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Designing IoT Applications for Smart Cities: extending the Tiles Ideation Toolkit

Francesco Gianni and Monica Divitini
francesco.gianni@ntnu.no, monica.divitini@ntnu.no

Norwegian Univesity of Science and Technology
Department of Computer and Information Science
Trondheim, Norway

Abstract The internet of things (IoT) is gaining momentum as a technical tool and solution for a diverse range of societal challenges. These challenges include smart cities sustainability issues which are widely recognized by decision makers and societies. Despite this, few works try to tackle these challenges empowering citizens through IoT technologies. In this paper we describe how the Tiles toolkit, a card based idea generation toolkit for IoT, has been extended to support non experts in creating ideas addressing societal challenges that affect modern smart cities. We briefly introduce the Tiles generic toolkit, then we describe in detail the extensions proposed on the cards, cardboard and how the new components are employed in a refined workshop protocol. We report the results obtained during a field study of the extended toolkit, where several groups of students collaborated to generate ideas involving IoT in the smart city. We discuss success and failures, drawing our conclusions after analyzing quantitative and qualitative data collected during the workshop. We conclude the article reporting the lessons learned, critical considerations about our experience evaluating the extended toolkit and reflections on possible improvements for future works.

Keywords: Smart-City learning, IoT, Design, Behavior Change

1 Introduction

The concept of smart-city has been used in many different contexts and is associated with distinctive and innovative aspects that are often quite different. Big diversities are observed on the reasons *why* different cities are defined as *smart* [6].

With his work, Komninos [10], tries to delineate the intelligent city, perhaps the concept most closely related to the smart city. Four are the possible meanings: (i) the introduction of a wide range of electronic and digital applications to communities and cities, (ii) the use of information technology to transform life and work, (iii) the meaning of intelligent or smart as embedded information and communication technologies, (iv) the spatial territories that bring ICTs and people together to enhance innovation, learning, knowledge and problem solving.

Despite this, in this paper we focus on smart cities as a place where citizens learn smart-behaviors supported by an ideation and rapid prototyping toolkit.

This scenario can involve traditional education which happens in facilities like schools and universities. The goal of our work is instead more oriented towards *lifelong learning*, defined as the continuous build of skills to adapt and collaborate in dynamic ecosystems like smart cities.

To achieve that, we envision the involvement of non-experts in design and prototyping of pervasive Internet of Things (IoT) applications for smart cities. Citizens are an example of *non-experts in IoT*, which we define as users that differ from professionals by the fact that they do not have any skill in electronic, networking protocols or assembly and configuration of IoT devices. They don't need either to be familiar with IoT and its definition.

The idea at the heart of IoT is that all the things and all the environments can be improved from a functional point of view via the embedding of technology that remains invisible to the eye of the users, which enables both products and environments to become smart [19]: meaning that they collect data from their surrounding producing high-resolution data [3], as well as communicating among themselves and with the humans, building ecologies of smart devices intertwined with urban communities and citizens.

Since the term Internet of Things was coined in 1999 [1], research has mainly focused on Wireless Sensor Networks (WSN) and Machine-to-Machine (M2M) systems. Few works have taken into consideration HCI theories and user involvement in the design of IoT applications [11]. WSN and M2M applications do not allow end users to directly interact with the technology, which is empowered mainly for data collection and remote sensing purposes. Yet, we foresee IoT as the enabling technology for ecologies of interconnected smart objects. These connected objects retain their original appearance but are augmented with technology to gain sensing capabilities and interaction properties.

In this paper we present an extension to the Tiles Ideation Toolkit (hereafter abbreviated as Tiles) [13], a card-based design toolkit for IoT user experiences. Design is seen as a matter of generating ideas then testing them, modifying and improving where necessary. Thus ideation – the formulation of initial ideas and thoughts as both personal and collaborative processes – is embraced as an enabling factor in design practices [4]. With Tiles, we only focus on applications where the user is kept *in the loop*, through tangible interaction and physical manipulation of augmented objects.

Tiles comprises a set of 110 cards and a workshop protocol to engage non-experts in idea generation. Providing non-experts only with a set of cards can be overwhelming and confusing. Browsing the cards without any guidance or constraint might not be a sufficient stimulus for creative and collaborative thinking [8]. For these reasons, Tiles provides an ideation technique and a set of workshop-related tools: (i) a cardboard, that scaffolds the use and placement of the cards, facilitates group collaboration, and contains a storyboarding and reflection phase, (ii) a playbook to guide the users step-by-step in the ideation

process, (iii) user-centered design artifacts such as *personas* and *scenarios*, to address specific problem domains.

In this paper, we further specialize the Tiles approach towards applications for smart cities. We aim at raising citizen awareness, facilitating lifelong learning and providing a tool to scaffold ideas to tackle societal challenges affecting modern cities.

Current research on smart cities presents a technological gap: few studies make use of IoT and smart objects [6]. Extending the Tiles toolkit we aim at establishing a first point of contact, exploring the solution space offered by IoT and smart objects in the context of smart cities. A recent review of the literature demonstrated that in the context of smart cities, citizens are not sufficiently involved in designing and implementing technological applications [9]. Their involvement in the studies, if present, is often relegated to a tokenistic role.

Participatory design is defined as a set of theories, practices, and studies related to end-users as full participants in activities leading to software and hardware computer products and computer-based activities [7]. Active user involvement in the ideation, design and development process through participatory design or others co-design techniques, is still scarcely adopted in the smart city domain.

2 Related Work

In this section we report related works on design, brainstorming and ideation tools for smart cities. An overview of card-based ideation toolkits for the IoT is provided on [13], where the generic Tiles Ideation Toolkit is also presented and described. Design thinking workshops are often used to scaffold and support brainstorming and cooperative practices. In [14], various ideation tools are used during a smart city workshop involving different stakeholders. Ideas are categorized using post-its and personas, with the ultimate goal of enabling energy integration into urban design and promoting energy consumption awareness in the citizens.

Wagner et al. [20] employ user-centered design methods for urban planning in their 'MR tent' study. Among the other tools, in their workshops they use scenarios and 'content cards', arranged on a whiteboard and used as placeholders for different urban objects and infrastructures. Schuurman et al. [16] adopt crowdsourcing as a method to brainstorm ideas for various scenarios related to smart cities. They used an online platform to collect and vote the ideas generated by the citizens. The ideas were also briefly evaluated using a combination of feasibility and originality criteria. The ideas were divided into the predefined categories of e-government, housing, mobility, security, sport & recreation and other. In a similar way, Mechant et al. [12] compared two crowdsourcing platforms to collect ideas for smart cities. The contributions of the users addressed several facets of the city, while the most popular idea categories were 'smart mobility', 'guiding applications' and 'social bonding applications'.

In their attempt to create a framework for co-design in smart cities, Fu and Lin [5] employed brainstorming workshops for the ideation phase, and rapid prototyping for the implementation phase. Their ultimate goal was to facilitate

the research, design and prototyping of a range of specialized products for new urban lifestyles. They also adopted personas and scenarios, but their use was limited to demonstrate possible solutions and to illustrate the findings.

All the smart city works presented employ some kind of ideation or brainstorming instrument to support the creative process, or at least mention that a part of the study was dedicated to generate and collect ideas. The main differences between the extended Tiles toolkit and these works can be summarized in:

1. **Timeframe** – the Tiles workshop is structured to generate and refine an idea in less then two hours of group work, regardless of the level of expertise in IoT or smart cities the users may have;
2. **Focus on smart cities** – the smart city extension of Tiles targets specific societal challenges of the city;
3. **Defined structure** – the ideation process is precisely structured, a step-by-step playbook and a cardboard allow the users to work in autonomy without direct supervision by researchers;
4. **Guidance** – the workshop is structured to encourage the users to design for a pre-determined persona and scenario, providing some guidance without limiting creativity, users are in any case free to provide their own scenario and persona;
5. **IoT oriented** – although having an idea as direct outcome, the Tiles workshop is oriented towards rapid prototyping of IoT applications, the idea generation process is tightly connected to the technical implementation.

As a comparison, the 'MR tent' study is a complex brainstorming workshop that took several days of work and multiple creative instruments to produce an idea. In their study, Schuurman et al. focused on collecting the ideas, without providing guidance in the actual process of idea generation. None of the studies presented is clearly structured towards prototyping with IoT technology or through other technologies.

3 Extending the Tiles Ideation Toolkit

3.1 The Tiles Toolkit

The original Tiles toolkit is intended to be generic, no particular focus on any application domain is provided, although the IoT role remains central. Tiles is composed of three essential elements:

1. **Cards** – a total of 110 cards organized in 7 decks, as shown in Fig. 1 each deck has a specific name and color;
2. **Cardboard** – shown in Fig. 2, is printed on a big paper roll sized 0.6 x 1.2 meters, it holds the cards during the idea generation process and includes a storyboard depicting a use case of the idea;
3. **Workshop protocol** – consisting in a step-by-step playbook which guides the users in the idea generation process, explaining how and when each deck of cards is intended to be employed.

Figure 1. The Tiles card decks composing the original toolkit, with a sample card for each deck on the bottom.

The workshop starts with the selection of an arbitrary number of everyday objects, represented in the *things* cards. The objects are chosen by the users based on the perceived usefulness, in relation to the idea and the problem addressed. These objects are then *augmented* through the addition of sensing and actuation capabilities: *services* and *human actions* cards allow to trigger a specific reaction when data coming from online services is received or when the object is physically manipulated by a human being. *Feedback* cards are used to specify how the object reacts when triggered. In addition, *connectors* cards can be used to indicate a condition that joins the behaviour of two or more smart objects. Finally, *missions* and *criteria* decks are used to stimulate divergent-convergent thinking and promote reflective learning. *Missions* provide creativity triggers through a set of provocative design goals, while *criteria* are composed by reflective statements that push the user to evaluate the idea from a different perspective.

3.2 Smart City Extension

To extend Tiles and specialize it for smart cities, we created several new cards, a new cardboard and a refined workshop protocol. The improved cardboard and the new cards are shown in Fig 3 and Fig. 4. The changes were also addressing minor usability issues that emerged during the first evaluations of the generic toolkit.

The new cards are domain specific for smart cities. Several *things* cards were added, representing urban furniture, public transport and objects usually found in a city. These new cards help the users to get familiar with the environment of the city, they are the first contact point and the initial trigger for the ideation process, together with *personas* and *scenarios*. The content of these initial decks of cards do not require any technical or scientific knowledge to be grasped, avoiding to overload the users with new concepts or abstraction from the very beginning. Letting the users free to browse through a set of plain objects and urban furniture is a strategy to smoothly introduce them into the augmentation process of the

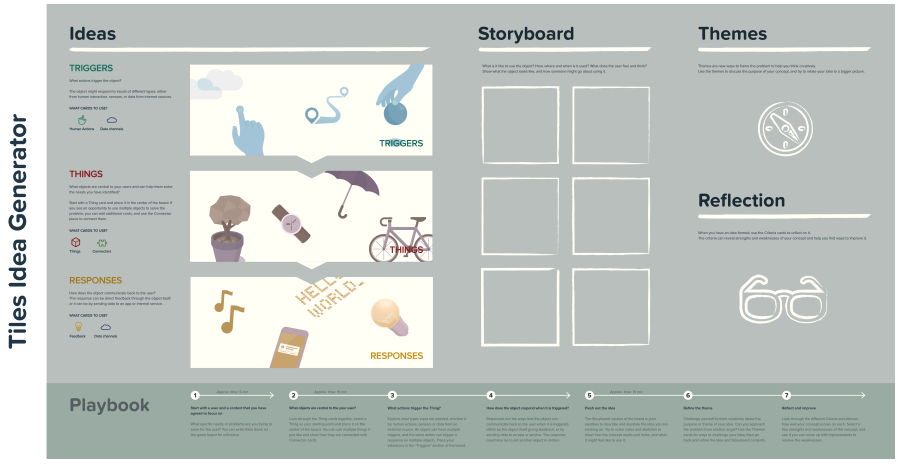

Figure 2. The Tiles original cardboard.

object(s). This allow for a progressive knowledge building process, where the more complex, augmented capabilities like ambient sensing and HCI interactions build on the top of an already established first idea seed.

A few new *feedbacks* and *human actions* were also added. Three new decks composed by 9, 10 and 5 cards were created. The first deck, *sensors*, represents sensor data from the ambient surrounding the object, like temperature, air pollution and relative humidity. These cards were meant to build awareness enabling 'augmented personal sensing', intended as the ability to provide personalized data sensing capabilities through technology. Ambient data sensing is nothing new, but it's important to take into consideration at which scale it happens. For example air pollution is known to vary considerably from street to street, while sensing stations usually operate at fixed locations, and are sparsely and strategically distributed for regulatory enforcement rather than situated to provide overall neighborhood coverage for human health [18]. Air pollution data provided by a wide area sensor network can then significantly differ from what experienced by singular citizens or urban communities. The same applies to other sources of urban data, the risk is to waste the effort of citizens trying to improve a near optimal, but unknown or misinformed, scenario while not taking action to correct a critical local situation because the city-level data are not alarming. Having an augmented object able to provide user-tailored sensor data can be an enabler and a trigger for reflective learning, motivating the users to take action effectively, accurately improving their behaviors in the city toward more sustainable ones.

The second deck is composed by 10 *personas* cards. A persona is an archetype of a user that is given a name and a face, and it is carefully described in terms of needs, goals and tasks. During the design process the design team tries to satisfy the persona's needs and goals [2]. The *personas* cards do not address only single individuals but also small groups of people like elderly people or construction

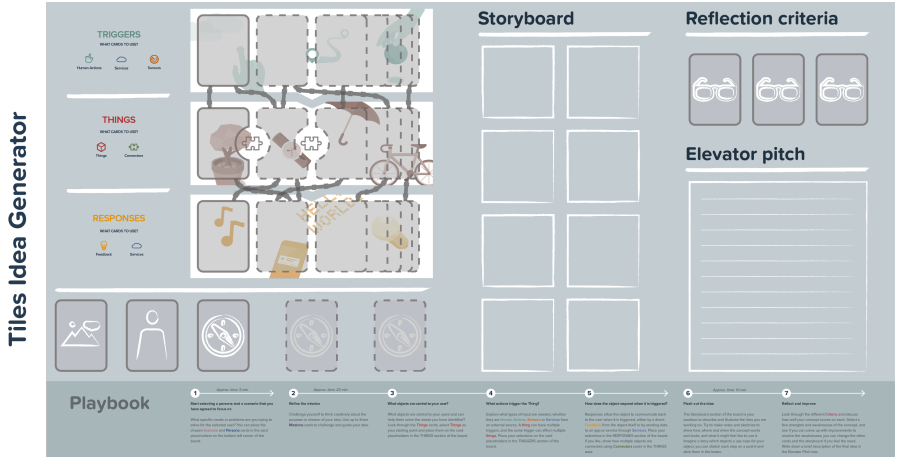

Figure 3. The new Tiles cardboard used during the workshops.

workers in the city. Personas are pushing the users to portray themselves as a particular group of citizens or individual, promoting out-of-the-box design thinking and ideation for minorities and less represented communities. The users are always free to define their own persona, but they are not allowed to start the design process without having one.

The third deck is composed by 5 *scenarios* or societal challenges affecting modern cities. Inspiration for the scenarios included came from the regional perspective report on smart cities, published by the United Nations [17] and from the sustainable development goals[1] adopted by the United Nations in 2015. More precisely, the *scenario* cards address themes included in sustainable development goals number 11, 'sustainable cities and communities' and 12 'responsible consumption and production'. *Scenarios* provide design space constraints, meant to help the users to focus the ideation process. They provide at the same time an opportunity to effectively contribute solving real world urban challenges through creative thinking and innovative technologies.

Each of the new decks adopt the same graphic style as the original cards, is color coded to be easily recognizable and contains a 'custom card': a blank card that can be used to add additional *sensors*, *personas* or *scenarios* directly by the users during the workshop.

The instructions on the playbook printed on the bottom of the cardboard have been updated to include the new decks. The first step became the choice of exactly one *scenario*. The users were free to pick any of the ones available in the deck. Once they decided about the problem to tackle, they were required to focus on solving it for a particular end user, chosen freely among the *persona* cards. The last new deck is the one containing the *sensors* cards. They were introduced

[1] http://www.un.org/sustainabledevelopment/sustainable-development-goals/

Figure 4. The new cards and decks composing the smart city extension, with a sample card for each deck on the bottom.

as an additional trigger element on top of *human actions* and *services*, they are all employed at the same time in the 'triggers' section of the board.

The workshop session usually started with a brief presentation introducing the users to the toolkit and the concepts of IoT and smart cities. The groups were then let free to follow the steps reported on the playbook in autonomy. Researchers and mentors supported or guided the participants only if explicitly requested by them. After the groups completed all the steps in the playbook they were encouraged to present their idea to the other participants and to the researchers, or alternatively write down the elevator pitch transcription in the apposite space on the new cardboard (Fig. 3).

We now report an example of idea generated with the extended toolkit, to better illustrate the use of the cards and the toolkit. We imagine to generate an idea for a *scenario* addressing waste management, using municipality employees as *persona*. A smart bin (*things* card) can be equipped with a tilt sensor (*human action*) and a sound alarm (*feedback*). The intended behavior might consist of the alarm sound to be triggered when the bin is detected to be falling into an horizontal position due to wind or other events. Another silent alarm is triggered when the air quality (*sensor*) surrounding the bin is compromised due to toxic emissions also causing bad smell, for example when the day is very hot. Using a *connector* card, it is possible to specify a cotemporality condition that involve a second smart object. As an example, when one of the smart bin alarms is triggered, the connector card instructs the same trigger to be used to make a smart ring vibrate, to alert a responsible person of the event. Smart objects can

be triggered by multiple events and provide multiple feedbacks, the smart bin can also be connected to twitter (*service*) to keep a trace of the events occurred, providing a secondary notification channel.

4 User Study

We evaluated the extended Tiles toolkit during several workshops with university students, high school students, decision makers, researchers and professionals in urban planning.

In this section we will present the evaluation methodologies adopted, the tools employed and the design of one of the workshops. The evaluation aspects considered include the new cards, the workshop experience and the ideas generated.

4.1 Material and Tools

The participants attending the workshop were organized in groups. Each group had at disposal a cardboard, a deck of the Tiles cards including the smart city extension, post-its of different colors and markers or pens. At the end of the workshop a questionnaire was distributed to each participant. A digital camera and a camcorder were used by the authors to document the process and the produced artifacts.

4.2 Design

The workshop participants were first year university students in computer science. The workshop took place as part of a university course in IoT, replacing one of the first lessons. The category of participants matched the definition of non-experts in IoT and at the same time provided a group of users motivated to learn more about IoT. 60 students participated to the workshop, divided into 16 groups. Every user participated to only one workshop. The average number or users per group was 4. A detailed overview of users and groups is provided in Table 1.

Table 1. Details of the workshop analyzed.

workshop	N	groups	age	occupation	date
W10	60	16	19-27	university students	15/02/2017

To start, the participants were briefly introduced to the concepts of IoT as object augmentation, smart cities and to the cards and cardboard. They were then let free to browse the cards and start following the ideation process, as indicated in the playbook printed on the cardboard. After 40 minutes the ideation process was concluded and each group presented the idea during a 60 seconds elevator pitch.

During the workshop, the authors were available to support the participants if they were in need or asked for help, notes on the observed user behaviours were collected at the same time. Pictures of the cardboard, storyboard and the cards were collected at the end of the workshop, as well as video recordings of the idea pitch. Finally, every attendant compiled a questionnaire using a five steps Likert scale.

4.3 Methodology

Based on the amount and nature of collected information, for the purpose of this paper we used both qualitative and quantitative data analysis.

A sample of the ideas generated was examined to understand and evaluate how the users employed the cards and how coherent the ideas were with the cards used. We chose the ideas based on the originality, quality and clarity of the pitch, variety of the cards used and role of IoT in the concept. More precisely, we took into account the following: (i) the presence of some type of augmented object, possibly excluding common technologies like smartphones and smart watches, (ii) the involvement of more connected objects to form an ecology of smart devices, (iii) the actual use of the objects as tangible interfaces, and not only as sensor probes, (iv) the novelty of the concept, which ought to be someway different to existing applications or solutions. The themes of object augmentation and IoT are fundamental and it was important to confirm that they did not get lost during the ideation process.

To understand if the newly introduced cards were perceived as useful and contributed to support the user in the ideation process, we analyzed the pictures of the final cardboard, paying attention to how and where the new cards were used. *Scenario* and *persona* cards were excluded from the analysis since they were mandatory to use in quantity of one each, and addressed in the very first steps of the playbook. We focused the analysis on the smart city related *things* cards and the new deck of *sensors* cards.

The statistics considered in the evaluation are:

1. How many users utilized the new smart city cards from the *things* deck;
2. How many users utilized cards from the new smart city deck of *sensors*.

Data from the questionnaires was used to understand if the users enjoyed the ideation process and if they believed that the smart city version of the Tiles toolkit helped them in creating new ideas for IoT applications. We will present the results of five of the questionnaire statements, covering perceived enjoyment, ease of use, guidance and usefulness.

5 Results and Findings

We present in this section the results of the user study, combining both quantitative data and qualitative observations.

5.1 Observed Attitude

During the workshop, some of the users were stressed about the short amount of time at disposal for the ideation session, limited by the rigid schedule of the university lectures. This sentiment of stress and frustration is clearly detectable in the questionnaires. However, even if they were forced into a fast pace of work, all the groups were able to successfully follow the complete set of steps in the playbook. All the groups succeed generating an idea in 40 minutes, a very limited amount of time, and finally pitched it to the other participants. It is clear that some users were more susceptible and sensitive to the stressful condition than others, which better tolerated working under pressure.

A limited number of participants expressed concerns about the level of constraints imposed by the workshop protocol. The comments were pointing in two opposite directions, but were equally balanced in number: half of the users were complaining about having too many constraints imposed, while the other half was lamenting having too few.

5.2 Cards

To evaluate if the newly introduced cards were perceived as useful, we analyzed how often they were used. Since the users were not obliged to use any of them, our assumption is that when they did, they considered the new cards as more helpful or fit for the idea being developed.

The new smart city cards in the *things* deck were used by 50% of the users, while cards from the *sensors* deck were used by 60% of the users.

5.3 Idea Generated

We now report two ideas that have been generated during the workshop.

The first idea targets disabled people in wheelchair which make use of public transportation. The concept empower an augmented bus stop and a smart key ring. Thanks to gps sensors and visual recognition, the bus driver is automatically notified when he is approaching a bus stop where a wheelchair user is waiting. Ramps and other accessibility measures can then be deployed without delays. Once on the bus, disabled persons can tap their smart key ring near the door to communicate that they will need to hop off at the next stop. The bus will automatically deploy the ramps since the stop was reserved using the key ring, and not the usual button. The cards employed, the storyboard and cardboard are reported in Fig. 5.

The *scenario* card used was addressing the need to increase participation in public life, improving awareness of urban activities among the citizens. The *persona* chosen by the group was Tom, a 43 years old disabled man living on a wheelchair.

The storyboard is composed of 8 illustrations and contains many of the elements represented on the cards employed, like the target user on wheelchair,

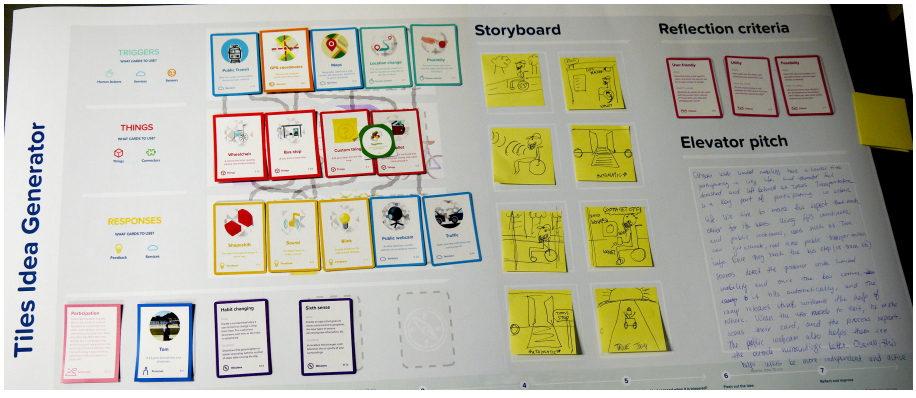

Figure 5. Cardboard and cards of the first idea.

the bus stop, the webcam, the online data service on public transport and the triggers of location change and proximity.

The second idea redefines the concept of 'dead man switch' in the context of construction sites. Electric hand tools employed by the workers are augmented with bluetooth proximity sensors. The same sensors are also applied to safety equipment like helmets and gloves. In order to guarantee safety at all times, the tools are equipped with a 'dead man switch' that prevents the use if the proximity sensor do not detect the proper safety equipment in the close surrounding. The cards employed, the storyboard and cardboard are reported in Fig. 6.

The *scenario* used in the second idea is the same used in the first one, participation in public life, but the *persona* is different: a group of workers is addressed as target of the second idea.

The storyboard is composed of 6 illustrations. The second idea uses less cards than the first one, but they are well represented in the storyboard: workers, wearable gear, location change and proximity triggers are all present in the illustrations of the storyboard.

5.4 Perceived Ease of Use and Enjoyment

The results collected through the questionnaires are shown in Fig. 7. The following statements are reflected in the statistics:

- **S1**: Using the Tiles cards was fun;
- **S2**: The cards concepts were easy to understand;
- **S3**: The design process provided enough guidance to develop new ideas;
- **S4**: The information printed on the cards was useful;
- **S5**: The proposed users and contexts helped me framing the problem for a given person/society.

For the statements S1-S4, N = 57, for S5, N = 55. This discrepancy in the number of users is due to the fact that some of the participants didn't compile

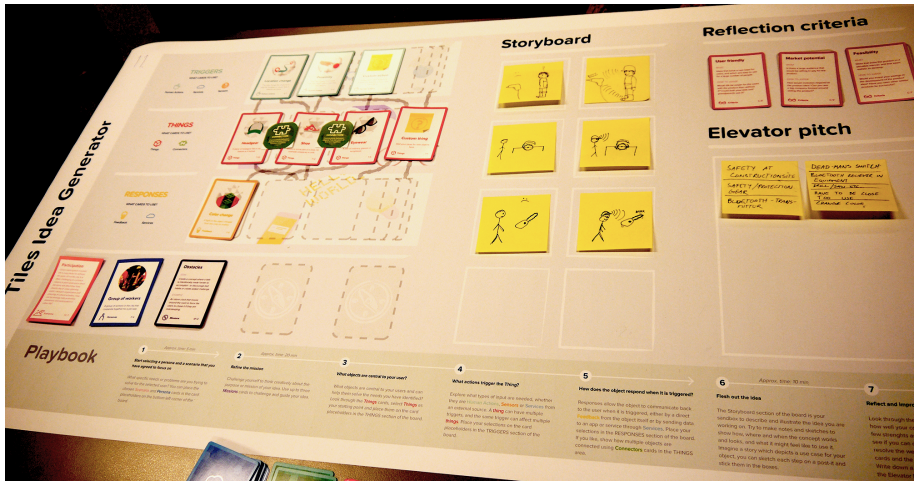

Figure 6. Cardboard and cards of the second idea.

the questionnaire or skipped part of it. The data show for all the statements a level of agreement between 60% and 85%. The disagreement is around 10% for S1 and S2, while it is much lower for S3, S4 and S5.

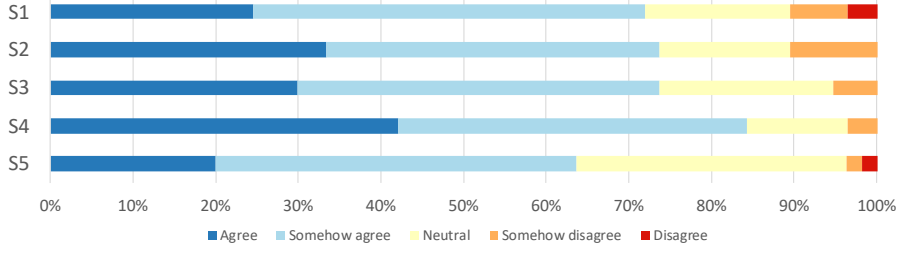

Figure 7. Results of the questionnaire statements.

6 Discussion

The goal of the smart city extension of the Tiles Ideation Toolkit is to support, motivate and empower non-expert users in ideation involving IoT and smart cities. This is envisioned as the first step toward the development of IoT collaborative applications that promote reflection and lifelong learning through increased citizens participation and awareness.

The smart city extension of Tiles successfully guided the users through the idea generation process: the final ideas matched most of the times the problem

proposed in the *scenario* card, the target *persona* and made use of IoT technologies. The new *things* cards for smart cities and the *sensors* deck were often employed in the ideation process. This is an encouraging outcome, the adoption suggests user interest and the usefulness of the new cards. We cannot expect a usage close to 100% though, since the use of specific cards is dependent on the idea developed. For a few idea concepts, the users didn't need more cards than the ones provided by the original base decks.

The *scenario* and *persona* cards not only provided a design goal, but also modified the design process providing guidance and constraints, without limiting creativity. This emerged to be a critical factor, especially when the time at disposal for the workshop was limited. The two ideas analyzed make use of the same *scenario*, but different *personas*. In connection to this, two interesting outcomes emerged: (i) the two ideas have very few in common despite the fact that they share the same *scenario*, which suggests freedom in the creative process, (ii) the 'group of workers' was not interpreted exactly as intended, in fact the idea address a single worker, there are no elements that restrict the use only to a group and not to an individual. The division between individual and group based *persona* might be easy to grasp when reading and choosing the cards, but has proven to be challenging to maintain during the ideation process. A possible solution might be introducing further support or constraints during the workshop to remind the users about the difference, or as an alternative remove the distinction in the *persona* cards, leaving the users free to spontaneously generate an idea for an individual or a group.

In a couple of occasions we experimented running the workshop without *scenarios* and *personas*: the users were never able to come up with an idea or problem to solve, they spent all the time at their disposal browsing the cards without producing any result: a set of tools too generic hindered creativity and prevented ideation. Of course is important to be aware of the trade-off nature of these supporting factors: having too many constraints or guidance can inhibit the vision of the users. From the questionnaire comments and the observations, we registered mixed feedback regarding these two factors. However, no significant evidence indicating that the current level of constraints is inadequate emerged. Our evaluation didn't focus on this aspect in particular, but it may be of interest to test the workshop protocol using different levels of constraints, studying how they can affect the idea outcome. This can help to precisely adjust the protocol, aiming at the most effective level of guidance and constraints.

All the groups were able to generate an idea of an IoT application for smart cities. During the workshop they managed to produce the idea after only 40 minutes, a very limited amount of time, and pitch it after that. The ideas reported in Section 5.3 successfully retained the concepts of IoT as object augmentation and physical interaction between the target users and the augmented objects. The concept of ecology of interconnected smart objects is also present. The cards used on the cardboards are effectively scaffolding the applications, which are sketched in the storyboard and presented in detail during the pitch. The themes of the vast majority of the cards used are is still present at the end of the ideation

process: for example the *persona* chosen, the *scenario* of interest and the *things* picked to be augmented were all mentioned when the idea was presented. Data from the questionnaire confirm that *persona* and *scenario* helped framing and contextualizing the process, providing additional support if compared to the original toolkit.

The storyboard demonstrated to be a useful step to bridge and refine the idea: it provided a simple instrument to quickly unfold the complete idea, facilitating the transition between the card based representation of the idea and the oral pitch. The storyboard also forced the participants to depict a use case for their concept, taking into account the temporal and cause-effect aspects of the flow of events composing the idea. These aspects were not explicitly enforced when the participants combined the cards in the first phases of the workshop.

In some occasions, a few of the cards placed on the cardboard were not present in the final idea pitch. This is anyway an acceptable twist, in the best case scenario the users didn't have enough time to go into all the details of the idea, but it is also possible that some concepts were simply abandoned during the process without removing the cards from the cardboard. Being the users non-expert in IoT, the real risk was that they could have fell back designing familiar application concepts, namely mobile apps or screen based applications. The toolkit and the design process effectively prevented this to happen at the end, although we have witnessed internal group discussions regarding the topics.

A positive outcome emerging from the user studies conducted is certainly the improved user independence during the workshop. It would have not been possible to run the workshop with more than 10 groups in parallel if the process would have required direct assistance by researchers and mentors. This is an important strength in the context of tool dissemination: the entire Tiles toolkit and the smart city extension are open source and freely available, the fact that they can also be used independently is a requirement for public adoption in learning and brainstorming contexts.

The low level of technical skills and knowledge required to use the toolkit is also supporting its diffusion. Most of the workshop users had no previous knowledge of IoT, smart cities or design methods, though they were perfectly able to complete the design process, sometimes with brilliant results in terms of originality and problem solving potential of the idea. The low barriers of adoption are particularly beneficial when promoting participatory design and co-creation for smart cities: extensive citizens involvement is still lacking in smart city applications [15] [9].

Based on our experience, schools and universities have demonstrated to be a valuable learning ecosystem where students can learn through the ideation of IoT applications. However, it also emerged that the same toolkit might yield significantly different experiences in different school environments. An effective toolkit is not enough, engagement and cooperation should also be supported by the teachers, which play a unique role connecting with the social circle of the students, facilitating the acceptance of an unfamiliar experience.

Although the goal of the smart city extension of Tiles is to stimulate creative thinking and ideation, the natural continuation of this process is the actual implementation of the idea, through prototyping and programming.

The extended Tiles toolkit can be a powerful tool for innovation, combining different cards can lead to exploring unprecedented solutions for smart cities. Creativity through serendipity is possible, from unexplored cards combinations innovative concepts emerge, which may constitute the core of the solution that users can refine through reflection and convergent-divergent thinking.

7 Conclusions

In this article we presented the smart city extension of the Tiles ideation toolkit, a card based toolkit supporting brainstorming of IoT applications. The smart city extension is composed of an additional set of cards divided into several decks and an updated workshop technique. Its goal is to facilitate the ideation of IoT applications for sustainability in the city.

The extended toolkit has been evaluated based on quantitative and qualitative data coming from a workshop with 60 users divided into 16 groups. Results showed that all the groups were able to generate an idea after a very limited amount of time. The participants found the extended toolkit fun, informative and helpful in providing guidance for idea generation.

We registered a good outcome in term of relevance of the ideas generated. The theme of IoT as object augmentation, the smart city elements and the ecologies of interconnected objects were all effectively used to scaffold the idea.

Future extensions of the toolkit can be oriented to tackle different scenarios of use like healthcare and governance, or other groups of *personas*. We plan to complement the ideation phase with prototyping and programming of the physical augmented objects. Thanks to low complexity programming paradigms to interact with sensors and actuators, end users can be facilitated in directly embedding the intended object behaviour into the electronics.

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