Real-World Tagging in the Wild: On the Usability and Accessibility of NFC-based Interactions

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ABSTRACT
With the introduction of NFC-equipped mobile phones real-world tagging technologies have become available to a wide audience. This provides us with the opportunity to investigate the usability of the mobile touch interaction paradigm in real contexts to ensure its acceptance among users. In this paper we discuss usability issues of mobile touch interactions regarding the user interface, user interactions, and the user experience. We further present results from a study on NFC interaction and a prototype to leverage the accessibility of real-world tagging technologies.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces – *Input devices and strategies (e.g., mouse, touchscreen), interaction styles (e.g., commands, menus, forms, direct manipulation).*

General Terms
Design, Human Factors.

Keywords
Touch interaction, near field communication, NFC, user experience, usability, accessibility.

1. INTRODUCTION
The mobile industry currently experiences an unusual high number of innovations. New interaction paradigms that have been examined in a research context are hitting the mass market. The most ubiquitous examples are accelerometers and multitouch displays. These technologies enable new forms of interaction, such as shaking [12], tilting [11], or multitouch gestures [6]. Confronting real users in real contexts with such new forms of interactions raises further research challenges, especially in regard to human-computer interaction. For example, user studies that investigate how people adopt new technologies yield new insights into potential application scenarios. Further, studies about the application of new interaction concepts in real-world scenarios often identify usability problems that had not been considered before [5].

In this paper we focus on the aspects of the quite recent technology, near-field communication (NFC). NFC describes a radio-frequency identification (RFID) standard that allows the transmission of data over very short distances (< 10cm). A main advantage of this technology is, that tags are passive, which means that they are robust, need no internal power-source and can only be read from a short distance. Tags are therefore cheap to produce and easy to distribute. They can contain different kinds of data or simply links to data stored in a network or on the device. NFC devices typically support three modes, which are tag reader, tag, and peer-to-peer.

NFC-equipped mobile phones have been available in Japan for quite a while and have been recently introduced in Europe. The main business cases currently are payment and ticketing. According to ABI Research forecasts for shipment of NFC-enabled phones are 6.52 million for 2008 and 450 million are expected to ship by 2011[1]. Currently research institutions and companies working in this area are putting a great effort into standardization and other issues, such as security and interoperability. While these are important matters, there is still a long way to go from defined standards to useable applications. There seems to be a lack of a consistent visual language for NFC. Every application introduces a new user interface, often featuring graphical icons that contain the label “NFC” or in some cases only the name of the company. This emerging landscape of NFC user interfaces somehow reminds of the early days of the Internet, where links were often not recognizable as links and/or it was not apparent to the users where they would be directed after clicking on the link[2].

This paper discusses and summarizes usability aspects of NFC interaction with the goal to explore the design space of this new paradigm. Thus, we want to add to the current progress in this area from a user-centered perspective. NFC devices allow new forms of device interaction as well as new ways of interaction with nearby objects or locations. By focusing on these emerging interaction scenarios, we discuss the application of NFC on a level that goes beyond standard use cases, such as payment and ticketing.

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[1] Report available at http://www.abiresearch.com, numbers taken from http://www.nfcnews.com

[2] Such websites still exist today, but overall the usability has improved a lot thanks to the proliferation of web standards and best practices in website design.

Figure 1. Icons for RFID interaction (taken from [2]).

2. THE TOUCH PARADIGM

Based on previous work [1] we use the touch paradigm as a metaphor for NFC interaction in this paper. Touch is an important human sense for perceiving the ambience, thus the application of NFC technologies in everyday scenarios is so promising. According to Jean Piaget touch (or haptic perception) is the first mode of spatial perception that humans develop [14]. Touch is intuitive since we use it everyday in every aspect of our lives, for various purposes. Based on this observation, we suggest the following categories for describing applications that rely on touch:

- touch to explore
- touch to manipulate, and
- touch for social interaction.

These categories are derived from the meaning and purpose of touch in everyday situations of human-human and human-object interactions. They also serve as an initial dimension into the design space for NFC applications.

In respect to *device interaction* the touch paradigm introduces a new way of interacting with a device through touch. Rather than navigating through on-screen menus that have to deal with certain constraints, such as screen size and a limited number of input elements, users can interact with information stored on their device by touching objects or locations in the real world. Body Mnemonics [1] represents a good example for the potential of this kind of device interaction. This system allows users to access applications or information by touching specific parts of their body. For example touching the heart with the device provides instant access to the phone book.

Tagging physical objects or locations with NFC allows users to interact with points of interest (POIs) in their vicinity. POIs can be both objects and locations, depending on the purpose of the application. Touching a POI with an NFC enabled device reveals further information about the respective object or location, allowing for *physical interaction.*

While touch seems to be an intuitive interaction technique, there are a number of challenges that application designers have to deal with. As intuitive as touch is in everyday situations, this paradigm can easily become very unusable, when applied to a mobile device interaction. It is therefore crucial to use metaphors that are well known to users. Further, the usability of NFC interaction can be improved by careful design of the user interface.

3. USABILITY ASPECTS

This chapter discusses previous work on NFC interactions that investigated usability aspects of this interaction paradigm. We classify their results into user interface, user interaction, and user experience, and also describe results from a study that we conducted on NFC interaction.

3.1 Usability Study Setup

We started with a study, where we confronted users that had no previous knowledge about NFC technology with an interface

Figure 2. NFC logo of an Austrian mobile network operator (left) and a digital UI for an NFC service in Japan (right).

based on touch. For the study we equipped a vending machine in a public area with NFC tags that allowed users to purchase an item by touching the respective tag. The tags were hidden beneath icons and we used two different design approaches for the visual appearance of the icons. Fourteen passers-by (8 male, 6 female) between 18 and 29 years participated in the study. Results of the study are discussed in the corresponding sections below. Further information about the study can be found in [9].

3.2 User Interface

The user interface of an NFC application is mainly the tag that is placed in the physical world and its label or other display, if existent. Sometimes this can also span the user interface of the mobile device, but only in case it directly relates to the tag's user interface.

By its nature NFC technology is invisible, which is both an advantage and a disadvantage [2]. Embedding NFC tags in objects allows for interactions without visually degrading the surface [2]. However, hiding the tag makes it difficult for users to identify possible actions they can invoke by touching the tag with their mobile device. Based on the results from previous studies we formulated three challenges in respect to the user interface of NFC applications: (1) *locating an NFC tag*, (2) *identifying the correct usage pattern*, and (3) *understanding the actions that are triggered by touching the tag.* Arnall published an approach to solve the first two challenges by defining a graphic language for touch-based interactions [2]. He investigated existing iconography for touch-based interactions with everyday objects and developed a set of icons for RFID interactions (Figure 1). A good approach to solve the first challenge is also the use of a standardized NFC icon or logo that is easy to recognize and therefore supports users in locating NFC services. The NFC Forum[3] has developed a logo with this intended purpose. Figure 2 (left[4]) shows another example for a logo that is used by an Austrian mobile network operator. Some NFC services in Japan employ flashing lights to attract the attention of users (Figure 2, right[5]).

As simple as the usage pattern for NFC-based applications is, it is often difficult for users to get the interaction right. The problem with NFC tags is that they are lacking any affordances. While a

[3] http://www.nfc-forum.org
[4] Image taken from http://www.nfc.at
[5] Image taken from http://www.slashphone.com

push button has the affordance to push it, an NFC tag embedded in an object does not have the affordance to touch it with the phone. In our user study on NFC interaction as well as in other studies [5], users even had problems to hold the NFC-enabled mobile device in the correct position onto the tag. The problem was that the NFC reader was integrated in the top of the clamshell phone, which did not match the users' mental model. While this issue might be less troublesome in everyday scenarios, since users would most likely learn the correct usage pattern, such usability flaws could still be avoided by carefully designing the user interface.

The third challenge – understanding the actions that are triggered by touching the tag – is mainly determined by the fact that there are no existing mental models for NFC-based interactions [10]. For example a user study on mobile interaction [10] revealed that users were surprised that tags acted as bookmarks that opened a web page. Similar to good design practice in graphical user interfaces, where button labels should inform the user about the action that would be triggered by clicking the button, NFC-tags should feature a user interface that gives clues about the actions initiate. However, in some cases this might not be possible since multiple actions can be triggered through one tag and tags are usually static, i.e. the interface can not adapt to represent the current functionality of the tag.

3.3 User Interaction

The user interaction describes how users interact with an NFC application through the user interface. Therefore the usability issues described in the previous chapter are also relevant for this category. A usable user interface ensures a fluid user interaction.

One specific aspect of user interaction with touch-based interfaces is *context of use*: user might interact with an NFC application while walking, standing, or sitting. The context of use mainly affects the kind and duration of dialogue the users are involved in by the application. It also affects the locality of the tag in the physical world. Both in turn have an impact on the user interface. If the tag has to be located while walking it has to feature a design that allows for a faster identification, than while users are resting at a location for a longer period of time.

When designing the *locality of NFC-based interactions* it is important to know and consider existing mental models. For example we equipped a soft drink vending machine with NFC in our study on NCF interaction by placing tags on the front of the machine. However, we observed that some users (5 out of 14) first attempted to pay for a drink by touching the coin slot with the mobile device. The reason for this is that they tried to apply their experience from buying drinks at a vending machine to the touch-based interaction.

Another aspect of user interaction is whether it happens on-screen or in the world. In the first case users activate an application on their mobile device and select further parameters in a screen-based dialogue. In the latter case all or most parameters are selected by touching specific NFC tags. We call these modes of interaction *on-screen* and *in-world interactions*. There are advantages and disadvantages of both forms of interaction. In certain contexts (e.g. bright sunlight) or for specific user groups (e.g. elderly users) in-world interaction might be advantageous, while it is quicker and less cumbersome for experienced users to directly interact with their mobile device.

3.4 User Experience

User experience describes the overall satisfaction of the users while interacting with an NFC application. Both user interface and user interaction are part of the user experience and therefore taking the usability issues described above into account also improves the user experience.

Furthermore, it is important to reflect on whether the application of NFC in that specific context adds any value for the users. In many cases new technologies are used just because they are available, not necessarily because they provide a better solution than other existing technologies. Especially in terms of mobile interaction this is an important issue, since users might get frustrated quickly otherwise. Application designers therefore need to consider any special cases that might lead to user frustration, such as missing network coverage or low battery.

It is also crucial to take any other issues into account that might affect the user experience, although some might be difficult to address by design solutions. For example an earlier study that we conducted on touch and point interaction revealed that users were reluctant to actually touch a real-world interface due to hygienic concerns [8]. An effective way to assess such issues is the evaluation of new applications or interaction methods with real users, even with a non-functional prototype.

4. ACCESSIBLE INTERACTION

Accessibility has become an important issue in web design in the last decade. In a similar approach it is important that new services that rely on NFC are accessible for users with special needs, in case they are part of the target group of the system. The main issues regarding accessibility are the placement of the tag in the environment and making tags "visible" for blind or visually impaired users. The mobile phone is a device that is already used by the blind community [15] and therefore it is important to take accessibility into consideration when designing real-world tagging applications. To address this issue we have developed an approach based on audio-tactile location markers that make the users aware of the presence of a tag in their vicinity and lead them to the tag through auditory location detection. Once they have reached the tag, they can determine its purpose through tactile identification and activate its content by touching it with their NFC-enabled mobile device.

We developed a proof-of-concept prototype for an audio-tactile location marker (ALM) based on a passive NFC tag and a standard computer, which represents a Bluetooth hotspot. The user's mobile device (a Nokia 6131 NFC mobile phone broadcasts a predetermined Bluetooth device name. This enables the Bluetooth hotspot (i.e. the ALM prototype) to detect the presence of a blind user. It consequently starts transmitting a signal to promote the location of a POI. Once the user touches the POI with the mobile device, the MIDlet detects the NFC tag and connects to the Bluetooth network (pairing keys are distributed via the tag). This initiates the replay of an audio stream stored on the user's device. Eventually the audio stream could also be transmitted over the Bluetooth connection. The design process for our prototype was driven by the results from an expert interview with a blind user. We evaluated the prototype with four blindfolded users to confirm the applicability of our approach. All participants were able to locate the ALM prototype within 33 seconds or faster. The feedback from the participants was very positive. They stated that they found it surprisingly easy to locate the ALM prototype by simply relying on their auditory-cognitive abilities. The average

rating on a 6-point Likert scale was 1.5 (1 being very easy). Details about the study can be found in [17].

NFC also represents a potential technology for assistive devices for blind people, who often suffer from a deficiency of information. It is therefore important to provide them with data that informs them about their environment and objects in their vicinity. This data should make information accessible that is otherwise lost, such as the list of ingredients or the expiration date on products. The integration of NFC tags in the physical world creates interfaces that can be used for specific data-feeds, which can provide crucial assistance. For example, Sherlock [4] is a commercially available system based on RFID that allows blind users to tag and later identify their personal objects. Seeingeyephone [16] is an NFC-based research prototype that was developed by the VTT Technical Research Centre of Finland, which additionally supports the retrieval of information about products in a supermarket scenario.

5. CONCLUSION

The integration of NFC technologies in mobile devices raises many usability issues that need to be investigated in formal studies. We claim that this area has not received enough attention in the HCI community so far. In this paper we gave an overview of existing work that is relevant to the usability and accessibility of NFC. We further presented some results of a study on NFC interactions and a prototype that we developed to make NFC accessible for blind and visually impaired users.

Applications based on NFC interactions have great potentials, since the technology is affordable and easy to distribute. However there are many usability challenges that need to be considered by designers and developers of NFC applications. Main challenges that we identified and discussed in this paper are improving the affordance of NFC interactions and providing users with a mental model for those interactions.

Due to the large design space for NFC applications there is no general solution to approach these challenges. User interface, user interactions, and the user experience depend on the actual implementation, e.g. whether interaction happens on-screen or in-world, whether the tag supports one or multiple actions, or whether the application was developed for a specific group of users in a specific context or for a general scenario and a wide application by users of different groups. We believe that addressing those issues in the research community will potentially lead to best practices for designing NFC interactions.

6. ACKNOWLEDGMENTS

This work was funded by the FIT-IT project on performant, usable and reliable embedded NFC systems (pureNFC).

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