Tiles: A Card-based Ideation Toolkit
for the Internet of Things

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ABSTRACT

The Internet of Things (IoT) offers new opportunities to invent technology-augmented things that are more useful, efficient or playful than their ordinary selves, yet only a few tools currently support ideation for the IoT. In this paper we present Tiles Cards, a set of 110 design cards and a workshop technique to involve non-experts in quick idea generation for augmented objects. Our tool aims to support exploring combinations of user interface metaphors, digital services, and physical objects. Then it supports creative thinking through provocative design goals inspired by human values and desires. Finally, it provides critical lenses through which analyze and judge design outcomes. We evaluated our tool in 9 ideation workshops with a total of 32 participants. Results show that the tool was useful in informing and guiding idea generation and was perceived as appealing and fun. Drawing on observations and participant feedbacks, we reflect on the strengths and limitations of this tool.

Author Keywords

Design tools; card tools; Internet of Things; IoT; augmented objects.

ACM Classification Keywords

H.5.2 Information interfaces and presentation (e.g. HCI): User interfaces—Theory and methods

INTRODUCTION

The Internet of Things (IoT) holds huge promise to change the way we work, play and learn. The core idea of the IoT is that a huge variety of things will be augmented with technology in order to become interactive and connected to the Internet, yet maintain elements of their traditional physical appearance. Examples include a paintbrush that samples colors from surfaces and uses them as a drawing

palette in a computer program [30], a water faucet that lights up in colors to display daily water consumption data [22] and wood bricks that can be used by children to create computer programs [15]. Technology can be used either to augment an existing purpose of an object, making it more useful, playful or engaging than usual, or to add new functions that are controlled using the object's affordances; at the extreme, the object may look magical or enchanted [28]. Although this vision is shared by long-established research in ubiquitous computing, by putting the emphasis on connectivity the IoT promotes the development of applications that make use of ecosystems of connected things that leverage and interact with online services [20].

IoT research has concentrated mainly on two ends: the technical, solving technological challenges such as connectivity and security; and the theoretical, following up on visions, e.g. [36] [13] of how computers integrated into the fabric of the physical world can serve human needs. Compared with these two goals, an exploration of the IoT from an HCI point of view is in its infancy [20]. As consequence, the user experience provided by several IoT devices is often unsatisfactory, at least when compared to traditional software products.

As noted by Rowland et al. [29], interaction design for connected things is different from, and in some aspects more complex than, traditional computer products. Functionalities can be distributed among multiple devices offering varying input/output capabilities, form factors, and purpose. User interface elements often leverage tangible interaction themes [16,19], such as direct manipulation and physical representation of data. Despite such a large paradigm shift, design tools for the IoT are mostly based on traditional methodologies that emerged in the pre-IoT era. Very few products provide specific design tools and methods, e.g. [9,16,17].

The aim of our research is to investigate how to foster human-centered design of novel IoT user experiences by providing tools to engage *non-experts* in idea generation. Non-expert participation in design is a long-established practice in human-centered design. With the term 'non-expert' we mean users without formal training in design techniques or previous knowledge in IoT or ubiquitous computing: for example, researchers and students, makers,

and children. Our approach is inspired by a *thing-oriented* vision of the IoT [see 2] and uses *object augmentation* [21 pag.254] as a design strategy.

This paper contributes to this strand by presenting the *Tiles Ideation Toolkit* (hereafter abbreviated as *Tiles*), a card-based ideation tool for Internet of Things user experiences. Ideation—the formulation of initial ideas and thoughts as both personal and collaborative processes—is an essential step in design methods [10]. Tiles comprises a set of 110 cards and a workshop technique to engage non-experts in idea generation. *Tiles cards* provide a source of inspiration for ideas by: (i) suggesting a set of technology primitives to describe the IoT design space, (ii) providing triggers for divergent and creative thinking, and (iii) offering criteria for reflecting on and evaluating the ideas generated. *Tiles workshop* structures the use of the cards in ideation workshops with step-by-step guidance, support for collaboration and by complementing the cards' use with traditional design thinking techniques and artifacts.

The cards and workshop materials are released under a Creative Commons license and available for download at http://tilestoolkit.io/cards.

We evaluated the usefulness of our tool in informing and guiding idea generation during nine workshops with a total of thirty-two participants. We discuss which features of the tool facilitated or hindered idea generation. In closing, we outline directions for future work.

RELATED WORK

Characteristics of cards-based design tools
Research projects have found card-based tools effective in supporting idea generation in design workshops [34]. Cards are useful for presenting theoretical constructs and making the design practice more engaging and playful, thus enlarging the group of people that take part in designing new systems. They can be an effective vehicle for transferring knowledge between theory and practice [9], for example to convert theoretical frameworks to guidelines that can be manipulated by designers [9]. Card-based tools help keep people at the center of the design process [18,24] and facilitate creative dialogue and shared understanding. Cards can be a source of inspiration to steer a discussion when it becomes unproductive [17], for example by proposing provocative questions to unlock thinking [27]. Cards can also be used to evaluate, rate or bookmark ideas generated during design sessions [17,24].

Cards facilitate collaborative and divergent thinking by providing a medium for conversation between stakeholders and designers [7,14,24]; furthermore, they allow externalizing ideas and ensuring that a design space is investigated from different points of view. Card play adds game mechanics helpful in exploring design alternatives in a playful manner [5,24], empowering users and engaging multiple stakeholders [34]. Game rules add constraints that may improve design outcomes [5] and foster creativity. For example turn-taking helps ensure that everyone is involved in the process [17] and role-taking help smooth power relations and conflict among participants [5]. From this perspective, cards act as physical props to externalize thoughts and help structure common grounds to which everybody can relate [5], helping them take risks within the framework of a game.

To summarize, the characteristics of card-based tools we aim to embrace with our tool are: (i) informative: helping to describe complex concepts to non-experts, (ii) inspirational: helping trigger and guide brainstorming and idea generation, (iii) collaborative: engaging users by helping collaboration and creative dialogue.

Applying card-based tools to IoT ideation
Card-based design tools have been applied to the design of technology for a wide range of domains related to IoT, including embodied interfaces [17], tangible interfaces for learning games [9] and exertion games [27]; to design for playfulness [24] and for influencing behaviors [23]. Recently a few card-based tools have specifically targeted IoT ideation [1,8,12].

Similarly to *Exertion Cards* [27] and *Tango Cards* [9]*, Tiles offers provocative questions that trigger creativity. Like *Plex cards* [24], it provides dimension to evaluate and judge the outcome idea generation. Yet these tools have a much broader domain than Tiles: for example, design for playfulness, where "*potentially any activity can be approached and performed in a playful manner*" [24] or learning games [9]. Similarly to *Know-cards* [1], our tool describes the components of IoT technology in a language accessible to novices, yet the former doesn't provide triggers for creativity or reflection. *Thingclash* [8] provides a structured ideation technique similar to that of Tiles. Yet rather than supporting ideation, Thingclash focuses on critical analysis of actual IoT products with the aim of finding friction points at the technological, societal, economic and policy levels. *IoT Service Kit* [12] shares with Tiles a goal of ideating IoT scenarios by merging physical objects, digital services and interaction metaphors. Interestingly enough, they provide objects as tiny 3D models rather than as drawings on cards, yet their focus is on involving tech professionals from different backgrounds rather than non-experts. Analogously to *Envisioning Cards* [11] and *Picking up artifacts* [35], Tiles provides "create your own" cards that can be freely customized by the user. The envisioning cards also present other similarities to our tool, like the focus on a specific group of stakeholders and criteria to facilitate reflection. Likewise with Tiles, some of the card tools are meant to be used in design workshops [3,7] but a defined and repeatable workshop structure is not reported. Finally, most of the tools reviewed are freely available, e.g. [9,24], or licensed under a Creative Commons license that allows for the tools' adaptation and customization, e.g. [8,12].

Augmentation as a design strategy for the IoT

Successful IoT product design requires one to take into consideration multiple, sometimes seemingly unrelated, criteria at once. This spans the spectrum from physical attributes, such as form factors and technical components, to intangible concepts, such as interaction patterns or user values. Rather than thinking up the mix of factors from scratch, a possible design strategy leverages starting from a non-digital, everyday object, preserving its broad purpose, and adding computation capabilities on top of it. Kuniavsky [21] motivates enriching everyday objects as a design strategy. He claims that augmentation leverages the advantages of using user-familiar shapes and functionalities: "Augmentation is most successful when it keeps what the target audience perceives as the core of the experience of an object intact, enhancing it without changing its perceived key attributes" [21 pag.262]. Because people are familiar with everyday affordances, technology needs only to extend those and can build on existing use patterns since "the more familiar is the tool the less effort it takes to learn it."

As with most of tools reviewed, Tiles adopts cards as a participation and learning tool. Yet based on the need found in previous work, e.g. [27] for more guidance in the process that cannot simply be provided by the cards *per se*, we aim to complement the card use with a structured process as well as design artifacts to support the process' adoption. Besides the fact that a structured process might restrict freedom during workshop supervision or facilitation, this comes at the interest of facilitating a broader adoption of the tool. The characteristics of our tool can be summarized in: (i) specific focus on IoT user experiences, (ii) ideation workshop with a repeatable structure and guidelines, (iii) can be specialized towards specific domains (iv) oriented to non-experts, (v) use object augmentation as a design strategy.

TILES IDEATION TOOLKIT

Tiles has been created to inspire ideas for IoT user experiences by fostering both divergent and convergent thinking. With Tiles, we aim to investigate how to facilitate human-centered, creative, and reflective idea generation by engaging users without expertise in design techniques and IoT.

Toolkit composition

Tiles comprises a set of 110 cards (Tiles Cards) and a workshop technique that makes use of the cards together with supporting design methods and artifacts (Tiles Workshop).

Tiles cards have descriptive and inspirational roles. Five sets of *primitive cards* (Decks 1-5, Fig. 1) inspire combinations of IoT components like everyday things, user interface elements, sensors, and services. Divergent thinking is supported by *themes cards* (Deck 6), suggesting a set of provocative design goals to provide creativity triggers. Finally, *criteria cards* (Deck 7) help converging

and formalizing ideas by providing arguments to reflect and evaluate design outcomes.

Providing non-experts only with a set of cards can be overwhelming and confusing. Browsing the cards without any guidance or constraints might not be a sufficient stimulus for creative and collaborative thinking [17]. For these reasons, the Tiles workshop provides an ideation technique and workshop-related tools: (i) a cardboard that scaffolds use and placement for the card, storyboarding, and reflection, (ii) a playbook to guide the users step-by-step in the ideation process, (iii) integration with user-centered design artifacts, such as personas and scenarios to address specific problem domains.

Following on from the descriptive framework by Atzori et al. [2], we look at the IoT from a "things-oriented" perspective. Several elements of their framework influenced our tool: (i) the foreseeing of internet nodes to reside in every object, like food packages, furniture, paper documents, and more, (ii) the concept of *spime*, defined as an object that is tracked throughout its lifetime and that will be sustainable, enhance-able, and uniquely identifiable [32], (iii) IoT as an architecture of independent federated services and applications, characterized by a high degree of autonomous data capture, event transfer, network connectivity, and interoperability. The focus on idea generation and design was also inspired by the work of Atzori et al. [2], who assess the lack availability of IoT applications, despite the potential the technology already offers.

Toolkit extendibility

Tiles has been designed as a flexible tool, adaptable to ideate augmented things for a variety of application domains. On the other hand, which *thing* to augment and how to intervene with technology is often related to the needs and values of specific user groups and contexts. Although Tiles does not provide tools to investigate a specific domain, insights can be gathered using user research methods borrowed from ethnography [4], including interviews, user diaries, or surveys. User research outcomes formalized in artifacts like *Personas* and *Scenarios* can be used in a Tiles Workshop to focus ideation toward a specific domain, problem, or need for a specific user group. Furthermore, because Tiles is licensed under Creative Commons, the set of cards can be extended by domain experts, adding cards related to a specific domain, for example, making adaptations of our work such as *Tiles for smart cities* or *Tiles for serious games*. Finally, although the cards have been developed in conjunction with the workshop technique, they can also be used with different ideation or brainstorming techniques or game mechanics.

The development of Tiles has been undertaken in three iterations, in collaboration with a design studio. The process benefitted from having direct access to designers' experience in workshop facilitation and participatory

Figure 1: Tiles Cards decks.

design. The contents of the cards and the workshop structure have been refined according to feedback gathered during focus groups with experts and formative evaluations with design students. In this paper, we focus on the final version of the toolkit and its evaluation. The initial design of the tool and a pilot study is described in [26].

In the following two sections, we describe the rationale behind the creation of the different decks of cards and the workshop technique.

TILES CARDS
The 110 cards are sized 9x6cm and shaped with rounded corners arranged in seven categories (decks) (Figure 1). All decks are color-coded to be easily discernible from one another.

The front side of each card explains its role and the deck to which it belongs. The back side provides content specific to each card. The object or concept for each card is illustrated with graphics and a short text. The contents on the cards have been chosen for understandability, not requiring any background in design or technology. The cards have a unique ID printed on the bottom right corner to simplify data collection and logging during design workshops.

For each deck, we provide blank cards that can be personalized by players. In this way, we expect to free participants' creative impulses and allow for out-of-the-box thinking. Popular user-designed cards can also be included in future versions of the tool.

In the remainder of this section, we describe the cards by grouping them according to their roles.

Description of IoT components
To help non-experts navigate the space of opportunities offered by the IoT, we created five groups of primitive cards. The cards help to deconstruct and explain IoT elements, such as data sources and user interface metaphors, in a simple language, hiding unnecessary complexities.

The Atzori et al. framework [2] has been adopted as a source of inspiration to simplify IoT characteristics in a set of primitive cards that can be used pragmatically for brainstorming. The heterogeneity of the groups of cards reflects their vision of systems composed of many subsystems, with extremely different characteristics. These cards are grouped in five categories: *things, human actions, feedback, connectors, and data channels*.

Things cards (deck 1) suggest a set of everyday, low-tech things that can be enhanced by technology. Objects depicted on cards belong to the following categories: the home (e.g. fridge, stove), the office (e.g. desk, pen), clothing (e.g. shoes, watch), outdoors (e.g. sporting equipment, plants) and transportation (e.g. bike). We included both objects meant for personal and shared use. We excluded objects that are relevant only to particular groups of people, such as work tools or weapons, or those that are already technology augmented, such as smartphones.

Figure 2: Group A playing with cards during a Tiles workshop. Cards, Board and Playbook are visible.

Human Actions cards and Feedback cards (deck 2-3) propose several interaction metaphors that can be composed to design the user interfaces of an augmented object. *Human actions* describe how the user can trigger a digital input via a physical action, such as approaching an object, manipulating it, or moving it. *Feedback* describes how the object communicates back to the user, for example via visual, audio, or haptic feedback. These interaction styles, popular in the field of tangible interaction, can be quickly prototyped using technology toolkits like Arduino [25] and Little Bits [3], facilitating complementing design explorations with prototypes. Conversely, because IoT devices usually don't feature a large screen or input peripherals, we excluded elements of GUI metaphors, such as menus or windows.

Connectors cards (deck 4) list logical relations among objects to be used to define their *interusability* [29 pag.340]. Those include logic operators common to programming languages, such as *if/then,* temporal operators like *while*, and spatial operators like *together.* Connectors make it easier to design user experiences that span an ecology of things orchestrated to show a coherent behavior, for example, when an action or a sequence of actions performed on an object triggers an output on another object. Their abstract nature helps combine physical things with digital services.

Data channels cards (deck 5) list popular internet services, social networks, and sensor devices that provide or store information accessible via public APIs, e.g. Twitter, traffic warnings, or cloud documents. They inspire the design of augmented objects acting as avatars for digital services. For example, a data channel card can be combined with a thing and a feedback card to design a device that visualizes data in a tangible way, e.g. a keychain that vibrates when a traffic alert is issued. Likewise, an association of a thing card and a human action card can define an object that provides a physical affordance to control a remote data source.

Support for creative thinking

Combining things, user interface metaphors, and data channels has the potential to turn individual components into meaningful combinations. Yet those combinations might not necessarily describe an augmented object that is novel, useful, or user-friendly. Without triggers for creative thinking and constraints in the design process, users of our tool could fall into designing artifacts that resemble existing products and make use of mainstream user interface metaphors. The following two decks of cards have been created to avoid these issues.

Themes (deck 6) help to engage users in creative thinking by providing twenty provocative design goals. Those triggers aim to support the generation of divergent ideas and creating a conversation momentum among participants. Example of themes are: "Sixth-Sense: Create an object that gives its owner some kind of superpower, like new types of senses, perceiving new information, etc." and "Trojan Horse: Create a concept that seemingly does one thing, but where the intention is to produce another, deeper effect."

Theme cards are centered on human behaviors and desires; they have been inspired by David Rose's *Enchanted Objects* [28] and the *perceptual lenses* of the *Design with Intent* toolkit [23]. Each card briefly describes a specific design theme and provides examples of how the theme can be implemented in an augmented object.

Support for reflection on generated ideas

After a number of ideas are generated, *Criteria cards* (deck 7) help participants to reflect on and evaluate their design outcomes by looking at their ideas through a set of nine critical lenses. Examples of criteria cards are: "Creativity: Ideas that solve a problem in a clever and unusual way"; and "Feasibility: Ideas that solve a problem in a plausible manner, and that seem realistic to develop."

The criteria act as triggers for collaborative reflection. While themes cards foster divergent thinking, criteria support refining ideas toward converging on a concept that satisfies one or more criterion. Criteria encourage trade-off discussions and enable finding inspiration for future design iterations. Criteria could be also used in the early phases of idea generation, for example, by discarding ideas that are evaluated as not innovative enough or feasible to prototype.

To summarize: primitive cards enable quick exploration of multiple combinations of physical things, user interface metaphors, and data channels. Themes cards introduce triggers to help re-frame ideas toward certain users' goals and values. Criteria cards provide lenses through which to reflect, evaluate, and select ideas, and to inform new design iterations.

TILES WORKSHOP

To provide guidance for collaborative ideation using the Tiles Cards, we developed a workshop technique to be used in sessions with 2-6 participants facilitated by professionals. The technique reflects the structure of the creative design process as defined by Schön [31], which iterates between problem analysis, problem framing, generation of potential solutions, and critical reflection on ideas generated.

The technique guides the use of the cards and complements it with traditional design activities, such as sketching and storyboarding and with user research artifacts, such as Personas. The activities of the workshops are supported by a *playbook* and a *cardboard*.

The playbook describes seven design actions the users must accomplish in a limited amount of time and according to certain rules, e.g. limiting the number of cards that can be used in a design session. The cardboard offers visual affordances to support the actions and rules described in the playbook. It guides the user in combining different type of cards and incentives, sketching, and note-taking. By adding constraints to the use of the cards, we expect to increase the creativity and number of ideas generated, as discovered by [5]. In the remainder of this section, we further detail the playbook and cardboard.

Playbook

The playbook guides workshop participants in designing an augmented object with a seven-step process. Although the ideation technique is meant to be supervised by professionals, the playbook helps keep the design process visible and minimizes the need for supervision.

The activities participants are asked to perform are the following:

1. *Select a user and a context you agree to design for* – it helps define the boundaries of the design space. A user and a context, formulized as persona, scenario or problem elaboration, are to be provided by workshop organizers to steer design efforts to a specific domain.
2. *Browse Things cards and select one or more objects that are central for a given user. Use Connector cards to define the relationships among the objects, as needed* – it defines what object(s) will be augmented by technology. It enables participants to start generating ideas leveraging their native knowledge of how everyday objects work, using technology to improve upon their original affordances and capabilities.
3. *Define which actions trigger the things by browsing Human Actions and Data Channels cards* – it allows users to define how humans and third-party services interact with the selected objects.
4. *Define how the things respond when triggered by browsing Feedback and Data Channels cards* – it allows users to define how the selected objects communicate back to the user, either via user interface feedback or via sending information over a data channel.
5. *Flesh out ideas on the storyboard section* – it allows participants to focus on one idea by sketching how the augmented object is used and what values it brings to the users.
6. *Use Themes cards to find ways to challenge one's idea, then go back and refine the storyboard contents.* – it provides triggers to diverge by iteratively modifying and expanding previous ideas.
7. *Look through the Criteria cards and discuss how well one's idea scores on each criterion* – it helps collaborative reflection and trade-off discussion.

Participants are expected to be given a limited amount of time to complete each step. A time constraint is added to the process in the attempt to avoid participants' getting stuck or converging too early on an idea before having explored different cards. Collaboration in the group is left informal; cards can be freely browsed and chosen according to the persona and scenario for which the group is designing. When needed, some strategies could be enforced to guarantee that everyone takes part in the discussion, for example, asking participants to draw and discuss one card each in turns or introducing rules to foster competition among participants.

Cardboard

A cardboard (Figure 2) is provided as scaffolding. It consists of four areas, to be used in sequence to scaffold the design activities in the playbook:

- *Ideas* helps outline the augmented things. It guides users in combining cards by suggesting grouping cards as *things*—the *things* to be augmented by technology, *triggers*—the set of *human actions* and *data channels* that initiate some interactive behavior of the thing(s), and *responses*—the kind of *feedback* and *data channels* the things use to communicate back to the user.
- *Storyboard* allows the sketching of the user experience with the augmented things in six blank frames. It facilitates moving from a static representation of several augmented things into a dynamic view of how people interact with the things.
- *Themes* allows for placement of *Themes* cards that are selected as relevant to the current idea and provides space for annotating how the themes have been used and discussing trade-offs.
- *Reflection* allows for the placement of *Criteria* cards and provide space for annotating strengths and weakness of an idea with respect to selected criteria.

By framing the cards in use during a design session, the board provides a conversation medium to foster collaborative brainstorming. Because of its large size, the board enables 3-4 people to sit shoulder-to-shoulder. Furthermore, the use of cards and cardboard recalls playing board games, an activity familiar to many.

USER STUDY

We conducted user studies to understand how Tiles was useful in informing and guiding ideation for the IoT. We focused on the following aspects:

1. Informing about IoT: as the capability to transmit knowledge and awareness of IoT basic components to non-experts
2. Creativity: intended as sparking design thinking and idea generation
3. Reflection: as the ability to change perspective and refine ideas in a critical way
4. Guidance: as the ability to support participants in idea generation

We do not aim to evaluate the contents of the cards, but rather their use as part of the workshop technique.

Participants

Participants (n=32) were a convenient sample of graduate and undergraduate students from a local university, high-school students, and one researcher in IT. Some of the participants had basic experience in programming, but none of them declared themselves to have experience in design topics or techniques. High-school students were aged 15 and 16; they were not mixed with university students or researchers when attending the workshop. University students came from the Computer Science and Architecture departments. The researcher was also from the Computer Science department, but not involved in IoT or design research. A movie-ticket raffle was used as an incentive for participation. The premise for the participation was to learn about the IoT.

Evaluation process

Participants used the Tiles Cards during Tiles Workshops organized in multiple sessions. Groups of two to four participants were formed according to their availability. Each participant attended one workshop only. Each workshop was supervised by two researchers and lasted for about 1 hour and 30 minutes.

The goal of each workshop was to design an IoT application to support sustainable behaviors in smart cities, a topic that has been considered interesting for a general audience. A set of sample *personas* and *scenarios* related to the domain were provided to the participants.

Participants were welcomed with a five-minute presentation about the IoT, followed by a brief description of Tiles. Participants were then asked to start an idea-generation session following the rules reported in the playbook, which was provided as a reference during the workshop. Participants were given about five minutes to complete each of the playbook's seven steps, resulting in sessions that lasted between 35 and 45 minutes. After the ideas were finalized, each group presented their outcomes in a short pitch. Participants were then asked to respond individually to a questionnaire about their experience in the workshop. A five-point Likert scale was used to assess the results. Each session ended with a 10-to-25 minute group interview, where participants were asked to provide feedback about the tool and the process and encouraged to comment on any detail they considered relevant. The interview was also meant to confirm the data collected by the questionnaires.

Data collection and analysis

Video and audio of each group session was captured. Researchers also observed and took notes and photos during idea generation and interviews. The videos were replayed later and a transcript was produced from them. Data from the questionnaires were aggregated and analyzed using spreadsheet software. Consent forms were signed by all participants.

The analysis of collected data was guided by the Strauss and Corbin process [33] and by the guidelines in [6]. We focused on patterns of actions that involved participants and elements of the Tiles workshop, especially in connection to the research questions. Observations were also meant to spot and discover the process, intended as unexpected usage of the toolkit or pre-defined procedures supported by the workshop. Transcripts of videos and free-entry comments from questionnaires were coded using the focus criteria of the evaluation. Quotations reported in the following sections are from the unmodified transcript of user feedback mainly collected through video recording.

RESULTS

Example of ideas generated

We first present one of the ideas generated during the workshop to exemplify the type and complexity of ideas that can be achieved with a ~40-minute ideation session using Tiles. We chose this idea because the participants rigorously followed all the steps in the playbook. The idea demonstrates everyday object augmentation well; special attention was also given by the participants to critical reflection and refinement of the idea.

The idea, developed by group C, describes "The Small-Talk Bench": a technology-augmented public bench to promote social interaction among the elderly. The augmented object is a public bench to be placed in a park. The bench is activated when one or more people are sitting. When only one person is sitting, the bench provides breaking news, bus schedules, and other useful information. When two or more people are sitting, the bench also has an "ice-breaker" function, asking questions to those sitting (with a synthesized voice) about popular topics in politics and science, such as "What do you guys think about the upcoming elections?" The goal of the *Small-Talk Bench* is both to act as a simple interface for the elderly to stay informed and to encourage social interaction among strangers by proposing small-talk topics.

Ideating the small-talk bench, group C choose to work with the Theme cards *Omniscience* (TM-18), *Safekeeping* (TM-19), *Social Interaction* (TM-5), and *Enjoyable Objects* (TM-6). They critically reflected upon and improved the idea using the Criteria cards *User-friendly (C-8), Utility (C-4), and Market Potential (C-9)*.

Roles of the tool

Data from the questionnaires suggest that Tiles was perceived as useful. More than 90% of the participants agreed at least partially with the statements in Figure 3. Almost 90% agreed that the visual design was appealing and more than 90% agreed at least partially that the cards were easy to understand and that the design process provided guidance to develop new ideas. In the following section, we report results for each evaluation goal.

Informing participants about IoT components

Observations and data from the questionnaires show that the tool was useful in helping users navigate through the IoT design space. The mind-opening capabilities and the possibility for non-experts to understand what IoT has to offer emerged from interviews and observations: *"This process shows you a lot of possibilities for IoT we haven't thought about", "I read a lot about IoT before, but the cards are more structured and made easier to remind and recall the concepts", "The process was also helpful to understand what the possibilities are", "I like that data channels are used both for triggers and output, that helped to see what the possibilities were."*
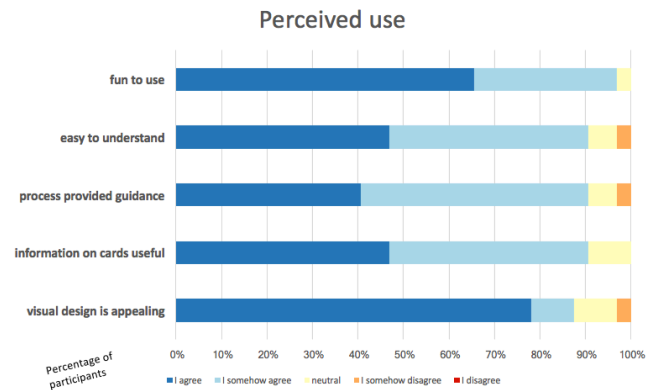

Figure 3: Use of the tool.

Primitive cards describing user-interface metaphors were considered particularly useful. From the questionnaire, more than 85% of the participants agreed or partially agreed that the Human Action and Feedback cards helped to understand the opportunities provided by IoT technologies. Participants stated that the Things cards were useful in connecting IoT technology with everyday objects: *"Things cards are useful because you can understand which everyday objects you can augment."*

The overall experience with the tool contributed to inform and introduce participants to the IoT field: *"I didn't have a clue of what IoT was before, now I feel I have a better knowledge", "I have a better understanding of IoT and I think it's more useful. I see IoT now more as a process than a network of objects."*

Support for creativity

Questionnaires show that Tiles was useful in sparking creativity. Almost 70% of the participants agreed or partially agreed that they had ideas they would not have had without the cards (Figure 4). Participants also agreed at least partially that *Themes* cards helped them to be creative and that it was easy to design interactive objects using the cards.
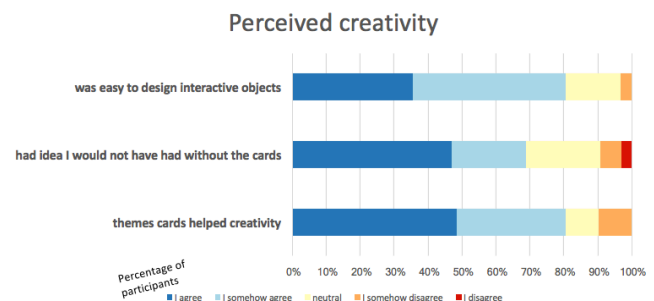

Figure 4: Perceived creativity support in using the cards.

Not everybody agreed on through which step creativity was best expressed and encouraged: *"For me the Things section was the grounding of the idea, it's where my mind worked more and I was more creative",* one participant said, while others pointed to the Themes cards: *"Themes category made us more creative, made us come up with new ideas for the product we already have."* Some participants declared that the *triggers* and *response* areas of the board contributed best to creativity, while others assigned some credits also to the context or the storyboard: *"A scenario like this can be used for a lot of things depending on your creativity", "We were most creative on the storyboard, we didn't choose a specific idea and object before the storyboard, we could make up whatever we want."*

Mixed opinions were also collected about diverging or converging on generating ideas: *"If you think about a problem maybe you only think about related objects, but this tool opens your mind and force you to evaluate objects that are not necessarily related", "The cards show a vast array of possibilities, opens your mind a lot."* On the other hand, some participants suggested the addition of constraints to the process: *"Better to have a context but not choose freely the card: can help to generate more unique ideas", "I think it's divided in two parts: left part of the board more opening your mind, right side more narrowing down."*

Cards were a source of inspiration for many: *"Cards were useful at the beginning to trigger the initial idea, a lot of possible different combinations", "What are you thinking when I say plants? Maybe is related to sustainable behavior…."*

Finally, some participants suggested improvements of the ideation process: *"Maybe a rule to restrict the number of events or objects, to narrow down more efficiently".* It is interesting that participants felt the need for more constraints to be more creative. This is in line with results from other card-based tools, e.g. [17,27].

Support for reflection
When interviewed about the support for reflection the tool provided, participants commented that they were able to reflect on the idea they generated: "*The reflection section is pushing you to think why you do it in the first place*", *"I learned more with criteria and themes: you get back on the idea, the rationale of the idea, you reflect on the idea Themes raise awareness, evaluate the idea under a different point of view."*

When asked whether *Criteria* cards helped to reflect and evaluate ideas, more than 80% of the participants agreed or partially agreed with the statement. Indeed, we observed participants reflecting on the idea while browsing Criteria cards: *"[looking at criteria C-2 Innovation] Innovative? The idea is probably out there but it's not of common use, it's the right direction", "[group while browsing cards] I think we need to focus on the social aspect because if not*

what's the difference between staying home watching the news and sitting on this bench watching the news?"

Support for guidance
More than 90% of the participants agreed at least partially that the tool provided guidance to develop new ideas. The interviews confirmed that participants were glad to have a clear structure to rely on and some sort of guidance: "*Normally [in IoT] everything is mixed, but it is useful to have a structure and to think about data channel, things and feedback, separately", "I think the cards guided me to a point, that was like [just] watching them, I was able to make the story."* Yet the high number of cards provided (110 cards in 7 decks) made some participants feel overwhelmed: *"At the beginning we struggle to understand, to pick up things", "Too many cards, too many possibilities."*

Analyzing the role of cardboard and playbook in guidance, we gathered mixed opinions. Comments were not positive regarding the role of the cardboard in supporting the ideation process: *"We followed some steps, but when we reached the end it was like what's now? Do we have an idea now?"* Many declared that the board was not explicit enough: *"I didn't really know what cards I have to connect", "We need a more specific guide on the board."* Because the board design was not immediately understood nor well accepted, it led participants to spread the cards all over it (see Figure 2), ignoring the card placeholder, hiding important sections, and adding to confusion. This is confirmed by the interviews, where users declared *"Didn't use the board, didn't get the vertical alignment of trigger-things-feedback", "I didn't notice the boxes [cards placeholder] on the board."* Participants were more positive about the guidance provided by the playbook: *"This is better than traditional brainstorming", "We need to move to the following step, it say 15 minutes here on the board!".* The playbook was often used as a support when getting stuck, as participants skipped to the next listed step to continue working.

DISCUSSION
The Tiles Card workshop proved to be an effective process to support design and idea generation for the IoT. Results show that in a very limited amount of time, participants were able to:

- Design one or more augmented objects;
- Use the augmented objects in a user story addressing a specific problem and scenario; and
- Reflect upon and improve the idea, looking at the problem from different perspectives.

In this section, we reflect on the strengths and limitations of our approach, identifying which elements played a role in facilitating or hindering idea generation. These reflections can be considered as useful guidelines for the design of similar IoT ideation tools.

Strengths of the tool

A structured process facilitated ideation outcomes
The design process was guided by the instructions reported on the playbook area of the board. This was an element of novelty compared to previous works that chose to not provide prescriptive guidelines about how to use the cards, e.g. [14,17,27], and it came at the risk of obstructing the creative nature of design work. Surprisingly, workshop participants called for even more constraints in the process rather than fewer. This might be justified by the process leaving room for freedom and to tweak the process as needed. For example, we did not put any constraints on the number of cards to be used and participants could always re-do or revisit previous steps if new information or ideas arose. Like the workshop technique in [14], we did not set up rules for roles or turn-taking.

Yet the strategy adopted by the groups was more articulated than we expected. The initial choice of the domain context drove the selection by the participants. Things cards were then excluded if not relevant for a certain context. During steps 3 and 4 of the playbook, participants were pushed to think about how to connect triggers and feedback to things and were advised by the playbook to use multiple cards for the same object. Despite the playbook's focus on triggers and feedback, participants continued referring to selected *context*, *user* and *things* to get inspiration. Sketching the storyboard forced participants to discuss a detailed scenario to use, while cards were added and/or removed and the idea was usually refined and improved, resulting in a more robust version. There was much more happening during this step than simply writing down a developed idea. Themes cards also helped participants to gain confidence in their idea: they were relieved to find that their idea fit one or more themes.

Driven by the progressive discovery of new cards, participants were often excited to include a specific card into an idea. If the card explicitly clashed with the core of the idea, it was easy for other group members to prevail in the argument, quickly discard the unnecessary card, and continue in the design process.

Given the novelty of the field, it was critical to support the user when exploring new paradigms. When allowed a great deal freedom, users tend to revert to what they already know. To avoid allowing this to happen, the process is delegated to support and point the user in the pursued direction. The Tiles Workshop succeeded in preventing the users from coming up with ideas that involved mainstream concepts and classical interfaces like screens, pointers, etc., which are not strictly connected to the IoT.

Finally, a structured process support by a playbook given to participants as a design artifact also helped to reduce the help given by professionals in workshop supervision. This can reduce the risk of adding the personal bias of workshop facilitators to the ideas generated by the groups, an issue that limited other projects [27].

Creativity permeated the whole ideation process
Divergent and convergent thinking were observed and sometimes even suggested by participants in relation to the cards. Some converging elements like Scenario and Criteria cards served the purpose of sparking creativity, but some participants wished for a more constrained approach, for example when dealing with the Things cards. Others, on the other hand, appreciated the diverging and mind-opening experience of getting to know the possibilities offered by the IoT. We believe that, given the novelty of the field, allowing participants to discover a wide design space can be more beneficial than restricting them to a limited set of cards randomly chosen—for example, enforcing turn-taking. This would also introduce the risk of pushing participants to generate an idea at all costs, losing sight of user and context, or the problem that drives the design.

Idea generation was a creative process that permeated the whole workshop, regardless of the specific phase. Participants continued adding to and refining the fundamental core of the idea during every phase of the workshop. In some cases, they added significant details not discussed before, even during the final pitch of the idea.

Intra-group coordination naturally occurred
Although not explicitly enforced by the workshop technique, group discussions and collaboration naturally occurred while taking decisions or developing ideas. Discussions were often triggered by the cards: *"[Browsing theme cards] Is there something we could change in the sequence here?", "Should we work on the social interaction card or we drop it?", "Should we change anything? Improve anything over here? [point at cards on the board]"*

We observed many groups splitting card decks among all the participants, who browsed and selected relevant cards to be evaluated collectively in a second step. A suggestion in this direction also came from the interview: *"Introducing game rules like turn based can help involve everybody. We split the deck so everybody was involved in the decision."* Due to the high number of cards provided, this has also been a way to divide tasks and speed up the card-selection process. Only one person browsed the cards in only a couple of groups, asking the others whether they agreed on the selection.

Sketching storyboards was an activity central to promoting discussion and collaboration. Even in groups where a clear leader emerged, all the participants contributed in some way to the storyboard. Groups didn't start sketching immediately: every step of the storyboard was discussed and elaborated upon, contributing to the development of the idea. Collaboration was also observed whenever different groups of cards had to be connected. In several groups however, a leader prevailed in the choice. To prevent this

from happening, it could be useful to introduce a mechanism to actively involve every participant in the process, like turn-taking.

Limitations of the tool

Session hijacking
In some groups a single user assumed the role of the leader, "driving the show" without involving the other group members much. Introducing some game mechanics, like turn-based contribution and card drawing, could help preventing this to happen, assuring more fairness in the process.

Effectiveness of the board
Several points of improvement to the board design were suggested. Some users struggled to understand how the cards were intended to be placed on the board or how the board was meant to be used. The fact that some groups randomly placed many cards on the board added to confusion: important sections of the board were hidden, hindering guidance and preventing the users from following the playbook. A more effective board design could have allowed for better guidance. Consistency in the design between the cards and the board could help to mitigate the observed issues. Research in board game design could also be used as a source of inspiration.

Evaluation process
So far, the Tiles Workshop has only been presented and run by the authors. Consequently, we cannot draw conclusions about the adoption or use of the tool by other researchers on the level of supervision needed. Because we did not attempt to evaluate or rank the ideas generated, we also cannot draw conclusions about their novelty. Finally, comparing the results from the workshop was limited by the participants having different levels of expertise and the groups consisting of both researchers and students. More user studies are needed in order to better focus the evaluation process towards possible criticalities.

CONCLUSIONS AND FUTURE WORK

The Tiles Ideation Toolkit aims to support explorations of the IoT design space and provide triggers for creative reflective ideation of augmented objects. We developed a set of 110 cards grouped in 7 categories and a workshop technique providing step-by-step guidance to involve non-experts in idea generation. The toolkit is extendible and can be customized to direct ideation efforts toward specific domains. During our user studies, the toolkit has been useful in informing and guiding non-experts in quickly generating ideas for augmented objects by supporting creative thinking and critical analysis of design outcomes. Furthermore, the toolkit facilitated articulate thinking and collaboration strategies among participants.

Future work point at multiple directions. We are revising the cards' contents, the board, and the playbook based on the findings from the user study. Furthermore, we plan to evaluate the use of the cards with different workshop

techniques and with other user groups in order to understand the entry barriers to the adoption of the tool. We aim to explore how the addition of mechanics borrowed from traditional card and board game play, as well as computer interactivity, can improve the fun and user-engagement aspects. We will also provide guidelines to extend the tool and templates for the design of new cards. Finally, we are interested in investigating how to complement ideation with prototyping. We will integrate Tiles with hardware tools and digital manufacturing techniques in order to support the rapid prototyping of the ideas generated.

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