Investigating Multi-User Interactions on Interactive Media Façades

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Figure 1. Examples of different media façades situated in public places with the potential of enabling multi-user interactions. On the left and in the middle light-emitting façade types, on the right a back-projection high-resolution façade type.

ABSTRACT
Designing interactions with media façades bears several challenges. One of them arises when multiple users are interacting with a media façade simultaneously. In this work we report on our experiences designing a mobile multi-user interaction system with a high-resolution back projection media façade in a public space (see Figure 1, middle). We compare different methods to distribute *temporary ownership* of a media façade. We further describe our systematic design process of prototyping such a system at different scales. Our presented work covers preliminary insights into the design process of media façade interactions and it addresses domain specific challenges such as designing multi-user interactions from scratch.

Categories and Subject Descriptors
H.5.2 Interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design.

Keywords
Media façade, design process, multi-user.

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1. INTRODUCTION
The augmentation of urban spaces with digital technologies, commonly referred to as *media architecture* [9,16], increased over the last decade. Besides sensor networks, the huge amount of mobile devices carried in urban spaces, the manifold variety of situated public displays and video walls, media architecture has become ubiquitous [21,22,32,33]. One domain aspect in this field deals with the augmentation of buildings through interactive technologies, summarized under the umbrella term *media façade* (see Figure 1). Prominent examples in the recent years denoted turning the outer shell of a building into a gigantic urban screen [4,7,13, 28,35].

In contrast to situated public displays, *media façades* are of architectural scale and they therefore require a certain minimal viewing distance for being able to perceive the displayed content as a whole (compare Figure 1). Due to their size, they also have great visibility, resulting in a large number of potential users. This stands in contrast to situated public displays, where the maximum number of people that can gather in front of a display is naturally constrained by the available physical space [8,24].

In the past years, researchers, architects and practitioners investigated means for interacting with media façades [6,11]. However, when multiple users are interacting with a *media façade* [12], users might not necessarily see each other; instead they might be scattered across a large open space. In such cases we face one major previously identified issue [11] with interactive media façades: When interacting with a media façade as a *shared screen,* with multiple users in parallel, territorial issues can arise on the façade causing user frustration [24]: (1) when users are familiar with each other, they often interact collaboratively, in contrast, (2) when they are unaware of each other, they compete for access to the shared *media façade*, which can cause several issues due to the absence of any moderation mechanism, deciding who is interacting at what time and for how long [4,35].

Our conducted research investigates the suitability of different *means* to distribute *temporary ownership* over a media façade to increase the users experience when interacting with multiple users and at the same time. In our previous research we explored the systematic design process and the investigation of suitable evaluation methods to address the domain specific challenges of media façade operation in public settings. In this work we report on our experiences of:

- **Transferring** an extended user-centered design process approach to different façade types (i.e., high-resolution back-projection media façades).
- **Designing** and **preliminary evaluating** suitable turn-taking mechanisms for the distribution of temporary ownership. To do this we designed and implemented three mechanisms to share *temporary ownership* on a media façade with multiple users: (1) ***Time-Multiplexing***, where users periodically have *exclusive* access to the whole façade, (2) ***Space-Multiplexing***, where each user is assigned a *fixed part* of the façade, as well as (3) as a ***Mayor-Mode***, where users need to accomplish local tasks on their mobile devices to earn *exclusive access* to the façade until being *removed* by another user. In particular, we compare these three approaches with respect to their ability to minimize frustration and to increase enjoyment when distributing *temporary ownership* on a shared media façade.
- **Investigating** if prototyping evaluations involving multi-user media façade interactions can be seamlessly transferred from a small-scale setup (i.e., in a research lab) to a full-scale implementation on the actual scale in a public setting. We applied a two-step approach using small scale and full-scale prototypes to test our concepts for different levels of abstraction from the final setting. We discuss the implications of the evaluation for both the applicability of different scale prototypes when designing multi-user interaction with media façades, and the potential of the previously introduced turn taking methods to minimize frustration and increase enjoyment when multiple users interact with a shared media façade.

Our investigations include a description of a case study using an extended design process that others can follow when being confronted with interactive multi-user installations for media façades.

2. RELATED WORK

Urban Spaces are emerging prime locations for the deployment of digital technologies, such as media façades [13,27,30]. In general, *media façades* (see Figure 1) refer to the concept of turning the outer surface of a building into an architectural scale public screen by equipping it with digital, light emitting elements or projections of various kinds [16].

2.1 Categorization of Media Façades

As previously discussed the umbrella term *media façade* describes the idea of transforming the outer shell of a building into a gigantic urban screen [6]. As Haeusler exemplified, they vary in their size and resolution and they can be constructed using different technological means [16,33]. Light emitting façade types, for example, use light emitting diodes embedded in the façade of a building to create the opportunity of changing the façade into different colors (see Figure 1, right). Further, technological solutions include the augmentation through high-resolution projectors that display their content via semi translucent materials applied on the façade to reflect the content on the surface, summarized as *back-projection façades* [16] (see Figure 1, right). In former investigations we dealt with light-emitting façades. Hence, we could not judge the transferability of our design process (i.e., miniaturization of the façade to a small scale model) approach to other façade types, with different color models and technical capabilities [16] (i.e., front or back-projection media façades). In this work we observed the design process of prototyping miniature models of the interactive system before the final implementation in full scale, using a high-resolution back projection façade.

2.2 Interactivity and Media Façades

In the past years, researchers and practitioners started to explore the capabilities of media façades for various reasons, including experimental realizations of interactive installations. In general, media façades can be categorized as follows: (1) **Narrative media façades** remain in a static state and *communicate* ambient or high-resolution information to an audience that has to be encoded by the recipient. (2) **Reactive media façades** gather their content through the surrounding environment via, for example, a network of sensors that provide input data. (3) **Interactive media façades** provide a direct or indirect interaction mechanism that let users access and manipulate content. The latter type also served as the focus of our research investigation. Early examples of interactive façade types include the arcade game classic "Pong" which has been transferred to a media façade by the Chaos Computer Club (CCC) in Berlin, Germany [7]. While this type of interaction was performed via a mobile device and a dial up modem hooked up with a server other examples including interactivity were using screens in front of the building, commonly referred to as *kiosk interfaces*. Embodied interaction mechanisms in this realm can utilize computer vision to empower users to interact with content. While the investigation of interaction mechanisms was tackled in our previous work, we investigated how multiple users could interact with content simultaneously including a *moderation mechanism*. Because the social protocol influences this type of interaction [14], it plays a significant role in the users experience compared to interaction forms were individuals have their personal screens (i.e., mobile devices) as feedback channels: when media façades become an output channel for multiple entities interacting with the system, conflicts are bound to happen as individuals might interact with the provided content in different ways and at the same time [35].

2.3 Interaction Techniques

Turning media façades into interactive surfaces has been subject to a wide range of research. In [4], Böhmer et al. used basic games to create playful engagement with a media façade, utilizing mobile devices as input devices. Boring et al. introduced Touch Projector [5], an augmented reality (AR) approach allowing multiple-users to simultaneously interact with a distant digital screen shown in the screen of a mobile device and using touch input in real-time. While *Touch Projector* is dedicated to indoor display environments, Boring et al. further adapted *Touch Projector* to allow multiple users to simultaneously interact with a media façade, in an outdoor setting [6]. While allowing for simultaneous interaction with a shared canvas (e.g., the media façade), this approach does not provide means for turn taking or moderating the interaction. As exemplified by Wiethoff and Gehring, this can lead to frustration among the users [35]. With *MobisSpray*, Scheible et al. utilized a mobile device as a digital spray can to allowed users to virtually *paint* graffiti onto a projected media façade [27]. Distributing temporary ownership over the façade was handled by passing the dedicated mobile device on which the MobiSpray application was running. Fischer et al. followed a similar approach of taking turns while allowing multiple users to simultaneously interact with a media façade [13]: With *SMSlingshot*, they presented an interactive installation allowing users to simultaneously *shoot* colored text messages onto a projected media façade by aiming at the façade with a wooden slingshot, a custom made input device [13]. The number of parallel users in this case was restricted by the number of available input devices, which forces the users to take turns by passing on the input device as well. In our work we explicitly focused on the interaction with a media façade using mobile devices [6]. Through this technology platform, we avoid the need for passing on a device to take turns and we utilize a commonly available and familiar input device. Simultaneous interaction of multiple users with a shared display is a well-known issue in the interactive tabletop community. Marshall et al. investigated how different configurations of input can influence equity of participation around a shared tabletop interface [20]. Users in groups of three had to work on a design task requiring negotiation on different interface conditions. They found that a shared multi-touch surface increases physical interaction equity and perceptions of dominance, but does not affect levels of verbal participation [20]. Shen et al. designed, implemented and evaluated different interfaces for shared tabletops, as well as interaction techniques and usage scenarios fostering simultaneous interaction of multiple users [31]. Scott et al. critically investigated collaboration around a shared tabletop displays [29]. They provided various guidelines for effective co-located collaboration, including that technology must support *natural* interpersonal interaction, as well as transitions between personal and group work. Greenberg et al. investigated how people move from individual to group work through the use of both personal digital assistants (PDAs) and a shared public display [15]. They highlighted a variety of problematic design issues that result from having different devices and having the system enforce a rigid distinction between personal and public information. Paek et al. also combined large, shared displays with mobile personal devices for simultaneous interaction of multiple users [23]. They built a platform to access content on the shared device with their personal mobile device while they demonstrated the platforms generality and utility in various group settings.

2.4 Regulating Participation

The main focus of our work lies on multi-user interaction with media façades: when multiple users interact with a shared surface, the users' interactions need regulation. Regulating conversations and interactions with groups of people had been subject to research in different fields. Sacks et al. investigated the organization of taking turns to talk in conversations [26]. They proposed a model for the turn-taking organization, which they examined for its compatibility with a list of grossly available facts about conversations. Their results suggest that a model for turn-taking in conversations is characterized as locally managed, party-administered, automatically controlled, and sensitive to recipient design. In a meeting scenario, Roman et al. presented a longitudinal study on the participation regulation effects on conversations in the presence of a speech awareness interactive table [25]. They showed that an effect of balancing participation develops over time and they reported other emerging group-specific features such as interaction patterns and signatures, leadership effects, and behavioral changes between meetings. Their work shows how introducing technology can regulate behavior in conversations. With *Reflect,* Bachour et al. provide an interactive table for regulating face-to-face conversation for collaborative learning [1]. They argue that in such a scenario, unbalanced participation often leads to the undesirable result of some participants experiencing lower learning outcomes than others. The *Reflect* table provides feedback to the participants on the level of their participation could have a positive effect on their ability to self-regulate, leading to a more balanced collaboration. Their evaluation of the system shows a positive effect of the table on the group regulation and the learning effect. Bergstrom et al. introduced the *Conversation Clock* for visualizing audio patterns in conversations of co-located groups [3]. They explored the nature of group interaction by augmenting aural conversation with a persistent visualization of audio input. The Conversation Clock displays individual contribution of a participant via audio input and provides a corresponding social mirror over the course of interaction.

The aforementioned research presents different approaches for regulation conversations with multiple, co-located participants. The characteristics of media façades in combination with the highly dynamic public setting they are situated in, raise additional needs. For example, media façades are very large in size and therefore visible – and interactive – from large distances. While users can simultaneously interact with a shared media façade locally, they are not necessarily co-located. In this paper we therefore investigated turn-taking strategies addressing such scenarios.

2.5 Challenges Designing Interactions

Due to their enormous size, resulting in a great visibility and the circumstance that media façades are situated in a highly dynamic context with rapidly changing conditions, new challenges arise for designers, architects, researchers and practitioners when designing interactions. Dalsgaard and Halskov summarized eight key-challenges [11] as a reference. One of them stresses that the developed content itself has to suit the medium: the installation has to address the diversity of situations in public spaces, such as a high and rapid fluctuation of users and multiple users in parallel. Furthermore, introducing public interfaces and allowing multiple-users to interact in parallel with a shared public screen can also transform social relations and cause disruptions in social protocols [12,14].

In addition to that, media façades limit prototyping on a large-scale: most of the previously described media façade types are not visible and active during daylight, which restricts the times suitable for pre-testing to only a few hours. Another aspect that makes pre-tests difficult is that the outcome of early experiments is already visible to a large audience, as media façades are mostly situated in prime urban locations, with many passerby. For these reasons, not many design iterations are feasible on the façade itself. This leaves designers and developers with pre-testing both novel interaction and/or content on smaller scales with different characteristics before deploying the resulting system on the target façade [35]. These matters justifies a miniaturized prototyping approach before going full scale [34]. Furthermore, there is very few reference literature available for this context. The same applies to the question if user data gathered on a small scale (i.e., in a lab setting) can be seemliness transferred to a full scale setting and result in similar findings. To address this shortcoming we compared similar setups in our work that would only differ in one parameter: scale.

3. INVESTIGATING MULTI-USER INTERACTIONS

3.1 Small Scale Lab Study

To follow the extended design process approach [35], a first experiment was conducted using a prototype in a lab setting (see Figure 2). Therefore, we created a true to scale 1:100 miniature model of the media façade in question of accordance to [34]. The miniature model was equipped with an A+K *AstroBeam* X20 projector to back-project content onto the miniature media façade, simulating the façade while correctly mapping the hardware interplay between client device and media façade. To put the prototype into context, it was situated on an interactive tabletop showing *Google Earth* images of the façade's *real* deployment location (i.e., a large European city) in a public place, correctly aligned around the mockup. The same computer controlled the content displayed on both the miniature media façade and the tabletop. During the study, the participants used a *HTC One S*[1]*,* a *Samsung Galaxy S2*[2] and a *Samsung Galaxy S3*[3] mobile device as a local client (see Figure 2).

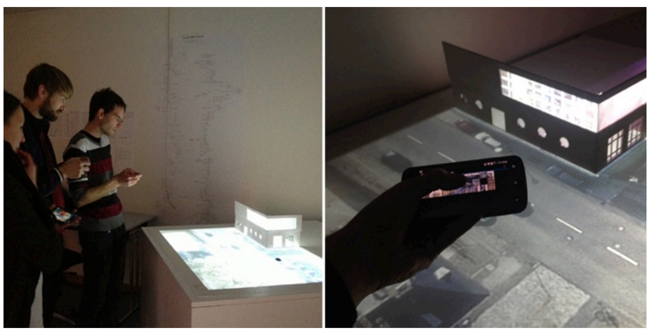

Figure 2. The participants interacting simultaneously with a small-scale prototype of the media façade in a lab setting.

Similar to the setup of the actual media façade, all components of the small-scale setup in this study were connected via a local *WiFi* network.

3.1.1 Tasks

As the overall task of study the participants had to solve a *tile puzzle* (see Figures 3&4) on the media façade with a mobile device as input. The application consisted of a tiled image with shuffled tiles in a randomized order. By moving an *empty* tile via touch input on the mobile device, the participants had to reorder the tiles to reconstruct the original image in order to complete the task. The task was chosen to (a) empower a short-term playful engagement with the media façade which could be played with multiple users simultaneously and (b) using mobile devices a access medium. A previously conducted field study revealed that the majority of the passerby in front of a public media façade appreciated the opportunity of being involved in a local game which would be performed on the façade [35].

Figure 3. Left: The user interface of the tile game played in the study. Right: The local qualification game (*Rock, Paper, Scissor*) played in the *Mayor Mode* to qualify for exclusive access to the façade.

Each participant had to solve the task in three different conditions: (1) *Time-Multiplexing*, (2) *Space-Multiplexing* and (3) the *Mayor-Mode* which were assigned to the participants via a 3x3 Latin Square.

Time-Multiplexing: The *exclusive* ownership of the façade was changing between the participants similar to a *token ring*. The participants sequentially had *exclusive* access to the façade for 30 seconds in each turn, where only the *temporary owner* (i.e., the person interacting with content displayed on the media façade) was able to interact while the remaining participants had to wait for their turn. In this mode, one tile game had to be solved collaboratively on the façade by taking turns.

Space-Multiplexing: In this mode we subdivided the media façade into three separate segments. Similar to the common split-screen pattern, each participant was the *exclusive owner* of one part. The tile game was therefore split into three regions on the façade, each assigned to one of the participants. To solve the tile game, each participant had to solve their own part. While this mode allowed each user to permanently interact with the façade, it also constrained the available façade space per user.

Mayor-Mode: In this mode, we introduced a local qualification game, inspired by a social media platform[4], played only on the personal mobile devices, as a competitive factor: the participants had to win a game – a clone of the *Rock, Paper, Scissors* game tied to a social protocol in phases of decision making to *earn* exclusive ownership on the façade and become the *mayor* until being replaced by another participant who had won the local game and earned more points (see Figure 3, right). By performing well when gaining access and playing the previously introduced *tile puzzle game* on the façade, participants were being able to extend their *mayorship*. In this mode, again one tile game had to be solved on the façade by one participant being able to interact with the media façade individually.

Since all possible interactions consisted of moving the blank tile to one of its neighbors' position (top, bottom, left or right), we designed the tile game that the participants had to use simple swipe gestures on the mobile device's screen implying the direction taking the location of the blank tile as a reference (compare Figure 4). Hence, by using the mobile device as a pure input device and by displaying the visual content of the tile game only on the façade, we lowered attention shifts and engaged the participants to focus on the façade while interacting and not on the mobile device (compare Figure 3, left).

3.1.2 Participants, Data and Analysis

For the small-scale lab study, we recruited a total of 15 participants (6 female) with an average age of 25.4 years. They rated their own technical experience with: novice (two), minor

[1] http://www.htc.com/de/smartphones/htc-one-s/
[2] http://www.samsung.com/de/consumer/mobile-device/mobilephones/smartphones/GT-I9105UANDBT
[3] http://www.samsung.com/us/mobile/cell-phones/SCH-R530MBBCRI

[4] https://foursquare.com/

experienced (two), average experienced (two), rather experienced (four) and very experienced (five), on a five-point *Likert-scale* ranging from 1, meaning “no experience” to 5 meaning “very experienced”.

The participants were divided into groups of three and we paid careful attention that participants did not knew each other before the experiment due to the aforementioned challenges. Each group received an initial five minutes introduction to the context, the application, and the three turn-taking methods previously described. After the introduction, each group had to solve the described task in all three conditions (Time-, Space-Multiplexing and Mayor-Mode), assigned via a 3x3 Latin Square. After completing all tasks, the groups were asked to fill out a questionnaire. The questionnaire consisted of three parts, covering (a) usability aspects and (b) user experience (UX) measures as described by [2,18,36]: The first part of the questionnaire was addressing the general usability of the prototype using open questions. The second part of the questionnaire investigated the perceived user experience while solving the tasks, as well as a subjective rating of the three applied turn-taking methods. The participants were asked to answer questions on a 5 points *Likert-scale*, ranging from 1, meaning “strongly disagree” to 5, meaning “strongly agree”. The last part included a *SAM Scale* [2] focusing on the overall experience in retrospective. The latter served as subjective means to investigate the perceived individual user experiences (UX) [18]. Additionally, we videotaped each group where we focused on both the participants’ behavior within the group as well as the interactions with the prototype.

We analyzed both the qualitative data on the general usability and the user experience collected through the questionnaire, as well as the recorded video footage via open coding [10,19], next we clustered the individual data pointers into main categories using *Affinity Diagramming* [17]. The UX part of the questionnaire focused on positive and negative emotions considering the overall interaction experience. In particular, we focused on what was assumed to be *strengths and limitations* of the three turn-taking modes, which were considering the social peer-pressure during the interaction, loss of façade access, inactivity, collaboration and motivation. In the following we exemplify positive (+) and negative (-) statements.

3.1.3 Results

Figure 4. Left: Moving the left tile of the middle row to the location of the blank tile by performing a swipe gesture from the tile towards the blank tile. Right: Moving the center tile of the bottom row accordingly.

Regarding their preferred turn-taking mode the participants voted the Space-Multiplexing followed by the Time-Multiplexing and the Mayor-Mode with similar scores. A broad set of reasons was given to explain the rating. While the Mayor-Mode was considered as “*very competitive”*, the Space-Multiplexing mode was perceived as a *“good compromise”* in contrast to the other turn-taking methods. One pattern in the data indicated that participants appreciated that *“no interruptions occurred during the game”* in contrast to the other mechanisms and that participants *“definitely got to play”*.

The data pointers collected via the video recordings for the **Time-Multiplexing** mode were matching the researcher denoted concepts [10] “pleasure stimulation” and “enjoyment” (ten positive statements), on the other hand the interaction also led to “frustration” and “irritation” (four negative statements). Reference Quote (+): “*Fun, simple and teamwork.*” Reference Quote (-): “*If you don’t pay attention and miss the start of your turn, you loose playtime before you have to wait again. That’s frustrating!*” While the Time-Multiplexing mode was perceived to have a *“cooperative character”* as idle players often tried to help active players while they had to wait for their turn, *“boredom”* was stated as a main reason for this. Further, the *balance* between activity and inactivity was causing *“frustration”* since three users played the game and each user had to wait twice as long as they were able to play per turn.

Using **Space-Multiplexing** users enjoyed having permanent access to one part of the façade, the competitive aspects solving one part of an overall task were creating both, *enjoyment* (three positive statements), and *frustration* (eight negative statements). Reference quote taken form the video footage (+): “*Classic competition!*” Reference quote (-): “*I felt rushed to complete my puzzle.*” Overall, this mode was being perceived as a *“good compromise”* compared to the other settings because participants traded *screen space* for continuous access to *their* part of the façade. However, for the described setup, the participants stated that due to the small size of the prototype, they emphasized to *“play the space multiplexing mode on a bigger screen*”.

The **Mayor-Mode** created the most diverse spectrum of statements (6 positive and 27 negative quotes) among the participants in contrast to the other turn-taking mechanisms. Concerning the previously described meta concept of *“frustration and irritation”* in this mode, the fact that the participants had to compete **before** becoming the *mayor* and getting *exclusive access* to the façade and that they did not automatically get access at some point was stated as one of the main causes of *“frustration”* especially by the technically very inexperienced participants. Positive reference quote from the video footage (+): “*I really liked that I can earn more play time by performing well.*” Negative reference quote (-): “*I often lost in the qualification game. That gave me a hard time to play on the façade at all!*”.

Asked about the most enjoyable mode in direct comparison of the three applied modes, the participants chose the **Space-Multiplexing** mode to be their favorite approach:

1. Space-Multiplexing (48.8%)
2. Time-Multiplexing (25.6%)
3. Mayor-Mode (25.6%)

Asked about the reason for their vote, the participants stated space multiplexing to be the most enjoyable compromise because they *“got at least enough time to play”* (the game).

3.2 Full Scale Study

3.2.1 General Technical Setup

The large-scale setup in the final condition was conducted at a media façade in a public space measuring 32 square meters (see Figure 5). The back-projection media façade embedded in this building utilized a total of five HD projectors that were aligned via a VGA signal splitter and custom software. The projection was visualized via an expandable curtain consisting of rear projection capable material that covered the large glass front on the first floor. A local *WiFi* network allowed simultaneous access for the provided smartphones. A Teamviewer[5] connection on a

Figure 5. The for the full scale study utilized media façade situated in a public place within the heart of a mid-size European city.

remote local laptop served as medium for monitoring the experiment constantly without leaving the space in front of the façade area where the participants were interacting. Two Samsung Galaxy S3 and one Samsung Galaxy S2 smartphones again served as local access devices for the participants to work with the provided content. The content and the interaction mechanisms were similar to the previously described small scale experiments.

3.2.2 Participants, Data and Analysis

For this setup we recruited a total of 16 participants with an average age of 28.9 years. In a self assessment consent form the participants rated their own technical experience with: novice (one), minor experienced (two), average experienced (five), experienced (five) and expert (three), on five-point *Likert-scales* ranging from 1 meaning "no experience" to 5 meaning "expert".

The study was conducted as follows: first the participants received a five minute introduction to the context, the application and the different turn-taking modes. After that the participants had to solve the task using the different turn-taking modes. After three rounds the participants were asked to a separate room where they had to fill out a questionnaire. The questionnaire was designed combining three investigation methods and focused on different parts of the perceived interaction experience and was similar to the previously presented study setup. This was done to investigate if the results of both (small- and full scale) study settings were indicating similar data cues and as a way to judge the transferability of both settings. The whole setup was again recorded via two video cameras focusing on (a) the participants actions, (b) quotes and (c) the overall interaction experience with the façade. Additional photographs were taken.

The recorded video material was analyzed via open coding [10] and emerging patterns summarized under the previously described positive and negative meta categories.

5 http://www.teamviewer.com

3.2.3 Tasks

The participants had to solve the same task as previously described setups. Assignment of the tasks and randomization via a 3x3 Latin Square were also similar.

3.2.4 Results

Despite the positive motivational aspects of the Mayor-Mode, (see Figure 6). The overall assessment of rating the different mechanisms with another in direct comparison indicated different tendencies: The Space-Multiplexing mode received the highest percentage of positive votes followed by Time-Multiplexing mode. The Major-mode was ranked last.

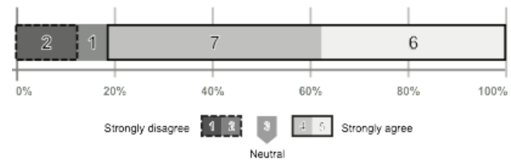

Figure 6. Response frequencies to the *Likert-scale* question: "I felt motivated to become the "mayor" and gain access to the media façade in full screen."

Regarding the perceived interaction experience in contrast to other participants interacting simultaneously on the media façade using the Space-Multiplexing mode, the majority of the users (15) did not find it disturbing that others were using the access to the façade via their mobile device (see Figure 7) at the same time.

Meta-concepts emerged after a first iteration of interpreting the video footage which focused on positive and negative emotions considering to overall interaction experience: "pleasure stimulation" and "user satisfaction" as positive emotions (+) vs. "frustration" and "irritation" for negative emotions (-).

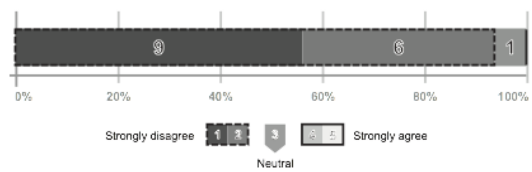

Figure 7. Response frequencies to the *Likert-scale* question: "I found it disturbing that other users were interacting with different regions of the screen."

In total, three positive data pointers were sorted for **Time-Multiplexing** matching the main concept "pleasure stimulation and user satisfaction" as well as three negative data pointers for "frustration and irritation". Reference quote from the video footage (+): *"We were able to communicate with each other during the breaks"*. Negative reference quote when using the **Time-Multiplexing** mode (-): *"I was interrupted in the middle of my thoughts which felt disturbing"*.

The **Space-Multiplexing** mode received also three positive data pointers for the concept "pleasure stimulation". On the contrary it caused more "frustration" among the users as a total of five negative data pointers indicated. Positive reference quote from the video footage (+): *"This mode is an appropriate mix of competition and cooperation."* Negative reference quote (-):

"Because of me, the others have to wait now (until I am finished solving the task)".

The **Major-Mode** was again causing a very diverse spectrum of experiences by the participants. On one hand eight positive quotes were sorted under the concepts "pleasure stimulation" and "user satisfaction". This was influenced by the circumstance that technological experienced users had a higher probability of gaining long term ownership over the façade. On the contrary 17 negative quotes were sorted under the meta-concept of "frustration" and "irritation" caused by users who had difficulties gaining enough points to get access to the façade. Positive reference quote from the video footage (+): *"I liked the competition in this mode which forced me to play fast to keep my status"*. Negative reference quote (-): *"I felt excluded form the group and in the task operation on the media façade while solving the qualifying game"*.

3.3 Summary

Considering both setups in retrospective we acknowledge that all of the investigated interaction mechanisms had their advantages and disadvantages (see Figure 8).

While the Time-Multiplexing mode was being perceived positively as users stated that is was *"self-explanatory", "fostering communication and collaboration"* among the participants it also caused frustration irritation as it was causing *"inactivity"* and *"boredom"*.

	Time Multiplexing	Space Multiplexing	Mayor Mode
Pro	Fostering Collaboration, Self-explanatory	Continuous Interactions, Simultaneous Tasks	Playful Competition, Rich Interaction Experience
Con	Inactivity	Isolation	Technical Skills Affect Interaction Experiences

Figure 8. Summary of the pros and cons of the different turn-taking modes in direct comparison.

The Space-Multiplexing mode was being perceived positively as it was *"self-explanatory", "provided clear constraints and borders"* and led to *"more tasks that could be performed on the media façade at the same time"*. On the contrary it also led to *"isolation"* among the participants and causing peer-pressure on the users to *"perform the given tasks fast"*.

The Mayor-Mode provoked the most diverse feedback in term of positive and negative statements. On the positive side participants stated it advantageous that *"no interruption occurred during the game"* as in case of the time-multiplexing mode. It led to positive experiences by the users who gained exclusive access to the media façade though the qualifying mechanism. On the other hand more user prompting was required compared to Time- and Space-Multiplexing mode due to its *novelty*. It further also caused "frustration" among technical inexperienced users who were outperformed in the qualification game and did not manage to gain access to the façade at all.

A direct voting collected throughout both setups identified the Space-Multiplexing as the *"most pleasant"* to use in direct comparison with the other mechanisms:

Space-Multiplexing (47.2% of positive votes)

Time-Multiplexing (30.2% of positive votes)

Mayor-Mode (23.3% of positive votes)

In both settings we observed that the feedback from the users collected through the questionnaires showed similar tendencies. However, in the small-scale lab setting the spatial configuration caused limitations in the sense of a shared space [10] in front of the media façade due to the miniaturization. Hence, in a future setup it would be advantageous to overcome this issue by providing multiple instantiations of the prototype to allow a *more fluid* positioning of the users in front of shared façades.

4. DISCUSSION

In our work we provided preliminary insights from using different turn-taking mechanisms in conjunction with interactive media façade interactions. Since media façade interaction is influenced by both, the properties of the façade itself in combination with the appearance of the content, as well as the spatial arrangement of the space in front of the façade from where people interact, we tested different turn-taking modes with prototypes on different scales. By using a small-scale prototype, we have noticed that the spatial setting in front of the façade cannot be modeled sufficiently. In general, the data collected in the both setups showed similar tendencies in both perceived usability satisfaction and the general user satisfaction with the different turn-taking modes. Hence, we acknowledge that using miniature prototypes to investigate interfaces for media façade interaction can provide valuable insights on the usability and the perceived user experience of the target setting. While the small-scale lab setup was focusing on the façade itself, the full scale setup was additionally focusing on the spatial setting around the façade and produced similar results (e.g., the participants' answers showed the same preferences). This could also be seen as a limitation of our approach: Since we utilized a miniature model of the final façade for the small scale prototype, we could correctly map the façade and the displayed application, but not the spatial setting in front of the façade. Hence, using the small-scale prototype, we could not investigate how people spatially distribute themselves within the potential interaction space in front of the façade and how they interact with each other or with the media façade when being spatially separated.

In summary we provide preliminary insights into the design process of interactive media façades in multi-user environments while investigating an extended design process for media façade interaction, involving a high-resolution back-projection media façade. To gather insights into the design, we conducted both a user evaluation *in the wild* and user evaluations in controlled settings with prototypes on different scales. We collected and compared the data sets gathered in both studies and compared them to find commonalities and differences of their applicability in particular stages. The collected data indicates that prototypes on different scales are generally applicable during the design, providing initial feedback on usability and user experience in this context. However, we have noticed that small-scale models are less suited when focusing on the behavior of users within the interactive space in front of a media façade.

5. CONCLUSION AND FUTURE WORK

The domain of interactions between people and buildings through interactive media façades is a novel yet emerging research context. However, systematic design process models or guidance literature on how to envision, prototype, pre-test and implement multi-user systems from scratch is missing. This becomes an even more complex task if domain specific challenges arise when interacting with media façades [11]. These circumstances demand special considerations to the human factors by the people who design and pre-test these systems. To preliminary investigate some of these challenges we have presented a case study, which describes (a) an extended design process for media façade interaction on different scales and (b) investigated the distribution of *temporary ownership* when multiple users are interacting with such a system in parallel through different moderation mechanisms.

In a following project we will focus on an deeper investigation on the social and spatial factors of the previously addressed challenges to create systematic prototyping tools designers and architects can use and make the interaction between people and media architecture usable and enjoyable.

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7. REFERENCES

[1] Bachour, K., Kaplan, F., & Dillenbourg, P. (2008). Reflect: An interactive table for regulating face-to-face collaborative learning. In *Times of Convergence. Technologies Across Learning Contexts* (pp. 39-48). Springer Berlin Heidelberg.

[2] Bargas-Avila, J.A., Hornbaek, K. Old Wine in New Bottles or Novel Challenges: A Critical Analysis of Empirical Studies of User Experience. In *Proc. CHI11*.

[3] Bergstrom, T., & Karahalios, K. (2007, January). Conversation Clock: Visualizing audio patterns in co-located groups. In *System Sciences, 2007. HICSS 2007. 40th Annual Hawaii International Conference on* (pp. 78-78).

[4] Böhmer, M., Gehring, S., Löchtefeld, M., Ostkamp, M. and Bauer, G. The mighty un-touchables: creating playful engagement on media façades. In *Proc. MobileHCI '11*.

[5] Boring, S., Baur, D., Butz, A., Gustafson, S. and Baudisch, P. Touch projector: mobile interaction through video. In *Proc. CHI'10.*

[6] Boring, S., Gehring, S., Wiethoff, A., Blöckner, M., Schöning, J. and Butz, A. Multi-user interaction on media façades through live video on mobile devices. In *Proc. CHI'11*.

[7] Borries, F., Walz, S., Böttger, M. Space Time Play: Computer Games, Architecture and Urbanism: The Next Level. Birkhäuser, 2007.

[8] Brignull, H. and Rogers, Y.,. Enticing people to interact with large public displays in public spaces. In *Proc. INTERACT'03*.

[9] Bullivant, L. Responsive Environments: Architecture, Art and Design. *V&A London*, 2006.

[10] Corbin. J. and Strauss, A. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. *Sage Publications*, 2008.

[11] Dalsgaard, P. and Halskov, K. Designing urban media façades: cases and challenges. In *Proc. CHI'10*.

[12] Fischer, P. T. and Hornecker, E. Urban HCI: spatial aspects in the design of shared encounters for media facades. In *Proc.CHI'12*.

[13] Fischer, P. T., Zöllner, C., Hoffmann, T. and Piatza, S.. VR/Urban: SMSingshot. In *Proc TEI'10*.

[14] Goffman, E. Behavior in public places: Notes on the social organization of gatherings. *Free Press*, 1966.

[15] Greenberg, S., Boyle, M., Laberge, J. PDAs and shared public displays: Making personal information public, and public information personal. *Personal Technologies*, Springer, 1999.

[16] Haeusler, M., H., Tomitsch, M. and Tscherteu, G. New Media Façades – A Global Survey. Avedition, Ludwigsburg, 2012.

[17] Hanington, B. and Martin, B. Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions. Rockport Pub, 2012.

[18] Hassenzahl, M., Diefenbach, S. and Göritz, A. Needs, affect, and interactive products–Facets of user experience. *Interacting with Computers*. Elsevier 2010.

[19] Lazar, J., Feng, J.H. and Hochheiser, H. Research Methods in Human-Computer Interaction. John Wiley & Sons, 2009.

[20] Marshall, P., Hornecker, E., Morris, R., Dalton, N.S. and Rogers, Y. When the fingers do the talking: A study of group participation with varying constraints to a tabletop interface. In *Proc. TABLETOP'08.*

[21] Mignonneau, L. and Sommerer, C. Media Facades as Architectural Interfaces. The Art and Science of Interface and Interaction Design. Springer London 2008.

[22] Miyaoku, K., Higashino, S. and Tonomura, Y. C-blink: a hue difference-based light signal marker for large screen interaction via any mobile terminal. In *Proc. UIST'04*.

[23] Paek, T., Agrawala, M., Basu, S., Drucker, S., Kristjansson, T., Logan, R., Toyama, K. and Wilson, A. Toward universal mobile interaction for shared displays. In *Proc. CSCW '04*.

[24] Peltonen, P., Kurvinen, E., Salovaara, A., Jacucci, G., Ilmonen, T., Evans, J., Oulasvirta, A. and Saarikko, P. It's Mine, Don't Touch!: interactions at a large multi-touch display in a city centre. In *Proc. CHI'08*.

[25] Roman, F., Mastrogiacomo, S., Mlotkowski, D., Kaplan, F., & Dillenbourg, P. (2012, October). Can a table regulate participation in top level managers' meetings?. In *Proceedings of the 17th ACM international conference on Supporting group work* (pp. 1-10).

[26] Sacks, H., Schegloff, E., J.efferson, G.: A simplest systematics for the organisation of turn-taking for conversation. Language. Journal of the linguistic society of America 50, 1974, p. 696-735

[27] Scheible, J., Ojala, T. MobiSpray: mobile phone as virtual spray can for painting BIG anytime anywhere on anything. In Proc. SIGGRAPH '09.

[28] Schoch, O. My building is my display: omnipresent graphical output as hybrid communicators. Swiss Federal Institute of Technology, Faculty of Architecture, 2006.

[29] Scott, S.D., Grant, K.D., Mandryk, R.L. System Guidelines for Co-located, Collaborative Work on a Tabletop Display. In *Proc. ESCSCW'03*.

[30] Seitinger, S., Perry, D.S. and Mitchell, W.J. Urban pixels: painting the city with light. In *Proc. CHI'09*.

[31] Shen, C., Ryall, K., Forlines, C., Esenther, A., Vernier, F.D., Everitt, K., Wu, M., Wigdor, D., Morris, M.R., Hancock, M. and Tse, E. Informing the Design of Direct-Touch Tabletops. *Computer Graphics and Applications* 2006.

[32] Struppek M. The Social Potential of Urban Screens, *Visual Communication*, 2006.

[33] Tscherteu, G. Media Façade Online Catalogue, http://www.mediaarchitecture.org/mab2010documentation/, 2010.

[34] Wiethoff, A. and Blöckner, M. Lightbox – Exploring Interaction Modalities with Colored Light. In *Proc. TEI'11*.

[35] Wiethoff, A. and Gehring, S. Designing interaction with media façades: A case study. In *Proc. DIS'12*.

[36] Wright, P. and McCarthy, J. Empathy and experience in HCI. In *Proc.CHI'03.*