PD-Survey – Supporting Audience-Centric Research through Surveys on Pervasive Display Networks

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ABSTRACT

We present *PD-Survey*, a platform to conduct surveys across a network of interactive screens. Our research is motivated by the fact that obtaining and analyzing data about users of public displays requires significant effort; e.g., running long-term observations or post-hoc analyses of video/interaction logs. As a result, research is often constrained to a single installation within a particular context, neither accounting for a diverse audience (children, shoppers, commuters) nor for different situations (waiting vs. passing by) or times of the day. As displays become networked, one way to address this challenge is through surveys on displays, where audience feedback is collected in-situ. Since current tools do not appropriately address the requirements of a display network, we implemented a tool for use on public displays and report on its design and development. Our research is complemented by two in-the-wild deployments that (a) investigate different channels for feedback collection, (b) showcase how the work of researchers is supported, and (c) testify that the platform can easily be extended with novel features.

CCS CONCEPTS

•**Human-centered computing** → **Field studies;** *Ubiquitous and mobile computing systems and tools;*

KEYWORDS

Public Displays; Surveys; User-Centered Design

1 INTRODUCTION

As a result of falling hardware prices, past years witnessed a quick proliferation of displays in public space. Many of these displays are augmented with sensors and connected to the Internet, hence forming large display networks [41, 52]. These trends enable researchers to develop novel interaction techniques, advance our understanding of how people behave in the display vicinity, and investigate the users' experience with particular apps and contents.

Doing so poses considerable effort and challenges to researchers and display owners. They need to ensure that UIs adapt to different screen sizes, resolutions, and orientations [34], fresh content must be provided to create value for users [28, 38], content needs to be scheduled [17], and the installation needs to be maintained [34].

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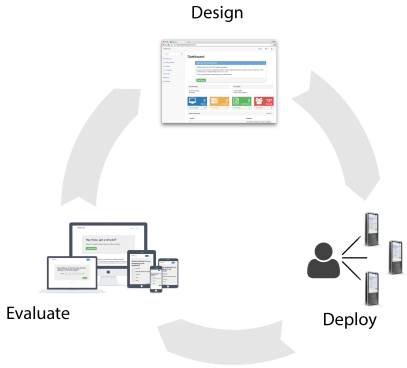

Figure 1: PDSurvey facilitates audience-centric research through surveys, distributed across a display network. Researchers design/choose an adequate questionnaire (1), deploy it to a set of displays (2), and evaluate the responses (3).

While addressing the aforementioned, mostly technical, challenges already requires significant effort, this is even more so true as the audience moves into the focus of research. Obtaining feedback in-situ requires researchers to be present at the display for observations and interviews. To keep the effort manageable, studies are often constrained to one location. However, depending on the research question, it may be desirable to conduct research using more than one display – which is increasingly feasible through display networks. Having deployments in different locations allows fundamentally different audiences (children, shoppers, commuters, etc.) and situations (waiting at a bus stop vs. passing by a shop window) to be investigated. Thus it becomes possible to understand, why an app may be successful in one location or at a particular time of the day, while being mainly ignored in a different context.

To allow a large variety of contexts to be studied while keeping the effort for researchers low, this work contributes *PD-Survey*, a platform that can be deployed across both single displays and large display networks. The platform allows feedback from users to be gathered in different contexts to support an audience-centric design process when creating novel display interventions. More specifically, PD-Survey is a web-based platform that allows the design, deployment, and evaluation of various surveys across a large number of interactive surface installations (Figure 1). PD-Survey contributes (1) guidance in accessing standard surveys and adapting them to novel research contexts and (2) deploying them to a network of displays without programming knowledge; it is (3) a platform for sharing surveys across researchers and practitioners; and it (4) makes use of various techniques for users to provide feedback: directly on the display, on a dedicated tablet-sized device next to the display, on their personal phone, or sent by email to be filled out on a preferred device at a later moment.

Compared to state-of-the-art web survey platforms (LimeSurvey, SurveyMonkey, UniPark), PD-Survey addresses a rich set of characteristics unique to public displays.

(1) *Pre-defined questions and questionnaires.* As a domain-specific platform, PD-Survey offers pre-defined sets of questions and standardized questionnaires that can be extended by researchers of the research field.
(2) *Distribution channels.* Public display users are diverse and encountered in different situations. Hence, PD-Survey allows distribution not only through the display, but also through smart phones, tablets, or the web. Thus, users in a rush who wish to take a survey, can do so later and on their personal device. Experimenters could also cater to privacy needs in public by providing a second screen where users can enter responses while being less exposed.
(3) *Embedding survey.* To leverage the potential of a survey platform, means are needed to embed the survey in as large a variety of apps as possible. We provide an API that allows questions to be fetched and answers to be sent to a server.
(4) *Cross-client campaigns.* Displays are often part of larger networks. PD-Survey enables campaigns across a subset of these clients, e.g., all displays in a shopping mall. PD-Survey allows all results to be aggregated and analyzed.
(5) *Multiple surveys per display.* Displays may run multiple applications in parallel [3]. PD-Survey supports such installations by allowing multiple surveys to be run per client.

Our research is complemented by an in-the-wild investigation of the platform, identifying the optimal feedback channel to distribute surveys to users as well as a case study in which the platform was used by three researchers in the context of a university project. We deployed the platform on two displays in a University setting and evaluated two interactive playful apps. Results from the first deployment yield, that most users prefer to provide feedback immediately after interaction – interestingly though not directly on the display but on a dedicated device that enables more private feedback. As for the second deployment we found that researchers are supported in the design process, for example, by being enabled and motivated to push new versions of the survey to investigate novel aspects without the need to physically visit the display. Furthermore, they found it easy to extend the platform by new sets of questions and by adding a novel feature to capture spoken, qualitative feedback.

Contribution Statement. The contribution of our work is threefold. First, we present a survey of standardized questionnaires that are relevant in the context of public display research. Second, we report on the design process and development of our survey platform. We make available the code of the platform through GitHub[1] for further development. Third, we report on two in-the-wild deployments of PD-Survey, yielding early insights.

2 RELATED WORK

Our work draws from several strands of prior research in the area of interactive public display. Most notably, methodology, research in display networks, and existing survey platforms are of interest.

[1] https://www.medien.ifi.lmu.de/pdsurvey/

2.1 Display Research Methodology

To collect valuable user feedback in the field, several study paradigms and methodologies are used [4]. These include methods to collect quantitative data through event logging or recording videos [1, 25, 36, 37] or qualitative data from semi-structured interviews [2, 7, 51] where researchers remain nearby the display and approach passersby after they interacted. Most interviewers collect survey-like data such as demographic data (e.g., age), usage-frequency of certain technology (e.g., a phone), or 'yes-no' questions such as 'do you own a phone' [2]. In some cases passersby fill out standard questionnaires on paper [2, 36]. However, one advantage of using survey platforms is that users can fill them out even when no researcher is present for an interview and that there is no overhead and possible mistakes when digitizing the survey.

2.2 Single / Networked Display Infrastructures

Researchers often conduct studies on a single public display and for a short period of time. To facilitate long-term large-scale real-world studies, we need dedicated pervasive computing infrastructure [36, 41]. For example, the city of Oulu in Finland provides a networked display infrastructure featuring a city-wide network of displays at indoor and outdoor locations such as market places, swimming halls, universities, and libraries. These displays hosted several research projects [40] that investigated social behavior and attraction to display content in the field. However, the high effort of conducting observations and interviews at several locations is counter-productive to the goal of running long-term studies.

Ojala et al. [41] performed a long-term public display deployment and evaluation in Oulu using automated surveys to collect community feedback. However, the surveys were firmly integrated into their software. PD-Survey provides a survey platform that can be used, extended, and adapted by researchers. It facilitates automated collection of user feedback in long-term studies and supports participatory design on public displays: several researchers identified the critical role of content to user participation [16], a question that is hard to answer in the lab and instead needs to be asked to the community surrounding the display.

2.3 Existing Survey Platforms

For web pages or desktop applications, there was an early interest in conducting automated surveys resulting in a myriad of platforms [20]. Commercial platforms support a large number of question types, some of which offer a pool of standard questionnaires and provide a sophisticated administration panel. Yet, networked public display setups pose different requirements to survey platforms. For example, one frequent channel for polling feedback from users is asking for participation using emails or links on web pages and some platforms even provide a mobile app for conducting and evaluating surveys. We lack, however, an analysis of requirements for networked public displays. The aforementioned feedback channels are not suitable since they do not allow feedback to be gathered in-situ. Also it is not clear when to best ask users to provide feedback: asking for feedback while users are engaged with other tasks may be distracting or frustrating. Asking at the end of a task (if this can be determined), may lead to users leaving the display due to low motivation or because they did not recognize that they were

Category	Questionnaire	Acronym	Ref	Used
Demography	Adult Literacy and Lifeskills Survey	AAL	[47]	–
	Program for the International Assessment. of Adult Competencies – Background Quest.	PIAAC	[49]	–
	Physical Activity Readiness Questionnaire	PAR-Q	[55]	[25, 41]
User Experience	AttrakDiff Questionnaire	AttrakDiff	[22]	[12]
	UX Questionnaire	UEQ / Short-UEQ	[29]	[43]
	Questionnaire for User Interaction Satisfaction	QUIS	[21]	–
	Game Flow Questionnaire	GameFlow	[54]	[24]
	Standardized UX Percentile Rank Questionnaire	SUPR-Q	[48]	–
Usability	System Usability Scale	SUS	[10]	[2]
	Usefulness, Satisfaction, and Ease of Use	USE	[31]	–
	Nielsen's Attr. of Usability	NAU	[39]	–
	Post-Study System Usability Questionnaire	PSSUQ	[30]	–
User Acceptance	Intrinsic Motivation Invent.	IMI	[32]	[24, 25]
Privacy	Privacy Awareness Quest.	PAQ	[15]	[42]
	True Ultimate Standards Everywhere Questionnaire	TRUSTe	[8]	–
Task Load	Nasa Task Load Index	NASA TLX	[11]	[18]
Immersion	Measurements, Effects, Conditions (MEC) – Spatial Presence Questionnaire	MEC-SPQ	[56]	[24, 25]
Social Impact	Social Support Questionnaire	SSQ	[46]	–
Display Context	–			[26, 33]
User Expectations	–			[13]

Table 1: Overview of research questions and related standardized questionnaires.

asked for feedback [6]. Finally, questions may need to be adapted based on the display context. To address this, PD-Survey enables various surveys to be associated with individual displays and offers different types of feedback channels (display, smart phone, tablet, email) tailored to the needs of public display evaluations.

In the following, we provide requirements for a public display survey platform. We present an open-source platform for designing and deploying surveys on several displays asking for user feedback in an automated way using four feedback channels. PD-Survey supports audience-centered design for public displays and supports long-term real-world investigations on networked displays.

3 SURVEYS ON PUBLIC DISPLAY NETWORKS

At the outset of our research we conducted a comprehensive review of prior work on investigating public displays by means of surveys. We searched for relevant articles on Google Scholar, the ACM Digital Library, project websites, and on personal websites of recognized experts in the field. In total, we found more than 100 articles that employed surveys in the context of interactive screens. In a next step, we grouped prior work by research questions that were addressed through surveys. The classification was inspired by the research questions introduced by Alt et al. [4]. The goal was to find patterns and to build clusters of questionnaires being useful for the evaluation through public display survey platforms.

We found that while many surveys contained customized questions, researchers also employed standardized questionnaires. We collected these questionnaires and complemented the list by standardized questionnaires from other domains, which we consider applicable and useful. Table 1 provides an overview of standardized questionnaires, classified by research questions. We provide sample publications employing these questionnaires.

In the following, we briefly introduce the research questions, questionnaires, and provide pointers to work using these.

3.1 Demographics

In many cases, the diversity of the audience makes it crucial to obtain demographic information. Exceptions may be environments where the audience is very well known or where this information can be obtained implicitly (for example, there is software to estimate gender and age group of users [27]). Questions range from general (gender, age, education) to more personal questions (relationship status, family, children, country of origin). In some cases character traits, skills, personal beliefs, or political affiliation are of interest. If performance is assessed, it may be reasonable to ask for the users' experience with certain devices or interaction techniques.

Standardized questionnaires assessing demographics are the Adult Literacy & Lifeskills Survey (ALL) [47] and the PIAAC [49].

A specific type of demographic information is physical activity readiness. This may be important to assess in cases where users are required to perform extensive and potentially exhausting movements (an interactive game that is controlled through user position or gestures). An example is the PAR-Q questionnaire [55] that was employed by Ojala et al. [41] and Jacucci et a. [25].

3.2 User Experience (UX)

User experience (UX) describes the users' overall satisfaction and experience with a display. Standardized questionnaires are AttrakDiff [22], UEQ [29], and QUIS [21]. Beyer et al. [12] used AttrakDiff for comparing the UX of users interacting with (non) planar screens and Panhey et al. used the UEQ [43] to investigate cognitive effects.

A particular case is the experience with games. The GameFlow questionnaire [54] measures experience through player skills, challenge, control, feedback, immersion, and social interaction. It was used in work by Huang et al. [24]. A final example that has not yet been used in the context of public display research is the Standardized User Experience Percentile Rank Questionnaire [48].

3.3 Usability

Popular usability questionnaires are the SUS (System Usability Scale) [10], USE (Usefulness, Satisfaction, and Ease of Use) [31], Nielsen's Attributes of Usability (NAU) [39] and the Post-Study System Usability Questionnaire [30].

In display research, the SUS has for example been used by Alt et al. [5] to assess the usability of different interaction techniques.

3.4 User Acceptance

To analyze users' motives and incentives for approaching the display, researchers assess user acceptance. The evaluation can be carried out qualitatively (subjective feedback, focus groups) or

quantitatively (questionnaires). To this category we added questionnaires related to expectations, goals, and motivating factors for using the display. One such questionnaire looking at motives for approaching the display is IMI [32], used by Jacucci et al. [25].

3.5 Privacy

Although privacy has been investigated in the context of public displays [2, 50], no standardized questionnaires were used during user trials. One questionnaire for measuring perceptions of privacy is the Privacy Attitudes Questionnaire (PAQ) [15], developed by Chignell et al. [15]. In the context of public displays, this questionnaire has been used as a basis for a privacy threat model [42]. Another survey assessing users' privacy concerns is TRUSTe [11].

3.6 Task Load

In particular for complex interactions it may be interesting to assess the inferred physical or cognitive load. An example for assessing physical load in primary and secondary tasks can be found in Alt et al. [6]. Rukzio et al. measured cognitive load of a navigation display using NasaTLX [44].

3.7 Immersion

Researchers also measured the immersion of display apps. This may be important in cases where displays are deployed in locations where too high an immersion may put the user at risk, for example close to a busy street or intersection. An example is the MEC-SPQ questionnaire [56] used by Huang et al. [24] and Jacucci et al. [25].

3.8 Social Impact

This category considers everything related to social behavior, the influence on social interaction and communities, as well as social effects. To the best of our knowledge no standardized questionnaire has been applied in public display research – despite questionnaires being available, such as the Social Support Questionnaire (SSQ) [46]. Social impact of public displays was studied in [9, 13, 14].

3.9 Display Context

For evaluation, the context of the display may be important. This includes static context (display size, display type, position on wall, position in room, or size of the room) and dynamic context (weather, other people, ongoing events, etc.). While the former information is usually available, the latter information may be difficult to assess, at least automatically. Hence, it may make sense to obtain this information from users. We did not find standardized questionnaires but instances, where research was conducted in very specific contexts, for example, during an annual fair [26]. Memarovic et al. provide guidelines, how the context of a display is best described [33].

3.10 User Expectations

In many cases, exposure of people to public displays may raise or change their expectations, for example, what they would expect from other public displays. One example is the work from Cheverst et al. [13] who asked for recommendations of possible new features on their Hermes displays.

4 PD-SURVEY PLATFORM

The following section introduces the architecture, design cycle, and implementation of the PD-Survey platform.

4.1 Architecture

PD-Survey consists of PD-Admin, PD-Server, and PD-Client. This separation supports refinement and independence.

PD-Admin contains the admin interface, allowing display providers to manage, configure, and deploy questionnaires for their public displays. Display providers have the ability to create their own questionnaires or to select from a list of standardized questionnaires. To get new users started a wizard serves as the entry point for deploying a survey to a display network (Figure 2–top).

PD-Server accommodates the persistence layer, the RESTful web service, and the majority of the application logic.

PD-Client is the web front-end users interact with in the field to submit responses to questionnaires (Figure 3).

4.2 Survey Design Cycle

The survey design cycle consists of three phases: designing a survey, deploying it to the network, and evaluating the received results. This cycle is best repeatedly iterated on different fidelity steps and used all along the life-span of a product or display application.

4.2.1 Phase 1–Design. The first step involves finding a suitable questionnaire. Designers can either use an existing standardized questionnaire, design an individual questionnaire, or customize a predefined questionnaire. This development process depends on the targeted domain. With PD-Survey we facilitate the step of finding an adequate questionnaire by (1) providing predefined questionnaires for different scenarios, (2) allowing users to share new questionnaires through the platform, and (3) allowing users to make individual adjustments of shared questionnaires.

After users sign up for PD-Survey they get guided through a wizard to create *campaigns* for their deployments. We introduced campaigns to resemble the mapping of n questionnaires to m displays. This allows for later comparing results based on differences in context in between displays and campaigns (e.g., when comparing two versions of an application, or partitioning networked public displays into distinct groups). By assigning an individual context to displays/campaigns, a more fine-grained analysis becomes possible.

The entry point for researchers wanting to use PD-Survey is PD-Admin (Figure 2–left), where display providers get an overview of all relevant deployment data, for example, how the campaigns are running and how many responses were submitted. For new users, who have not yet created any campaigns yet, a wizard helps to get started. Users are guided through the process step by step.

4.2.2 Phase 2–Deployment. A main benefits of PD-Survey is the ability to easily deploy and maintain questionnaires across networks. The deployment process is steered through campaigns, allowing the specification of a duration (start/end date), limiting the survey to specific displays, and specifying a context.

For embedding surveys into existing applications there are three options: (1) linking directly to the responsive website (Figure 2–right), (2) developing a native implementation for clients (e.g. Java, Swift) and using HTTP calls to the RESTful API, or (3) using JavaScript embed code (based on JavaScript code injection).

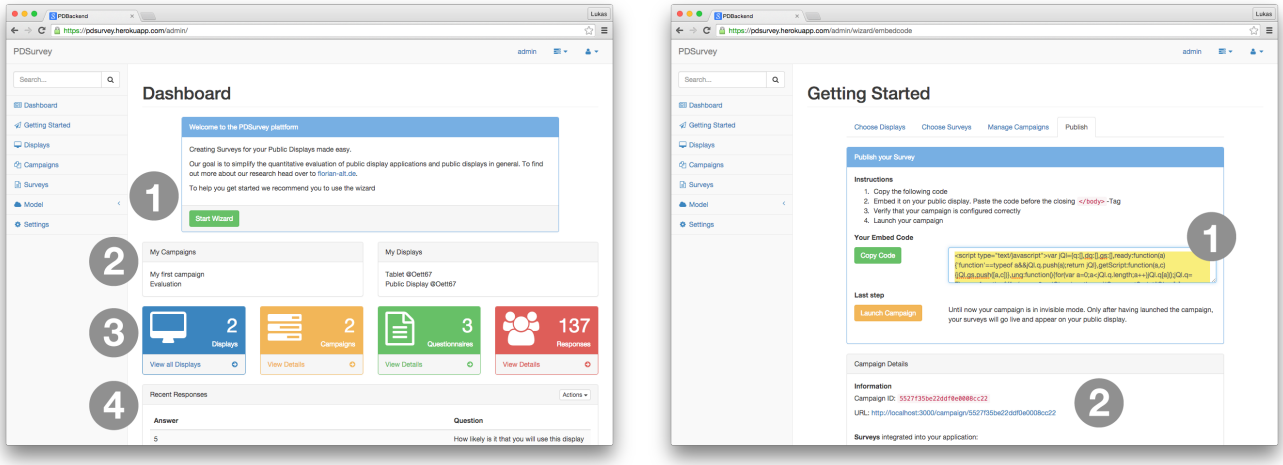

Figure 2: Left: The PD-SurveyAdmin Interface facilitates designing and deploying questionnaires for networked public displays. A wizard (1) helps new users get started, overview and statistics (2) inform experienced users on the current state of their campaign, and results give live-stats (3) on latest responses (4). Right: For deploying and embedding questionnaires on public display networks, developers either inject a JavaScript embed code (1), link to PD-Client (2), or use a REST API.

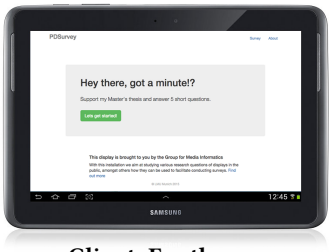

Figure 3: PD-Survey Client: For the purpose of our study we integrated the responsive website through an Android kiosk app on a Samsung Galaxy Tab.

4.2.3 Phase 3–Evaluate. The PD-Survey client (Figure 3) was kept as minimalistic as possible and has a separate code base to reduce application size. The goal is to reduce complexity on client-side and to shift the majority of the logic to the server. PD-Client consists of a survey page, a welcome page, and an about page. The survey page is the central element of the client. All questions for the campaign are loaded on start-up from the server. Then one question is asked at a time. Once the user submits a response, it is directly logged on the server. To increase the motivation to participate, a welcome screen and an about page were added. In our deployment, it turned out that a larger number of people participate in a survey in public, after finding out the duration and the objective of the campaign. This finding correlates with the self-determination theory [45]. We stated on the welcome screen how many questions are asked, the approximate completion time, and the survey purpose, which resulted in an increased response and acceptance rate.

4.3 Requirements

In the concept phase we gathered conceptual and technical requirements. The conceptual requirements are based on the literature review. The technical requirements emerged through evaluating other platforms and from discussions. Requirements by Huang et al. [23] and Jacucci et al. [25] also influenced the development.

Conceptual requirements include (1) supporting quantitative and qualitative methods for data collection, (2) being able to cluster questionnaires into multiple sections and possibly spreading questions across multiple users, (3) supporting various question types (text, numeric, Likert scale, multiple choice, yes-no questions), (4) providing configuration options for display owners, (5) different feedback channels, (6) and also taking the opportunistic nature and the surrounding environment of public display setups into account.

Technical requirements include (1) easy embedding of questionnaires on websites of public display owners (REST API / embed code), (2) supporting public displays of all sizes (TV screens, tablets, phablets, smartphones, desktops), (3) easy scalability of PD-Survey, (4) using a modular approach for development, allowing others to extend and further refine the platform, (5) supporting clients not capable of embedding a website or making REST calls, (6) taking the context into account for evaluation (focus on public display evaluation), and (7) allowing data to be exported in CSV format for analysis in other tools (e.g., R, SPSS, etc.).

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.

4.4 Implementation

PD-Survey is based on JavaScript, to support an as large number of platforms and devices as possible. A benefit is the ability to use JavaScript on all tiers, from client to server to persistence layer. For the development we used the MEAN stack (MongoDB, Expess.js, Angular.js, and Node.js).

The PD-Client front-end was built with Bootstrap, Angular.js, and AngularStrap. For the back-end it was important to have a solid performance and scalable solution. Since we wanted our system to allow many clients to submit and query questionnaires, scalability is of importance. Hence, a back-end built solely on the principles of a RESTful API was preferred. This allows us to query data no matter from which client. We use Node.js on the server side.

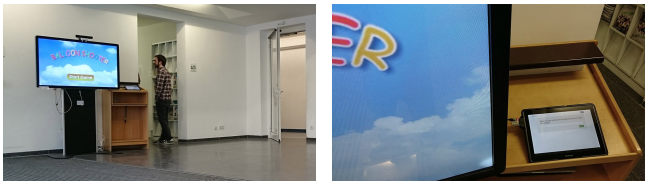

Figure 4: Study setup: The Balloon Game was deployed on the large public display (left). The tablet (right) was mounted to the console, serving as a feedback channel.

5 FIELD STUDY: USER VIEW

In the first study, we focus on the users. In particular, we investigate how people approach and use our platform. Traditional survey platforms gather feedback from users on their desktop computers by contacting them via email or asking them to participate by clicking on a link that redirects them to a website. The situation in a public setting is very different. We hence expect three challenges when transferring the concept of surveys to public displays: (1) users might not feel comfortable revealing personal information, such as their email address, in public [2, 50], (2) they might not take the extra effort of using virtual keyboards for entering text, or (3) users might feel embarrassed filling in surveys on largely visible displays [35]. Hence, our investigation focuses on the users' preference for a particular channel as well as on their behavior.

5.1 Apparatus

We placed a 55-inch touch-sensitive display into the entrance hall of the university building and placed a Samsung Galaxy Tab 10.1 on a conductor's stand next to the display, both running PD-Survey (Figure 4). The application installed on the large display was a game called Balloon Shooter, where people had to destroy balloons floating across the screen through simply touching them. Users had a one minute time-limit before the game ended.

After users finished the game, we displayed a screen (Figure 5), prompting users to fill in a questionnaire using one of four feedback channels: (1) on the large display, (2) on a separated but nearby tablet, (3) on their smart phone or (4) via email. The displayed order of feedback channels was randomized.

(1) Large Display: Users fill in the survey at the display. PD-Survey was embedded into the game and sent data to the server.

(2) Nearby Tablet: We placed the tablet next to the display. The tablet displayed the responsive PD-Client front-end.

(3) Mobile Phone: Users either scan a QR code guiding their phone browser to the survey or they manually type in the URL.

(4) Email: Users type their email into a text field in the game. PD-Survey sent out a survey participation request via email.

Data for the field study was gathered through event logging of the Balloon Shooter and responses and logs from PD-Survey. We conducted in-situ observations and interviews.

5.2 Limitations

The described study has several limitations. Firstly, the number of participants may have been influenced by a novelty effect. Yet, technology in public space in commonplace today and we ran several deployments in the same location within two years before conducting this study. Hence, we assume the novelty effect to be rather small. Secondly, for the tablet condition we could not be sure that people played the game before[2]. Overall, 6 people clicked the 'next' button, though (Figure 5), which provided further explanation on using the tablet. For researchers also the reported overall number of users should be of interest, since questions could also assess reasons for not interacting with the public display. Thirdly, we had a high number of student participants.

Figure 5: Options panel embedded after the Balloon Shooter game, prompting users to choose a feedback channel to complete the survey on. Clicking 'Next' describes the channel.

Log Data	
50 (87.7%)	on tablet
4 (7.0%)	on public display
2 (3.5%)	on smartphone
1 (1.8%)	via email

Interviews	
42.9%	on tablet
32.1%	on public display
7.1%	on smartphone
17.9%	via email

Table 2: Distribution of preferred feedback channels: (left) the percentage of users using each channel (N=57) and (right) the answer of participants in interviews (N=28).

5.3 Results

During the two weeks of evaluation, Balloon Shooter was played 117 times. Note, that this is not the number of unique users, since there may have been returning gamers. We received 57 filled-in surveys and carried out 28 interviews.

In the following, we review which feedback channel was most popular, followed by results of the questionnaire and interviews.

5.3.1 Quantitative Findings. We determined the preferred feedback channel through analyzing the log files and from interviews (Table 2). According to the log file, the most popular feedback channel was the tablet (87.7%), followed by the large display (7.0%), smart phone (3.5%), and email (1.8%). This is also reflected through responses from interviewees (N=28): Here, the tablet (42.86%) was most popular, followed by the large display (32.14%). Also, email (17.86%) was slightly more popular than smart phone (7.14%)[3].

On all feedback channels we asked the same five questions. From 57 responses, 49 were complete. On three occasions, people stopped filling in the survey after the first question, once after the second question, and four times after the third questions.

[2]Note, that this could have been achieved through asking users to enter a code obtained at the display on the tablet. Yet this would have made interaction very complex.
[3]Due to the low sample size we deliberately decided to report descriptive statistics.

One question assessed the users' motivation (*What was your motivation for approaching and using this display?*). The main reasons mentioned were "curiosity" (12 answers), "fun" (10), "boredom" (8), "interest" (2), and "during breaks" (2). Other reasons were "it is there, so why not?", "it is there and colorful", or "I've never seen it before in this spot and wanted to know what it is about".

The average age per feedback channel was highest for public displays (31.6), followed by tablet (28.2), email (24.0), and smart phone (23.0). The time for responding to all questions was on average 1:02 minutes, ranging from 0:36 to 3:06 minutes. The acceptable number of questions ranged from five to ten questions.

5.3.2 Qualitative Findings. We conducted 28 interviews both with people who interacted / provided feedback as well as with people who did not. The evaluation of the semi-structured interviews was based on Grounded Theory [53], promoting a systematic evaluation of the interview transcripts.

The interview provided insights into *why users chose / would choose a particular feedback channel*. Reasons in favor of the *large display* were, because it is the "most direct" feedback option (4 answers). Two participants favored it because they were "already standing here". Participants who did not like to fill in the survey on the large screen said this was because "it was too large" (4 answers), "everyone could watch me" (2), and "it feels too public" (2).

Participants liked the *tablet*, because "the display is smaller and better laid out" (5 answers), "has a higher sensitivity / better usability" (2), "feels more private" (2), "you are not in the way of others", "I am more used to it", and "less people are watching me". Negative answers included "redundancy" (2) and "personal aversion" (1).

People responding via *smart phone* because "it belongs to me", and "I use it most often". Participants did not like the smart phone option because it was "too much effort" (4 answers), "too indirect" (3), "requires too much personal information" (3), and "I am not sure how complex and time-consuming it would be" (2).

Finally, with regard to *email*, most people preferred this option because "I can do it at home" (4 answers), "I have more time to complete the survey", and "better warranty of privacy". People would refrain from submitting their email, because "I would forget about [responding]" (5 answers), "I don't like to submit my email" (4), "I don't like to postpone things" (3), "it would take too long to complete the survey" (2), and it would be "too much effort" (2).

The main *motivation* for approaching the display was "curiosity" (6). Other reasons 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" (2) and "it feels strange to play in the University entrance" (1).

5.3.3 Other Findings. The open coding phase of the Grounded Theory produced new aspects beyond users' reasons for and against using the different channels. One person in his 50s preferred the large display due to short-sightedness. In addition, one retired person refused to use any of the digital feedback channels, even when being offered to be assisted. Furthermore, one participant was willing to provide her email address on the tablet, but not on the large display. User requirements on what they 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.

6 FIELD STUDY II: RESEARCHER VIEW

To understand how the platform could assist and would be used by researchers, PD-Survey was tested in a 4-week deployment by three undergraduates in the context of a course project. Students received an in-depth introduction to public display research through two 90-minute lectures, a book [19] and a reading list. Thus we made sure they were familiar with fundamental concepts, interaction models, and challenges of conducting display research. The project investigated users' motivation to interact with displays in groups.

6.1 Apparatus

We used the same setting as in previous study. In addition, a second 55" display was deployed in another university building, close to an area with benches and tables that students used for group work and waiting. Both displays were equipped with a Kinect and a tablet. As application we used a game that could be controlled through mid-air gestures. The goal of the game was to collect different items falling down from the top of the screen by collecting them with the hand. Each user was represented through a skeleton. The application could be played by six people in parallel. It was a collaborative game, where all collected items counted towards a joint high-score.

A survey with three question types was created by the researchers using PD-Survey: (a) *demographic questions* (for example: 'Please select your gender'), (b) *closed questions* ('Please rate the following statement – Playing the game in a group was fun.'; ratings on a 5-Point Likert scale; 1=don't agree at all, 5=totally agree), and (c) *open questions*, both such that required rather short answers ('For which reasons do you (not) like to play in groups?') as well as longer answers ('Please describe a situation in which bystanders were observing you while interacting and how you felt about it.').

6.2 Survey Results

In total, 31 people filled in the survey. People indeed provided qualitative, yet concise feedback. With regard to the open questions allowing for short answers, people provided comma-separated lists. For example, being asked for reasons why they would not like to interact with public displays in groups, people answered 'feeling uncomfortable', 'shame', 'coyness', 'the group is too big'. For longer questions, most people remained concise, however writing entire sentences. Being asked about situations in which they were observed , people answered 'I behave differently, because I'm feeling observed'. Some provided short answers, e.g., 'reserved', 'insecure'.

We conclude that surveys cannot easily replace methods such as short interviews. Yet, users do provide valuable, qualitative answers. For example, all provided answers about reasons to interacted in a group could be collected in a list and be used for a later version of the survey where users are asked about how strongly they agree. Thus, the number of on-site interviews and observations could be reduced while still being able to gather rich feedback.

6.3 Extension of the Platform

To obtain richer qualitative feedback, the students decided to implement a feature that allowed participants to use the tablet's microphone to provide spoken feedback. Therefore, the screen for qualitative questions showed both a record button and a brief description of this feature as well as a text field.

The students found that participants were quite reluctant to use this feature. The fact that after a week into the deployment only a hand full of participants had used this feature led to that the researchers started to conduct a series of personal interviews and asked people why they opted for written feedback. Answers revealed that while some of the participants did not use the feature for privacy reasons, some mentioned, that they had not noticed it. As a result, the students made the record button more noticeably and added a brief description. This shows, that PD-Survey can be easily extended through novel features.

6.4 Supporting Audience-Centric Research

We also found instances, in which the platform supported the student researchers in the design process. As they developed the multi-player game, one goal was to increase the number of users and interaction time. The researchers created and posted a brief questionnaire asking participants whether a more collaborative or more competitive game concept would, in the players' view, lead to playing more often in groups. Since answers suggested collaboration to be a good motivation, the researchers added a high-score towards which group performance counts. The high-score is constantly shown on the display and reset daily. This modification led to an increase in number of games and in the length of games – probably because people tried to beat the high-score.

From this we learn not only that our platform can support the design process through involving users in-situ, but also that users are happy to take short surveys – even if interaction time is short.

6.5 Researchers' View

Through interviews with the researchers we found that they particularly liked that the survey could simply be pushed to different displays without additional effort by simply creating one campaign and assigning it the displays. This came in handy when they did several modifications to the audio UI. They also liked the fact that they had access to the GIT repository and could easily add the audio functionality as a new question type, which would have been difficult with existing platforms. One researcher also pointed out not having to visit the displays every time something was changed saved a lot of effort (displays were 3 km apart from each other): "The first time we changed something we went there so see whether everything was fine. Later we simply pushed the update." What was also mentioned positively was that neither the app crashed a single time during the deployment, nor any participant 'hacked' it.

Though this was not a comprehensive assessment of the entire functionality of the platform, these early insights yield that researchers found many display network-specific features useful. PD-Survey helped them to keep the effort low while at the same time providing a powerful tool to realize novel features.

7 DISCUSSION

PD-Survey offers different channels. We found that when asking people to provide feedback in public space, public channels (display, tablet) are most suitable and receive high uptake among users. There is some evidence that if sensitive information is requested, the tablet is preferred since it feels more private than the large screen. The good thing with these channels is also that feedback is gathered in-situ, i.e. in the display context and shortly after interaction or exposure to the display. Hence, feedback can be considered to be of high ecologic validity. Other reasons that impacted on the users' choice for a particular channel were display size and effort.

We also found that the choice of a feedback channel might be affected by age: older generations seem to find typing in their email or opening a link on their smart phone too cumbersome. To address an as large audience as possible, it is, hence, beneficial, to let them choose among a wide variety of feedback channels. PD-Survey supports this freedom of choice, offering different channels in parallel. It might also be beneficial to choose channels according to the type of questions: e.g. public displays subjectively felt "large" and "public"; people might incorrectly answer questions out of social desirability when they feel like someone "could watch" them.

Most people stated curiosity and spare time to kill as main motivation to interact. This confirms prior findings that waiting situations are particularly suitable to engage passersby. Still, the number of questions should be chosen carefully. For us, 5 questions that required 1–2 minutes worked well. Open questions are answered to a certain extent. Future work could explore this in depth.

While we found instances in which the platform was able to support researchers, there were also limitations. For example, in the case of competitive gameplay, the users' opinions could be easily quantified. However, in the case of the audio-feedback, it would have been difficult, to find out the reason for why people did not use this feature. Hence, our platform can be seen as complementary to other research methods – yet with the potential to reduce effort.

8 CONCLUSION

We presented PD-Survey, an open-source platform designed to support audience-centric public display research. Field studies and deployments gather data through logging, video analysis, or semi-structured interviews. Each method has trade-offs: event logging provides little information on subjective user opinions; semi-structured interviews and observations are time consuming, ultimately leading to smaller sample sizes. PD-Survey offers an automated way to collect feedback at any time, which makes it a valuable tool for complementing other methods.

Two deployments showed that channels allowing feedback to be provided in-situ are most promising but that to address a large audience, providing multiple options is a good choice. Early insights show that researchers can both use and extend the platform.

For the future we will actively promote our platform among researchers in the community, which we envision to lead to a better understanding of our research field. We also plan to extend the platform so as to also include audience measurement, providing basic statistics and plot diagrams, hence supporting a rich analysis of deployments. Furthermore, offering the opportunity to connect surveys with other display applications (e.g., through an API) would allow the results to be better linked to actual user interaction.

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