Exploring the Augmented Home Window – User Perceptions of the Concept

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ABSTRACT
In the future, transparent displays can be utilized as information and communication channels in our everyday environments. Home windows form an interesting, yet unexplored platform, which could be utilized in the future e.g. as a mixed reality display or a personal or family communication channel. We explored the early user perceptions of an augmented home window through two user studies. In the first study 21 participants from 12 households commented our concept ideas and created their own. In the second study (12 households, 12 participants), developed concept ideas were assessed in a diary and a user study based on probes. The probes were used as experiential probes to gather perceptions of an augmented home window concept. Based on the studies, we present four communication modes for the augmented home window. The detailed findings reveal that contextual relevance of the content is highly important in the augmented home window, and that pragmatic use cases were valued, whereas social features were less appreciated.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

General Terms
Design, Experimentation, Human Factors.

Keywords
Smart home; augmented window; mixed reality; user study; concept creation; expectations.

1. INTRODUCTION
Homes are central places in our lives where we spend time, and hubs for a large variety of different activities around the family and oneself. Recent years have witnessed an emerging trend of computing becoming more and more entwined with our everyday domestic life. It is highly probable that new technologies will be introduced in the future e.g. in the form of different displays [22].

In our research, we set ourselves to investigate the early user perceptions with a yet unexplored technology platform, which has the potential to become a part of future smart home infrastructure – the home window. The home window as an artifact is an interesting interface between the home and external world, and has the potential to function not only as a conventional screen but also as a mixed reality display. In this paper, we use the term *augmented window* to describe *a window which is formed by augmenting the existing window view with information which may or may not be based on the outside view context, and which is perceived as a transparent display.* Because the lack of available technology prevented us to implement the concept of augmented window with a see-through display for an in-the-wild user study, in this paper we approach the concept with an initial user study utilizing probes, which were used to stimulate the participants and help them to assess different ideas of an imaginary home window concept (see Figure 1).

Figure 1. Using probes to assess the concept ideas for interactive home window concept.

In this paper, we report on our research on early user perceptions of an augmented home window concept, based on a diary study, interviews, and personalized experiential probes used to stimulate and understand the possibilities of a smart home window. We present two user studies, first gathering the initial ideas and the second assessing and probing feedback of design concepts. Both studies contained 12 households (with no overlap).

The goals of this research were to understand the nature of the home window as a context of the smart home, to chart user perceptions of different application types that could utilize an augmented window, and to create new knowledge on user perceptions of potential mixed reality (MR) applications in the home context. Our research contributes to creating new knowledge of potential application concepts

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related to situated displays in smart homes, especially utilizing transparent screen technologies in the window context. Our work has novelty in the following:

- To the best of our knowledge, no earlier research has addressed the home window context with a user study conducted in the home domain
- Novel findings from the end-user perspective on different application types for augmented home window are provided.

The findings presented in this paper can then help in developing and adopting augmented window technology for the home domain.

2. RELATED WORK

2.1 HCI Research in the Home Domain

Home is one of the central places for numerous everyday life activities, and a central place where people spend their time. Earlier research has looked at the home context of the viewpoints related to both technology usage and general practices that can enlighten the possibilities of technology adaptation. For instance, users' practices with current technologies are investigated in [9]. Examples of technology domains addressed in earlier research include smart home controls [2], mobile phones [15], music [14], and public displays [6], [13], [21], where situated displays at homes have so far been investigated especially in the form of photo displays and ambient information displays. Here, especially connecting distant family members is seen as a potential use case [6], [21]. Moreover, sharing information in a peripheral and aesthetically pleasing form through a home display has been addressed, as demonstrated for health and care related information with an informative photo frame [13][11]. Home windows have been used to investigate the concept of a public display where the house residents were able to create and determine about the display content. [27]. However, while public display research as such has gained quite much attention, augmented reality displays and window displays have so far have not been investigated for domestic use.

User research methods addressing the data collection in the home domain has been addressed in several papers. For instance, Gaver et al. introduced cultural probes method for charting the everyday life practices [7], and different type of diary study methods have been used. To investigate the perceptions of new technologies on imaginary level, Davidoff et al. have suggested speed dating methods [3], where different concepts and use scenarios are gone through with comic type drawings. Truong et al. [24] have used comic strips for investigating user perceptions with ubiquitous computing.

There is a vast amount of research on home domain, whereas topics related to augmented reality and smart windows in this context have so far been rare. Thus, our research focuses on an under-explored domain.

2.2 Augmented Reality

Due to the window context, our research has a strong tie with mixed reality (MR), which fuses together information from the physical world and digital world [12], and is an emerging technology trend. Already a number of commercial smart phone applications such as Layar and Wikitude present mixed reality content in a city scene. Despite of this, research looking at user perceptions of mixed reality service concepts is scarce, and Dünser et al. report that only 10% of the MR articles published in 1993–2007 included any kind of user evaluation [5]. The home domain is especially unexplored, the prior art in early user perceptions focusing on contexts such as shopping malls [16] and cities [25].

2.3 Interacting with Transparent Displays

Augmented home window concept visions the use of transparent display technology, which is predicted to become one of the future technology trends. By now, transparent displays have been introduced in selected commercial products, and investigated to some extend for interaction research as well as introduced with concept level ideas for future technology applications.

Earlier research has used a car windscreen as a mixed reality display, where the driver can see e.g. the navigation information displayed directly on a head-up AR display [23]. Similar concepts have been suggested for motorbike visors [11]. On the commercial side, Samsung has recently introduced a transparent screen [20], which, when forming one wall of a product sales box, e.g. for shoes, can be used to present information about the product. Also visionary industrial concept videos utilizing glass have been presented [1]. In addition, Olwal et al. [17] presented an autostereoscopic Optical See-through Augmented reality system (ASTOR) which enables users to see AR information through a window using two projectors and a transparent holographic optical element. Interaction with a see-through PC display has been investigated in [10], where the user is able to manipulate the objects e.g. by placing his hands behind the screen.

Our research focuses on home window, which has not yet gained much attention in the research investigating computing with see-through materials. However, already two decades ago Weiser described a scenario involving an augmented view of the world through a home window [26]. Also Rodenstein has explored the possibilities of windows as peripheral interface for displaying short-term weather forecasts [19]. Although the idea of displaying information at home window is old, to our knowledge, we present one of the firsts studies addressing the user perceptions of the concepts in the area.

3. USER RESEARCH

3.1 Methodological Approach

Our research is based on Zimmerman's Research through Design approach, where the researchers ground the experiments on upfront research and through an ideating, iterating and critiquing process the researchers reframe the problem forward trying to make the "right thing" [28]. Our qualitative study consisted of two studies (Study I and Study II). The first one consisted of an ideation phase, followed by iterating the ideas into the concept ideas of the latter phase, where the concept design ideas were transformed into experiential probes to stimulate the participants and address different aspects of the imaginary augmented window concept, as illustrated in Figure 1. Such experiential probes enable gathering of early user perceptions and understanding the user perceptions and communication modes of the augmented home window. By using experiential probes in participants' everyday life, researchers can involve people into the development of new systems and gather understanding of their early perceptions and experiences with the novel concept [8].

Here is the overall research process

- Study I - Ideation

- During one week user study:
  - Assessing an annotated photo of the home window
  - Brainstorming task with low-fi prototype material
  - End-interview
- 2 months later:
  - Brainstorming task to annotate the home window photo

- Study II – With experiential probes
  - During one week user study:
    - Assessing contextualized window views
    - Creating and documenting concept ideas with a study diary
    - End-interview.

4. STUDY I - IDEATION

4.1 Set-up, Participants and Research Data

Study I was a field study, where people developed potential use cases and provided feedback on early mixed reality application concepts for the home environment at their homes. As a whole, the study design involved diary study as well as explicitly defined prototyping and brainstorming tasks which the participants were asked to complete during a one week period. The participants were asked to invent ideas of what kind of information they would like to be able to access in different parts of the house and in different situations (e.g. in the kitchen, on the doors, in the bathroom, in the living room or first thing at morning). One of the tasks was to chart the potential of the window as a mixed reality display. This part of the study is considered in this paper. Altogether 12 households (comprising a total of 21 participating persons, children excluded) took part in the study. Each household consisted of either 1 or 2 (adult) persons with varying professional backgrounds. The participants were aged between 24 and 70 years, with an average age of 40 years.

Study I research data consisted of audio-recorded end-interviews and diaries (10 page), including the comments of the annotated photos as well as brainstorming tasks and photographs taken by the participants. In addition data consisted of printed window pictures annotated by the participants. The qualitative data from the diaries and interview notes were analyzed by thematic coding.

4.2 Phase I – Annotated Window View

To start the study, a photo of one of each participant's home windows was taken. This was done either by the participants who sent it to the researchers, or the researchers took the photo during the starting session at the participants' house. The participants were asked to photograph one of the most central windows in the house which they often used for looking out. Researchers added graphical annotations to the photo, same type of content for all participants, to demonstrate the concept, see Figure 2. The annotated picture was then emailed to the participants at the end of the study week and they were asked to comment the different annotation types to the diaries. Diary entries and comments were discussed during the end-interviews with participants after the one week period. The qualitative data was analyzed by transcribing the notes from the interviews and diaries, and then grouping them bottom-up to form the relevant themes which lead to the main findings.

Findings. In general, using a window as a mixed reality display was perceived as acceptable, with some limitations. The information placed on window had to be *important* and *useful* but not *oppressive*; the issue of information overflow was raised, and the participants stated that the information should have a *valid justification to be on the window* - *"The other than weather related stuff could be located on a door or anywhere else. From a window you would rather see outside than look at that kind of information"* (#11).

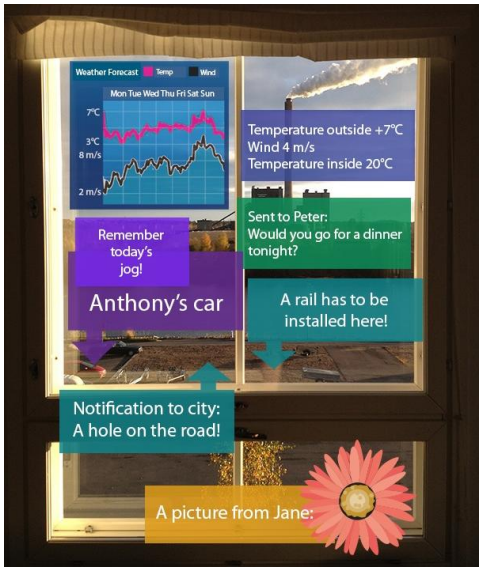

Figure 2. Imaginary content placed on a real window, creating a mixed reality window display (household #2).

All participants perceived the idea of showing weather forecasts, temperature and other weather related information on the window positively - *"Weather is something what you look from the window anyway, and seeing when the clouds will go away and the rain stop would be nice"* (#4). Messages related to the context of the scenery seen from the window were better received than general messages. For instance, communication with local infrastructure services, for example sending messages to maintenance or waste management departments, was considered useful. However, not all type of content relating to an object seen through the window was something the participants wished to see. For instance, a reminder to take care of the hedge was thought to increase stress level than to lower it. Sending and receiving private messages to and from friends via the home window was considered rather odd and useless.

4.3 Phase II – Brainstorming Concepts

The use of window glass was also investigated with brainstorming tasks, which were given to the participants during the one week study period. The tasks involved ideating concept ideas for doors, kitchen, bathroom and morning, and on one study day the participants were explicitly instructed to innovate on the following topic: "*What kind of information would you like to see on your home windows and mirrors*". An example of the task's outcome is illustrated in Figure 3.

After two months, when it was estimated that the participants were more detached from the first brainstorming phase, the participants were sent printed photos of their home windows (the same as used in annotated window view task) again. The participants were asked to brainstorm one more time what kind of information they would like to see on their windows. The participants were encouraged to use post-it notes for marking the desired content types, see Figure 4.

Figure 3. Example outcome of the second brainstorming task of mixed reality content on window. Translations: Temperature outside -5C -> Heat the car! Warning of icy roads - Child's practise -> Which of us will drive him there? - Waste collection today) (household #6).

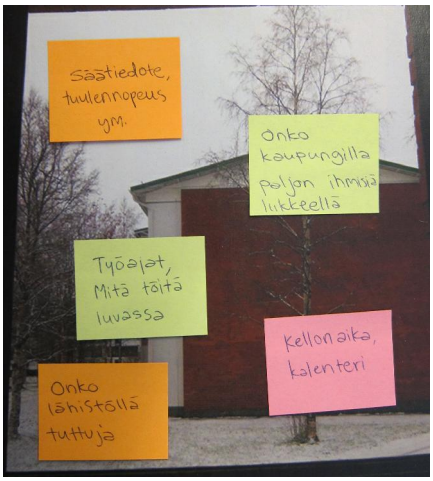

Figure 4. Example outcome of the follow-up task of the study I. Translations: 1) Weather forecast, wind, etc. 2) Are there many people at downtown. 3) To-do list 4) Time, calendar 5) Friends nearby (household #3).

Findings. Altogether 55 concept ideas were created for the window surface in the brainstorming tasks; 22 from the first round of brainstorming task and 33 from the follow-up task. To summarize, in these ideas the window was used for decorative purposes for displaying beautiful landscapes or decorations (7), as augmented reality display for augmenting information about what is visible on the scene (4) and weather information (22), for own reminders and calendar (7) and receiving and sending messages between family members and neighbors as well as authorities (5).

In conclusion, the findings of the Study I indicated that home windows were perceived as acceptable surface for displaying different kinds of information and a number of potential use cases for utilizing window glass as an information display was discovered. It was also noticed that although the study aimed to chart user perceptions of mixed reality, the participants also suggested use cases that utilized the window glass simply as a display rather than displaying information related to the view seen through the window. The findings of Study I were then conveyed to the example scenarios and experiential probes used in Study II.

5. STUDY II – ASSESSING THE CONCEPT WITH PROBES OF THE WINDOW VIEWS AND DIARIES

5.1 Designing the Content for the Experiential Probes

After conducting the Study I, we iterated the use cases of window as semi-transparent surface for displaying content and create a prototype around that idea. To probe the participants to think different aspect of an augmented home window, we photographed each participant's home window and used them to create experiential probes. The photographs of the images we used as experiential probes in two ways: 1) as pictures on the page of the paper diary to be filled in by drawing and writing the desired content and 2) as digital images with personalized content, which were then sent to the participants' smart phones during the one week study. Here, the participants were instructed to view the pictures in front of the window. The content ideas of the views came from the Study I, see Table 1. This method was chosen, because probes have been found to be a suitable technique for examining the overall concept, before focusing on the more detailed aspects of the design [8].

Altogether 12 augmented window views were generated and sent to each study participant. These 12 created window views contained altogether 17 different types of content items (e.g. weather, advertisements, etc.), with some of the content types being placed on two different window views, and some screenshot containing more the one item. Between 2 and 4 window views were sent to each participant per day during five days. Table 1 demonstrates how the content ideas from study I, were iterated in the study II window views.

To make the views contextual, we visualized the content on the photo which we took of the specific window beforehand. We then customized the content for the window views to correspond to

- temporal variables (e.g. weather)
- spatial variables (e.g. nearby shops)
- personal information.

The personalization was made based on the background information gathered from the starting session, e.g. about family, friends and communication habits, and what was seen from the window.

Table 1. Content ideas from Study I and content types in simulated window views of study II

Content idea from Study I	Corresponding content type in Study II
Weather information / Air quality	Weather now (and in 3 hours), temperature, feels like temp, wind
Dressing instructions	Clothing instructions according to the weather

Announcement for residents of the neighborhood	Announcement for housing company / neighborhood residents
	Proposal for housing company / city government
Advertisements / Sale offers	Nearby Restaurant menu
Advertisements / Sale offers	Local store offers
	Local store opening hours and distance
Beautiful landscapes from other places	World window (beach view picture and weather conditions from Barcelona)
Friends near by	Facebook status update of a friend
Friends near by	Message for a friend
Weather information / Air quality	Air quality
	Mobile graffiti (greetings)
Augmented reality information of visible objects	Notices of sale (car, bike, lawn mower; contact information of the seller)
Augmented reality information of visible objects	Housing ad (sale, rent)
Decorations (Christmas lights, children's drawings)	Virtual card from a friend
Augmented reality information of visible objects	Future / past vision (visualization of an ecofriendly house to be built here at 2020)
Greetings for neighbors	Posting greetings for others (view from outside)

5.2 Study II Set-up

The Study II included sending participants augmented window views (Table 1), which were sent to the user's smart phone as probes to stimulate the feedback on the concept, and a diary study. The users were instructed to open the messages while standing in front of the particular window holding the device towards it. The messages were sent to the users during the day and users were instructed to open them as soon as possible. The diary included a short introduction to mixed reality and existing application and application domains. In addition to assessing the smart window views (see Figure 5 for examples), the diary included brainstorming tasks, probed e.g. with pictures of the user's window view on which the users were asked to write or draw the content type they wanted to see on their windows. Example illustrations of the window views are illustrated in Figure 5.

Altogether, Study II consisted of the following steps:

1. Taking pictures of participants' home window during a visit to the participant's home.
2. Introduction session and start interview at users home (9/12) or at office (3/12), handing out the diaries.
3. Creation of 12 simulated window views.
4. Sending the experiential probes to the participants' smart phones during five days (2 - 3 per day), Table 1.
5. Viewing the probes in front of their window by the participants using their smart phones.
6. Filling in the diary for 7 days.
7. Completing an open ended brainstorming task
8. Conducting the end interview.

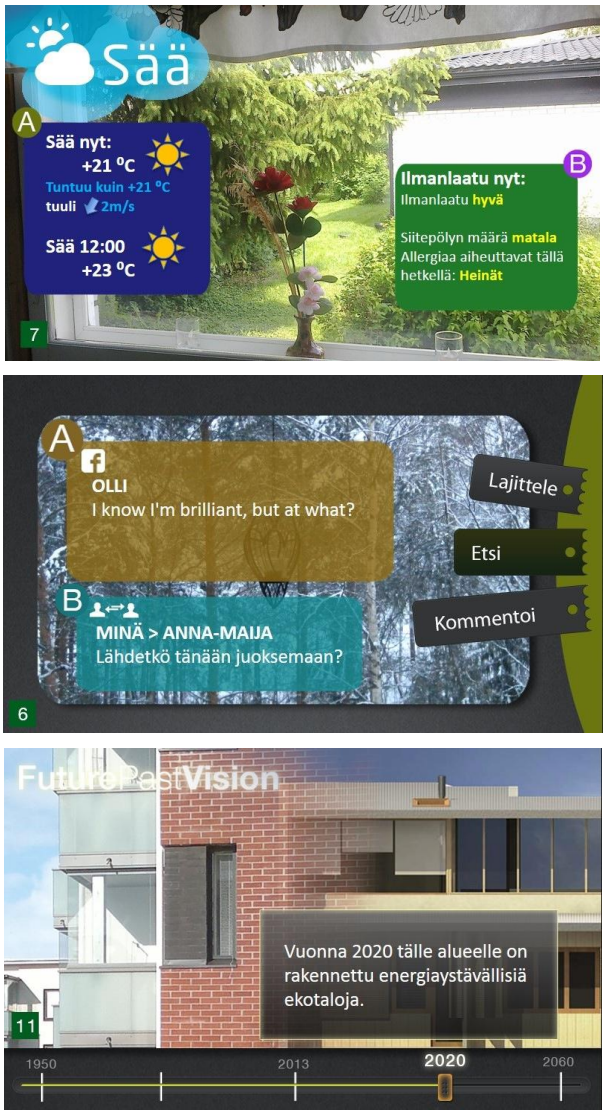

Figure 5. Examples of augmented window views with different contents. Translations: Top: A. weather now +21 C, feels like + 21 C, wind 2 m/s, weather at 12:00 +23 C, B. Air quality now: Air quality good. Amount of pollen low, Allergens currently: hay. Middle: B. Do you want to go for a run today? Bottom: Eco-friendly houses has been constructed in the area in 2020.

5.3 Participants and the Collected Data

Altogether 12 participants (7 males, 5 females) from different households were between 23 and 66 years (average 37). There was no overlap between Study I and Study II participants. Eight of the participants were students and lived in blocks-of-flats in student apartments and 4/12 in detached houses. The students were recruited through poster ads placed on the notice boards of the student apartments. Also most of the users in detached houses were recruited from same area by asking them personally. The idea was to get participants from the same area in order to be able to use the same kind of content types as much as possible. All participants used Internet and email on a daily basis. 2/12 had tried out MR applications, 2/12 had heard of them, and 8/12 participants had no earlier experience of them. Most participants used their own smart phone in the study, but 3/12 users borrowed a phone for this purpose.

Our research data consisted of audio-recorded end-interviews and 27 page diaries containing open questions and 5-point Likert scale ratings on each content type, as well as brainstorming tasks and illustrations. Examples of diary entries showing participants' sketches are presented in Figure 6. The qualitative data from the diaries and interview notes were analyzed by thematic coding.

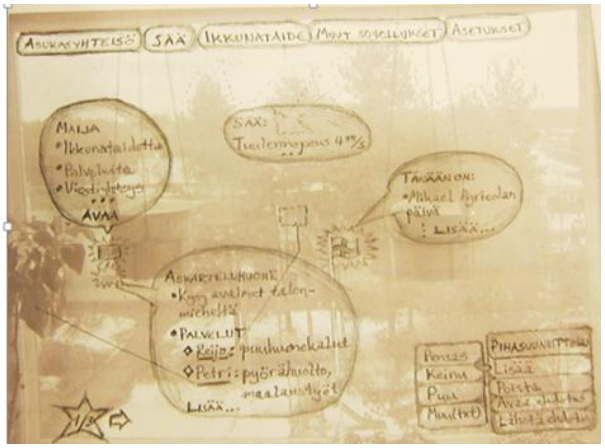

Figure 6. Example of mixed reality window views created by a participant. Translations: Top row: resident community, weather, window art, other applications, settings. Left bubble. Maija, window art, feedback, messaging, open. Below bubble. Crafting room, Ask the keys from the janitor, services, Reijo wood furniture, Petri: bike maintenance, painting. more… Middle bubble. Weather, wind speed. Right bubble. Today is the day of Mikael Agricola, more… Bottom right: Garden design, bush, swing, tree, something else, add, remove, open the proposal, send the proposal.

5.4 Findings

5.4.1 Framework for Four Communication Modes for an Augmented Home Window

While analyzing the concept ideas from study I and feedback from the participants in study II, we found patterns in how the home window was utilized for displaying information. In different types of ideas the *visibility* of the information and the *source* of the data were varying. In some cases the information was supposed to be visible only for the users inside the house and in other cases for those who look the window from outside. On the other hand, in some cases the content was created by the users, sometimes by someone else - a friend or a visitor - and sometimes it was automatically generated context-aware, not personal information. According to these variables we created a categorization of four different modes of augmented window communication (Figure 7).

A. *Window as a private home display* for showing content for users inside the house.

B. *Window as a see-through augmented reality display,* where the window works as a magic lens which augments the external, real world view with virtual information.

C. Window as a display targeted for *communication from outside to inside*.

D. *Window as a public display* for displaying information for users outside the house.

In A, B and C modes the content is visible from the inside only. In A the information can be any kind of private content which is not necessarily location aware e.g. personal calendar or local news. In B the information is location aware in the sense that it augments information about the physical view which is visible from the window. In C mode window is used as interaction channel between home and external world, so that user outside is able to send messages to apartments through the window. In mode A the window functions as any other display at home but in modes B, C and D the connection between the home and the external world has an essential role.

This initial framework can be used in the further design of augmented window concepts and content applications.

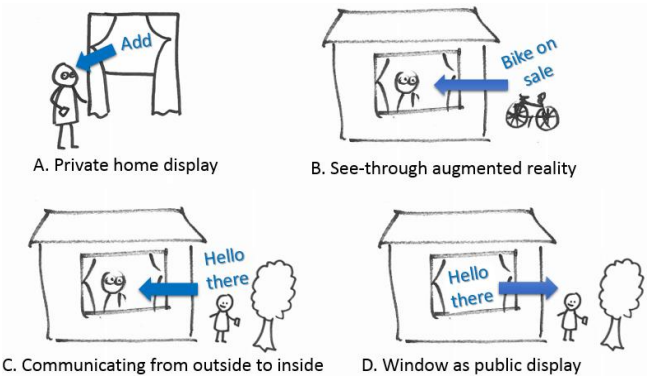

Figure 7. Four communication modes of using the augmented window interface.

5.4.2 Window as a Home Display

Using the home window as a platform for presenting different kinds of content which was not related to the view awoke both negative and positive emotions in participants. On one hand, the window is in a very central place, and people often look at it it on purpose, or unconsciously when thinking of something else. In this light the information on the window surface would be easily visible and important announcements would reach the receivers. When designing personal window views, at the end of the diary, most (11/12) participants selected this type of content to their windows. However, for the same reason the idea of displaying content publicly at home on the window was not appreciated when the content was more private (e.g. Virtual card, Facebook status updates). For the personal window views, participants selected public weather related information or information related to local

services, public reminders and schedules, which are traditionally placed on wall calendars at home.

Moreover, information overflow and the fear of spamming with notices was raised several times:

"I don't want this kind of information [announcements from the housing company] to fill up my window" (#4).

This was argued both from the aesthetics as well as functional point of view, as the window had many natural functions in itself (e.g. illumination, providing information about the current weather).

5.4.3 Augmenting the Home Window View

Most (11/17) of the content types of the evaluated concept had an aspect of mixed reality (MR) in them. The contents which clearly utilized the window view (Future/Past view, housing ad) were rated as the most interesting by the users (See Figure 8).

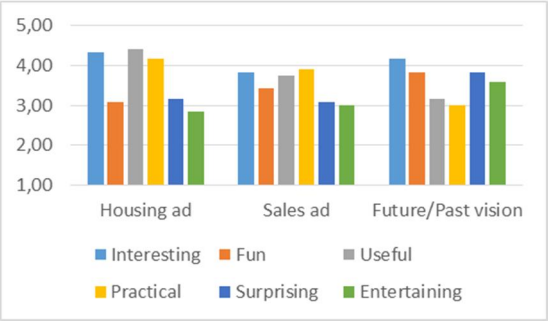

Figure 8. Averages of the Likert scale ratings of content types from mode B.

Most advantages were seen in the cases which utilized the window for augmenting real world objects, offering additional information linked to the direct physical view. For example, moving trees could trigger augmented information about wind speed (participant #9), or a bike could initiate a notice of a sale (#5). Views of the future or past were perceived mostly as hedonic, but an especially interesting area for the MR concept. The possibility to see how the same view looked 20 or 100 years ago was highly appreciated, for example a participant wanted to have a historical view in his window to see how the tree in the yard had grown since 1986. What is more, seeing how buildings which are planned to be constructed will change the landscape was perceived interesting, especially when considering buying a house or apartment. In the view of the future, the importance of the reliability of the content was highlighted many times. Although ideas which combined virtual information and reality were appreciated, the value was considered even higher in foreign contexts, were the environment is unfamiliar and information about the surroundings is needed.

However, reading MR information with a smart mobile device at the window was not perceived as an ideal way of using the applications. Standing by the window with a camera device such as smart phone was considered odd and uncomfortable, and participants were afraid that this would raise suspicions in people seeing this from outside:

"Standing by the window with a camera for a long time arouses wonder and annoyance in people who cherish their privacy. The law forbids pointing with instruments with zoom lenses to private spaces." (#9).

Instead of using mobile devices for viewing the content, the window itself should work as a transparent display for MR information.

5.4.4 Communicating with the Outside World

The concept of a public display for the resident to present content for users outside the house was well appreciated after the first impressions. The public display concept was mainly dominated by hedonic aspects: users rated the concept idea as fun and surprising (See Figure 9).

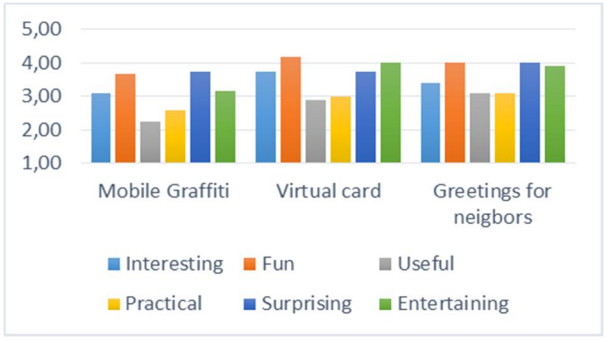

Figure 9. Averages of the Likert scale ratings of content types of mode D.

Besides the hedonic values, participants found many use cases also with pragmatic purposes for the concept: *apartment rental or sales ads* (#5, 11), *apartment address* (#8*), information about an entrepreneur* (#8, 12), other *ads* (#8) and *sales offers* (#5). Status updates on the windows could also be used for bluffing outsiders to prevent burglary, for example displaying a text *"we are at home"* on the window, when the residents are actually on a long holiday (#11). Secret communicating code with neighbors was also suggested: a picture of a dog could mean *"we are at home*" and an image of a car could stand for *"we are on holiday"* (#9). The main concern with public display communication was maintaining the privacy and possible abuse of the information.

"If that kind of information would be visible for strangers someone would most likely empty our apartment" (#9).

In addition, the idea of passers-by looking (with e.g. smart phones) at someone's private windows was perceived as a violation of privacy.

In turn, leaving messages on others' windows from outside was seen interesting, playful and fun, as demonstrated in the following comment about the Mobile Graffiti idea (Table 1, case 8), where a user can leave messages on others' windows:

"You could write funny messages for neighbors and friends. Definitely the best idea" (#6).

Sending messages to other users' windows was seen as a chance to strengthen the community engagement amongst neighbors. Especially when designing one's own augmented window views the community engagement aspect was discussed and half (6/12) of the participants located this type of content to their imaginary window views. It was suggested that through the window users could leave suggestions, design for example a community garden or contact neighbors. On the other hand, leaving messages this way was also considered "*creepy"* (#4) since anyone could leave anything anywhere. In general, the content ideas with social aspects were least appreciated of all. Old techniques were seen as better for communicating between friends.

5.4.5 Methodological Observations

In this study the users were asked to look at augmented view probes of their home windows with smart devices. The views were constructed in top of the users actual window view. The idea was to probe a context aware mixed reality system which augments

information on the user's window surface. The question of how the information would be visible for the users (whether it was displayed directly on the window surface, or did the user had to use an additional device such as smart phone for reading the information) was not defined specifically, but the focus of the study was in different content types, and the idea of displaying it on the window platform.

This caused some confusion among the participants.

"I didn't got quite genuine feeling. It felt more like picture. The information should have been on the window. – I was wondering whether the application was in the window or in the phone." (#6)

The impression of which the user got seemed to vary between the content examples.

"At sometimes I felt like I would have looked through the window – mostly in the views from the beginning – messages from friends felt least like "real" (#12).

This might have happened because in the beginning users did everything as instructed and opened the probes in front of the relevant window, but after getting used to the tasks and the device, they did not follow the instructions but looked the sent picture messages of the simulated window views anywhere and answered the questions in the diary. At this point the mental model of the window display was already understood and the users purely commented the content and how it would feel of having it on the window.

On the other hand, the fact that the probe was just a still image and did not follow the user's movements might have affected positively on imagining that the information was displayed on the window surface.

"Yes [the probe felt real] in the sense that the image didn't move according to the hands movements. It was ok as a simulation. (# 8)."

Although the views were just images, we believe that the fact that the users got to see them in the context during many days allowed them to reflect on their perceptions in a rather realistic manner.

6. DISCUSSION

6.1 User Perceptions

Using the home window as a communication platform has possibilities to entwine with the patterns of domestic life, which is today an important feature of technology use at home [9] – The window is always there, and people look at it frequently. Based on the results from the user studies, especially Study I, participants could easily come up with a number of ideas how augmented window could be utilized at home.

Although the hedonic content was perceived as inspiring and fun, mostly users wanted to have pragmatic information at their windows. Especially, the role of contextual information and augmenting the visible, physical window view was perceived valuable. Moreover, having just an extra device or 'yet another media platform' was not wanted – here, AR and contextual information as well as the easy and immediate visibility (as a window draws attention) were seen as the strong points with the augmented window concept. Interestingly, although hedonistic content, such as pictures from past or from far-away locations, were perceived as fun, the social communication content was not a desired concept.

Negative aspects related to the perception of having too much information visualized in the immediate surrounding – both from the information overflow as well as aesthetics point of view. Using a magic lens technique and viewing the content e.g. through a smart phone camera viewfinder (as e.g. in [4]) would solve this problem, but on the other hand, would not be as immediate to access. Moreover, the participants pointed out that it felt suspicious and intrusive to point at a window with the phone. In this respect, a solution where one could turn the augmented view off and enjoy the conventional, clean window glass would probably be an ideal design solution. However, projecting the information directly to the window glass raises other potential problems. For example limiting the visibility of private content from outside needs to be solved before implementing real installations.

6.2 Limitations

The results of this study are based on a relatively small and homogenous sample (8/12 participants were students) and a non-functional experiential probes. This may have affected the ecological validity of the results. However, this approach suited well the primary intention of this qualitative study, which was to gather early user perceptions and to understand the communication modes with the novel MR concept. Furthermore, we believe that conducting the study in real a context (at home) and with customized, contextual information helped to communicate the concept and to get relevant feedback.

7. CONCLUSIONS

In this paper, we have presented two user studies on the concept of augmented home window. The main contributions of our paper are:

- the framework of four communication modes with an interactive home window and
- insights of the user perceptions of the augmented home window concept grounded to two user studies.

User perception of the positive aspects with the augmented window related to the possibilities

1. to present contextual information from the outside
2. to have a real-time information channel
3. to replace other formats (e.g. less lost papers; less technical gadgets around house).

Generally, the utilitarian content was valued over the hedonic, and social content was not desired to be displayed in the window. Negative aspects related to the information overflow, and concerns related to the social acceptability of both content and behavior where someone was pointing or staring at a window.

In the future, our aim is to continue this work with functional prototype development on a selected MR concept, and further study the holistic user experience with it in long-term use.

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