Pico-ing into the Future of Mobile Projector Phones

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Abstract
Ten years ago we were on the verge of having cameras built into our mobile phones, but knew very little about what to expect or how they would be used. Now we are faced with the same unknowns with mobile projector phones. This research-in-progress seeks to explore how people will want to use such technology, how they will feel when using it, and what social effects we can expect to see. This paper describes our two-phase field investigation, with results and design recommendations from its first, experience-sampling phase.

Keywords
Mobile, projector, handheld, exploratory, field study.

ACM Classification Keywords
H1.2 [User/Machine Systems]: Human Factors. H5.2 [User Interfaces]: Interaction styles, Prototyping.

General Terms
Design, Human Factors

Introduction
Ten years ago, before camera phones became commercially available, we were faced with the exciting prospect of being able to take photos on our mobile phones. Early exploratory field studies revealed the ways in which mobile-phone cameras would be used and the kind of social impact they would have [4, 9].

The technology is now available, however, to build projectors into our mobile phones. What will people want to project? How will people feel? On to which types of surface will people project? And what will be the social response? There are many unknown questions we can ask, and this research has begun to answer some of them through a combination of experience-sampling and diary field studies using a prototype projector phone system.

Related Work

Handheld pico projectors have recently become commercially available, and projector phones are now arriving on the market. While industry has been developing the technology, academia has been researching how people will use projector phones to interact and share experiences.

Most existing work, generally using simulated hand-held projections, has focused on individuals projecting and augmenting their physical environments. Beardsley *et al.*, for example, studied the augmentation of physical environments using small desktop projectors mounted on a one-handed joystick [1]. Sugimoto *et al.* took a different approach, using a static projector to simulate mobile projections. Their work investigated annotation, manipulation, and file-transfer techniques, using overlapping projections [10]. Later, after creating and studying a more portable handheld projection prototype [2], Cao *et al.* investigated multi-user projection scenarios, such as games and business meetings, by enabling techniques like the joining of two projections, and the augmentation of one projection with another [3]. Hang *et al.* performed an empirical study of map-based tasks using a mobile phone strapped to a small desktop projector [6]. The projector

Figure 1: Prototype projector phone, where the projector and pen video camera face the same direction.

was connected to a laptop to provide a higher projection resolution than that available from the phone, and Bluetooth was used to synchronize the displays. Comparing screen, projector, and screen+projector variations showed that the phone's screen was important for text entry, but having the higher resolution projection improved task performance and satisfaction.

Many of these studies have been limited to lab environments due to technology constraints, but since handheld projection devices have become commercially available, studies have moved into the field. Greaves *et al.*, for example, projected maps in public spaces and enlisted the support of bystanders for directions [5]. Like SMS and camera phones previously, participants were unsure how or when projector phones would be otherwise used. Further, unless directly addressed by the experimenters, the majority of bystanders did not

react. Some participants, however, were concerned about accidentally projecting private data.

Our work, presented below, has focused on how users feel while making projections in public and private spaces. Consequently, our studies echo early research into camera phones. Although much was learned about camera phones after widespread use (e.g. [7]), preliminary studies investigated potential forms of audio, image, and video capture techniques with prototypes. In 2000, for example, Mäkelä *et al.* built a camera phone and deployed it with two small groups of children [9]. Our investigation applies a similar methodology to study a prototype projector phone.

Two-Phase Investigation

With the same exploratory aims as the early studies into the potential of camera phones, our focus has been to explore where and how people might use projector phones, and how they may feel while using them. However, while camera phone studies investigated the creation of new media, the study of projections often involves the display of existing media. Consequently, we have chosen to perform our research in two phases to study both participant reactions to a range of media types, and their potential self-motivated uses of projections. First, we performed an Experience Sampling Method (ESM) [8] study to elicit the reactions of participants to a range of media regardless of whether they would consider projecting them during undirected usage. Second, we will be performing a diary study of potential mobile projector scenarios. This combination will help us to understand both when such projections might be used, and the reasons why some media types are not used. We chose to begin with an ESM study to calibrate our understanding of human reactions to projected material before studying potential user needs in more realistic circumstances.

While we wait for the wide-scale availability of commercial mobile projector phones, we have created the prototype shown in Figure 1. The device consists of a standard mobile phone attached to a handheld pico projector. Further, by pointing a pen video camera in the same direction as the projector, we are able to gather video recordings of projection events in context.

Study 1: Experience Sampling

The aim of our first study was to record behaviours and reactions of participants to a range of media-types. An ESM experiment allows for the media to be an independent variable in the study, thus enabling us to capture responses to several types of content. 15 participants, aged between 18 and 65 (8 younger than 35 and 7 older) were provided with the prototype for either one working day (7 male, 5 female) or a weekend (2m/1f). The majority already used camera phones regularly and one had previous experience with a pico projector, having played with one in a shop.

Each participant received five ESM events each day, which presented one of five types of media: website; map; photo slideshow; short TV clip; text message. The range of media and times presented were designed to capture a range of responses to different content in both working and social spaces. Further, there were variations within each media type, such as a work message, a comedy video, or a sports website, to elicit more nuanced responses to content. The involvement of weekend participants also provided an extended experience window, with events in the home and events outside of daylight.

(a) Photo on the ground

(b) Video on an LCD screen

(c) Website on a person's leg

Figure 2: Example projections captured during the first study.

Each ESM event, initiated by a beeping alarm, lasted around 2-5 minutes and comprised of four stages: setup; project; take-down; questionnaire. The user was given setup and take-down instructions on the phone's screen to prepare the camera and projector. When ready, they projected the content onto any surface until the phone instructed them to stop. Finally, they were asked a series of likert-scale questions regarding aspects such as projection clarity, emotional responses, and social responses. Users were able to immediately begin, delay or cancel any event if they wished. A total of 90 ESM events were triggered, and only seven were cancelled, four of which were during the weekend. While being outdoors was the most cited reason for cancellation, the rest related to events such as meetings. Although a couple of participants found the combination of technologies confusing, most used it confidently, one saying *"[it was] really pleasant to use."*

Social Responses: 51 events were triggered while participants had company present, and participants reported choosing a socially visible projection space on 34 of these occasions. In line with previous anecdotal evidence [5], complete strangers stopped to watch for only 11 projections. Further, none of these bystanders were reported as having commented or engaged during these few events. Participant P1 said: *"One person looked up, but then continued working." and* P5 said: *"Other people were around, but [there were] no comments."* In public spaces, perhaps surprisingly, participants did not feel significantly less comfortable or safe, nor significantly more self-conscious. Participants did, however, report projections as being significantly more useful ($t(80)=2.19$, $p<0.05$), when in public, whilst finding it significantly harder to locate a suitable surface ($t(80)=2.39$, $p<0.05$).

Personal Responses: Weekend participants felt significantly less self-conscious ($t(81)=2.35$, $p<0.05$) than 1-day participants, who were usually at work. ANOVA and Tukey tests also revealed that participants had a significant aversion to projecting text-based content compared to other media types for: a) wanting to project that media from their own phones ($F(4)=5.87$, $p<0.0005$), b) being useful ($F(4)=6.43$, $p<0.0005$), and c) the projection being better than the phone screen ($F(4)=3.45$, $p<0.05$). P1 said: *"[the text message] made me feel self-conscious, even though I was alone."* and P8 said: *"I wouldn't project [a text message] though. Never."* While many participants noted general concern over projecting private data, a deeper analysis showed that they were less keen to project work-oriented text ($p<0.05$). P11 said that their work email often included confidential data.

Surfaces	A	P	Surface	A	P	Surface	A	P
Wall	76	47	Cupboard	8		Pinboard	2	
Desk/Table	30	7	Door	5		Fridge	2	1
Paper	16	8	Person	5		Trainseat	2	2
PC Monitor	14	5	PC tower	4	1	Bin	2	
Floor	12	5	Chair	3		Printer	1	1
Ceiling	11	2	Window	2		**Total**	195	79

Table 1: All 195 surfaces (A) and 79 primary used surfaces (P) used during the 79 events captured by the pen video cameras.

Surfaces: During the 79 events successfully captured on video a total of 195 surfaces were used; 75 were reflective surfaces and 120 were matte. Participants typically tried many surfaces. Table 1 shows all the surfaces tried (*A*), and the main, or primary (P), surface used during each ESM event, while Figure 2 shows three example projections. Figure 3 also shows surfaces used by media projected.

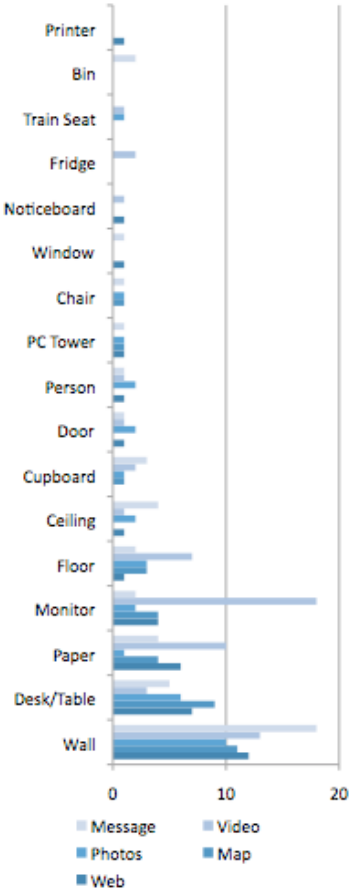

Figure 3: Analysis of surface used by media type projected

Although many different surfaces were used, including bins, windows and other people, the majority were walls, tables, floors and ceilings. These, however, were biased to 1-day participants. 93% of desk/table projections, for example, were by 1-day participants. The most commonly used surface by weekend participants was the wall (24/51). Two potentially interesting surfaces used were pieces of paper and computer monitors. According to comments during debrief, paper was used in the quest to find a clean white surface. Participants may have thought the monitor would provide a suitable surface, as shown in Figure 2 (b), as it is built to display digital content. Notably, from Figure 3, computer monitors were mainly used for video projections. Figure 3 also shows that text-based messages were nearly always projected onto walls. Conversely, P15 stated that, for all media except the map, the back of a chair was best. The map, however, was distorted by the chair's curvature. Several participants noted that surface colour had a large effect on projections, suggesting that black and white were often clearer.

Finally, while many participants tried to enlarge the content by projecting far away, the projector was often not bright enough to do so. While maintaining a visible picture, however, some struggled to get a sufficiently large projection, with P1 saying: *"[I] tried the desk, but the wall was better, I had to stand up for the desk."* Another participant, after projecting on the back of a train seat, noted that it was difficult to get a sizable projection in a confined space. Four participants further expected to be able to go from small to large projections within an arms length, with many using their arm position, rather than the projector's controls, to focus the content.

Design Recommendations

Given the significantly negative reaction to text-messages, we would recommend that projector phone designers add careful privacy controls to the display of text messages and emails. It is common for notifications, of new messages for example (which typically identify the sender), to interrupt or overlay other applications. Designers may wish to avoid such automatic interruption and display during projection, or display them on the phone's screen only. Despite the novelty of the pico projectors used, there were very few cases where bystanders notably reacted, and at no time did they approach participants. Rather than the keen, inquisitive reactions seen for earlier mobile innovations, more recent non-ambient interventions appear to be increasingly acceptable in public spaces. Mobile technology has already shaped the design of physical spaces; consider, for instance, 'quiet zones' in offices and train carriages. Our findings suggest that architects and furniture designers, amongst others, should begin thinking now about how to accommodate future pico projection needs.

Study 2: Diary Study of Self-Motivated Use

The second phase of this investigation will take a closer look at participant needs for spontaneous mobile projections. The initial phase has allowed us to collect user reactions to several types of content, gathering general feedback about surface types and content suitability. We will now focus on the capture of potential projection environments and scenarios.

Ten participants will take part in one-week video-diary study sessions. Participants will be provided with a video camera enabling them to record locations and surfaces that they personally deem suitable for content

projection. In addition, participants will be encouraged to describe the types of content they envisage at each location, and also provide contextual reasoning for their choices. This suggested content need not be static, though – participants are free to suggest potential augmentation of everyday objects with interactive projections. As more of a diary study, this second phase will allow us to get deeper, and more ecologically valid insight into users' ideas about projections during everyday life. Consequently, its qualitative results will complement the quantitative data from the first study.

Conclusion

This paper describes our two-phase approach to investigating human responses to mobile projector phone technology. We have reported on phase 1: an experience-sampling field study, where 15 participants were provided with a projector phone prototype and asked to project different types of media, at different times of the day, wherever they choose. Users were willing to project content, even when in social spaces and with other people around. One contribution so far has been to highlight the significantly negative reaction to text-oriented content, indicating that projector phones should support careful control over projected content so that users can easily maintain privacy. To complement and strengthen our findings, the second phase will focus on reactions in more ecologically valid contexts, studying potential projector locations and augmentations. Together, these findings should elicit a rounded and insightful view of both desirable and undesirable projection circumstances and scenarios.

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