumers should consult data on MyGreenServices portal while responding to questionnaires.

A second added value of Citizen Production is the generation of a pollution database from mobile and fixed IoT sensors with around 4 million pollution measures through the ICT Usage Lab, and also other valuable user contributions (usage scenarios and ideas during the workshops, posts on the forum).

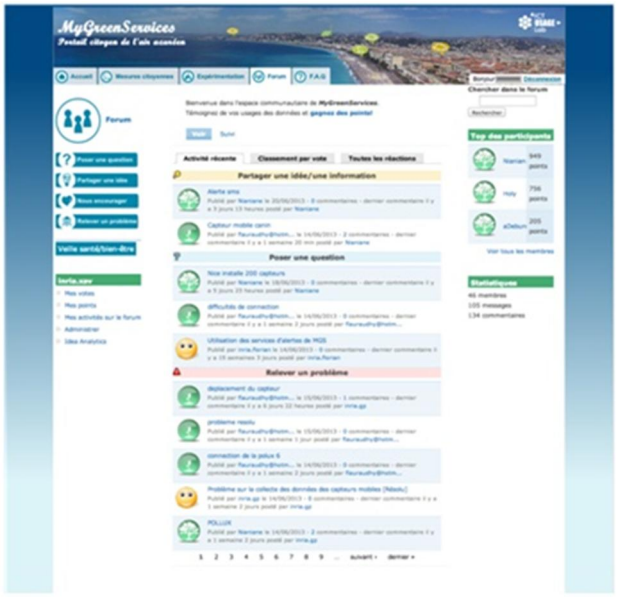

Figure 14. MyGreenServices "Gamified forum" Page

User Experience

The two experiments related to MyGreenServices indicated very similar good qualitative results in terms of UX properties (high and medium) with better quantitative results for the second experiment (as shown in Figure 15) mainly due to the improvement of MyGreenServices (v2) based on user feedback and on an improved community management.

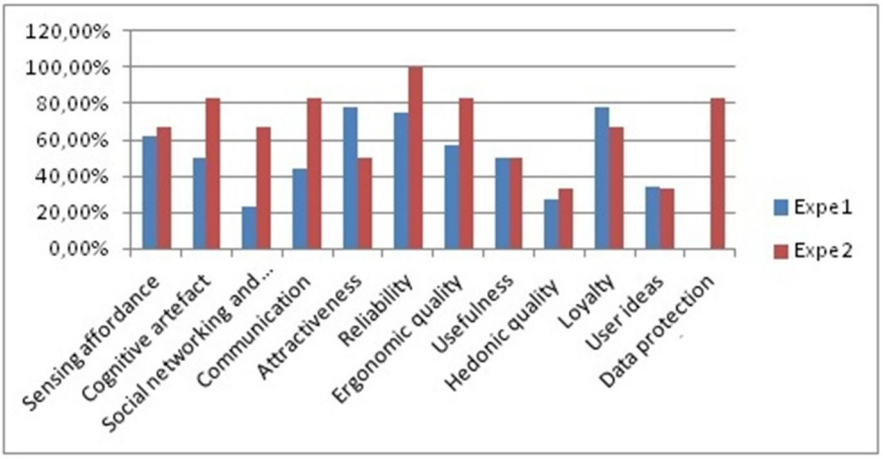

Figure 15. Quantitative Values of UX Properties.

The percentage of users finding MyGreenServices portal and its components intuitive increased between the two versions. Concerning Reliability, participants of the second experiment are more confident in the measures provided by MyGreenServices than those in the first experiment, due to an improvement of the exchange quality between participants and experts. Regarding Social Networking and Openness, the percentage of users having activities of posting ideas, comments etc. in the forum (pro-active user) increased in an important way.

Using MyGreenServices and Citizen sensors, 62,5% of users declared a change of perception in the awareness against air quality (cf. K2.2) and 44% of users declared a modification in their activities during the experiment (cf. K3.2): for example two participants chose a less polluted place for their jogging, one reduced the indoor heat temperature when loading the sensor at their home and another participant chose a common urban transport in case of high pollution.

Related to Business dimension, the second version of MyGreenServices based on user feedback has been perceived as a real improvement compared to the first one (more data access, more curves, IoT data synthesis, a better community management, etc.). For more details on UX related to MyGreenServices, see Section 5 in the Elliot deliverable of Tiemann and colleagues (2013).

Discussion – Conclusions

Primarily Green Services Use Case deployed in the context of the ELLIOT European Research project on the Riviera Coast (France) was a very fruitful experience for our LL in deploying an XD process related to green IoT-based services. The main lessons concern: the positive impact of engaging citizens in all steps of the XD process and in the interest community creation; the impact for people of sensing environmental data on their engagement with space; the improvement of the first version of MyGreenServices and of IoT guides based on user feedbacks; and the usefulness of measuring UX of such services in order to better understand and evaluate their impact related to citizen awareness and behaviour change.

Secondly, concerning implications on methodological research, we have experimented an original Ideation methodology for IoT based services (Negri and al., 2012), elaborated during the ELLIOT project and coupling two ideation methods and a gamified idea generation tool. Gamification was also very efficient for encouraging citizens to participate during our two experiments of MyGreenServices. The improvement of the community management during the last

experiment of MyGreenServices had very positive impacts. The diary study was very effective and efficient related to the "fake green watch" experiment and also for the two MyGreenServices experiments. More lessons were also learned from internal tests aiming at installing the IoT devices in a "live setting". Such tests also enhanced the list of requirements and warnings to be presented to the participants volunteering for hosting IoT devices (battery charge for instance requires participants to really take care of the IoT device, but also protection of the sensor was an issue).

The UX holistic model used for elaborating our UX model was useful as a first step but Indicators and metrics for the measurement of each selected property of the different types of experience are not obvious to identify and often quite demanding. Writing rules linking UX indicators and UX properties has appeared as a difficult task requiring some referential thresholds that are not always available or consensual in the scientific community. We have started to elaborate an UX measurement methodology in order to support UX model instantiation and measurement dedicated to various types of UX or service goals in the context of IoT-based services. More interdisciplinary research on UX is needed involving Human and Social Sciences and ICT. Exploiting user contexts based on IoT data stream analysis as we have started in ELLIOT project seems also very promising in order to improve the UX understanding and to report it to users. Designing persuasive interfaces in order to increase pollution awareness and provoke eco-responsible behaviour changes is also very challenging at the urban level. Finally, in addition to our UX approach and the XD process followed in the design of MyGreenServices, more research should be done to articulate UX and Agile approaches.

Thirdly, to conclude on UX of MyGreenServices, after the two 16-days experiments, participants have increased their awareness on air quality. This can be considered as a first step in the behaviour changing process. We also noted some behaviour changes based on using MyGreenServices but more data are required with a statistical point of view. At the end, a community of around 50 active contributors (citizen/professionals, co-creators/data producers) has been created and they exchange on these questions in our forum. The MyGreenServices pilot can be seen as a successful pre-test. Our lab is now studying how to pursue this case study with more experiments involving more users with a smartphone version of MyGreenServices that is already specified. More citizen sensors are required in order to cover in a relevant way a large territory such as the city of Nice; and to better promote some existing interesting functionalities of MyGreenServices such as the customised alert service by email or sms. More research and experiments are required where new economical models should be elaborated involving the territory's stakeholders and citizens based on the value of their productions.

Finally, current and future work concern the study of various ways to exploit the numerous assets for our lab issued from the ELLIOT project (sensor data collection, citizens productions, user experience data, know-how, etc.) and to manage other experiments on the economical aspects. So we are pursuing our interaction with NCA viewed as an ecosystem to co-create sustainable applications/social innovations in partnership with citizens, stakeholders, research institutions and public agencies such as Air PACA.

References

Aarts, E, and Marzano, S. (2003). The New Everyday: Views on Ambient Intelligence, E. Aarts, S. Marzano (Eds.), Uitgeverij 010 Publishers, Rotterdam, The Netherlands.

Alben, L. (1996). Quality of Experience: Defining the Criteria for Effective Interaction Design. Interactions 3(3), 11-15.

Bifulco A. and Santoro, R. (2005). A Conceptual Framework for 'Professional Virtual Communities'. In: IFIP International Federation for Information Processing, Vol. 186 (January), 417-424.

Bloom, B. S., Krathwohl, D.R. and Masia, B.B. (1973). Taxonomy of Educational Objectives. Handbook 2: Affective domain. London. Longman Group Limited.

Curley, M. and Salmelin, B. (2013). "Open Innovation 2.0: A New Paradigm", OISPG White Paper, June.

Erkinheimo-Mennander, P. and Harjanne, K. (2011). "The Usage and the Benefits of Internal and External Crowdsourcing", Open Innovation Yearbook.

FIREBALL (2012). FIREBALL White Paper - Smart Cities as Innovation Ecosystems Sustained by the Future Internet. http://hal.archives-ouvertes.fr/docs/00/76/96/35/PDF/FIREBALL-White-Paper-Final2.pdf

FocusLab (2013). FocusLab, a Web-based Platform for Supporting the Observation and Analysis of User Experience Data – v2 CPER Telius (2010-2013) – PACA Region and FEDER - Inria@ICT Usage Lab.

Galver, B., Dunne, T. and Pacenti, E. (1999). Design: Cultural Probes. Interaction 6(1), ACM New York, January-February, 21-29.

Goodchild, M. F. (2007). Citizens as Voluntary Sensors: Spatial Data Infrastructure in the World of Web 2.0. International Journal of Spatial Data Infrastructures Research, Vol.2, 24-32.

Hassenzahl, M., Platz, A., Burmester, M. and Lehner, K. (2000). Hedonic and ergonomic quality aspects determine a software's appeal, Proceedings of the SIGCHI conference on Human factors in computing systems, 201-208, April, The Hague,

ISO 9241-210 (2009). Ergonomics of Human System Interaction - Part 210: Human-centered design for interactive systems (formerly known as 13407). International Organization for Standardization (ISO). http://www.iso.org/iso/catalogue_detail.htm?csnumber=52075

Kankainen, A. (2002). Thinking model and tools for understanding user experience related to information appliance product concepts. Doctoral dissertation, Helsinki University of Technology, Finland.

Kuznetsov, S. and Paulos, E. (2010). Participatory sensing in public spaces: activating urban surfaces with sensor probes. In Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS'10). ACM, New York, NY, USA, 21-30.

L'Atelier (2013). [Innovative City] Involving Citizens as researchers, Co-creators and testers of the Smart City – Interview by Ruolin Yang, June 24. http://www.atelier.net/en/trends/articles/innovative-city-involving-citizens-researchers-co-creators-and-testers-smart-city_422073

Maisonneuve, M., Stevens, M., Niessen, M. E. and Steels, L. (2009). NoiseTube: Measuring and mapping noise pollution with mobile phone. Information Technologies in Environmental Engineering (ITEE 2009) Proceedings of the 4th International ICSC Symposium, Thessaloniki Greece, May 28- 29,Ioannis N. Athanasiadis, Pericles A. Mitkas, Andrea E. Rizzoli & Jorge Marx Gómez (Eds.). Published by Springer Berlin Heidelberg, 215-228.

Medeler, B. and Magerko, B. (2010). The Implications of Improvisational Acting and Role Playing on Design Methodologies. Proceedings of CHI 2010, April, Atlanta, Georgia, USA .

Negri, A.-L, Trousse, B.and Senach, B. (2012) Ideation of IoT Services with Citizen: Coupling GenIoT and AloHa! Methods, in: Serdev'2012 - Service Design and Innovation Conference, Helsinki, Finlande. http://www.ep.liu.se/ecp_article/index.en.aspx?issue=067;article=017

Norman, D. (1999). Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex and Information Appliances Are the Solution. MIT Press. ISBN 978-0262640411

Pallot, M. (2009). The Living Lab Approach: A User Centred Open Innovation Ecosystem". Webergence Blog Retrieved January http://www.cwe-projects.eu/pub/bscw.cgi/715404

Pallot, M., Trousse, B., Senach, B. and Scapin, D. (2010). Living Lab Research Landscape: From User Centred Design and User Experience towards User Cocreation. In Proceedings of the Living Lab Summer School, Paris, Cité des Sciences, August.

Pallot, M. and Pawar, K.S. (2012). A Holistic Model of User Experience for Living Lab Experiential Design, In Proceedings of the 18th International Conference on Engineering, Technology and Innovation, ICE'2012 "Innovation by Collaboration and Entrepreneurial Partnerships", Munich, Germany, June.

Pallot, M., Pawar, K. S. and Santoro, R. (2013) A User Experience Framework and Model within Experiential Living Labs for Internet of Things, In Proceedings of the IEEE International Technology Management Conference & 19th International Conference on Engineering, Technology and Innovation, ICE'2013 "Responsible Innovation and Entrepreneurship", The Hague, The Netherlands, June.

Pallot, M., Krawczyk, P. and Kivilehto, A. (2013). "User Centred Open Innovation Domain Landscape within the European Network of Living Labs". In Proceedings of the ISPIM'2013 Conference "Innovating in Global Markets: Challenges for Sustainable Growth", Helsinki, Finland, June.

Roto, V. (2008) User Experience Research in the Design and Development Phase. Keynote at the User Experience & User Generated Content workshop, Salzburg, Austria.www.icts.sbg.ac.at/media/pdf/pdf1684.pdf

Roto, V., Law, E., Vermeeren, A. and Hoonhout, J. (2011). User Experience White Paper: Bringing clarity to the Concept of User Experience (Result from Dagstuhl Seminar on Demarcating User Experience, Sept., 15-18, 2010). http://www.allaboutux.org/uxwhitepaper.

Rubinoff, R. (2004). How to Quantify the User Experience. Retrieved January 2012? http://www.sitepoint.com/article/quantify-user-experience

Sanders, E. B.-N. (2000). Generative Tools for CoDesigning. In: "Collaborative Design". Scrivener, Ball and Woodcock (Eds.), Springer – Verlag London Limited, pp 3-12.

Scapin, D., Senach, B., Trousse, B., Pallot, M. (2012). User Experience: Buzzword or New Paradigm? In Proceedings ACHI 2012, The Fifth International Conference on Advances in Computer-Human Interactions, Valencia, Spain, January.

Schaffers H., Kommninos N., Pallot M., Trousse B., Nilsson M., Oliveira A. (2011) Integrating Living Labs with Future Internet Experimental Platforms for Co-creating Services within Smart Cities. In Proceedings of the ICE 2011 Conference, June, Aachen, Germany. Published at IEEE Xplore.

Schrepp, M., Held, T., Laugwitz, B. (2006). The influence of hedonic quality on the attractiveness of user interfaces of business management software. Interacting with Computers, 18(5), 1055-1069.

Simsarian K T. 2003. Take it to the next stage: the roles of role playing in the design process. In CHI '03 Extended Abstracts on Human Factors in Computing Systems (CHI EA '03). ACM, New York, NY, USA, 1012-1013.

Tiemann, M., Badii, A., Kalverkamp, M., Vinci, S., Trousse, B., Tiffon, C. and Augros, X. and Pilot, G., Bonacina, F., Lechevallier, Y. and Negri, A.-L (2013). Report on IoT Living Labs Continuous Exploration and Evaluation (final). ELLIOT Public Deliverable Number n°4.3.3.

Acknowledgements
This work was carried out in the context of the ELLIOT EU ICT Project that was partly funded by the European Commission. Authors wish to acknowledge their gratitude and appreciation to the European Commission, all partners, stakeholders and users/citizens for their contribution to this use case. Special thanks to other Inria members of Green Services Use Case team: Anne-Laure Negri for her contribution in Ideation methods and UX measurement methodology, Guillaume Pilot, Xavier Augros, Mylène Leitzelman and Semi Gaieb for MyGreenServices development, Bonacina Florian for his support in user interface design and communication aspects and Bernard Senach for the improvement of IoT installation guides on ergonomics aspects. Thanks also to Arnaud Cristini of the Air Noise Environmental Monitoring Department of Nice Côte d'Azur Metropol, Georges Gallais from VULOG, Didier Dufournet and Claire Maçon of Azimut Monitoring SME and Jérome Boyé of CKAB SME and Thierry Marcou from Fing for their support in the Use Case setting up and finally the i-lab (Numtech, CLIME Inria team) in collaboration with Air PACA agency for their study on IoT data assimilation in real time. Inria thanks also the International Design for All Foundation for having selected MyGreenServices as "Good Practice" for the awards 2014 (http://designforall.org/new/awards.php).

About the Authors

Brigitte Trousse received the M.Sc. degree in Mathematics (1984) and the Ph.D. degree in Computer Science (1989) all from the University of Nice, Sophia-Antipolis, France. She is a permanent research scientist at INRIA since 1990. She was head of the "AI in Design" (AID) research group then of the AxIS research team until 2013 (www-sop.inria.fr/axis). She conducted more than 25 years interdisciplinary research in Artificial Intelligence in collaboration with researchers in human sciences (Ergonomics, Cognitive Psychology, Linguistics, Semiotics, Sociology, etc.) related to user centred design support tools. Her research interests in AI in Design are mainly in knowledge engineering, reasoning technics, CSCW, case-based reasoning, recommender systems and these last years in usage mining, web mining, user co-creation, user experience modelling and measurement, user driven innovation and living lab process in the context of smart cities and health&well-being. From 2008 she has been very active in the European community of living labs (ENoLL). As Inria representative of ICT Usage Lab which is founding member of ENoLL, she was elected member of the ENoLL administration council in 2010. She was also elected President of the new association France Living Labs in 2012. In the context of the ELLIOT project, she was the scientific responsible for Inria partner.

Dr. Marc Pallot is Senior Research Associate at the Nottingham University Business School. He teaches "User Driven Innovation" at ISTIA Innovation and ENSAM Engineering School. His fields of interest are among Future Internet, Smart cities, Experiential Design, User Experience, Collaborative Innovation, User Co-creation, Open Innovation ecosystem (Living Lab) and eCollaboration. He has 17 years industrial experience (1978-1995) within R&D and product marketing & engineering in various sectors such as Telecom, Avionics, Defense, Engineering and CAD/CAM/PDM. He was formerly Vice-President for Product Marketing & Engineering at Win Technology, a software house specialised in Workflow and Product Data Management.

Caroline Tiffon is sociologist specialized in urbanism and new technologies. She is interested in the involvement of citizens in co-creation process and questions concerning appropriation of new behaviors. She was part of the AxIS research team at Inria during the deployment of Green Services Use Case within the ELLIOT European project (2010-2013): she was involved in engaging citizens in all the eXperiential process steps, in community management and in measuring citizens'user experience mainly for the two versions of MyGreenServices.