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**Masterarbeit**

# Design and Development of a Public Display Survey Platform

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## Zusammenfassung

In den letzten Jahren haben sich Public Displays (PD) in der Öffentlichkeit stark vermehrt und wurden Teil unseres täglichen Lebens. In Einkaufszentren, Bahnhöfen und Flughäfen gibt es immer mehr interaktive Anwendungen für PDs. Ihre Entwicklung erfordert eine umfassende Evaluation, was ein komplexes und zeitintensives Unterfangen ist. Bisher greifen viele der interaktiven Anwendungen noch nicht auf die Möglichkeit zurück, den Rückkanal vom PD zum Display-Anbieter zu nutzen. Um dieses Problem zu lösen wurde eine interaktive Umfrage-Plattform entwickelt und eine umfassende Literaturrecherche durchgeführt. *PDSurvey* soll die Durchführung von Umfragen auf Public Displays erleichtern und als Werkzeug zur weiteren Evaluierung dienen. In dieser Arbeit wird der Entwurf und die Entwicklung unserer Plattform vorgestellt und eine Liste an standardisierten Fragebögen vorgeschlagen, welche aus einer umfangreichen Literaturrecherche resultieren. Außerdem stellen wir die Ergebnisse unserer Feldstudie vor, in der wir untersucht haben wie Umfragen auf Public Displays wahrgenommen werden und welcher Rückkanal am besten für den Nutzer geeignet ist um in digitaler Form auf einen Fragebogen zu antworten. Die Ergebnisse lassen folgern, dass eine Mehrheit der Nutzer es vorzieht Umfragen direkt vor Ort zu beantworten. Allerdings hat auch ein Viertel sich gegen die Möglichkeit entschieden, direkt vor Ort auf den Fragebogen zu antworten. Ein Tablet als Rückkanal anzubieten hat sich als beste Option herausgestellt, auch wenn der Benutzer zwischen den Geräten wechseln muss. Umfragen welche direkt auf PDs durchgeführt werden stellen eine sinnvolle Alternative zu Online-Umfragen dar, mit der Einschränkung der sozialen Erwünschtheit und der Abnahme der Privatsphäre.



## Abstract

In recent years, public displays (PD) have proliferated in public space and become part of our daily lives. New interactive applications for PDs are flourishing in shopping malls, train stations, and airports. Their development requires extensive evaluation, which is a complex and time intensive endeavor. So far, many interactive PDs still lack a feedback channel from display to display provider. To solve this problem an interactive survey platform was developed and an extensive literature review carried out. *PDSurvey* aims to facilitate the execution of surveys on public displays and is a toolset for further PD evaluation. In this thesis, the design and development process of our platform is presented and a list of standardized questionnaires proposed, resulting from an extensive literature review. Furthermore, we present the findings of our field study, in which we assessed the general acceptance of questionnaires being conducted in public space and which feedback channels are best suited for users to respond to questionnaires in a digital form. The findings imply that a majority of users prefer to complete a survey directly on-site. However, a quarter refrained from using PDs for responding to the questionnaire. Offering the tablet as a feedback channel represented the best choice, even though users have to switch devices. Surveys conducted on public displays are a reasonable alternative to online surveys, with the limitation of social desirability and a decrease in privacy.

# Aufgabenstellung

**Development of a Public Display Survey Platform**

**Problem Statement** Public displays are quickly proliferating in public spaces. At the same time, interactive applications are still scarce, since their development is costly and the effect on the user - and thus their benefit - is often not clear. Hence, interactive display applications are usually developed, deployed, and carefully evaluated in research contexts. In most cases, evaluation focuses on particular aspects only, such as user performance, user experience, or social implications, due to the significant effort associated with planning, preparing and conducting public display evaluations.

**Scope of the Thesis** To tackle the aforementioned challenge, the objective of this thesis is to develop a survey tool that allows interactive public display installations to be comprehensively assessed. As a first step, an extensive literature review will be conducted with the aim of identifying important aspects of public display deployments - from a researchers' as well as from a practitioners' perspective - as well as to develop an understanding of how these aspects could be addressed through surveys. Based on the literature review, a web-based survey platform will be implemented that can easily be used to evaluate and compare public displays through different channels. Such channels include evaluation directly at the display or through a (mobile) website that allows participation also via a smartphone or tablet. The platform should allow public display owners to configure their own surveys based on their needs. Optionally, the survey tool itself will be evaluated with an interactive public display application.

**Tasks** (1) conduct a literature review to identify (research) questions that are of interest to researchers and practitioners
(2) produce a comprehensive set of questions that can be used to assess these questions by means of a survey
(3) develop a web-based public display survey platform consisting of (a) an administration interface that allows (groups of) questions to be selected for use within the tool and (b) a responsive UI that can be rendered on different devices (public display, smartphone, tablet, laptop)

**Requirements** Strong skills in web programming, independent scientific work and creative problem solving, experience in creating questionnaires is a plus.

**Keywords** Public displays, interaction, applications, survey, questionnaires, web

Ich erkläre hiermit, dass ich die vorliegende Arbeit selbstständig angefertigt, alle Zitate als solche kenntlich gemacht sowie alle benutzten Quellen und Hilfsmittel angegeben habe.

München, 30. April 2015

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# Contents

# 1 Introduction

Throughout the last decade public displays have evolved from screens used for advertisement, to interactive displays with bidirectional capability, enabling an entirely new type of interactive experience. With the rise of touch and gesture input, a new era of interactive applications is waiting to be used. Public displays can already be used at airports for finding your gate, in shopping malls as a store locator, or in brand stores for assessing user satisfaction and giving users a more immersive shopping experience. The areas of application for public displays are ever growing. However, still no common design guidelines exist [3] and an individual evaluation of each setup is of importance [38]. This reinforces the need for evaluating all new applications through lab or field studies. However, the evaluation of public displays however is a very time-consuming task and requires prior knowledge.

Based on the evaluation of related work and the time-consuming nature of field studies (even for small quantitative questionnaires) the demand for simplification and automation of the evaluation process becomes apparent. Due to the essential importance of the validation of public display installations and research in general, such an evaluation platform can be a great benefit. With the advent of the Internet a similar transition was visible. New capabilities such as direct feedback enabled new ways to conduct surveys. Already in 1983 Sproull and Kiesler [55] looked at the benefits of email vs. traditional mail surveys. The demand for extensive evaluation of the new economy was met with emerging online survey platforms. One such survey platform is SurveyMonkey, founded in 1999 and currently one of the most popular solutions on the market to conduct web-based surveys [5]. Other well established solutions are eSurvey Creator, SoGoSurvey, and UX Suite by UsabilityTools. A closer evaluation can be found in chapter 2. These survey platforms focus on evaluating the users' opinion through web-based or mobile interfaces.

However, for our type of use the approaches which already exist aren't enough, since the evaluation of public displays has additional requirements. One such constraint of public display research represents the opportunistic nature of the setups and the discrepancy between lab studies and field studies [43]. Thus there is an additional demand for evaluating each public display setup individually and if possible directly in the field. Another significant difference for evaluating public display setups is the additional abstraction layer. Not only is it of interest to understand how the user perceives the application, or to assess the users opinion independently of the display setup, but in particular what influence the context of the public display setup has on the users perception. Another important difference is that not only does the application itself needs to be evaluated, but so does the whole display setup including the influence of the surrounding environment. So far none of the platforms reviewed offers this level of evaluation.

To facilitate this step and to allow for a better comparison and analysis of public display setups, we developed *PDSurvey*, an interactive public display survey platform. The interactive capability of public displays is of similar importance for our setup as the rising of the web in the late 1990s for online survey platforms. It is now possible to conduct surveys and to log data directly from public displays and to use the display itself as a feedback channel to the display provider. This facilitates the collection of quantitative and qualitative data from entire public display networks. When additionally collecting the context of every survey response, new insights into the differences between different display setups and the influence of the surrounding environment can be gathered. One interesting question could be which role the context plays on the users' perception of the public display setup, while running identical software settings, but only varying the context.

Our research contributions are the categorization of questionnaires used for the evaluation of public displays, based on an extensive literature review. Furthermore we introduce the *PDSurvey* platform, and present first practical experiences from our field study. We assess which feedback channel is preferred for responding to surveys. Our fundamental goal is to facilitate the evaluation of public display setups via interactive surveys on the displays themselves. Additionally we present results from the field study, including the motivation for approaching the display setup.

The main part of this thesis is structured as follows. Chapter 2 provides an overview of related work and introduces the reader to the area of public display evaluation. In chapter 3 we present the results of the literature evaluation and our clustering of standardized questionnaires. Chapter 4 deals with the implementation of the *PDSurvey* platform. First the requirements and design decisions are discussed, followed by a short overview of the architecture, and concluded with an overview of the finished platform. In chapter 5 we present the descriptive field study and make first evaluations of our survey platform. Future work is discussed in chapter 6. A conclusion complements this thesis.

# 2 Related Work

The goal of the literature review was to find out how other researchers evaluated public displays and to develop an understanding of how these aspects can be addressed through surveys. The focus was to identify important aspects of public display deployments, from a researcher's as well from a practitioner's perspective. A summary of the most relevant papers is provided in this chapter.

## 2.1 Evaluation of Public Displays

Public display evaluation has already been addressed in literature. Alt et al. [3] give an overview of study types, research paradigms, and evaluation methods used for evaluating public displays. Müller et al. [39] present with MirrorTouch, a follow-up evaluation and additionally extract metrics used for quantitative field studies. According to their findings, almost exclusively descriptive field studies are used in the area of public display evaluation. For a more in-depth introduction to public displays, the doctoral thesis by Alt [1] provides an ideal overview. For a general recap of how to best design, evaluate, and report experiments, the book by Field and Hole [20] was used. Kirakowski [32] provides a useful introduction for practitioners of what to watch out for, covering the most important aspects for conducting surveys.

## 2.2 Exemplary Papers

A selection of papers, which have inspired us and have a good approach towards the evaluation of public displays, are amongst others: Overcoming Assumptions by Huang et al. [28], Worlds of Information by Jacucci et al. [31], and Digifieds by Alt et al. [2]. In the following a short overview of these and other papers is given.

Jacucci et al. provide with [31] not only a superb overview of evaluation methods, but also the way they evaluate their results is exemplary. The evaluation is detailed and all questions asked in their questionnaires are stated. For evaluation they used video ethnography and a variety of questionnaires. Their focus lies on the aspects of group use and user engagement, measured through questions adapted from Flow (GameFlow), Presence (MEC), and Intrinsic Motivation (IMI) questionnaires.

In *Overcoming Assumptions* Huang et al. analyzed how "large ambient information displays in public settings" [28] (public displays) were deployed and tried to understand how such displays are used, in order to derive best practices and offer design recommendations. These include elements like the position of the display, content, dynamics or the best way to present a message, which is to be transported to the reader. In *IM Here*, another publication by Huang et al. [29] observations, informal conversations and questionnaires are used for evaluation. The focus of their evaluation is social awareness and collaboration aspects. Questionnaires were conducted before and after the primary task.

Ojala et al. [44] present an evaluation of their long-term public display deployment in downtown Oulu, referred to as *UBI Hotspot*. They conducted their surveys in-situ and evaluated data from a time span of eight months. Surveys were also already embedded directly onto the UBI hotspots. They aimed to analyze the usage and user acceptance rates for their setup with questions based on Nielsen's system acceptance model. Two general demographic questions (age and gender) were asked first, followed by a random selection of 8 statements from Nielsen's system acceptance model.

Alt et al. [2] created a digital noticeboard called *Digifieds* and evaluated the platform using observations, interviews and a field trial. The Digifieds platform was deployed during the UbiChallenge 2011 to an urban environment in Finland and evaluated with the help of SUS questionnaires. The questionnaire accompanied the field trial and was structured as follows: after the users got a brief introduction to the study, general questions were asked regarding the mobile phone usage,

whether the display setup had been used before, and how they were affiliated towards public notice areas. Thereafter, two practical tasks were carried out, each followed by a SUS questionnaire. Finally, questions were asked regarding the user's opinion on public notice areas.

Müller et al. [40] present an in-depth evaluation of *Looking Glass*, an interactive display setup inside of a shop window. Looking Glass gives visual feedback to passers-by and mirrored their movements. Their evaluation consisted of a pre-study, a controlled lab-study, and an "in the wild" field study. Both quantitative and qualitative data were collected. However, no questionnaires were used. Müller et al. relied on observations, semi-structured interviews, and manual video recording, combined with interaction logs and a depth video log for quantitative data.

The publication by Beyer et al. [9] used the AttrakDiff questionnaire for evaluating user experience in their lab study. Ballagas et al. [7] used a background, subjective and a ISO 9241-9 based questionnaire[1], for measuring performance. In the *Hermes Photo Display* publication by Cheverst et al. [12] a non-standardized questionnaire is used. The questionnaire is split up into four sections. The first section collected background information, "the second section consisted of seven questions related to interface issues and general acceptability. The third section contained 14 questions related to social and community issues. Finally the fourth section contained two questions relating to possible future features" [12]. All questions were answered on a 5-point Likert scale. The focus was on measuring the "notions of community". A later publication by Cheverst et al. [13] focused on determining the "sense of community" index. They first collected ethnographic and cultural data, followed by a focus group and a design workshop.

## 2.3 Overview of Survey Platforms

In order to get an overview of survey platforms and to verify that a toolset like *PDSurvey* doesn't already exist, we evaluated a list of survey solutions [10, 19].This helped us better understand how web-based survey platforms were designed, research was first carried out by analyzing similar approaches which already existed on the market. Since the early days of personal computers there has been an interest to conduct computer-aided surveys [63]. Snap Surveys was founded in 1981 and is one of the pioneers. The rising demand for enhanced evaluation during the new economy was met with a multitude of new web-based survey platforms. One such survey platform is SurveyMonkey, founded in 1999 and currently one of the most popular solutions on the market for conducting web-based surveys [5]. Other well established solutions are eSurvey Creator, SoGoSurvey, and UX Suite by UsabilityTools.

The first solution we considered was SosciSurvey [2], a popular tool developed by the Institute for Communication Science of Ludwig-Maximilians-Universität München. It is well suited for surveys executed on personal computers and distributed via email, however, one major drawback for us is the difficulty in extending the platform and embedding questionnaires on mobile devices and non-web-based platforms. For this purpose it was easier to build a new platform already supporting a responsive layout and RESTful interaction. Another tool, comparable to the SociSurvey platform, is LimeSurvey [3]. LimeSurvey is an open-source project based on PHP and providing an out of the box web-based survey platform. Commercial solutions considered are eSurvey Creator[4], Free Online Surveys[5], UX Suite by UsabilityTools[6], SurveyMonkey[7], SoGo-

[1] `http://www.yorku.ca/mack/gi2009.html` (last accessed on April 24, 2015)
[2] `https://www.soscisurvey.de/` (last accessed on November 26, 2014)
[3] `http://de.wikipedia.org/wiki/LimeSurvey` (last accessed on April 6, 2015)
[4] `https://www.esurveycreator.com/` (last accessed on April 6, 2015)
[5] `https://www.freeonlinesurveys.com/` (last accessed on April 6, 2015)
[6] `http://usabilitytools.com/ux-suite/` (last accessed on April 6, 2015)
[7] `https://www.surveymonkey.com` (last accessed on April 6, 2015)

Survey[8], SurveyPlanet[9], and Qualtrics[10]. These platforms often offer a larger variety of features compared to solutions free of charge.

Many of the reviewed solutions already support a large number of question types and provide a sophisticated administration panel. However, the main disadvantage is their lacking support of mobile phones, the missing REST API, and a lack of functionality for embedding pre-configured standardized questionnaires. In addition, there are many special requirements in the field of public display research. UX Suite by UsabilityTools offers a handy backend for configuring surveys, however, it is lacking the pre-configured standardized questionnaires. SurveyMonkey provides sample surveys[11] and a mobile app for conducting and evaluating surveys. Their approach better fits the requirements of this thesis' project. However, SurveyMonkey does not offer an API for embedding platforms with other programing languages and the standardized questionnaires are relevant to public display research. The best commercial solutions found on the market were SoGoSurvey, SurveyPlanet and Qualtrics. SoGoSurvey offers mobile support, advanced question types (Likert scale, matrix grid, etc.), and industry-specific solutions. SurveyPlanet supports a comparable set of features as SoGoSurvey, additionally, also an embed code for remote embedding. This code, however, is based on iFrames, which in turn will not work for solutions without support of web platforms. Qualtrics is another commercial solution offering a large product spectrum of surveys for website feedback. The product coming closest to the projects requirements is 'Qualtrics Site Intercept'[12], supporting a sophisticated way of embedding on websites. Sliders, feedback links, infobars and popovers are supported.

## 2.4 Distinguishing Features

The key difference between our approach and the already existing evaluation platforms is the ability to associate each survey with the display on which the survey is carried out, and that our platform is tailored specifically to the needs of public display evaluation. For example, some question types from traditional web-based questionnaires are not well-suited for large displays. By limiting ourselves specifically to the evaluation of public displays, the platform can gather more specific data and deliver better results. Not all question types are, for example, well suited for touch-based or gesture-based input devices. Another difference is the context-based approach. By default, *PDSurvey* asks the display operator to specify the context of every display connected to the platform. When enough context data is specified, this will allow for a thorough evaluation and comparison of public display installations, also considering the influence of the environment. Further technical differences are the ability to conduct surveys across a variety of platforms. Not only due to the responsive layout, but also due to the modular and extensible method of construction. One of the benefits is that the whole platform is retrieving all data via a RESTful API, allowing for the greatest possible coverage of end consumer devices. As a result, surveys can also be conducted on non-web-based platforms. For the solutions, currently available on the market, this flexibility is not yet standard. The sum of these measures allows for a simplified evaluation of public displays. Additionally, a range of standardized questionnaires is supplied to facilitate the evaluation of public displays. Based on a crowd-sourcing approach more additions are possible. The pre-configured standardized questionnaires will be introduced in chapter 3.

[8] `http://www.sogosurvey.com/Features/List-of-All-Features.aspx` (last accessed on April 6, 2015)

[9] `https://surveyplanet.com/` (last accessed on April 6, 2015)

[10] `http://www.qualtrics.com/site-intercept/` (last accessed on April 6, 2015)

[11] `https://www.surveymonkey.com/blog/en/sample-survey-questionnaire-templates/` (last accessed on April 6, 2015)

[12] `http://www.qualtrics.com/site-intercept/` (last accessed on April 6, 2015)

# 3 Literature Review

Our research is based on an extensive literature review of over 100 articles. This has led to the development of the public display survey platform (see chapter 4) and the categorization of standardized questionnaires (see section 3.2). A side effect of the literature review was, besides getting a better understanding of how public displays were evaluated, getting an overview of the questions asked to evaluate public displays and their applications. This turned out to be a quite valuable approach, since we haven't seen any compilation of questionnaires used for public display evaluation so far. The goal was to find patterns and to build clusters of questionnaires being useful for the evaluation through automated public survey display platforms.

In the following we will first describe our methodology for gathering the information (section 3.1), followed by a categorization of standardized questionnaires (section 3.2), rounded off with results drawn from the literature review (section 3.3). The categorization of the standardized questionnaires can be found in table 3.1 on page 9.

## 3.1 Methodology

The procedure for the selection of papers to review, was as follows. As a starting point all papers from the appendix of the doctoral thesis by Alt [1] were read. Afterwards, interesting related work and citations were examined based on the papers from the previous step. This was supplemented with targeted research on Google Scholar and the APM Digital Library. To round off the literature review, publications of two authors whom are very active in this field, were reviewed.

The first step was fairly straight forward. The papers from the appendix were read, in order to get a first overview of the current state of research. The second step, pursuing related work and citations of interest, was carried out in a more subjective manner. Whenever interesting papers or projects were mentioned, the cited paper was also taken into account. In a third step, a more strategic approach was used. Based on the insights gained from the previous steps, Google Scholar and APM was checked for literature relevant to our research question. The keywords used amongst others for the research in these online libraries were: *standardized surveys for usability*, *standardized surveys for user experience*, *user satisfaction questionnaire*, *public display evaluation*, and *standardized public display evaluation*. The last step for collecting relevant papers consisted of profiling publications of two relevant authors in the area of public display research, namely Jörg Müller and Marcus Foth. The process started out by first finding a list of their publications. Since the literature review made by Alt (see first step) already covered papers up to 2011, only ones published between 2012 and 2014 were viewed. On each opened paper from this time frame a keyword search was carried out in order to see whether it contained an evaluation which might be relevant for us. These keywords were: *questionnaire*, *survey*, *question*, *interview*, *(field) study*, and *evaluation*. If none of these words could be found, the headlines and the abstract was skimmed through. All papers containing a reference to an evaluation of public displays were saved and analyzed in more detail. For Müller the best list of his publications were found on his personal website[13], and for Foth two websites were evaluated [14].

[13] `http://joergmueller.info/publications.html` (last accessed on November 17, 2014)

[14] `http://www.vrolik.de/publications/` (last accessed on November 18, 2014) and `http://eprints.qut.edu.au/view/person/Foth,_Marcus.html` (last accessed on November 18, 2014)

## 3.2 Standardized Questionnaires

As a result of the literature review process, a overview of questionnaires arose, which can be seen in table 3.1. All questionnaires found during the literature review phase were categorized into a scheme inspired by the research questions introduced in chapter 2.8.2 of Alt's doctoral thesis [1]. Alt listed eight research categories for public displays: audience behavior, user experience, user acceptance, user performance, display effectiveness, privacy, and social impact. These categories served as a guideline for our classification of standardized questionnaires. We extended the prior categorization with findings from literature review and added four new categories: *usability*, *context*, *demographics*, and category for *miscellaneous* questions. In the case that no questionnaire was found for a research category introduced by Alt [1], individual research was done on the web. It can be seen based on the rightmost column of the table whether the questionnaire has been used by other researchers for the evaluation of public displays or not.

A change that has been made to our categorization is the distinction between *user experience* and *usability*. In literature different opinions exist for this subject. For our approach, however, we will list usability as it's own research category. Both can be evaluated using questionnaires. However, usability can be measured based on hard facts such as response time, number of clicks, number of errors and has more to do with the effectiveness and efficiency [8].

Furthermore, the *display effectiveness* is considered as a separate research category by Alt [1], aiming to measure the effectiveness of public displays from an economic perspective. Here we combined this category with user experience. One newly introduced category is the evaluation of the *context*. Once detailed information regarding the context is logged, the differences can be evaluated with knowledge discovery algorithms for big data, a whole research field for itself. So far, no previous works are known for a context-based evaluation approach for public display research. Other research questions which came up during literature review were user goals, aspects of collaboration, and user awareness of the display setup.

A list of other people's collections of standardized questionnaires can be found in the bibliography. Lewis and Sauro [35] list 19 questionnaires at the HCI conference. Garcia [22] describes the SUMI, PSSUQ, and SUS questionnaire. The Université de Genève [18] gives an overview of usability and user experience surveys. HTW Chur [16] provides an overview of ISONorm 110, ISOMetrics, AttrakDiff, UEQ, QUIS, and SUMI. For further information regarding standardized usability questionnaires and evaluation methods for multimodal systems the book by Wechsung and Naumann [62] can be used.

| Category | Questionnaire | Description | Used In |
|---|---|---|---|
| **User Experience** | AttrakDiff [25] | Measurement of perceived hedonic and pragmatic quality (in German) | [9] |
| | UEQ / Short-UEQ [27] | User Experience Questionnaire | |
| | QUIS [24] | Questionnaire for User Interaction Satisfaction | |
| **Usability** | SUS [51] | System Usability Scale | [2] |
| | USE | Usefulness, Satisfaction, and Ease of Use | |
| | SUM [53] | Summative Usability Evaluations, for regression analysis, hypothesis testing and usability reporting | |
| | SUPR-Q [52] | Perceptions of Usability, Trust, Credibility, Appearance and Loyalty of *websites* | |
| | NAU [42] | Nielsen's Attributes of Usability | |
| | PSSUQ [22] | Post-Study Usability Questionnaire | |
| **User Acceptance** | IMI [15, 37] | Intrinsic Motivation Inventory | [29, 31] |
| **User Performance** | ISO 9241-9 based [11] | Measuring Physical Demand | [33, 41] |
| | NASA TLX [60] | Subjective Workload Assessment Tool | [6] |
| **Privacy** | PAQ [14] | Privacy Attitude Questionnaire | |
| **Social Impact** | *no found* | Sense of Community-Index | [7, 12, 13] |
| **Context** | *no found* | Systematic and comparable evaluation of the surroundings | |
| **Demography** | PIAAC | Conceptual Framework of the Background Questionnaire Main Survey | |
| | AAL | Adult Literacy and Lifeskills Survey | [21] |
| **Miscellaneous** | MEC-SPQ [61] | Spatial Presence Questionnaire | [29, 31] |
| | GameFlow [58] | Measures the challenge-skills balance, concentration on task, and sense of control | [29] |
| | NSAM | Nielsen's system acceptance model | [31, 44] |
| | NHE [42] | Nielsen's Heuristic Evaluation | |
| | ISONorm110 & ISOMetrics | | [16] |

Table 3.1: Overview of Standardized Questionnaires

**User experience** describes the overall satisfaction and experience the user has with a display. Standardized questionnaires used for evaluating user experience are UEQ, QUIS, and AttrakDiff. In the publication by Beyer et al. [9] AttrakDiff had been used for evaluating the user experience of two public display setups. For measuring the **usability** of an application a large number of questionnaires are available. The most popular ones are SUS (System Usability Scale), USE (Usefulness, Satisfaction, and Ease of Use), and SUM (Summative Usability Evaluations). SUS is the questionnaire most used for measuring perceptions of usability and was created in 1986 by John Brooke [51]. In public display evaluation SUS has already been used by Alt et al. [2]. For all other questionnaires no information could be found, whether they are also suited for public display evaluation. **User acceptance** analyzes user's motives and incentives for approaching the display. The evaluation can be carried out qualitatively (subjective feedback, focus groups) or quantitatively (questionnaires). To this category we added questionnaires related to expectations, user goals, and motivating factors for approaching the display. One such questionnaire taking a look at the user's motives for approaching the display is IMI, used by Jacucci et al. [31]. Although the topic of **privacy** has already been examined by Alt et al. [2], no standardized questionnaires were used. One questionnaire for measuring perceptions of privacy is the Privacy Attitudes Questionnaire (PAQ), developed by Chignell et al. [14]. Another survey found online was is from TRUSTe[15], which takes a look at the users privacy concerns. The category **social impact** considers everything related to social behavior, the influence on social interaction and communities, as well as social effects.

**Context** is a category that was newly added for this work. For most evaluations of classic computer applications, the context changes infrequently. However, for the evaluation of public displays, especially when multiple displays are deployed in different locations running the same application, it is important to also assess the context of the display setup. External influences can be of static and dynamic nature. Influences such as weather, time of day, or special circumstances in the displays' environment count as *dynamic context*. Parameters like display size, display type, position on wall, position in room, or size of the room count are referred to as *static context*. These characteristics can vary between display setups and can influence how the public display application is perceived. Since the evaluation of context differs in between research areas, no questionnaires designed specifically for determining the context of a public display in a standardized way were found. **Demographic** background information gets evaluated in most surveys. These questions range from general (gender, age, religion, education), to more personal questions (relationship status, family, children, country of origin). Often times also character traits, skills, personal beliefs, or political affiliation are of interest. Three detailed background questionnaires which weren't used, but might serve as inspiration are the Adult Literacy and Lifeskills Survey (ALL) [16], the PIAAC Conceptual Framework of the Background Questionnaire Main Survey [17] and a Police Background Questionnaire [18]. **Miscellaneous** contains all questions and questionnaires, which can not be assigned to any of the previous categories. As an example, Cheverst et al. [12] asked for recommendations for possible new features and whether there were any previous experience with Bluetooth. Alt et al. evaluated more detailed usage patterns regarding mobile phone usage, "e.g., how often they used it, if it had a touch screen, if they used it to surf the web, and if they had installed third party apps" [2]. These types of questions do not directly belong to demographic survey, but are part of many questionnaires. Some of the mentioned questionnaires were used in literature [29, 31, 44].

[15] `http://www.cc.gatech.edu/gvu/user_surveys/survey-1998-04/questions/privacy.html` (last accessed on April 23, 2015)

[16] `http://nces.ed.gov/surveys/all/` (last accessed on April 1, 2015)

[17] `http://www.oecd.org/site/piaac/PIAAC(2011_11)MS_BQ_ConceptualFramework_1Dec2011.pdf` (last accessed on April 1, 2015)

[18] `http://www.slmpd.org/images/hr_forms/commissioned/BackgroundQuestionnaire.pdf` (last accessed on April 1, 2015)

## 3.3 Findings

The following results were drawn from the literature review, which can be turned into requirements for our or future survey platforms (see chapter 4).

1. Support both *quantitative* and *qualitative* methods for data collection, since not all research questions can be evaluated only with questionnaires. In the long term it will be necessary to support logging, observations, and/or interviews.

2. Support *multiple* sections. Many questionnaires are built up of different sections. These can either be displayed all at once, be spread across multiple pages, or possibly even be spread across multiple users (see chapter 6, future work).

3. Support various *question types*. The analyzed questionnaires use a variety of question types for evaluation. Amongst others, 5-point Likert scale, 7-point Likert scale, multiple choice responses, numeric answers, text fields, yes-no questions.

4. Evaluate not only the application running on the display, but also the *entire environment*. Differences in the context of the public display often result in different perceptions and user interaction.

5. One constraint of public display research represents the *opportunistic nature* of the setups and the discrepancy between lab studies and field studies [43]. Thus there is an additional demand for evaluating each public display setup individually and if possible directly in the field.

6. Additionally, a *larger number of devices*, platforms and form factors needs to be supported, to cover the whole range of public displays.

These findings from literature review bring us to the next chapter, the development of the survey platform.

# 4 Implementation

In this chapter we will deal with the infrastructure and technical realization of the public display survey platform. First, the requirements for the survey platform are discussed (section 4.1). Subsequently the architecture resulting from the design decisions will be the main focus (section 4.2). To facilitate the training period for successors we will also take a brief look at the software model (section 4.3). For more specific information and for information regarding maintenance of the project, please refer to the documentation found on the CD enclosed (see Appendix A) or on the GitHub repository[19].

In figure 4.2 a brief overview of the *PDSurvey* platform and its components is given. The platform consists of three major parts: a backend for display providers (PDAdmin), a RESTful server (PDServer) and the user interface itself, being embedded on the end user devices (public displays, tablets, smartphones or other devices).

## 4.1 Requirements

Initial requirements were set by the problem statement of the thesis[20]. These requirements were also a trigger for further literature review and talks with people from the industry. The full listing of the initial problem statement is as follows.

1. *development of a survey tool* that allows interactive public display installations to be comprehensively assessed
2. implementation of a web-based survey platform that can easily be used to evaluate and compare public displays through *different channels*
3. *different channels* to support: 1) evaluation directly at the display or 2) through a (mobile) website that allows participation via smartphone or tablet.
4. *configuration options* for public display owners

Additional requirements, that emerged during research and in discussions, are listed below:

- easy *embedding of questionnaires* on websites of public display owners (provide API / embed code)
- support of *various devices*: public displays of all sizes, tablets, phablets, smartphones, desktop devices (responsive web design)
- easy *scalability* of platform; host on a cloud platform
- use a *modular* approach for development, allowing successors to extend and further refine the platform
- support *non web-based platforms*, which are not capable of embedding a website or making REST calls
- focus on *public display evaluation*, take the context into account for evaluation

These requirements combined with knowledge from literature review (see section 3.3), are what makes this platform unique. The long term goal is to create a research platform, optimized for public display evaluation, delivering new insights into how users react to public display setups. Additionally, the requirements mentioned by Huang et al. [28] and Jacucci et al. [31] also influenced the concept and development of the survey platform. All of the mentioned requirements had an impact on the chosen architecture, which will be discussed in the next section.

[19] `https://github.com/lukaszieg ler/masterarbeit/tree/master/docs` (last accessed on April 15, 2015)

[20] `http://www.medien.ifi.lmu.de/lehre/arbeiten/detail.xhtml-php?pub=alt_pdsurvey` (last accessed on March 24, 2015)

## 4.2 Design Decisions

Having assessed all requirements for the platform (see section 4.1), the next step was making design decisions for the programming language and frameworks to use, before starting with the practical implementation of the platform. All options were checked, on the one hand to get informed about what is currently trending, on the other hand because every decision made has a substantial impact on the architecture.

**Programming language** Due to the requirements and objective to support a large number of devices, operating systems, and form factors, a device-independent programming language was preferred. The choice was made of Javascript, not just due to the growing popularity[21], but also because it can be used on the largest number of platforms and devices. Another huge benefit is the ability to use JavaScript for all tiers of development, from client to server to persistence layer. Using the same language on all tiers allows us to share some parts of code between server and client. This approach has become very popular in recent years, now often being encapsulated in a technology stack referred to as the MEAN stack, consisting of MongoDB, Express.js, Angular.js, and Node.js. Some fundamental differences to the LAMP stack (Linux, Apache, MySQL, PHP) are its shift form server-side to client-side single-page applications (SPA), faster prototyping, shift from synchronous to asynchronous, fast page loading times, less time spent writing SQL (schemaless), and the shift to using RESTful services for the backend. [17]

At this point, first thoughts of using the MEAN stack[22] for the entire development arose. Nonetheless, each part of the architecture was compared and evaluated separately, in order to find the optimal solution for this project. Alternative languages considered were: PHP, Python, Ruby, Java and ASP.NET. The biggest drawback was the additional workload on having to maintain the object model on multiple platforms. Javascript reduces the number of models needing maintenance to one. This way consistency across all platforms (backend, frontend, server) can be achieved easily. Based on our requirements of the platform, the feedback received from discussions with industry experts, and the desire to be able to embed questionnaires on 3rd party website, the choice to use JavaScript for the whole development process already became evident.

**Frontend** In recent years single page applications (SPA) have become more popular for creating complex websites [45, 46]. As of 2014, the JavaScript model-view frameworks most frequently used for creating SPA, are Angular.js, Ember.js and Backbone.js. When looking at the numbers and the trend from recent years, Angular.js is the clear favorite [54]. It has by far the largest user base on GitHub, Stackoverflow, and Youtube. When comparing the number of third-party modules, Angular.js also takes the lead with 800 ngmodules vs. 236 Backbone.js backplugs vs. 21 emberaddons. All these factors together indicate a short training time and give hope for beginners making fast progress. One of the biggest benefits of using a framework like Angular.js, is the ability to use two-way data-binding. Changes made to the model are automatically represented in the UI, and vice versa. Furthermore, the possibility to use the templating functionality, combined with the custom directives in Angular.js, was a big plus for this choice. This functionality was used for creating custom HTML tags for the question types in our surveys. These were, amongst others, the reasons why we chose Angular.js for this project, hoping that it will also simplify the ramp-up time for other students.

To speed up frontend development we chose Bootstrap[23] as our CSS framework of choice. Reasons for choosing Bootstrap were the large community, extensive documentation with helpful examples, large number of free tutorials and templates, its excellent integration with Angular.js

[21] `http://www.sitepoint.com/javascript-internet-things/` (last accessed on November 27, 2014)
[22] `http://mean.io/` (last accessed on March 26, 2015)
[23] `http://getbootstrap.com/` (last accessed on December 1, 2014)

(AngulatStrap[24] and AngularUI[25], the short training time, and its broad acceptance. Alternatives considered were Foundation Framework by Zurb. However, at the time of writing there was no prefabricated integration for Foundation and Angular.js. Additional frameworks were also taken into consideration, evaluated [23] and compared [36] to currently popular frontend frameworks.

**Backend** For the backend it was of importance to have a solid performance and scalable solution. Because our system has a multiplicity of clients submitting and querying questionnaires to the survey platform, scalability is of importance in order to be future proof. Additionally, it was of importance to offer an interface for administrators and to be able to easily be able to exchange data with a large number of clients. For this reason a backend built solely on the principles of a RESTful API was preferred. This allows us to query data no matter from which client. Based on the decision to use JavaScript for all tiers, it was also clear to use Node.js as the underlying platform for building web applications. Reasons speaking for Node.js are its event-based and modular approach, only requiring the parts needed for your project. Another benefit is the easy implementation of authentication and internationalization, due to the concept of middlewares [47] and the native serialization of JSON. Furthermore it is ideal for reusing code, due to its modular and lightweight architecture and the npm package manager [48, 56]. To simplify and speed up development with Node.js, Express.js[26] was chosen as the web application framework. Alternatives considered were Connect (simpler, less functionality, predecessor of Express), Koa[27] (generator concept) and Resitfy[28] (Express reduced for pure REST services).

Due to the decision of building a single-page application, it became vital to separate the data from presentation layer. Using a RESTful service is the current de facto standard. An alternative would be to use SOAP for message exchange. This would not only lead to an increase of data overhead, but also to a higher complexity on the server-side, and to the loss of statelessness in the requests. In the case that a client does not support HTML or JavaScript execution, the required surveys can still be requested directly through HTTP function calls from the REST API. Such an exception was Quest3D[29], a software package used by Jiamin Shi for the development of the Balloon Shooter game. When in a situation where HTTP calls are not supported natively, then one can still use logging combined with a scheduled task or create a proxy on the operating system layer and tunnel all data to *PDServer*.

**Database** Another fundamental aspect presented the question of where to store the data permanently. Criteria for choosing the right database management system (DBMS) for this project was made according to criteria like the size of community, suitability for prototyping, and ease of integration with Node.js/Angular.js. The first question presented was whether to choose a SQL or a NoSQL DBMS. We chose NoSQL for this project, because of better scalability, a schemaless data representation, faster response time and a decreased development time [59]. Otherwise, NoSQL is better suited for rapid prototyping, because multiple schemata can be mixed inside of one collection and easier evolve more easily over time.

Out of the NoSQL databases MondoDB[30] represents the most popular DBMS, especially since it integrates seamlessly into the MEAN stack. Benefits of MongoDB are that it is non-relational (and schemaless), along with its ability to directly store JavaScript objects inside the database. Other characteristics of MongoDB are the non-blocking write operations, which is ideal for log-

[24] `http://mgcrea.github.io/angular-strap/` (last accessed on April 10, 2015)
[25] `https://angular-ui.github.io/` (last accessed on April 10, 2015)
[26] `http://expressjs.com/` (last accessed on April 10, 2015)
[27] `http://koajs.com/` (last accessed on April 10, 2015)
[28] `http://mcavage.me/node-restify/` (last accessed on April 10, 2015)
[29] `http://documentation.quest3d.com/index.php?title=FAQ#What_is_Quest3D.3F` (last accessed on April 10, 2015)
[30] `http://www.mongodb.org/` (last accessed on March 26, 2015)

ging data. MongoDB provides a good compromise between scalability/performance and the depth of functionality. One disadvantage is that MongoDB does not support joins or transactions. For our use case, however, this is no major drawback. The benefits outweigh the disadvantages. Alternatives that we looked at were CouchDB and Redis. Redis is useful for fast changing data, which is not required on our platform. CouchDB would be an alternative worth looking at, as it has a better replication and conflict resolution. However, this additional security is not needed. The speed benefits of MongoDB are preferred.[31]

To facilitate the object modeling process in Node.js, Mongoose[32] was chosen, providing object relational mapping. Mongoose is an object modeling package for Node.js, allowing application data to be modeled based on schemata. Mongoose takes care of performing CRUD applications and simplifies the process of keeping the object model synchronized across all layers.

**Hosting** For the hosting of the platform a free and easy scalable solution was of importance. Services offering Platform as a Service (PaaS) were preferred over ones offering Infrastructure as a Service (IaaS), because our focus is on developing and evaluating the platform. We considered the following platforms: Heroku (PaaS), IBM BlueMix (PaaS), Google App Engine (PaaS), Amazon AWS (IaaS), or hosting the entire platform on a local machine.

Our first choice was Heroku[33], due to its simple setup, its native support of Node.js, and seamless integration with Mongolab[34], a platform for hosting MongoDB collections. IBM BlueMix was considered as an alternative, which was recently overhauled and now offers full out-of-the-box Node.js support. However, only the first 30 days are free and the pricing model wasn't as attractive. Google App Engine still has no native support for Node.js (as of December 2014) and custom runtimes had to be used to get Node.js support up and running. Amazon Web Services, offering Infrastructure as a Service (IaaS), would have required too much administration of the server. This would have slowed down the main objective of the project, the development of the survey platform[35]. The same goes for the last option, hosting a MEAN-stack environment on our own servers at LMU Munich. All of the above are well-known solutions in the industry. However, due to simplicity and ease of use we chose Heroku. For our requirements during the prototype phase Heroku was sufficient, offering one free Heroku *dyno* [26].

[31] `http://kkovacs.eu/cassandra-vs-mongodb-vs-couchdb-vs-redis` (last accessed on March 26, 2015)
[32] `http://mongoosejs.com/` (last accessed on November 14, 2014)
[33] `https://www.heroku.com/` (last accessed on March 26, 2015)
[34] `https://mongolab.com/` (last accessed on March 26, 2015)
[35] `http://smashingboxes.com/ideas/heroku-vs-amazon-web-services` (last accessed on April 10, 2015)

## 4.3 Modeling

The development process of the *PDSurvey* platform was inspired and influenced by the concept of extreme programing[36], making iterative improvements, and working agile and user-centered. First user stories were written and assessed in a small group[37]. The next step was to transfer these stories to user models, describing in detail which functionality the stakeholders of *PDSurvey* are supposed to have. Later a first software architecture and software model was built. Dependencies between models were defined and the model was continuously refined and improved throughout the development phase. The last phase included screen designs, getting a clear view of what the interface should later look like.

The development of the REST API was influenced by current best practices [4, 30, 50]. The API is separated into logical resources, while each resource gets manipulated through an HTTP request. For public access GET and POST methods are defined, for authenticated users also PUT and DELETE methods. For a more information about *PDSurvey*'s REST API refer to the documentation (see Appendix A). The model for the *PDSurvey* platform is maintained with Mongoose. Angular.js builds its model from the REST API, and maps all changes via dynamic two-way-binding to it's scope. The REST API is provided by the Node.js server, which maps all incoming requests through an Express router to the corresponding Mongoose models. Thus all changes to the model originate from Mongoose. The software model is modeled in Mongoose and stored as MongoDB collections. There are the following collections: Question, QuestionType, Response, Category, Surveys, DisplayModel, Display, Campaign, Context, and User. Of special interest are the following four collections: Surveys, Display, Campaign and Responses (see figure 4.1).

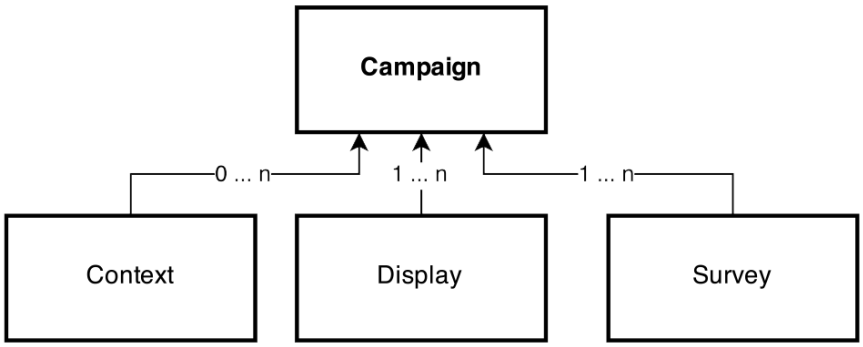



Figure 4.1: Campaign model dependencies.

**Surveys** Surveys are the foundation of *PDSurvey*. In the current version of *PDSurvey* questionnaires are implemented as one possible method for assessing the users' opinion. The 'Survey' model consists of multiple sections, which in turn are made up of multiple questions. Each question is of a corresponding question type and every questionnaire belongs to a category. This allows questionnaires to be filtered based on certain research questions. Additionally we added the ability to set surveys *private* (by default), *shared* (for sharing with other users), *standardized* (scientifically recognized), or *pending* (waiting for review, to be shared). Every survey is assigned to an individual user of the platform, with the aim of reuse and standardization of questionnaires.

[36] `http://www.extremeprogramming.org/rules.html` (last accessed on April 10, 2015)

[37] `http://www.tigertech.de/wie-schreibe-ich-eine-gute-user-story-und-was-ist-das-uberhaupt/` (last accessed April 10, 2015)

**Display** In the display collection all displays connected to the *PDSurvey* platform are contained. To allow evaluation across multiple display models and based on the context of the displays, the display model and a static and/or dynamic context is assigned to it.

**Campaign** Campaigns resemble the most integral part of the platform. Each campaign consists of multiple displays and multiple surveys, resulting in a mapping of surveys to public display networks. Additionally, to each of those mappings an individual context can be assigned, enabling a comparison of results of public displays later on.

**Response** All responses made to each survey are logged in the Response collection. The queries are logged individually per user, per display and per campaign. This model will be the base for further extensions, such as the automatic evaluation of the survey responses and the comparison of different displays inside one display network. This enables the administrator to find out which properties of a display might cause certain effects.

**Context** One of the benefits of creating this survey platform is the ability to collect and evaluate large amounts of data, without increasing the workload on the human component for conducting and evaluating the responses. The idea is to collect a large number of responses from a variety of displays in various settings, and assign a specific context to every display connected to *PDSurvey*. Once enough data is collected, the results can be evaluated and compared between the displays. Interesting questions for analysis would be, what role the context plays on how the users respond to the display, when running identical software settings on the displays, but only varying the context (position, size of display, surrounding environment of the display, positioning it outdoors or indoors, influence of the weather, type of building it is positioned in).

## 4.4 PDSurvey Platform

The public display survey (*PDSurvey*) platform aims to facilitate the execution and evaluation of surveys on and for public displays. The interactive survey platform, which can be embedded directly onto public displays and be used as a direct feedback channel from inside another application, can be split into three main parts: PDAdmin, PDServer, and PDClient (see figure 4.2). *PDAdmin* contains the administrative interface, allowing display providers to configure questionnaires for their public displays. *PDServer* accommodates the REST service, the persistence layer, and the majority of the application logic. *PDClient* is a web-based interface, containing one possibility for responding to the deployed surveys. The code base of all three parts is deliberately separated from each other, allowing the independent refinement and less dependence between the frontend, the backend, and the server.

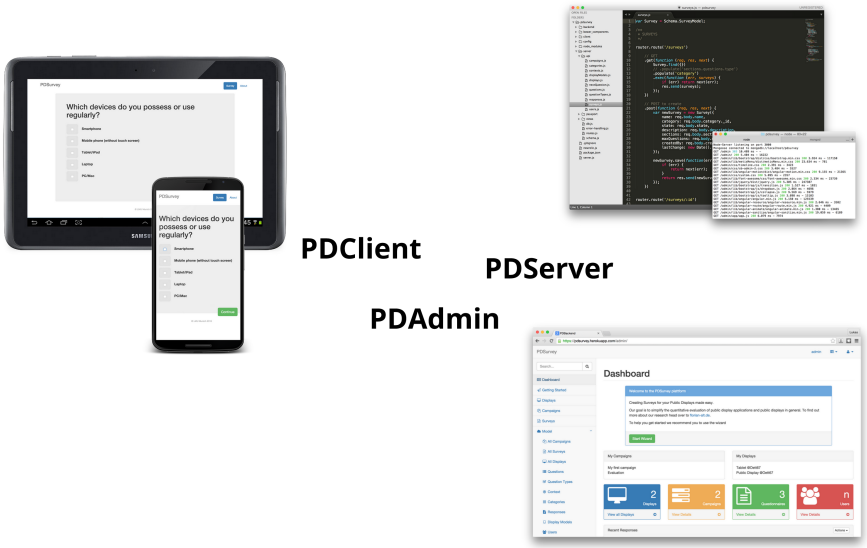
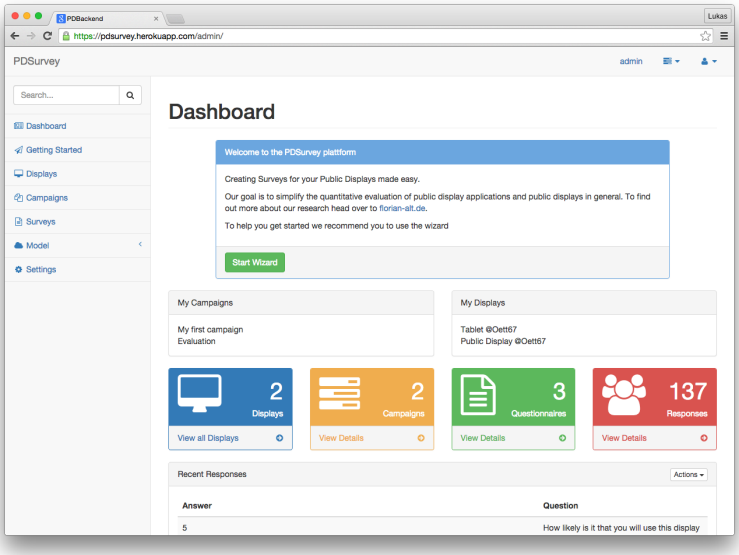


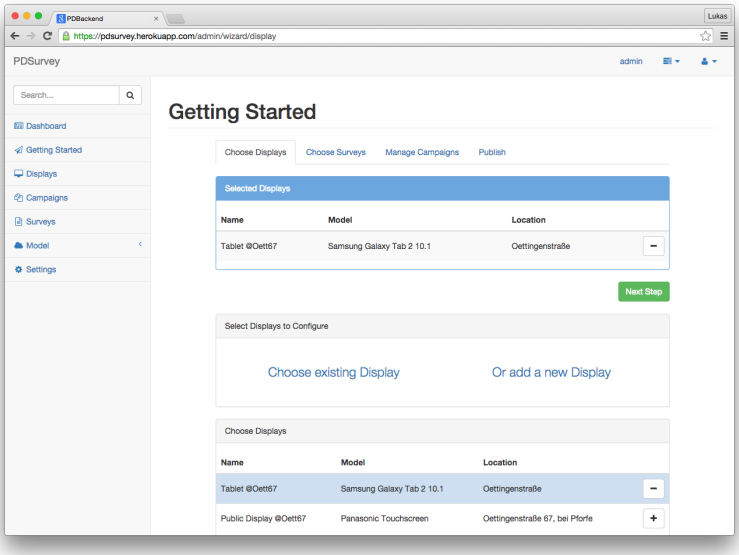

Figure 4.2: Overview of the PDSurvey platform: (a) PDClient contains the responsive interface for PDs, (b) PDBackend is the entry point for administrators, (c) PDServer consists of Node.js and provides a REST API.

### 4.4.1 PDAdmin

For administrative purposes an admin interface was created, enabling display providers to create, manage and distribute surveys to public displays. Display providers have the ability to create their own questionnaires or to select from a list of standardized questionnaires (chapter 3). The entry point for PDAdmin is the dashboard (see figure 4.3a). There users get an overview of all relevant information such as how their campaigns are running, and how many responses have been submitted already. For new users, who haven't created any campaigns, questionnaires or displays yet, the *Wizard* (see figure 4.3b) will be the best place to get started with the survey platform. Users get guided through the creation process of campaigns step by step. For more experienced users the navigation options *Displays*, *Campaigns*, and *Surveys* are more advisable. Administrators of the survey platform additionally have the ability to add new *Users*, *Question Types*, or research *Categories*.




(a) Dashboard




(b) Wizard

Figure 4.3: Overview of PDAdmin.

### 4.4.2 PDServer

The server was written in Node.js and to the outside only offers a RESTful API. All interactions users or developers make with the server are HTTP calls. When performing CRUD operations, all REST calls need to be executed and JSON objects are returned. Besides this REST functionality a rudimentary authentication mechanism is already implemented on the server and the capability for further logic, determining which client should ask which question next. This functionality might become of interest when trying to spread standardized questionnaires of longer length across multiple users or multiple displays. It would be intended for the server to keep track which questions have already been answered and to tell each instance of PDClient which question to ask next, in order to achieve a balanced question profile. The specification of PDServer's REST API can be found on GitHub[38] and on the enclosed CD (see Appendix A).

### 4.4.3 PDClient

Our client tool was kept as simple and minimalistic as possible. The only communication between PDClient and PDAdmin is via REST calls, exchanging JSON objects. Even though both PDClient and PDAdmin are developed using Javascript frameworks, they have a separate code base. Reasons for this were on the one hand reduction of the application size, on the other hand different requirements of the client version and the administrator panel. PDClient needs to be highly scalable and offer a low latency and fast response time. For PDAdmin it is more important to offer a better usability and a more visual appealing presentation of the results. The goal is to reduce logic and complexity on client-side. Currently PDClient loads all questions for the questionnaire at startup and caches them for later access.

PDClient has three main components (see figure 4.4). The principal part is the *Survey page*. All questions are loaded at once on startup. Then one question gets displayed at a time. Settings for the survey can be modified from PDBackend (e.g. number of questions to display and duration of the survey). Once the user makes a choice, it is directly logged on the server. In a case when a participant aborts answering the survey, the questions answered so far are still recorded. The *About page* was added, since some employees from university said they were skeptical and had doubts regarding the research project, when there is no information whatsoever about which information is logged. To motivate people to participate, a *Welcome page* was added. It turned out that a significantly larger number of people were willing to participate in a survey, after finding out that it will only take one minute, the research is university-related and that it will be used for a Master's thesis.

### 4.4.4 EmbedCode

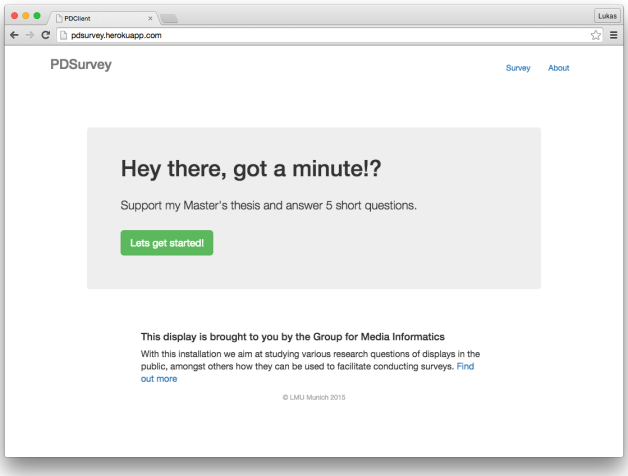
Offering an embed code for surveys, turned out to be a pure proof-of-concept. The problem was that the Balloon Shooter game, on which *PDSurvey* should be integrated, did not support any HTTP calls or overlays. Thus, we had to fall back on another solution. This embed code was intended to be used by display operators, wanting to include questionnaires hovering over their web-based public display applications (see figure 4.5). The technical realization was inspired by Web Bug [39], and the embed code offered by Google Analytics[40].

One minified line of JavaScript code needs to be added before the closing HTML <body>-tag. This minified line creates a <script>-tag in the Document Object Model (DOM) of the HTML page and injects a JavaScript file from the *PDSurvey* platform. This personalized scripts first loads jQuery and/or Angular.js asynchronously, creates an instance of PDClient inside of the primary

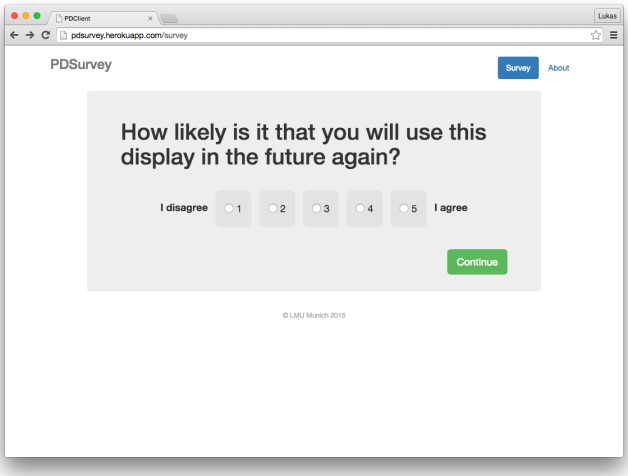
[38] `https://github.com/lukaszziegler/masterarbeit/tree/master/docs` (last accessed on April 15, 2015)

[39] `http://en.wikipedia.org/wiki/Web_bug` (last accessed on November 26, 2014)

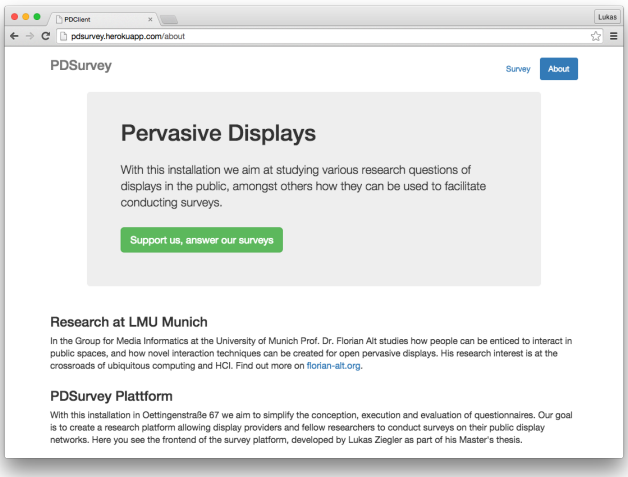
[40] `https://developers.google.com/analytics/resources/concepts/gaConceptsTrackingOverview` (last accessed on November 26, 2014)




(a) Welcome Page




(b) Survey page




(c) About page

Figure 4.4: Overview of PDClient.

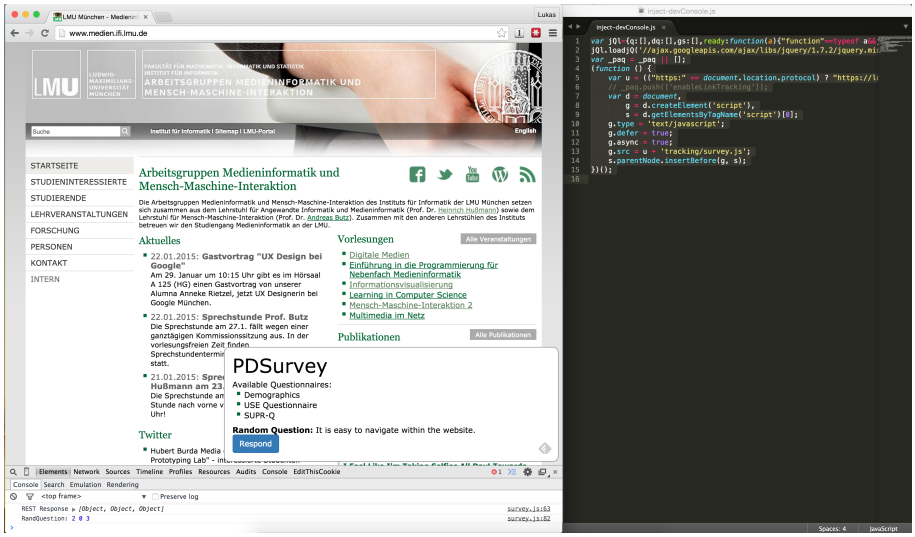



Figure 4.5: Embed Code - Prototype for injecting a questionnaire on a remote website.

website's DOM. All questions for the questionnaire get loaded via PDServer's RESTful API and the responses get sent back to the server for logging. To avoid conflicts caused through the code injection, all classes and files are prefixed with a unique namespace. Depending on the type of implementation it is better to use jQuery or Angular.js [34]. In the current prototype the full version of PDClient is not mirrored yet entirely to the browsers DOM.

# 5 Field Study

The field study took place during the first two weeks of March, from 3/3/2015 to 3/15/2015 in Oettingenstrasse 67, a faculty building of Ludwig-Maximilians-Universität München. Data was collected from the display setup on 14 consecutive days and 28 semi-structured interviews were carried out on five working days during the same two weeks. A total of 117 interactions were registered with the public display installation and 57 survey responses were recorded. The goal of this study was to test our research questions, and to see how users respond to questionnaires conducted on public displays. We chose to carry out a descriptive study, with a focus on ecological validity, since the research prototype was still in an early stage at this point.

## 5.1 Research Questions

One of the main reasons why we conducted this field study, was to get a better understanding of our assumptions and to see how users react to questionnaires on displays in public settings. Besides, it was of importance to conduct a study "in the wild", because there often is a discrepancy between lab studies and field studies. This phenomenon was discussed by Ojala and Kostakos in 2011: "The first important conclusion we have arrived at, [sic] is that there exists a huge difference between results obtained in a lab and in the wild using the exact same configuration" [43].

One hypothesis we made for the development of our first research prototype of the *PDSurvey* platform was that we can simplify the process of conducting and deploying surveys to large public display networks. Since this is a rather large claim, we broke down this hypothesis to the following more fine-grained statements:

1. Which feedback channels are best suited for completing surveys in public?
2. Why did users approach the display? What motivates them to fill in surveys in public?
3. How did the user notice and perceive the survey on the display?

In addition to these questions we were also interested in user stories, the feedback real-world users gave us in regards to answering surveys on screens in public. For this reason we also conducted semi-structured interviews in parallel to the quantitative evaluation of the *PDSurvey* platform. In order to get as authentic and personal feedback as possible, we stuck loosely to the designated questions of the semi-structured interview (see Appendix B), in order to allow users to also tell us stories about areas which we had not thought of before. These research questions influenced the questionnaire we deployed using *PDSurvey* and the questions we asked in the semi-structured interviews. Questions which go beyond the scope of this thesis, and might serve as follow-up questions for further research, are gathered in chapter 6, Future Work.

## 5.2 Pre-Study

Before starting the field study, multiple small pre-studies were made with fellow students and research staff at the chair for Media Informatics. We wanted to get early feedback in the development process for *PDSurvey*. For PDAdmin findings include providing a suitable entry point, general comments regarding how to improve layout and user flow, and to offer a Wizard for beginners. For the admin interface it turned out to be important to reduce all available features to a minimalistic interface, even though the platform is designed to support a wide variety of options.

The days prior to the launch of the actual field study were used for assembly and for last adjustments, like change of font size, adjustment to the position of certain UI elements, and for collecting implicit feedback from users observing but not approaching the display. From only watching the people passing by, it could be seen that a more effective call-to-action was needed. Many people looked at the display and noticed that something had changed with the setup, but no

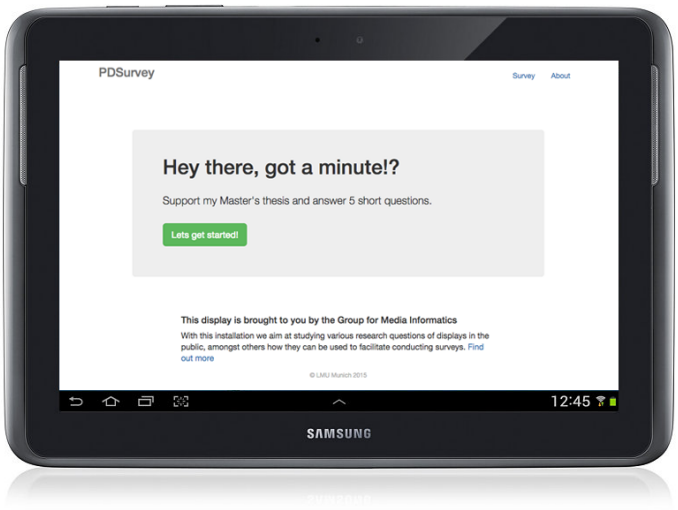



Figure 5.1: The Welcome Screen of PDClient, using intrinsic motivation to motivate users to participate in a short questionnaire.

one started interacting or was willing to complete the questionnaire. To increase the motivation for users to participate, the start screens were improved based on the findings of the self-determination theory introduced by Richard Ryan[41] [49]. We stated on the Welcome screen of the tablet (see figure 5.1) and on the Options panel of the TV Screen (see figure 5.2) that the questionnaire only consists of five questions, that it will only take one minute to complete and the results are for a Master's thesis at the university. This resulted in an increased response and acceptance rate of the survey.

## 5.3 Study

We deployed the *PDSurvey* platform to a public display setup, which had already been running since several months in the entrance hall of the faculty building. The public display setup had consistently attracted new and returning users to participate. A descriptive research type was chosen as the study type. Our aim is to describe and observe how users react to the new display setup. Only one study prototype is deployed, without varying any variables. The goal was to get first feedback on how people perceive filling in questionnaires on digital signage in public, before getting into more fine-grained research (see chapter 6). Both quantitative and qualitative data was collected as part of the field study. Quantitative data was obtained through the *PDSurvey* system and qualitative data was collected through semi-structured interviews. The distribution of the preferred feedback channel was logged inside of the Balloon Shooter game (see section 5.3.2) and asked in all semi-structured interviews.

### 5.3.1 Design

Our primary goal was to find out which feedback channel users preferred to respond to surveys in public. Each user had the choice to respond to the questionnaire on a TV display (1), on a tablet (2) to the right of the TV screen, via their own smartphone (3) or via email (4). The order of all four feedback options was randomized. After completing the Balloon Shooter game on the primary TV screen, each participant was confronted with an options panel (see figure 5.2), asking the user to support our research and to respond to a short questionnaire. The feedback channel

[41] http://www.selfdeterminationtheory.org/


Figure 5.2: Options panel, embedded after a game of Balloon Shooter, prompting the user to choose a feedback channel. Screenshot by Jiamin Shi.

chosen was logged and the user had the opportunity to respond to the same questionnaire on any of four feedback channels. We displayed the same five questions (see table 5.1) and chose to limit the number to five questions, to avoid low participation rate and low response rate.

| **Wording** | **Question Type** |
|---|---|
| 1. How often have you used this display before? | Numeric |
| 2. How likely is it that you will use this display in the future again? | 5-point Likert scale |
| 3. Which devices do you possess or use regularly? | Multiple choice, 5 options |
| 4. In which area do you study / work? | Text field |
| 5. What was your motivation for approaching and using this display? | Text field |

Table 5.1: Questions asked on all four feedback channels.

In order to also get first insights into how well certain question types are suited for surveys in public, where a short completion time is crucial, we varied between the following question types and kept them in the same order: numeric questions, Likert scale, multiple choice (based on check boxes) and two text fields for responses of undefined length. Due to the nature of descriptive studies, we only observed the users' behavior and observed how our study setup was used. The parameter of interest was the feedback channel chosen to respond to the survey. Since we didn't vary any conditions, no independent variables are present. To find out more about the users' motives for approaching the display setup, we also carried out semi-structured interviews in parallel to the field study of the PDSurvey platform. The goal of the interviews was to get qualitative feedback from all age groups and backgrounds. Getting a better understanding of how people respond to questionnaires in public, helps us improve the *PDSurvey* platform.

### 5.3.2 Apparatus

The permanent setup consisted of a 55-inch touch-sensitive TV screen, connected to a laptop running on Windows 7, and a Samsung Galaxy Tab 10.1 tablet positioned to the right of the TV screen on a console. The TV screen was positioned on a 60cm high stand, resulting in a positioning at eye level. The tablet was placed on and fixed to a conductor's stand to the right of the TV screen (see figure 5.3). Our object of investigation was the TV screen with touch support, running an interactive game called *Balloon Shooter*, developed by Jiamin Shi. After users completed the game, they were asked via a prompt to fill in a questionnaire on one of the four provided feedback channels (see figure 5.2). The courtesy for the Balloon Shooter game and

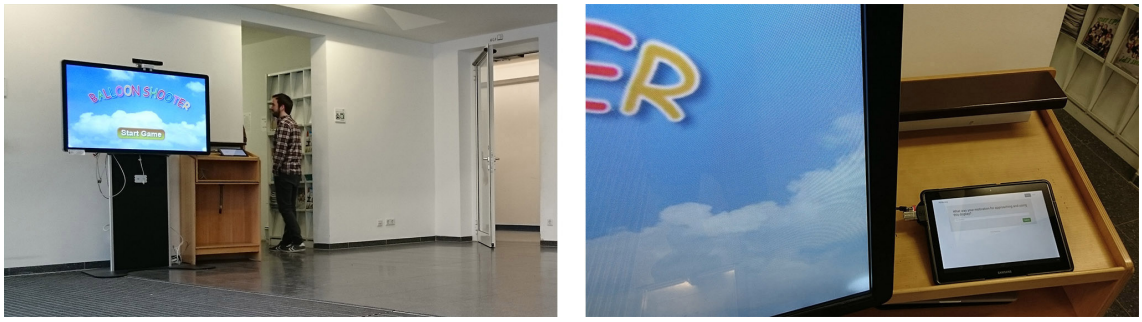



Figure 5.3: Overview of the study setup in the entrance hall of the faculty building.

the survey implementation on the TV screen goes to Jiamin Shi.

Each user had the opportunity to respond to the *questionnaire* either directly on the TV screen (1), on the tablet to the right of the big TV (2), via their own smartphone (3) or via email (4). The first option was embedded natively into the Balloon Shooter game, offering a consistent UI and the most direct feedback channel. When choosing the tablet as an option, users were prompted to move to the right and to answer five questions on the tablet. The Android tablet was running KioWare Lite[42], a kiosk app for Android, and displaying the responsive frontend of PDClient for the entire time of the study. Choosing the third option prompted the user to either scan a QR code with their smartphone or to open a URL[43] in their mobile browser. The last option consisted of an input field embedded into the Balloon Shooter game on the TV screen, asking the user to enter their email address. The address was logged to a txt-file, which was scanned every 5 minutes by the Windows task scheduler. An email reminder was sent to the user with a request to complete the survey. For sending the email from the TV screen, a Python script[44] was written, using a modified version of TLS authentication in order to comply with the university's SMTP server. Screenshots of all four options can be found in Appendix D on page 49. For the permanent setup the following data was logged: the timestamp of the users' choice, which feedback channel the user chose to respond to the survey, and whether they skipped the call to participate in the survey or if they stopped playing the game (determined via timeout). On all four feedback channels a self-made questionnaire was used, since the focus was on finding which channels and question types are best suited in general for being used on public display. This was the reason why we did not use any of the standardized questionnaires mentioned in chapter 3.

For conducting the *semi-structured interviews*, two questionnaires were used as a rough guide, one for participants, and one for passerby. A voice-recorder (smartphone) was used additionally to record the interviews, to be able transcribe and code all of conducted interviews. Each semi-structured interview loosely followed the outline presented on page 48. Audio recordings and transcriptions are on the attached CD. The main application installed on the public display was a game called *Balloon Shooter* developed and run by Jiamin Shi, a PhD student at the Group for Media Informatics at LMU Munich. It was first installed on January 7th 2015 and has been running in different versions since then. The public audience had already used it for roughly two months and had adapted to it well. In 2.5 weeks in February[45] usage statistics reported that the game was played a total of 305 times.

[42] `http://www.kioware.com/android.aspx` (last accessed on April 21, 2015)
[43] `https://pdsurvey.herokuapp.com/` (last accessed on April 21, 2015)
[44] `https://github.com/lukasziegler/python-send-mail` (accessed on March 15, 2015)
[45] Based on the evaluation of log data from 05/02/2015 to 23/02/2015, reported by Jiamin Shi.

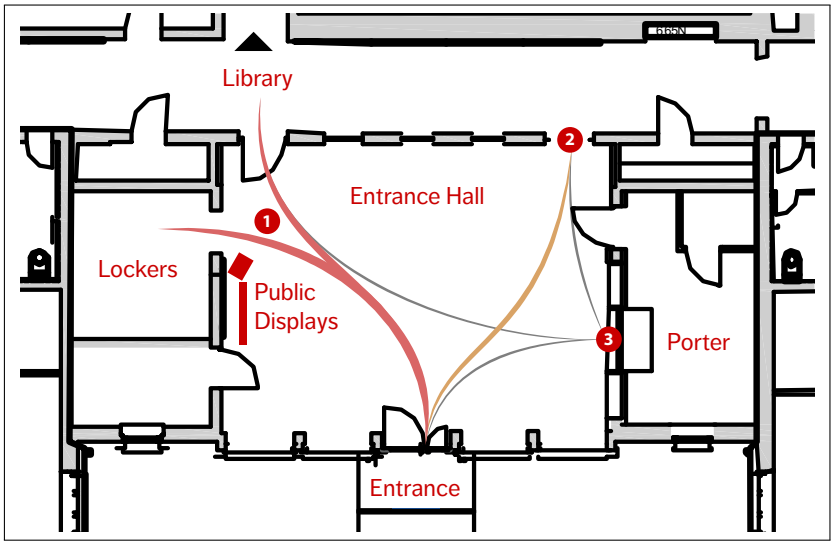



Figure 5.4: Floor map of the entrance hall, where the field study was carried out. User paths, and the surrounding environment including facilities such as the library can be seen.

### 5.3.3 Location

All parts of the field study were carried out in Oettingenstrasse 67, the faculty building for Computer Science of Ludwig-Maximilians-Universität München. Research institutes for Ethnology, Political Science, Japanese Studies, and Physics are also located in the same building. The study was carried out in the entrance hall of the university building. Figure 5.4 gives an overview of the entrance hall and of the paths most people take while crossing the room. The excerpt is based on the universities floor plan[46], and was inspired by Sandra Zollner [64]. For her bachelor's thesis she conducted a study in the same location one year ago and analyzed the visitor flow. According to Zollner "approximately 59% of all passers-by used path 1" to get something from the lockers or to leave through the door to the library. 28% of the people were taking path 2 and 13% were taking path 3. In our field study it was also evident that the majority of the visitors took path 1. This group usually was fairly target-orientated, or in a hurry. Otherwise, on days with bad weather, people had their break in the entrance hall, or waited for someone. On days with good weather people usually took their breaks outside and only passed through the entrance hall, coming from the library, picking up something from the locker room and going outside.

### 5.3.4 Procedure

All participants of the semi-structured interview were asked a similar set of questions (see Appendix B). Based on the group they belonged to, either questionnaire 1 (for participants of the display setup) or questionnaire 2 (for passersby) was chosen. In order to speed up the interviewing process and to get away from a plain question-response schema, the questions on the printed out questionnaire only served as a rough guideline.

For people having trouble understanding the concept of the public display installation, the situation was described as follows. "Imagine you are in a shopping mall or at an airport using one of those large displays to find some information. After finding what you were looking for, you are asked to answer a short questionnaire. How would you react to it?" A full transcription of all questions and responses can also be found on the enclosed CD.

[46] `http://www.uni-muenchen.de/funktionen/gebaeudeplaene/7070_d_00.pdf` (last accessed on March 22, 2015)

The participants for the PDSurvey questionnaire were not additionally motivated. All they saw was the options panel after completing the Balloon Shooter game (see figure 5.2) or the welcome screen of the tablet (see figure 5.1) while passing through the entrance hall. A complete copy of what the users were able to interact with, can be seen on the attached CD (see Appendix A).

### 5.3.5 Participants

In total 57 questionnaires were submitted and 28 semi-structured interviews were conducted during the two week study period. As for the study size, we took the findings from Alt et al. [3] as a rough guide, for how many participants to include in our study. According to Alt et al. most field studies have an average of 26.9 interviews and 38.4 questionnaire responses. Information about the background of the participants was assessed both in the questionnaire and in semi-structured interviews (see table 5.2). Due to the limited number of questions in the questionnaire, only one the age of the participant was asked. In the semi-structured interviews information regarding the participants' age, gender, and working/study area were asked.

Based on the fourth question ("In which area do you study / work?") we can draw a conclusion about the study field of the survey participants. As far as indicated all people responding to the *questionnaire* installed on the public display setup were students. Out of 57 responses, 42 could be assigned to a study field. The remaining 12 submissions consisted of responses such as *bavaria, bib, home, munich, muc* or were left empty. The study fields most frequently represented were Computer Science (23.8%), followed by Political Science (14.3%), Japanese Studies (11.9%), and Anthropology (11.9%), Cultural Science (9.5%), and Business (9.5%). Other study fields mentioned were Physics, Sociology, Ethnology, Communication Science, Sports, and Science & Technology.

For the *semi-structured interviews* we collected more detailed information about the participants' backgrounds. Out of the 28 participants, 72.4% were male and 28.6% were female. The average age was 31 years, with an age distribution ranging from 20 years up to 69 years (median=25, SD=13.2). Due to the wide variety of faculties and a library being located in the same building, various technical backgrounds were present. What they all had in common was their affiliation to LMU Munich, either because of being a student themselves, working at the university or being otherwise connected to the university. In total 23 students, three employees, and two retirees were interviewed. The study fields which were most frequently represented are Computer Science (16.7%), Japanese Studies (16.7%), Ethnology (12.5%), and Political Science (12.5%). Other areas mentioned were Sociology, Communication Science, Law, Physics and Engineering. Eleven of the 28 interviews were conducted with actual participants of the public display study setup (39.3%), the remaining 17 interviewees (60.7%) consisted of people passing-by the display setup.

The selection of participants for the completion of the *questionnaire* was not influenced by us. All survey responses were made in their own interest and no reward was given for participating in this "in the wild"-study. The selection of the participants for the *semi-structured interviews* was influenced by how users reacted to the display setup. Our primary goal was to observe and interview active users of the public display setup, in order to get a better understanding of how they perceived the setup and to get insights into which feedback channel they chose and why they chose it. In order to also understand why people did not approach, or if they have any concerns, people passing by were also interviewed.

Before starting the semi-structured interviews, all people participating were asked whether they had already noticed the display setup and/or the option to fill in a survey. This allowed us to consider the novelty effect for evaluation and to differentiate between three groups: participants who approached the display by themselves (and were observed doing so), people passing by the display (noticing the display, however not approaching it) and the last group of people simply passing by (not having noticed the display). The distribution between the groups was as follows:

| | Participants Of Survey | | People Interviewed |
|---|---|---|---|
| 10 | Informatics | 4 | Informatics |
| 6 | Political Science | 4 | Japanology |
| 5 | Japanese Studies | 3 | Ethnology |
| 5 | Anthropology | 3 | Political Science |
| 4 | Cultural Science | 3 | *employees* (PhD, public officer, SysAdmin) |
| 4 | Business | 2 | *in pension* |
| 2 | Physics | 1 | Communication Science |
| 2 | Sociology | 1 | Sociology |
| 1 | Ethnology | 1 | Law |
| 1 | Communication Science | 1 | Physics |
| 1 | Sports | 1 | Engineering |
| 1 | Science and Technology | | |

Table 5.2: Demography for the survey data (left) and the semi-structured interview (right).

11 active participants, 14 passerby (who had noticed the displays before), and 3 passerby (who saw the display setup for the first time).

Out of all people passing by no one has noticed the option to fill in a survey. Out of the active participants, 5 out of 11 have noticed the option to respond to a survey on different channels. To increase the amount of feedback, we approached people from all three groups. The number of survey responses was not artificially increased by asking passersby was.

## 5.4 Results

We received a total of 57 filled in surveys, submitted via all four of the provided feedback channels, and carried out 28 semi-structured interviews. No treatments were applied to the dataset, descriptive statistics will follow below. The presentation of the evaluation is divided into three parts. First, we review which feedback channel is most popular, followed by the quantitative results of the PDSurvey questionnaire, and concluding with the results from the semi-structured interview.

### 5.4.1 Feedback Channels

The preferred feedback channel was determined in three ways, first, based on the log file from the options panel of the TV screen (see figure 5.2), second, based on the interview responses, and third, by analyzing all of the logged questionnaire responses made on all four feedback channels. The third way, however, has to be treated with caution, since it evaluates all logged responses, which is prone to distortions.

For the first way, users had the option to choose one of the four offered feedback channels through a selection on the large TV screen. Based on this log data of the TV screen, a good comparison of the feedback channels can be made, since all direct responses made on the tablet are excluded from this summary. The most popular feedback channel was the tablet (46.15%), followed by the TV screen (30.77%), smartphone (15.38%), and email (7.69%). In order to have another source of input, the same question was asked at the end of every semi-structured interview. Based on this quantitative data from the interviews the response via tablet (42.86%) was most popular again, followed by the TV screen (32.14%). Interestingly, for the interview data the option to respond via email (17.86%) is more popular than smartphone (7.14%).

When evaluating all logged responses, the same sequence can be seen. The majority of the surveys were completed through the tablet, followed by the TV screen, smartphone, and email. The ratio, however, is highly distorted for this scenario. This is due to the tablets sole purpose being used to fill in surveys in our setup, and the additional intrinsic motivation given directly on the tablet's start screen (see section 5.3.1). The following ratio has to be treated with caution. In

| From Log Data | |
|---|---|
| 30.8% | on public display |
| 46.1% | on tablet |
| 15.4% | on smartphone |
| 7.7% | at home / via email |

Table 5.3: Based on survey responses.

| From Interviews | |
|---|---|
| 32.1% | on public display |
| 42.9% | on tablet |
| 7.1% | on smartphone |
| 17.9% | at home / via email |

Table 5.4: Based on interview questions.

Table 5.5: Preferred feedback channel for answering surveys.

total 57 responses were made on all four feedback channels, 50 originated directly from the tablet (87.72%). 4 responses were recorded on the TV screen (7.02%), 2 via smartphone (3.51%), and 1 via email (1.75%). Since this listing only contains the number of responses, it should not be taken as a base for the comparison of the feedback channels' popularity. For a comparison of the feedback channels the log data from the options panel and the responses of the semi-structured interviews are more suitable (see table 5.5).

### 5.4.2 Survey Responses

Next is the evaluation of all responses made to the questionnaire. In total, 5 questions were asked on each feedback channel and 57 responses logged. Three times the response was canceled after the first question, once after the second question, four times after the third questions, the remaining 49 responses were complete.

The first question (*How often have you used this display before?*) was measured as a numeric response. People have on average used the display 6.9 times before. For 25 people (43.9% of the users) it was the first time using the display setup, 11 people (19.3%) have used it once before, 18 people (31.6%) between two and ten times, and the remaining 3 people (5.2%) more than ten times. For the second question (*How likely is it that you will use this display in the future again?*), based on a 5-point Likert scale, the response was fairly uniformly distributed (average=3.04, SD=1.46). The whole scale from 1 (not likely at all) to 5 (very likely) was represented. No clear trend could be seen. When only considering the responses collected from the large TV screen, a clearer perception can be seen. There, the responses to this question had an average of 4.5 (SD=0.866), showing a trend towards a positive perception of the large display setup. However, due to the low number of responses for the TV display (only 4 responses), this conclusion cannot be regarded as significant. Taking a look at the devices users possess might give us first insights into why users chose which feedback channel (*Which devices do you possess or use regularly?*). Overall, the majority of the people participating in the survey already owned a smartphone (79.3%). The second most popular response was laptop (73.6%), followed by tablet (41.5%), and desktop computer (26.4%). 18.9% of the users indicated that they possess a feature phone and use it regularly. On average each participant possessed 2.4 devices. When looking at which combinations of devices were most frequent, twelve people responded that they own a smartphone, tablet, and laptop. Twelve other people indicated that they possess a smartphone and laptop. Six people own a smartphone, laptop, and desktop. The fourth question (*In which area do you study / work?*) was used to get a little insight into the background of the survey users. Only the occupation of each participant can be derived from the questionnaire. For a full evaluation of the demographic background of all participants, refer to section 5.3.5. The last question (*What was your motivation for approaching and using this display?*) collected the main reasons why people have approached the display setup. The main reasons mentioned were "curiosity" (12x), "fun" (10x), "boredom" (8x), "interest" (2x), and "during breaks" (2x). Other reasons mentioned were "it is there, so why not?", "it is there and colorful", or "I've never seen it before in this spot, wanted to know what it is about".

### 5.4.3 Interview Responses

The evaluation of the semi-structured interviews was based on Grounded Theory [57], promoting a systematic evaluation of the interview transcripts. To avoid any interferences between the two groups of people who have already participated in the study setup and people passing by, each passerby was asked, before starting the interview, whether he had noticed the public display setup, and whether he had already interacted with the installation. Out of all passersby no one had previously been interacted with the game or survey platform. 82.4% (14 of 17) of the passersby had already noticed the public display installation before. However, none of the passersby had previously participated in the game. The remaining 17.6% had neither approached the display nor noticed it prior to the interview.

The semi-structured interview was most useful to get a better insight into why certain users chose which feedback channel. Reasons mentioned speaking for the *TV screen* as the preferred choice were, because it is the "most direct" (4x) feedback option. Another popular reason was, because "I am already standing here" (2x). Reasons speaking against the TV screen for a lot of people are "it is too large" (4x), "everyone could watch me" (2x), and "it feels too public" (2x). For the most popular feedback option, responding via *tablet*, the following reasons speaking for the tablet were introduced: "the display is smaller and better laid out" (5x), "better sensitivity / better usability" (2x), "it feels more private" (2x), "you are not in the way of others", "I am more used to it", and "less people are watching me". Overall, only three people mentioned a reason speaking against the use of a tablet: "redundancy" (2x) and "personal aversion". Two reasons, that were mentioned by participants of the semi-structured interview speaking for responding via their personal *smartphone* were: "it belongs to me", and "I use it most often". Reasons why participants did not pick their smartphone, were more frequently: "too much effort" (4x), "too indirect" (3x), "requires too much personal information" (3x), "I am not sure how complex and time-consuming it would be" (2x). The last option, responding from elsewhere by submitting the *email address*, turned out to be more popular than the previous option, responding via smartphone. Most people preferred this option due to the following reasons: "I can do it at home" (4x), "I have more time to complete the survey", and "better warranty of privacy". People would refrain from submitting their email address, because: "I would forget about [responding]" (5x), "I don't like to submit my email address" (4x), "I don't like to postpone" (3x), "it would take too long to complete" (2x), and it would be "too much effort" (2x). For a full list of reasons mentioned for or against one of the feedback channels, refer to Appendix B.

From what has been mentioned, the main reason for approaching the public displays was "curiosity" (6x). Other reasons mentioned were "for fun", "I was waiting for someone", "as a balance to studies", "I saw others using it", and the novelty effect. Reasons for not approaching the display were "no time" (2x) and "it is in the entry zone of the university, it feels strange when one plays with it" (1x). Additional observations made during the field study, are mentioned here briefly without comment. When correlating the *age distribution* per feedback channel, the following ratio can be seen. The highest age is on average on public display (31.6), followed by tablet (28.2), email (24.0) and smartphone (23.0). The *response time* for responding to the five questions was on average 1:02 minutes, ranging from 0:36 to 3:06 minutes. The number of questions found acceptable on this setup ranged between five and ten questions. The open coding phase of the Grounded Theory produced a few new aspects. What was to be expected, were the reasons speaking for and against each feedback channel, listed above. What wasn't predictable was that one person in his 50s preferred to use the large public display, due to his short-sightedness. In addition, one retired person refused to use any of the four offered digital feedback channels, even when being offered to be assisted by a person. This case should not be forgotten. Further, one participant was willing to provide her email address on the tablet, but not on the TV screen. Requirements stated, what the users would expect from a survey being conducted in public, are: "it must be interesting on first sight", "it would help to see a benefit for oneself", plus a "good

readability" and " understandability" of the questions.

## 5.5 Discussion

In the field study we assessed which feedback channel users preferred, why users approached the display setup, and for which reason they made which choice. A vast majority of users preferred to respond directly in the public setting to the questionnaire. The tablet turned out to be the most popular feedback channel in the display setup, followed by the TV screen. Options email and smartphone accounted for only around a quarter of the total. Reasons for approaching the public displays were curiosity, novelty, for fun, mental balance, and pastime.

It is interesting to see that the tablet is the most popular *feedback channel* in all scenarios, although responding via the TV screen would be more a more direct approach and not require moving to another device. Nevertheless all offered feedback channels were present in the evaluation and during the semi-structured interviews for each channel a good reason for the choice was given. What can be said is that our participants can be distinguished into three groups. The first (and slightly larger) group preferred the option of *direct response*. They are not as concerned about answering questions in public and their privacy. For them it is more important to complete the survey as quickly as possible and not have to think about it later, as long as nothing too private or personal is asked. One person said "If something too private would be asked, I would simply abort and go away from the display". The second group is more concerned about *privacy*. They are often of older age, or actually wanting to take the time to think about all of their responses in depth in order to give high-quality responses. This group prefers to take the questionnaire away from the public setting into their home. The third group chose the feedback channel purely based on their *habit* and what they are accustomed to. Two women in their mid-twenties responded immediately "on my smartphone, because I am most used to it". These observations go along well with the five adaptation factors stated by Huang et al. [29]: task specificity and deep integration, tool flexibility and generality, visibility and exposure to others' interaction, low barriers to use, dedicated core group of users.

Another assumption we had made was encouraged by our observations and the semi-structured interviews: the smaller the display, the safer and more private the users feel. An exception to this finding could be old people. Once people's eye sight deteriorates with age or they get more insecure and uncertain with using new devices, they prefer to have a large input surface. But for the majority of younger people our assumption held true. Additionally, we made the observation that questionnaires on public displays are best suited for quantitative surveys. Users want a short interaction time, not having to think much about their answers and for roughly 25% of the participants it holds true, that they do not like being observed while making responses in public. From this observation, the implication for the *question types* can be derived: question types ideally with a single-click interaction are preferred (e.g. Likert scale, multiple choice with all options given, yes/no-questions). Followed by numeric, dropdown and multiple choice questions with one option for open-end responses. For these question types with a longer interaction time the user has to think a little bit more and assess more precisely to make a response. One example stated by a participant, in regards to the numeric question '*How often have you used this display before?*', was that "It would be great if you had the possibility to choose from a predefined range, because typing is not always optimal. I would prefer if areas would be given instead of oneself having to think about the exact number." Last, being no big surprise, are text fields combined with open-ended questions. As a take away for text fields: wherever possible rephrase the question so that the response can be as short as possible.

What should not be forgotten are the fears mentioned during the qualitative evaluation. Concerns regarding loss of *privacy*, and the increase of *social desirability* in public settings. These are the two main constraints for surveys being conducted on displays in public settings, and should be taken into consideration when constructing new interactive display setups, which should offer

the evaluation through a survey platform. Possible ways to cope with these concerns are to adjust the position of the display in public (not so exposed), and to vary the screen size depending on the required privacy.

We are aware of certain limitations of our descriptive study. Our limitations are consistent with the findings found by Ojala et al. [43]. The effects of curiosity, impact of novelty, and influence of weather had an influence on our field study. Due to the novelty effect caused by the tablet, and the intrinsic motivation we added through the splash screen on the tablet (see section 5.3.1, self-determination theory), the participation rate on the tablet was increased. For our primary research question, which feedback channels is best suited, the impact of novelty, curiosity and of the always-visible tablet, should not have an impact. We based the evaluation of the feedback channel not on the overall number of responses, which was therefore distorted, but on the options panel and on the interview responses. Despite these effects, it was striking to see a response rate of 42.4%, when comparing the 50 responses made on the tablet with the total number of 117 interactions made with the public display setup. When we exclude all participants who directly accessed the tablet and did not see the options panel to use one of the four feedback channels, the response rate on the tablet was still 5.1%. Otherwise, it should be mentioned that both the TV screen and the tablet were always on and that all questions were optional. One suggestion for improvement is to only turn on the screen of the tablet when it is selected on the TV screen as the desired feedback channel.

All in all, it can be said that people prefer to respond to questionnaires in public directly, as long as the questions don't get too private. Nonetheless the more feedback channels offered, the better it is, since the variety of user backgrounds also bring different preferences and attitudes. When designing public display setups for getting more private user input, the display size should also be taken into consideration. So far we have made the observation, that users feel more secure on smaller screens. For the development of our public display survey platform the study has shown that people of different age groups are willing to respond to questionnaires in public.

# 6 Future Work

Based on the development process of the *PDSurvey* platform, inspired by the literature review and survey responses, we came to the following thoughts on what else might be of interest for follow-up studies.

For the survey platform itself we had to cut back on our goals early, due to the limited resources and development time of 2.5 months. Since the intention is to further improve the platform by fellow students, certain aspects of a classic survey platform were omitted. It would be interesting to see some of the following extensions to *PDSurvey*. The first and most important need for improvement is a proper visualization of the quantitative and qualitative results, e.g. with the use of information visualization and JavaScript libraries such as Morris.js[47] or D3.js[48]. Because this was not the main focus for the thesis, we only implemented basic logging of all results, without any automated evaluation or visualization. A second aspect for improvement would be to support more data sources. Currently 'only' data from questionnaires are logged, but it could also be of interest to support the logging of video feeds, audio feeds, touch interaction (pixel coordinates), or other meta data from the display setups. For logging large amounts of data, an integration with storage solutions such as Dropbox could be of interest. Based on their Dropbox API[49] files can be stored and referenced from third-party applications. It is conceivable to also log audio or video responses to questionnaires. A third chance for improvement could be to offer more sophisticated evaluation mechanisms. When combining more log data with advanced evaluation mechanisms, better insights can be achieved. One such enhancement could be a context-based approach for evaluation. When collecting the context of each display setup and of every response, a comparison across a multitude of displays becomes feasible. This can provide new insights into patterns responsible for certain effects. Another improvement would be to integrate the automatic evaluation of all survey responses based on their validity, reliability and on metrics such as standard deviation. This will not only simplify the overall evaluation of public displays and their interactive applications, but also improve the overall quality of the end product being evaluated. As more information is collected and as the platform grows, it would be useful to further refine the context model and to add a proper authentication mechanism. From a technical perspective the next step would be to add unit testing and to add a sophisticated authentication to the platform.

While executing our field study we thought of additional research questions, which would be of interest, but would go beyond the scope of this thesis. One such aspect is the number of questions tolerated per feedback channel. While executing the field study and semi-structured interviews some people noted that they would be willing to give more detailed responses, when they could fill in the questionnaire at home. Getting better insights into the constraints of each feedback channel would be of high interest for the construction and deployment of questionnaires in public settings. It would be interesting to find out whether this variable differs between the chosen feedback channel, location of the display setup, and its surrounding environment, or if other factors also play a role here. Another interesting question might be in which setting a user is most willing to answer surveys on public displays.

Another research question of interest might be how to best deploy standardized questionnaires consisting of 20+ questions. The problem is that no user wants to complete too extensive questionnaires in a public setting. One approach could be to analyze, whether it is possible to break down long questionnaires across multiple users, and aggregate the results, taking into account that the derived findings will not be as extensive and may not allow any inferences. According to Jacucci et al. [31] there are often significant similarities between standardized questionnaires. Therefore it might be useful to break down each questionnaire to its principal components, to bundle all matches, in order to reduce the total amount of questions and to be able to split all ques-

[47] `http://morrisjs.github.io/morris.js/` (last accessed on April 13, 2015)

[48] `http://d3js.org/` (last accessed on April 13, 2015)

[49] `https://www.dropbox.com/developers/datastore` (last accessed on April 13, 2015)

tions across multiple users on the same display. Should this turn out not to be feasible approach, then questionnaires of different length could still be distributed based on metrics such as user involvement, or the chosen feedback channel. Users choosing a well-established and comfortable feedback channel, such as email, might be willing to respond to longer questionnaires than participants in public. Another approach could be to track users across time and recognize returning users, in order to continue with the questionnaire where they last left off.

Getting a better understanding of public displays in general, and their design guidelines in particular, will also improve how to integrate questionnaires in public display deployments in the best way possible. Finding better design guidelines for the development of interactive applications will also be of benefit for this platform. Questions can include the influence of the environment, e.g. how personal questions can get in different public settings, or how much privacy the display should offer (the smaller the display, the more private the context seems). This is one assumption derived from the interview responses in our field study. The influence of the display size on parameters such as perceived privacy and security is an area of high relevance when conducting surveys in public. Other questions of interest might be what the ideal placement of the question itself on the screen is, how to best embed the survey (as a pop up, overlay, or full screen), how (un)obtrusive the design should be, or when to best interrupt the user from his primary task (before, during, or after).

Last but not least, getting better insights from experiments in controlled lab settings on the effects of the content, context, environment and further parameters would be interesting. Being able to assess how many qualitative and/or quantitative questions can be posed, is of interest. Also getting insights into which question types are best suited for which feedback channel. Doing further research on these questions would not only improve the *PDSurvey* platform, but also lead to getting better insights into how surveys should be constructed.

# 7 Conclusion

Evaluating interactive applications on public display installations is as crucial as the development process itself. In this thesis we gave an overview of how other public display applications were evaluated in literature, presented a categorization of standardized questionnaires, and introduced the *PDSurvey* platform. This survey platform allowed us to assess our research questions through a lab study. Our main research questions were which feedback channel is best suited for completing surveys in public and what motivated our users to participate. In the field study we offered the users four feedback channels to respond to the questionnaire. The options allowing users to respond directly in-situ were most popular. However, the tablet turned out to be more popular than the primary display (TV screen). The tablet was preferred due to its smaller form factor, better usability, and because responding did not feel as public. Despite the additional effort for responding via smartphone or email, these feedback channels were still an option for some. Reasons stated for smartphone use were personal possession and habit, for email because of having more time, being able to do it at home, and better warranty of privacy. It is interesting to see that around a fifth of the participants chose an indirect and more time consuming option, even though they had the opportunity to use low effort input devices such as the tablet or the TV screen.

Our field study has shown that there is an area of application for surveys being conducted on public displays and that this approach can simplify and support the evaluation of interactive applications. Of importance is a fast interaction time and low-effort input technique. When scaling this approach to large display networks, the evaluation process of new interactive applications can be simplified. In order to gain insights into why certain effects and differences arise in public display setups, it is vital to assess detailed information about the context of each application, allowing us to determine which characteristics cause certain effects. This aspect is also the point which makes our platform unique. We expect the number of interactive public display applications to increase in the future, and therewith also the demand for fast and easy evaluation of such. Utilizing the interactive capability of todays public displays as a feedback channel can be beneficial in many situations. When running large display networks, this can be the first step towards a better understanding of the displays surrounding the environments and a faster problem analysis.

With this thesis we gained first insights into which feedback channels are suited for which context. We delivered a proof-of-concept for the evaluation of public displays to be executed on the displays themselves. The response rates were good (10%), especially since the attraction of participants was solely based on intrinsic motivation. We came to the conclusion, that using public displays for assisting in the collection of survey data is a viable approach and worthy of further research. With our work we addressed the issue of time-consuming public display evaluation and contributed to the systematic evaluation of public display setups. With the overview of standardized questionnaires for public display evaluation we hope to bring a benefit the research community.

# Appendix

## A Content of enclosed CD

1. */documents/* - Documents which were made during the Master thesis
2. */evaluation/* - Raw data of the field study, including audio recordings of all interviews and the questionnaire logs.
3. */misc/* - Screenshots, photos and other files for this work.
4. */papers/* - All scientific articles read for this thesis.
5. */presentation/* - Presentations 'Antrittsvortrag' and 'Abschlussvortrag' (held in German).
6. */repository/* - A copy of the GitHub repository including all development files.
7. */thesis/* - LaTeX version of the thesis.

*PDSurvey*'s source code and documentation can also be found in the following GitHub repository: `https://github.com/lukasziegler/masterarbeit/tree/master/docs`

# B Evaluation of Public Displays

Reasons stated in the semi-structured interviews for and against each feedback channel.

| **Pro "TV Screen"** | **Contra "TV Screen"** |
|---|---|
| 4x Most direct, immediate feedback | 4x Display is too large |
| 2x I am already standing here (2x) | 3x Feels too public |
| 1x Seems easiest | 2x Everyone could watch me |
| 1x Requires less personal information | 1x That is mean, when the screen is so large |
| 1x All on one device | 1x The keyboard on the display would have been too large and confusing |
| 1x I can use it without putting my glasses on | 1x Display is uncomfortable for reading long questions |
| 1x Seems to be the fastest option | 1x Don't feel comfortable standing in focus in such a large room |
| | 1x The system is too innovative, that is why I wouldn't trust it yet |
| | 1x Because of social desirability influencing my responses |

Table B.1: Reasons mentioned for/against using the *TV screen* as a feedback channel.

| **Pro "Tablet"** | **Contra "Tablet"** |
|---|---|
| 5x The display is smaller and better laid out) | 2x Redundancy ("why do I need a tablet when I can respond on the TV screen?") |
| 2x Better sensitivity / user experience | 1x Personal aversion (he had bad experiences with tablets) |
| 2x It feels more private | |
| 1x Because it is its sole purpose | |
| 1x You are not in the way of others | |
| 1x I am more used to it | |
| 1x Most interactive option | |
| 1x Less people watching | |
| 1x Because I expect a better input | |
| 1x Requires less personal information | |
| 1x More comfortable standing here | |

Table B.2: Reasons mentioned for/against using the *Tablet* as a feedback channel.

| **Pro "Smartphone"** | **Contra "Smartphone"** |
|---|---|
| 1x I use it most often | 4x Too much effort |
| 1x It belongs to me | 3x Too indirect |
| | 3x Requires more personal information |
| | 2x I am not sure how complex and time-consuming it would be to set it up |
| | 1x I don't know if I would know how to do it |
| | 1x Too small display for comfortably answering surveys and long questions |
| | 1x Too cumbersome |
| | 1x I would assume that I would have to install some sort of software |
| | 1x Privacy |

Table B.3: Reasons mentioned for/against using the *Smartphone* as a feedback channel.

| **Pro "Email"** | **Contra "Email"** |
|---|---|
| 4x I can do it at home | 5x I would forget about it |
| 3x I have more time to complete the survey | 4x I don't like to submit my email address |
| 1x Better warranty of privacy | 3x I don't like to postpone it |
| 1x I could deliver qualitatively better results | 2x It would take too long to complete |
| 1x I wasn't sure which kind of questions to expect | 2x Too much effort |
| | 1x Requires more personal information |
| | 1x Too indirect |

Table B.4: Reasons mentioned for/against using the *Email* as a feedback channel.

# C Questionnaires for Field Study

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## Questionnaire for Participants

**1. General information** Date: _____ Time: _____

Gender: male / female Age: ____ years

Study field / work area: _____

Coming from: _____ Going to: _____

**2. Feedback channel** (1: PD, 2: Tablet, 3: Smartphone, 4: Email)

a. Which feedback channel did you choose? Why did you choose it?
(1) on the public display
(2) on the tablet next to the public display
(3) via smartphone
(4) via email

**3. Awareness**

a. At what point of time did you notice the opportunity to answer a survey?
(1) before starting the game
(2) while playing the game
(3) after finishing the game / when the sign showed up

b. What was your motivation for approaching the display? _____

**4. Experience**

a. How often have you used this display before? _____

b. Which of the following devices do you possess?
(1) Smartphone
(2) Tablet
(3) Laptop
(4) Desktop PC

**5. Other feedback**

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# Questionnaire for Passersby

**1. General information** Date: _____ Time: _____

Gender: male / female Age: ____ years

Study field / work area: _____

**2. Feedback channel** (1: PD, 2: Tablet, 3: Smartphone, 4: Email)

a. Which feedback channel would you prefer for answering surveys?
(1) on the public display
(2) on the tablet next to the public display
(3) via smartphone
(4) via email

**3. Why did you pass by**

a. Did you notice the display? yes / no
b. Did you notice the option to participate in a survey? yes / no

c. Why didn't you stop? _____

**4. Experience**

a. Which of the following devices do you possess?
(1) Smartphone
(2) Tablet
(3) Laptop
(4) Desktop PC

**5. Other feedback**

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# Semi Structured Interview

for passersby

Date: _____ Time: _____ Voice-Recording: _____ Group size: ____

**1. Introduction**

Do you also get so many surveys via email?
When do you usually answer them?

What is your motivation to complete a survey?

We are looking at Surveys on displays in the public.
How do you perceive completing a survey on a public display?

**(optional: For Passersby)**

Did you notice the *option to participate* in a survey? Why didn't you stop?
*What is your attitude* towards completing a survey on a public display?
*How many questions* would you find acceptable on a public display?

**2. Feedback channel** (1: PD, 2: Tablet, 3: Smartphone, 4: Email)

Why did you choose channel ___ to complete the survey?

Which *pros/cons* do you see per channel? / Why would you use which one?

1: PD
2: Tablet
3: Smartphone
4: Email

**3. Awareness**

How did you get attracted to the display? Why did you approach the display?

**4. General information**

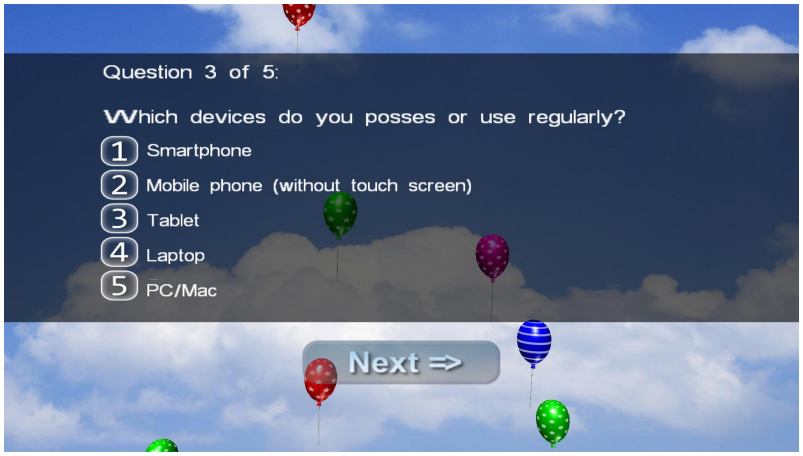
What did you just do? Where are you coming from / going to?
coming form: _____
going to: _____

**5. Other feedback**

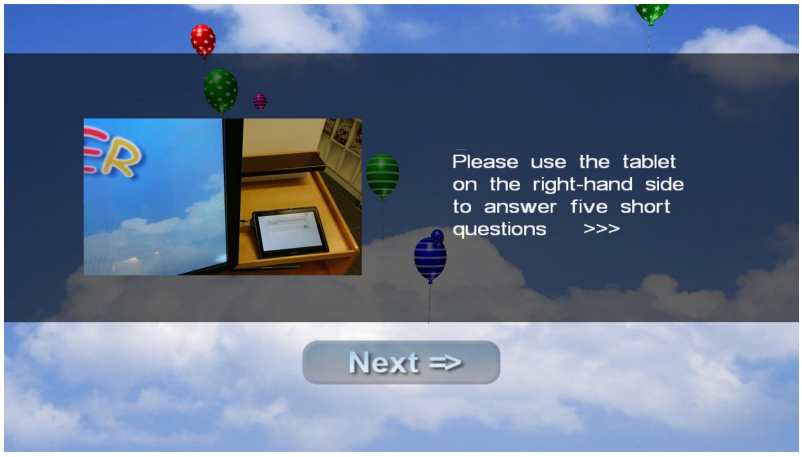
# D Screenshots of Platform

**Balloon Shooter Game** The following screenshots originate from the Balloon Shooter game developed by Jiamin Shi. Each user first saw the options panel (see figure D.1a) after completing a game of Balloon Shooter. Four channels were offered for completing the questionnaire. The order was randomized.


(a) **Options panel** - Four feedback channels are offered in a randomized order for responding to the questionnaire.

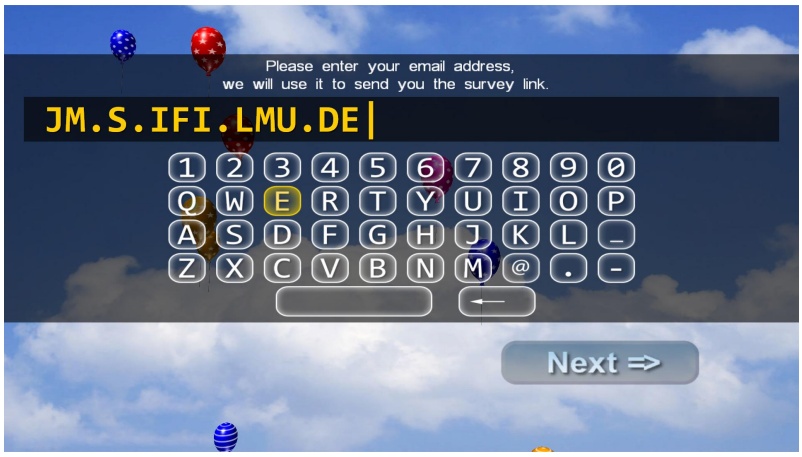



(b) **TV Screen option** - directly answering on the TV screen. Here you see a sample question getting asked on the interactive display.




(a) **Tablet option** - The screen the user sees when choosing to complete the survey on the tablet.

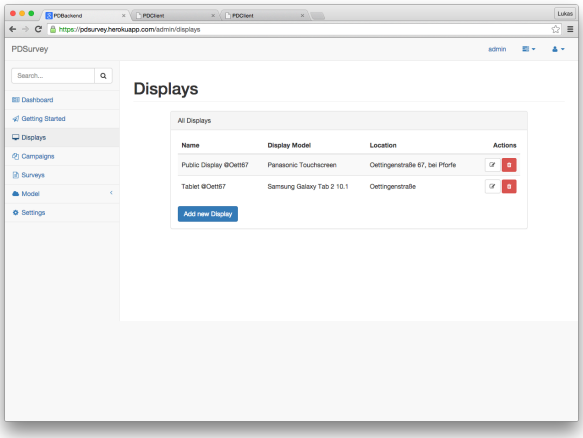

(b) **Smartphone option** - participating with your own smartphone, either by scanning the QR code or by typing the URL in the mobile browser.



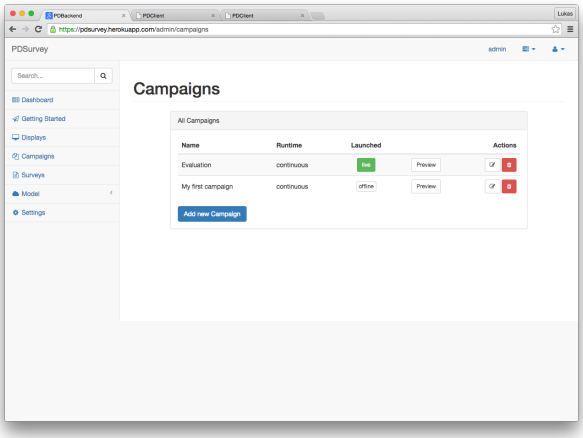

(c) **Email option** - submitting ones email address and getting the survey link to participate in response.

Figure D.2: Further screenshots from PDAdmin

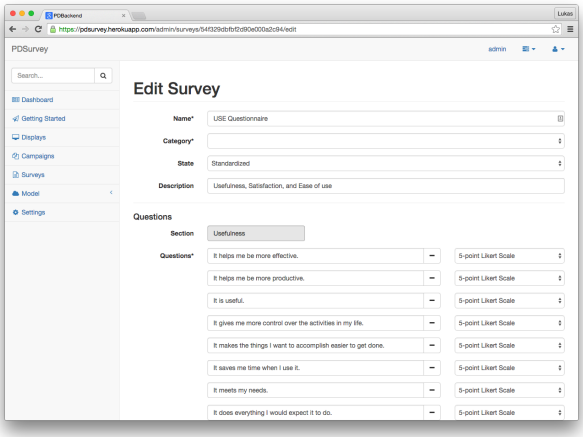
**PDAdmin**




(a) Displays list view




(b) Campaigns list view




(c) Survey edit page

Figure D.3: Further screenshots from PDAdmin

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