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Abstract	We describe a field prototyping project where open-ended prototype tools for web-connected tags are weekly co-designed and programmed with and by the user. We call this approach Extreme Co-design to denote how design is inscribed in Extreme Programming sessions with rapid cycles of use, design and development that allow extensive exploration and experiencing of appropriation scenarios. Such an approach is particularly suited for repurposing malleable technologies such as RFID/NFC, which can take a variety of affordances and be applied for many uses, in particular acknowledging trends such as composition at end-user level of web functionality. We analyse the results of a one-month field work highlighting how to document explored ideas, appropriation scenarios, use try-outs, developed features and gained insights. We discuss this successful approach as a design tactic for unfinished products to foster end-users' creativity through situated use and show how Extreme Programming and in-situ deployment supported meaningful designer-user interactions that resulted in the advancement of the initial design.

Keywords (separated by '-')	Appropriation - Field study - Co-design - Extreme programming - In-situ deployment

Extreme Co-design: Prototyping with and by the User for Appropriation of Web-Connected Tags

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Abstract. We describe a field prototyping project where open-ended prototype tools for web-connected tags are weekly co-designed and programmed with and by the user. We call this approach Extreme Co-design to denote how design is inscribed in Extreme Programming sessions with rapid cycles of use, design and development that allow extensive exploration and experiencing of appropriation scenarios. Such an approach is particularly suited for repurposing malleable technologies such as RFID/NFC, which can take a variety of affordances and be applied for many uses, in particular acknowledging trends such as composition at end-user level of web functionality. We analyse the results of a one-month field work highlighting how to document explored ideas, appropriation scenarios, use try-outs, developed features and gained insights. We discuss this successful approach as a design tactic for unfinished products to foster end-users' creativity through situated use and show how Extreme Programming and in-situ deployment supported meaningful designer-user interactions that resulted in the advancement of the initial design.

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1 Introduction

Since computation has left the desktop to become embedded into mobile devices and tangible objects to support people in their everyday activities, the panorama of modern IT has grown in complexity and the need to design open-ended systems that "allow the unexpected" has become more pressing. In the same way a screwdriver could become a tool to open paint bins, interactive appliances

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can be reconfigured in ways that cannot be envisaged at design time, especially in the case of technologies such RFID/NFC. This makes design a never-ending reflective process that continues with the use and requires the practical involvement of the end-user to disclose technology adoption, use and appropriation, as exemplified by design-in-use practices [11], field studies on appropriations [8] and everyday design [7]. Following Suchman's perspective that an action cannot be interpreted as separated from the environment in which it has been accomplished [26], usages need to be observed and evaluated in everyday settings with field approaches rather than formal laboratory studies. Field research of everyday design practices [7] and domestic appropriations of tangible tokens to web content [17] uncover a plethora of use scenarios and ideas of appropriations that are not readily supported by simple implementations or laboratory prototypes, indicating the potential to pursue design of open-ended technologies through continuously evolving prototypes and in-situ deployment. To this end, novel agile approaches that allow the deployment of always-available exploratory prototypes in real-world settings are needed to design technologies informed by user practices and experiences and to gain practical insights from the end-user's personal experience [12].

Our intention is to discuss an approach to design *with* and *by* the user we called Extreme Co-Design, to denote how design is inscribed in Extreme Programming sessions with rapid cycles of use, design, development and in-situ deployment that allow extensive exploration and experiencing of appropriation scenarios. In this paper, we present results from a one month field study with one family in which weekly co-design sessions were organized alternating use, design and development of an open-ended tangible technology (the T4Tags open prototype) that exploits NFC to link digital web content to physical objects at home. Findings from the analysis of appropriation scenarios show how the Extreme Co-Design approach allows for a wide exploration of the design space through use try-outs that capitalize on end-users' knowledge of the domestic space, their practices and interpersonal relations. Gained insights allowed to reflect on how to derive implications to design open-ended technologies that assist end-user's creativity.

2 Background

Our work draws on the literature on domestic appropriations of tangible technologies, end-user development of tangibles and iterative co-design from use.

2.1 Re-interpreting Tags as Domestic Technologies

Tags as tokens and links to digital information have been investigated for more than two decades as material for interaction design. An often cited early example of tags to digital information is Durrell Bishop's Marble Answering Machine [22] where voicemails are represented by coloured marbles. The Marble Answering Machine is an instance of a tokens+constraint interface [27] that models

tokens as discrete physical objects representing digital information, and that offers constraints suggesting how tokens can be manipulated. Other research prototypes have explored different scenarios of the tokens+constraint framework for linking digital information to physical tags. WebStickers [19] uses barcode stickers as bookmarks to web content. Souvenirs [21] allows people to connect photos to physical memorabilia that remind them of a particular holiday, trip or event. MyState [10] provides a way to augment any kind of object with tags that can be annotated through mobile phones and published to a social networking site as a status update. While such designs have been influential in research, showing possibilities that might be supported through tangible artifacts [25], the challenge of actual end-user appropriation of such solutions has been neglected. Recently, through extensive field studies, Tokens of Search [17] have revealed how domestic appropriation of tokens to web affords a variety of unanticipated possible use scenarios that are not easily supported by a single prototype. The variety of needs and appropriation possibilities can be ascribed to the specificity and diversity of use contexts that include aesthetic, social and material aspects [28]. Given the challenge of supporting these appropriation possibilities, approaches that allow end-user involvement in field could be particularly effective.

2.2 End-User Development of Tangibles

Several projects lowered the technical barriers for developing tangible interaction at the hardware composition level, by using simplified input mechanisms and providing toolkits of ready-to-use physical widgets such as sensors and actuators, like the case of Phidgets [9]. Other projects tackled the problem from the software level and provided languages and prototyping environments that ease the acquisition and management of raw data from input/output devices, such as Papier-Mâché [16]. Designing interactive tangibles demands a rich and grounded understanding of device re-combinations in the physical space and how technology becomes part of everyday practices by inspiring new appropriations [13]. For instance, by reflecting on common use scenarios of RFID technologies, Marquardt et al. [20] revisited RFID tags for the end-user and developed a do-it-yourself design strategy to build custom tags with enhanced capabilities, such as reader awareness, visibility and information control. RFID is a particularly versatile technology that can be exploited in different contexts and applications as demonstrated by OnObject [6], which provides a toolkit to rapidly program gestural-based interaction with physical objects, and the more recent TagMe [2] that allows the end-users to tag objects and easily develop intertwined interactions with mobile devices. By providing the technological substratum those projects represent a first step toward more articulated designs of flexible and open-ended technologies, as researchers argued that practical experiments are needed that allow to materialize abstract concepts and ideas through the in-situ deployment of prototypes [12].

2.3 Co-design from Use

Designing "for, with, and by users" has been researched in participatory design movements for decades [5] and given the challenges of ubiquitous technologies has found renewed interest ([14], [15], [3]). User-oriented design of tangible applications benefits from real-world deployment, since it has long been agreed that ubiquitous interaction cannot be evaluated in the vacuum of a laboratory [7] and that it is necessary to provide realistic conditions for the exploration of complex design spaces in order to enable constructive interactions between designers and users[4]. Capitalizing on informed participation, design-in-use has increasingly embraced agile development techniques to continuously iterate the development of prototypes while in use, making design practical and gaining insights of situated use of otherwise abstract ideas. Heyer et al. [12] proposed the RAID design approach that fosters longitudinal studies with an open prototype, which functionality is shaped over the time according to use. The approach is made of three iterative stages: (1) the design of an exploratory prototype from previous experience, (2) the observation and documentation of use try-outs, and (3) the analysis of gathered information to produce the next iteration of the prototype in terms of new implemented features).

There are other documented cases of in-situ deployment of a prototype for co-design, such as BubbleBoard [18], a visual answering machine deployed in five households with the goal of discovering appropriations over the time. Other researchers promoted the concept of non-finito products [24], in which exploiting incomplete technologies that can be used in different ways become a design choice and the exploration of the design space is carried out through the continuous evolution of prototypes in parallel with real usage.

3 Extreme Co-design

In this research we studied the application of the Extreme Co-Design tactic to explore the development of technologies with undefined purposes and indeterminate usages, informed by direct observations and reflections of situated uses. Our contribution is to adopt Extreme Programming (XP) and provide insights of its integration in a process for the co-design of open-ended technologies exploring appropriation scenarios. XP [1] is an unconventional development model that gives prominence to the rapid availability of usable prototypes to accelerate the exploration of the design space through rapid cycles of software release. Its core principles of promoting iterative development and being customer-centered and scenario-driven meet the critical demand of having a continuously working prototype always available. Attempts to combine XP with user-centered design are not new [23]. Nevertheless, while they showed to speed up the design process, further research is needed to understand the potential of XP with respect to end-user development practices. We describe the application of the Extreme Co-Design approach with the in-situ deployment of the T4Tags open prototype and discuss the findings of our field study alternating use, design and development.

3.1 The T4Tags Initial Prototype

T4Tags builds upon the concept of Tokens of Search [17] and provides a platform that allows the user to easily link physical objects to web content via NFC. While Tokens of Search implements limited functionality, e.g., only one single URL could be associated to a physical token and the content can be read only at a designated spot in the house, T4Tags is designed to be as open-ended and versatile as possible: (1) there are no limitations on the number of URL that can be associated to a token and (2) users can read the content of a token with their mobile phones, thus extending uses to more ubiquitous scenarios.

The main design principle was to assemble the prototype as an open toolbox that provides means for: (a) the users to be able to easily implement envisioned scenarios and (b) the designers-developers to rapidly extend the prototype to support future appropriations. The toolbox of T4Tags consists of (see Figure 1):

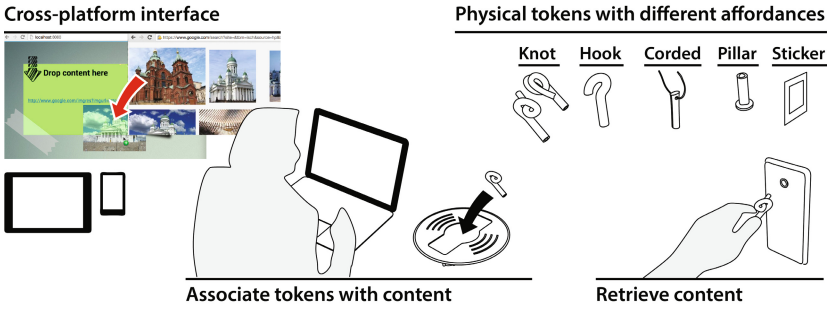

Fig. 1. The T4Tags open prototype.

- a set of 3D-printed physical tokens with different shapes, colors and affordances with embedded NFC tags and NFC stickers;
- a web server that stores the content of the physical tokens;
- a web interface that allows to edit the content of a token by adding or removing (drag and drop) web links. Being web-based, the application can run via a web browser from any computer or mobile device and, therefore, it is not needed to install a resident application in specific devices;
- a tray that embeds a WiFi-connected device with a NFC reader that is used, in combination with the web interface, to access the content of a token by retrieving its NFC identification number;
- an Android mobile phone that runs an application to retrieve and display the content of a token;

T4Tags implements a core set of functionality, informed by findings of previous studies [28][17]. Users can associate any number of web URLs to a token. To do so, they first put the token they want to use over the tray, making the reader to retrieve the id of the token together with the associated content. The user

can then add or remove content by dragging and dropping URL addresses from a browser to the window of the web interface (see Figure 1). This functionality is implemented through websockets that connect the reader and the web interface to the server in order to maintain the synchronization of content. Users can then retrieve the content of a token either by placing it on the tray again or by using a mobile phone with an installed Android application that automatically recognizes the NFC tag and displays the list of associated URLs retrieved from the server.

3.2 Research Approach

The motto of the Extreme Co-Design approach is *"prototyping with and by the user"*. The core idea is based on the integration of Extreme Programming with co-design sessions as a tactic to quickly deploy an evolving prototype that can be readily and continuously evaluated by the user thus allowing the designer to reflect on a variety of real-world usage scenarios and the user to learn from appropriations and to envision new uses.

The process starts with the design of an initial prototype of a technology that has undefined purpose, a variety of design affordances and potentially a variety of usages. Functionality is loosely implemented in the prototype in a way it gives the freedom to explore interactions without restricting the users into pre-established patterns. A core set of functionality is developed depending on requirements gathered from any kind of previous activity, such as preliminary workshops, interviews or other field studies [12]. Once developed, the initial prototype is deployed in-situ and inscribed into a one-month design process that involves weekly co-design sessions alternating use, design and development.

While co-design sessions give a reflective account of various daily situations as articulated by participants, real-world deployment allows participants to use the prototype to support existing practices and construct novel solutions devised from their usage experience. In a domestic setting, this allows participants to generate use scenarios at different times of the day and in private spaces that are not accessible during co-design sessions. Participants are asked to record their interactions with the system in a *diary*, documenting use with pictures and videos. The *diary* would serve as a communication artifact to support the dialogue between participants and researchers that would weekly visit the deployment site to run the co-design sessions. During the weekly sessions, researchers collect impressions and feedback about participants experience with the systems as well as usage scenarios they were able to document but also non-usage of implemented features and misusing. Co-design sessions are the meeting point between users and designers, in which the latter learn from situated uses of the prototype and are able to determine the new design choices that would alter the prototype and materialize in features to be added, modified or removed. The evolution of the prototype occurs during the week after each session, in which designers consider opportune responses to the try-outs. Alternatively, the prototype could also be altered during the co-design session itself in the case designers

become aware of envisioned scenarios that were no readily supported by current prototype and the issue can be quickly fixed or implemented in-situ.

In order to analyze usage try-outs, together with the *diary* from participants, a template-based *journal* is created that designers can fill in to document ideas, scenarios, use trials of scenarios without the need of new implementations and use trials of implemented features. The *journal* is intrinsically a working document and contains information regarding usage scenarios such as when they were firstly envisioned and/or enacted, authors, actors, a short description and any kind of related material such as photos, videos or excerpts from interviews. The templates are meant to keep track of usages and appropriations and offer an accessible way to organize observations regarding successfully repeated usages, abandonment after use or non-use of a feature.

4 Field Study

An in-depth study was performed in a household in Finland with the aim of exploring how the prototype would be adopted to support existing practices of the family or inspire appropriations and new social organizations. The initial T4Tags prototype was deployed in-situ and remained in the household for four weeks. During the first visit all the necessary hardware and software were provided to the family, which included: (a) the device, the NFC reader, used to link physical tokens to web content, (b) the mobile phone used to retrieve tokens content and, (c) a set of physical tokens of different shapes, colors and affordances. The web server was installed in one of the family computers.

They were then interviewed about their normal routines, family life and organization and computer use, including Internet (e.g., what they use Internet for, if children are allowed to connect to web alone, etc.). After the interview, the main functionality of the system were introduced with an example of sharing photos with friends. The family was showed how a photo could be associated to a NFC sticker and then, for instance, by attaching the sticker to a postcard it is possible to create a digitally-augmented message to send to a friend. After the example of use, a brainstorming session was undertaken, from which participants came up with many ideas and scenarios. Some of them were ready to be tried out, while others required some tweaking and programming and eventually they would have been available in the following weeks of the field trial.

Participating Family. The family studied consists of four members: father, mother and two daughters. Pseudonyms are used to protect members anonymity. The father, Kari, is a researcher. The mother, Päivi, works as a cultural producer. Kari and Päivi have two daughters Sini and Anna. Sini is 12 years old and Anna is 9 years old. The family lives in a spacious apartment house in southern Helsinki. According to Kari's words, the family provided an eclectic sample for the purposes of the study: *"[...] there's a woman who would not care less about technology. And if it works for such a person, then it will work for many others. And we have kids who are kind of normal usual girls [...] they're curious for new*

kind of things and they would be delighted to adopt something that they find helps them create some good experiences." All family members use their smart phones and the parents also use laptops to access the Internet. In general, Internet is used mainly for individual purposes (e.g., working, playing or shopping) and watching shows and series from Yle Areena[1] and Netflix[2], since the family does not have TV. They also have a tablet in their entrance hall that shows the weather and when the trams and buses go.

Data Collection and Analysis. The interviewing was done partly in Finnish and partly in English. A Finnish researcher interviewed the family weekly and the English speaking researcher attended the first co-design session on the premises and the other sessions via Skype. The interviews were video taped and transcribed to both Finnish and English. The family members documented their experiences with the system throughout the study with the help of photos, videos and notes (the *diary*). The transcriptions were inspected to fill in the template-based *journal* with information about usage scenarios. Next, we present the analysis of how tokens were used.

5 Results

The T4Tags prototype was able to support purposeful interactions between users and designers that resulted in the advancement of the design, such as appropriating features, proposals for new features, for transforming existing features, and implementation of transformations into existing features.

5.1 Exploration of Usage Scenarios

At the end of the field trial, we were able to document 14 distinct scenarios organized in three categories we detail below (see Table 1 at the end of the paper).

Tokens as Prompts for Content. Tokens as a means to retrieve content were mostly exploited to augment other objects in the household (Scenario 10 and 11). Participants wanted to capitalize on the physicality of existing objects and they firstly devised the idea of embedding a NFC sticker into soft toys to retrieve media content through some interaction with the augmented toy. Kari attached a sticker to a Hello Kitty toy after having added a web link to a song into the token. He also connected the smartphone to the radio speakers. He then gave the toy to Sini and, when she placed the toy sitting on top of the phone (see Figure 2, on the left), the song started to play from the speakers . The kids were really excited and wanted to share the rewarding experience with their friends as

[1] http://areena.yle.fi/tv
[2] https://www.netflix.com/global

Fig. 2. Usage scenarios from the field study. From left to right: Scenario 10 (Toy), Scenario 11 (Poster) and Scenario 5 (Memento).

well. Kari said: *"[...] when I made it work Sini wanted immediately to show it to Anna and then Anna wanted to show it to Laura (Anna's friend) and then came Ritva and Vesa (family friends) to visit the same day and they wanted to show it to them."* The successful try-outs of the toy scenario engaged participants in thinking on other possible reconfigurations of the same idea. In fact, they later decided to augment the static content of a movie poster with a sticker that would trigger a trailer of the movie from Youtube.com (see Figure 2, in the middle).

Tokens could also work as a place where users can put things they have to remember (Scenario 5). They could contain both the description of what it needs to be done as well as instructions on how to do it. For instance, T4Tags was used by Kari to attach a list from Wunderlist[3] to a token and create a "reminder". He then put it on his pillow (see Figure 2, on the right) for remembering to help his daughter with her piano homework before going to sleep. The physicality of the token worked as a knot in a handkerchief and Kari realized that he reminded the content of the token without reading it. Other ideas of possible usages of the Memento scenario were proposed, even if not explored, such as using the token as a reminder for paying bills or as a card from hairdresser or a dentist with information of next appointments.

Tokens as Triggers of Actions. As the field study progressed, the family devised several ways of using the tokens to trigger meaningful actions, such as to log in to applications or services. Kids, for instance, could use it as a password for WiFi, Yle Areena or Netflix. Kari suggested that the token password (Scenario 6) could work only in certain hours, for instance the kids could have access to Netflix in the afternoon, but not when it is time to go to sleep, thus highlighting that the platform should support more articulated functionality of end-user tailoring that allows to program the context-aware behavior of tokens. Kari actually wondered if tokens could be programmed as IFTTT[4] applications (Scenario 13). This means that a token would become a trigger to create

[3] https://www.wunderlist.com/es/
[4] https://ifttt.com

powerful connections with online digital channels and, via simple rules, develop intertwined interactions between the digital and the physical world that allow to use the token, for instance, to switch on/off the lights or update the Facebook profile. This idea was envisioned during the closing co-design session and therefore there was not time for further developments or implementations.

During the last week of use Kari, Sini and Anna came up with the scenario of opening a game in the computer with a token (Scenario 14). Kari attached a token into a stick that was called *magic wand* and then used the wand to open a game called Pottermore[5] in the computer by touching the reader with it, as if he was casting a spell. Kari was surprised how positive reactions the wand application triggered: *"[...] it was emotionally quite appealing, which is visible in how Sini, who is very reluctant in showing emotionally loaded expressions, responded to the event with a 'wow!'."*

Tokens for Shared Activities. One of the most appealing ideas for the family about how to use the tokens came up very early in the first workshop. It was described as the "to-do application" (Scenario 2). All tokens would contain one thing to do in the household and by scanning a token with the phone it would be possible to mark a task as done. To make domestic chores organized and motivating, the to-do list could be associated with Wunderlist or other already existing application and the things to do could be a video, audio or a picture, not just text. The family could gather around a table at a fixed time and distribute the to-do tokens or each person could take a token once they have time and this could become a new shared routine. Päivi said that: *"the children are motivated to do household chores in an absolutely different way if the they decide the chores together and then they can choose any."*. They envisioned, and enacted during a co-design session, that the communication between family members could be done as simply as having a certain place for the tokens, for example a bowl. If the bowl is full of things to do in the morning and, when the mother comes home in the afternoon, she notices that the bowl is only half full, she immediately knows that the other members of the family have done housework that day. When talking about the family's daily routines and ways of organizing the daily life it became apparent that there is a need for new ways of coordinate shared activities as well as improving the internal communication about the schedules of each family member. A first scenario was developed that allowed participants to add and physically share events from personal calendars by using the tokens, which required the implementation of a new feature that exploited Google Calendar APIs to link events to tokens. Since they make heavy use of paper-based calendars to organize their routines (see Figure 3), the family was particularly willing to try the functionality. However, after a first try they decided to not pursue the development any further, since they realized the technology did not fit into their current practices of using calendars. They did not want to change all their calendars to Google since everyone was currently using a different kind of calendars. Päivi concluded that: *"[...] we felt we did not want to put our lives on*

[5] An online game inspired on Harry Potter: https://www.pottermore.com

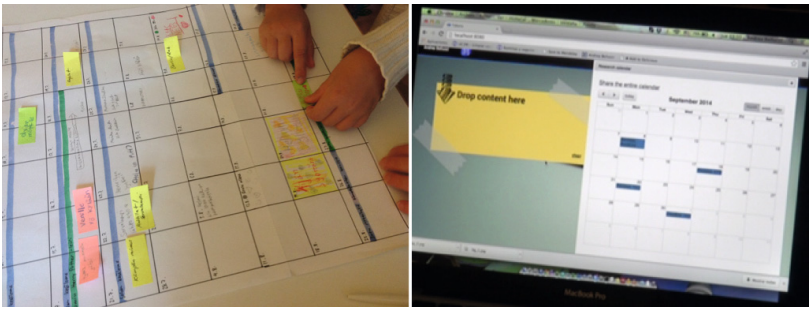

Fig. 3. Personal calendar scenario. Discussion during the co-design session (left) and the implemented Google Calendar feature (right).

Google calendars. So we did not use the calendar application." Even though the calendar application was not found useful, the example inspired new to develop during the field study. For instance, a discussion of a design for a shared calendar system started. The calendar was envisioned to contain the time tables of the whole family and also the events from all free time and work calendars of each person. This was envisaged would better support the organization of family's shared events.

These scenarios demonstrate deep knowledge of the participants about the domestic space, different activities that take place within, conventions established among family and interpersonal relationships. Tokens in some cases has been associated not only with web content but with specific items and places within house. When tokens are used as messaging devices to facilitate communication among family, this also requires a knowledge of conventions about where to leave the token so that it can be seen. Various ideas like using calendars and limiting the functionality of tokens to certain time periods (such as before bed time or after doing homework) are shaped by routines and also interpersonal relations between family members (mothers authority over children). These, in turn, called for extended functionality as described below.

5.2 T4Tags after the Extreme Co-design

Field studies on appropriations of web connected tags [18][17] reveal that discovering new routines in the circumstances of existing practices and engaging users in forming new practices around novel technologies is hampered by static prototypes that cannot be adapted or modified at use time. That was not the case with T4Tags, which supported enactment and usage try-outs of unanticipated scenarios through the rapid evolution of the original prototype in response to users' feedback through use. Various scenarios were envisioned by users that were not supported by the original prototype and required the implementation of additional features. For instance, one design response was to have calendars attached to physical objects or to share digital archives from the cloud. To this end, T4Tags was shaped to provide an interface[6] for enabling users to create

[6] We exploited the Google APIs: https://developers.google.com/apis-explorer

links to events from their Google Calendar accounts and files from Google Drive or their personal hard drive (in this case files were automatically uploaded to Google Drive). Another feature was implemented that exploited the ubiquity of T4Tags, especially the fact that web content could be displayed in any kind of browser-enabled device. The feature invented by Kari (Scenario 9) was called "Pairing" and consisted in creating associations between devices in a way users can choose to automatically display content on different devices at the same time. For instance, by associating a NFC sticker to a laptop, the pairing service allowed to display on the laptop the content of a token read with the mobile phone, as happened in the Scenario 14 (Pottermore).

On the other hand, designing for appropriation requires a degree of under-designing and possible removal of features along the process. Indeed, in few instances pre-configured parts became an obstacle for appropriation. For instance, when family wanted to embed solid NFC tokens into the plush toy, the plastic casing around the tokens proved to be an obstacle and Kari demanded the unadulterated NFC tag itself (this problem has been later resolved by using a sticker instead). This suggests that the design of tokens could be left unfinished and the users could design their own tags in ways that are more meaningful to them, for instance, exploiting configurability through templates of 3D-printed tokens that could be modified or designed from scratch.

6 Discussion and Conclusion

The evolution of the prototype promoted discoverability for both designers and users and accelerated the invention of new usage ideas. While at the beginning (first co-design session) participants were trying to use the technology for existing needs they already have, like organizing their daily routines with calendars, in the latest sessions the appropriation led to the creation of new practices at home, as shown in Scenario 10, 11 or 14. Moreover, our findings show how the interactions between the users and the designer-implementers through the prototype enabled local appropriations to be translated into suggestions that were relevant to the implementation of features that support meaningful user experience.

In this discussion we consider firstly how the development of new features led to the widening of the use space of tokens linked to digital information. The exploration highlights considerations for the development of serendipitous systems, where the same technology is appropriated deeply and for long but the diversity of uses are transient. We finally provide reflection on the role of Extreme Co-Design as a tactic for the development of open-ended technology and outline directions for future research.

Chain Reaction Exploration of Uses. The field work with T4Tags demonstrated that pursuing the timely development of features is an effective strategy —if compared with previous research [18][17]— that resulted in the expansion of the use space in the domestic environment. Shaping the prototype during use favored the experimentation and experiencing of complex usage scenarios

and embodiments that, in turn, informed the invention of new scenarios. For instance, Google Calendar allowed the experimentation of Scenario 1 that led the family to envision new uses of a shared calendar that could better fit into their routines. Google Drive support was developed for Scenarios 7. Again, even if this specific scenario was not tried, it inspired the invention of Scenarios 5, 4 and 8. In particular, Scenario 5 (Memento) was explored throughout the entire field study and shows how the Extreme Co-Design approach enables technology to fit into the context of use. We were able to document, in fact, the use of the token as a reminder at different time of the day, by different people and in different context. The functionality implemented to support Scenario 9 enabled the usage try-out of Scenario 14 (Pottermore game), which activated the most emotional and playful user experience during real-world use.

Developing Serendipitous Technology. Our findings show that tokens were used to store media content, make information tangible, log in to applications, be kept as memories or gifted, amongst others. Having a continuously available prototype gave users the freedom to explore multiple usages of tags that were timely re-configured to support different models of use, from a vehicle for sharing information between family members, to a means to trigger specific actions in the household or to support individual practices. This exhibits a multiplicity of uses some of which with an transient others with a more habitual character. While some specific developed features can be used rarely and ephemerally the tags technology as a whole is appropriated deeply and for long. An approach such as Extreme Co-Design that exploits incompleteness as a design strategy and provides rooms for the end-user to participate could be a solution to build technologies that need serendipitous and quick means to be used.

On the Role of Extreme Co-design. If we think of the Extreme Co-Design as a method, crucial for the success is the process of translating local appropriations influential to the implementation of features into the suggested system, since the approach emphasizes on the implement-ability of ideas directly into the prototype. The following aspects demonstrated to be foundational for a successful approach:

1. The designer-developer must be able to communicate the foundations as well as the versatility of the technological agenda, for instance, that the intended system is an open-ended technological exploration with some key technological functionality.
2. The current prototype must be a sketch of how it could be tackled. The users need to able to construct relevant appropriations, and spin-off ideas, with the proposed prototype. A prototype in an unfinished form fosters the user engagement [24] allowing the system to adapt to user experience.

Table 1. Scenarios according to categories. *The scenarios were "Only envisioned", in the case T4Tags does not provide any support for usage and no ad-hoc features were develope; "Not tried", if technical support was available but the scenario was not tested; "Tried and abandoned" if the scenario was tried but abandoned after first use, and; "Succesfully repeated usage" if the scenario was tried in different occasions all along the field study.

Category	Id and Name	Short description	Informed by	*Try-out	Developed Features
[redacted] prompts for content	7. Personal content	Everyone in the family would have one token defined by color/form for her personal use	2	Not tried	Already supported Google Drive
	5. Memento	Tokens to store things to remember informed by their affordances	7	Successfully repeated usage	Already supported Google Drive
	10. Toy	Augment toys with tokens to provide digital content	–	Successfully repeated usage	Autoplay
	11. Poster	Augment static posters with tokens to retrieve content	10	Successfully repeated usage	Autoplay
	12. Cleaning Podcast	A token that contains an audio record that motivates and instructs on cleaning	10	Not tried	Already supported
[redacted] triggers of actions	6. Password	Tokens used as passwords to log in to other applications	–	Only envisioned	–
	8. Accessory	Tokens as accessory to wear	7	Only envisioned	–
	9. Pairing	Use tokens to pair devices, for instance pair a mobile phone with a TV so that the content read with the phone would appear in the TV	–	Successfully repeated usage	Pairing service
	13. IFTTT	Use tokens to trigger IFTTT actions	6	Only envisioned	–
	14. Pottermore	Use the token as a trigger to open a game	6, 10, 11	Successfully repeated usage	Pairing service
[redacted] shared activities	1. Personal and Shared calendar	Add and share events on ones calendar by using the tokens. Tokens for a calendar that has the time tables of the whole family, but also the events from all (free time/work) calendars of each person	–	Tried and abandoned Only envisioned	Google Calendar
	2. To-do	Tokens would contain one thing to do in the household. By reading the token it should be possible to mark the task as done	–	Successfully repeated usage	Already supported
	4. Gift	Token to be given as a gift to people in or outside the family	3, 5, 7	Not tried	Google Drive
	3. Reward	Markers for childrens weekly duties to be done in order to get allowance	2, 6	Not tried	Google Drive

3. A wide degree of tailorability must be provided to empower end-users to materialize the experience of their everyday actions and needs into technical features of software development. This can be exemplified by Scenario 6 (Password) and 13 (IFTTT), in which users needed to develop more complex re-configurations of tags functionality to design their own organizing system.

We acknowledge some aspects of the research that are not explored in this paper. For instance, making the Extreme Co-Design strategy scalable to the community reveals a series of potential issues that needs further investigation, such as how to implement a sustainable process increasing the number of users while maintaining the efforts of the designer-developer. Moreover, while XP demonstrated to be successful for the thorough exploration of the use space with only one family and in a restricted time frame, it is necessary to test its applicability in case of long-term studies with a greater number of families. Scalability introduces issues to the use of XP that need to be considered, such as how to decide what feature to implement and how to communicate changes. Finally, even if our study uncovered a wide range of meaningful use scenarios, it takes time to appropriate a new technology and longitudinal studies are needed to understand the effect of novelty usage and gain insights that are more representative of the normal use of the technology.

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