Exploring Multimodal Feedback for an NFC-based Mobile Shopping Assistant

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***Abstract*—This paper explores how mobile devices can provide useful multimodal feedback during interactions with NFC-tagged objects. We exemplify our approach with a mobile shopping assistant that uses haptic-visual and audio-haptic feedback to inform diabetics about the agreeability of tagged grocery products. A preliminary laboratory study shows a preference for haptic-visual feedback which is regarded as more helpful, easier to learn and more pleasant to use. The results stress the usefulness of multimodal feedback for mobile interactions with NFC-tagged objects in this context and inform future work, e.g. about the expressiveness of different feedback modalities and patterns.**

I. INTRODUCTION

Mobile devices are great means for interactions with everyday objects. They can capture and identify objects according to their location (e.g. with GPS), by taking pictures of attached visual markers (e.g. barcodes, QR codes) or by touching NFC-tags (Near Field Communication) [18]. That way, mobile devices allow users to interact with physical objects, to access associated digital information and to use the latter for different applications and services. Examples are mobile applications for the retrieval of information about groceries, medicine or other commercial products, such as availability, shelf life, origin, ingredients or nutritional value (e.g. [13], [17]). Mobile applications can use this information to compare products or to combine it with information about users, like personal preferences, allergies, diet plans or medications, in order to recommend products or to advice against them.

During mobile interactions with tagged objects, the focus of attention can quickly shift from mobile devices to the real world. This effect is reinforced by objects with multiple tags that adopt more application features and attract more attention than single-tagged objects. As a result, mobile devices can lose the attention of their users and are often degraded to auxiliary pointing devices. However, they can still serve as personal output devices that communicate information about captured objects to users through haptic, visual or audio feedback.

Research on mobile feedback has investigated interactions that draw the attention of users onto mobile devices (e.g. [6]). In this paper, we explore how applications can use the feedback mechanisms of mobile devices to communicate information about NFC-tagged objects while users focus on interacting with them in the real world. For our approach to this topic, we have developed a mobile shopping assistant for diabetics who have to live on a special diet. In our scenario, grocery products are augmented with NFC-tags that users can touch with their NFC-enabled mobile devices (see Figure 1 for a mockup). The shopping assistant uses two multimodal feedback mechanisms (haptic-visual and audio-haptic) to inform users about the amount of sugar in tagged products and its agreeability with personal diet plans. This way, the interaction with tagged grocery products can raise the awareness of diabetes patients for the composition of these products as well as their agreeability.

Fig. 1. Mockup of a diabetes shopping assistant revealing the amount of sugar in NFC-tagged grocery products

After an overview of related work, we describe the design of the shopping assistant and its feedback mechanisms. A preliminary laboratory study shows a preference for the haptic-visual feedback which is regarded as more helpful, easier to learn and more pleasant to use than the audio-haptic feedback. The results underline the usefulness of multimodal feedback for mobile interaction with tagged objects and inform future work on this topic, e.g. about the expressiveness of different feedback modalities or patterns.

II. RELATED WORK

Mobile interactions with tagged objects build on technologies like visual markers, Bluetooth, GPS, RFID (Radio Frequency Identification) or NFC to tag everyday objects and to associate them with digital information, applications or services. Mobile devices that support these technologies enable physical interactions with tagged objects, which again facilitate interactions with associated digital resources [18]. This paper focuses on NFC, a wireless technology for exchanging data over short distances that is based on passive RFID-technology and targeted at mobile devices [20]. Both technologies can store data on passive tags that can be attached to arbitrary objects. Users can retrieve data from tags by touching them with a reading device, e.g. an NFC-enabled mobile phone, or by holding devices and tags closely together. Mobile interaction with NFC can greatly facilitate more complex mobile interactions and is adopted for an increasing number of use cases, like mobile payment, ticketing or interactions with mobile services.

In retail, shopping, healthcare and other application areas, mobile interaction with NFC-tagged objects can reduce the retrieval of product information or recommendations to the simple touching of a single tag. Resatsch et al. [17] for example have developed a mobile sales assistant that allows retailers and customers to check the availability of products and to retrieve additional information about them. Similarly, Nepper et al. [13] use the interaction with tagged CDs, DVDs or books to provide previews of them on mobile devices. The SeeingEyePhone [19] is a mobile application that reads product information to elderly or visually impaired people upon touching tagged products with an NFC-enabled mobile device. APriori [16] uses the interaction with tagged objects for creating and retrieving recommendations on-site. Retail companies like the Metro Group [12] explore the combination of RFID-tagged products with smart shopping carts [8] or self-checkout systems, to improve the shopping experience and to provide more information to customers.

Multimodal feedback [14] can support interactions in dynamic scenarios entailing noise, movement, distraction, attention-shifts [7] and cognitive load, like our envisioned shopping scenario. Touchless or remote interaction supported by multimodal feedback has been demonstrated before by Krol et al. [9] or Badshah et al. [1]. Complimentary, we tried to exploit the characteristics of visual and tactile information presentation to enhance the interaction using standard mobile devices in real-world scenarios. Here, semantic meaning is usually conveyed using symbols that exist in all three modalities: icons, earcons/audicons and tactons ([2], [5]). For the application of a mobile device in an everyday scenario, we decided to use additional tactile cues for the discrete communication of information. The sense of touch is described as a "break-in" sense that is highly attention demanding especially when experienced in unusual patterns [4] and can have a strong emotional impact [15]. Hoggan et al. [6] stated the importance of shifting modalities and provide advice on when to use which modality for multimodal feedback in different environmental distraction levels.

III. Design Process

In order to investigate feedback mechanisms for mobile interactions with tagged objects, we followed a user-centered design approach [11] to develop a shopping assistant for diabetics that uses multimodal feedback to inform users about the agreeability of grocery products. The initial user research phase was fueled with insights on diabetes type II through a previous industry project. In order to reveal design needs for assistive systems, a core phase of this project comprised semi-structured interviews with type II diabetics, who have to assess the ingredients of grocery products to balance their diet. One research finding was the participants' need for discreetness while shopping for food (further details of the study cannot be described due to a non-closure agreement). We addressed this issue by creating various design ideas which were filtered and turned into user scenarios, considering the technology from a user's perspective. Next, we picked the most promising design ideas and created a high fidelity prototype [10] for a shopping assistant. This prototype helped us to conduct a first evaluation of a) the general usability of multimodal feedback for mobile interactions with tagged objects and b) how well certain feedback mechanisms are accepted by users, thus informing future work on this topic.

IV. High Fidelity Prototype

Following the design process, we developed a high fidelity prototype for a shopping assistant that allows type II diabetics to scan products by touching their NFC-tags with an NFC-enabled mobile phone (see Figure 1). The assistant on the phone uses multimodal feedback to inform users about the successful reading of tags and the agreeability of scanned products with personal diet plans and previously selected products. When users decide to buy a product, they can add it to the virtual shopping basket by pressing a button. The shopping assistant tracks all products in this basket and evaluates the agreeability of new products with respect to the products in the basket.

This scenario points out different requirements for the design of feedback mechanisms for interactions with tagged objects: It should be informative and expressive enough to communicate different items of information at the same time. For that purpose, feedback can be multimodal and comprise sound, vibration and visual cues from the phone's display. It should also be simple, unobtrusive and discreet in order not to overwhelm or confuse users and to conserve their privacy, especially in public environments.

These aspects influenced the final design of feedback mechanisms for the shopping assistant prototype, which we implemented as a Java ME application on the Nokia 6131 that features visual feedback via its display, audio feedback via speakers and haptic feedback via vibration. The prototype gives users feedback about a) the successful reading of tags and b) the agreeability of products, based on their sugar-level, including warnings about possible allergies.

For this first approach to multimodal feedback, we focused on audio-haptic and haptic-visual feedback out of all possible combinations of three feedback modalities for two items of information. We excluded all combinations with the same feedback modality and decided not to use audio to communicate the agreeability of products as it might violate the privacy of users. We also did not use visual feedback to confirm the reading of tags because it may cause too many attention shifts between mobile devices and tagged objects [7] for this comparatively little information. The audio-haptic feedback confirms the successful recognition of products with a short beep. The amount of sugar is indicated with one (very little sugar) to five (a lot of sugar) short vibrations. A long, steady vibration indicates the allergy warning. The haptic-visual feedback confirms the recognition of products with a single, short vibration. Their amount of sugar is indicated on a colored scale from green (very little sugar) to red (a lot of sugar) and by a numeric value. A text-alert indicates the allergy warning.

V. Laboratory Study and Evaluation

Before we tested the shopping assistant with diabetics in a real world setting, we conducted a preliminary laboratory study to evaluate the overall effectiveness, usability and user acceptance of the multimodal feedback mechanisms for mobile interaction with tagged objects.

A. *Study Design and Setup*

The study was designed to evaluate whether the feedback mechanisms of the shopping assistant are expressive enough to let participants of the study differentiate products according to the feedback about their sugar content. We simulated eight products with plain white, NFC-tagged boxes and assigned a sugar content value to each one, resulting in two identical and seven different values. Two of the eight products could also cause a virtual allergic reaction. During the study, the participants had to rely on the feedback from the shopping assistant to sort the products according to their sugar content, to find the two products with identical sugar content and to point out products that caused an allergic reaction.

After an introduction to NFC and the use case, each participant had to carry out this task with both feedback mechanisms in a counterbalanced order. We measured the task completion time with a logging feature in the prototype and gathered qualitative feedback with a questionnaire. We also recorded the participants on video to assess their behavior. However, we did not count the number of attention shifts between mobile devices and objects, because the participants used different strategies to sort them, resulting in too many variations of attention shifts.

This preliminary study was conducted with 12 participants (two female) with an average age of 24. Most of them were students with a technical background and thus rated their experience with mobile phones and technology in general with high mean values (5.8 and 5.6) on a 7-point Likert-scale from 1 (“no experience”) to 7 (“very experienced”). Four participants were already familiar with NFC and two of them had participated in a previous NFC-related study.

B. *Results*

On average, the participants needed 43.1 seconds (SD = 7.67) to complete the task with the haptic-visual feedback and 50.4 sec. (SD = 10.43) with the audio-haptic feedback. This could be explained with the duration of the vibration feedback – up to five vibrations to indicate the sugar content, a long vibration to indicate allergic threats. After the participants had sorted the products with one of the feedback mechanisms, they had to fill out a questionnaire to indicate their agreement with statements about the tested mechanism on a Likert-scale from 1 (“totally disagree”) to 7 (“totally agree”). The mean values in Figure 2 show that both feedback mechanisms were well received in general, although the participants often rated haptic-visual feedback better. They thought that it gave them a greater feeling of control, was less obtrusive, slightly more helpful to confirm the touching of tags, more pleasant and helped more to solve tasks quickly and effectively. Neither feedback mechanism distracted the participants. The questionnaires also showed that the variations in the feedback, e.g. the different vibration patterns, were well received, again with better ratings for haptic-visual. The variations were clear to distinguish, easy to learn and suitable to determine different states, respectively amounts of sugar in products.

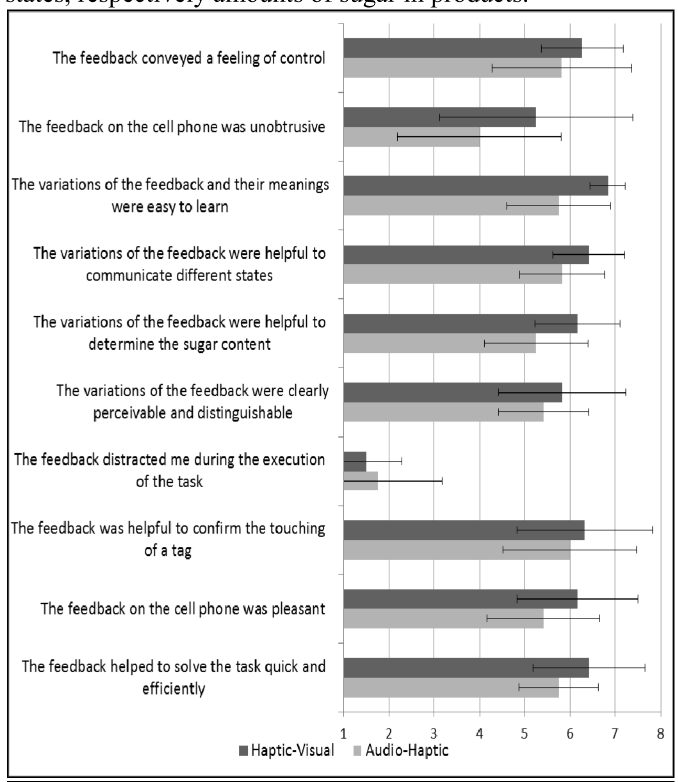

Fig. 2. Results of the questionnaire for haptic-visual and audio-haptic feedback (Likert-scale from 1 (“totally disagree”) to 7 (“totally agree”))

10 out of 12 participants preferred the haptic-visual feedback and pointed out that the visual feedback allowed a quicker assessment of the sugar content of products, which explains the different task execution times. Two participants also stressed that the visual allergy alarm message was much more alerting than the long vibration of the haptic feedback. Another two participants explicitly stated that counting the vibrations of the haptic feedback involved too much concentration and took too much time. Only one participant perceived the haptic feedback as unpleasant and another one stated that he would prefer the audio-haptic feedback only if he had a lot of time for shopping. Two participants proposed to use vibration intensity instead of consecutive vibrations to express the quantity of sugar. Two participants preferred the

audio-haptic feedback and did not think that the visual bar graph allowed for exact assessments of the sugar content. One participant mentioned the potential of the audio-haptic feedback for visually impaired users.

VI. Discussion and Conclusion

In this paper, we have investigated multimodal feedback mechanisms for mobile interactions with tagged objects. We have exemplified our approach with a mobile shopping assistant for type II diabetics that uses multimodal feedback to communicate the agreeability of NFC-tagged grocery products. A preliminary laboratory study showed that the participants preferred haptic-visual feedback which was faster than the audio-haptic feedback, whose long vibration patterns were less suitable to indicate the amount of sugar in products than the visual representation of the haptic-visual feedback. These quantitative results were confirmed by qualitative results of the questionnaire, according to which the participants preferred the haptic-visual feedback and rated it as more helpful, easier to learn and more pleasant to use. Some results also indicated that purely haptic feedback with various patterns (e.g. vibration intensity) could provide an added value, e.g. for visually impaired users.

The presented designs and their evaluation are only first steps towards a more thorough investigation of multimodal feedback for mobile interaction with tagged objects, but motivate and inform future work on this topic. A logical next step is a more systematic evaluation of different feedback modalities, their properties (e.g. vibration intensity, different sounds) and interplay. New feedback designs could go beyond standard technologies in current mobile devices and include new technologies, e.g. for expressive vibration patterns [5]. Future studies can involve diabetics and their preferences once again, e.g. regarding different (combinations of) feedback modalities, the tolerance of attention shifts or the violation of privacy by different kinds of feedback - issues that were presumed or neglected by this paper. Other coherent topics are a real world implementation of the shopping assistant in a supermarket and an evaluation with target users.

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