Movable, Kick-/Flickable Light Fragments Eliciting Ad-hoc Interaction in Public Space

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ABSTRACT
We describe the design process, technical concept and first insights from a lightweight in-the-wild evaluation of a movable interface for public places. Our wider aim is to understand how the environment can be utilized for novel interface types. Our moveable prototypes are an intermediate step that confirmed known behavioral patterns in public space but also revealed new ones (e.g. creative inclusion of urban furniture and trees) as a result of having multiple objects within a larger interaction space.

Categories and Subject Descriptors
H.5.2 User Interfaces

General Terms
Design, Human Factors.

Keywords
Urban HCI, light, Urban IxD, foot interaction, public interfaces

1. INTRODUCTION
With the technical advances over the last decade, the number of pervasive displays in urban spaces tremendously increased. However, the majority of existing research on pervasive displays focuses on wall-sized displays (e.g. [4, 14, 17]). This often translates to integrating screens into the built environment and existing settings, and devising new ways of interacting with screens from a distance (e.g. using mobile phones [12, 26]). Yet the urban environment allows for much more than just flat screens and projections [2, 25]. When the "urban setting prompts new forms of interfaces or alternative assemblies" (Dalsgaard's first challenge for media façade design [9]), this may mean exploring options beyond the traditional form factor, positioning and visual aesthetics of the screen display.

In our work we focus on an under-explored area of the design space for urban displays, that of smallish and movable interface devices (see figure 1). With these kinds of floor-based interfaces, we shift the attention of people away from vertical displays to the ground, that is, the pavement of plazas, walkways and pedestrian zones. Following Dalsgaard's aforementioned first challenge for media façade design [9], we investigate new modes of interaction for these floor-based devices. Using the feet (instead of hands) might enable new, playful ways of interacting. Here, we describe the design process, development and an initial in-the-wild evaluation of our working prototypes of kick-flickable interfaces. The design of the interface is further inspired by existing work exploring the notion of 'light bodies' [23] and configurable pixels [22].

Our system consists of an ensemble of light objects, which reacts with different light patterns to being moved and to each other's vicinity. They are designed to invite and support manipulation with the feet. Furthermore, they each have a distinct personality, resulting in different behaviours (physical and digital).

Figure 1. Three of our light fragments.

Our general research focus lies on how the urban space and novel urban interfaces interact in eliciting user interaction patterns, and in how such novel systems may foster appropriation of public spaces and lead to 'shared encounters' [20] by creating a visual focus, talking and meeting point for urban dwellers. In exploring the potential of movable interfaces, we build on our previous research [10, 11], which found movable interfaces to encourage social interaction more and have the potential to create a larger 'potential interaction space' than fixed interfaces [10]. Movable interfaces support body movement and can be passed around, allowing for a different social dynamics than immovable displays, which furthermore leads to a dynamic spatial configuration of the interactive space, following the dynamic character of urban spaces. The *movable* bridges the gap between stationary and mobile interfaces, which have so far have been considered as the two possible interface types for urban spaces. Mobile phones create an almost exclusively private interaction space which often inhibits

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exchange and discussion. With custom, movable input devices [10], more performative interaction scenarios can arise. In contrast, situated public displays based on fixed interfaces, e.g. touchscreens (e.g.[15]), open up the interaction space to the public, but still provide a rather limited physical space for interaction, constraining how many users can simultaneously interact and see the display. The spatial setup of most public display installations, once determined by designers, tends to be immutable. In our earlier work [10], we have begun to analyze how an installation's spatial setup and integration into the existing environment affect interaction patterns. With movable interfaces, users can change the configuration, which ideally might create a self-adaptive system where users optimize the configuration to allow or enhance social encounters.

Prototyping interfaces for the public environment is still a daunting task, especially for deployment-based research [1]. To realize public interfaces allowing users to continuously interact from various places within a given space, it is often required to instrument the potentially interactive space with additional technology. To avoid this, we decided for a wireless, modular approach. We believe this approach can reduce hardware integration efforts, as interaction can be orchestrated on a central server, while making it easy to add or remove components and it further allows for a dynamic interaction space that can be easily moved or modified.

We illustrate our design approach and discuss the outcomes of a first deployment in the wild. With this, we contribute to a better understanding of the design and development of public interfaces and the creation of shared encounters in an urban environment.

2. RELATED WORK

Different from conventional public displays [4, 15] or media façade installations [7], the Kick-/Flickable Light Fragments constitute a distributed display and interface. Thus, we investigated previous work on non-screen-like urban installation projects. Our use of light as medium and of light objects was greatly inspired by some of these. The rich interaction set of Seitingers "Light Bodies" [23] inspired the idea to lend individual devices different characters and accordingly, behavior, to invite users' subjective interpretations of these characters. This leaves more room for open-ended exploration. Memarovic et al. [15] posit that design for discovery is more appropriate in public environments than a predefined interaction sequence, such as game rules. A somewhat underspecified system allows for richer interpretation, not only from users but also observers, and can elicit a large variety of different types of interaction [23]. The rather simple light bodies [23] that somehow react to music, engender various interpretations, depending on the context of use, while creating a rich and diverse "performer display" for observers.

The "Urban Pixels" installation" has a less direct interaction [22]. Here, distributed pixels are switched on and off by pointing a flashlight at them. However, the 'display' of pixels is positioned quite far away from the user and there is no determined place to store the flashlight. Media façade installations such as the SMSlingshot [10] that rely on a dedicated handheld device also have this 'placement problem'. Floor-based objects do not suffer from this issue, as they naturally 'live' on the ground. "Pixels" [25] uses multiple plastic light cubes, which change color and brightness when rotated. Each block is wirelessly connected to the others and can be stacked. The design is robust and mediates between body and architecture as the cubes can easily be manipulated by hand, but may be used to create larger architectural structures. Also very inspiring were "DJ Light Installation" and "21 Swings" [2, 24], public sound and light installations that enable users to improvise an ad-hoc performance of light and sound across a large public space. These designs especially reward simultaneous usage with several people. "Liquid Bricks" [5] embeds a water-filled pouch beneath a city street, creating the impression of a liquid pavement. This is an analog version of a digital surface prototype by Fatah gen. Schieck et al. [19] which invites people to playfully test the effect, jump and move about.

While foot based interaction is starting to become more prominent in HCI, this tends to adhere to standard HCI interaction patterns. Rather than using the feet for touch or freehand gestures or turning the floor into a large touchscreen (cf. [3, 18, 21]) our project aimed to develop interactive objects that invite playful exploration and manipulation (with the feet) of their physical form, as well as behavior and interactive responses.

3. Design and Implementation Approach

In the initial phase of the design process, we reviewed related literature and observed how public spaces in urban environments are used. We explored core concept ideas, and investigated form factors and shapes that lend themselves to manipulation with one's feet. After deciding on the initial concept, the technical development commenced in parallel with refining the design.

3.1 Ideation and Concept Development

As a first attempt to investigate how public places are being used, project members analyzed a public plaza in Weimar. They marked which paths people took and which areas were used in what ways. This provided common ground for discussions and helped imagining interaction scenarios.

Fundamental issues to be resolved were the placing problem, multi-user support and how interaction can create a performance with active and passive engagement value (cf. [8]). A core problem also is how to make people aware that something is interactive. In an early public test of a colored light chain we saw that blinking is very effective in attracting people and raising curiosity. This led to the early idea of using coloured blinking lights. We also had to consider how to minimize the risk of pedestrians tripping over our devices or them being kicked into moving traffic or someone's path. Most importantly, we wanted to make people interact with each other through multiple devices. A puzzle seemed a simple but effective solution (figure 2). This could be two or more parts that in combination produce a new response. Then, there should be an incentive to move them apart again, so that the process can start anew. In parallel with exploring the puzzle concept, we explored shapes and forms such as tubes, cubes, shells, pins and balls, which can be combined and put together easily, but do not require the user to use their hands.

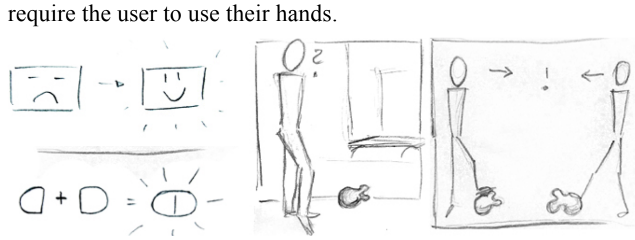

Figure 2. Positive feedback on connecting puzzle pieces. Early sketch of user interaction and shapes.

We decided on a minimalistic concept that plays with people's interpretive imagination. Light patterns and sounds can be associated with animate beings; for example a fading light resembles breathing. Thus, each device was to have its own character with preferences and quirks. The objects can talk to each other, argue, be in love, and have a good or bad mood. In addition, we decided not to use any textual screen displays but to restrict ourselves to abstract coloured light patterns.

3.1.1 Shape and Material Exploration

To determine forms that can be operated with the feet we conducted a body-storming session. Various everyday objects and household items were taken outside and the entire team took rounds, exploring how these could be moved around only using one's feet. Boxes, cans, a hockey stick, shin pad, shoetree, candy cone, an old radio, balls and a toilet brush were kicked, pushed and flipped. We identified shapes that one can easily pull, lift or push using just one foot (using both feet challenges balance), favoring a foam knee pad, tubes, and a radio with rotary switches. Round, barrel-shaped objects felt satisfying in interaction, as it is fairly easy to flip them or push them forward from underneath with one's foot, and when let go, bounce in characteristic and interesting ways. Some unpredictability in movement was felt to provide the object with character. But more complex shapes (e.g. the toilet brush) were found too difficult to control.

Figure 3. Body storming with everyday objects.

This was complemented with a visit at a hardware store, pound store and animal toy store in search of robust construction methods and materials. We experimented with objects such as fruit boxes, trash cans, and sewage pipes, how to handle (or foot) them. An organic lamp shape from the light department inspired one of our later prototypes. Dog toys turned out to have well thought out form properties, some supporting short-range but unpredictable bouncing, while being robust, and others were ideal for travel over distances (ball-like behavior). We considered that our device should not move too quickly and easily, limiting potential hazards for pedestrians and surrounding shops (e.g. a ball may quickly roll into traffic or trip someone), but should nevertheless behave somewhat unpredictable and surprising.

Figure 4. Shape generation.

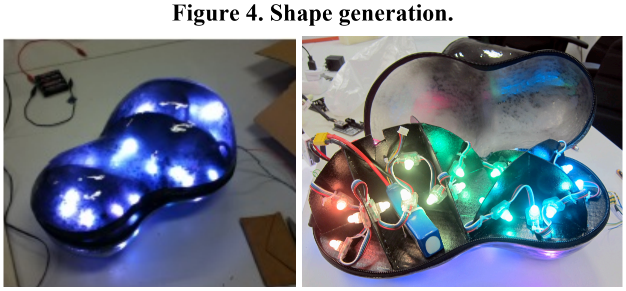

Figure. 5. Final light fragment and its inner life.

Based on these exercises we chose six organic shapes based on our main form inspirations. The devices should look related but unique, and fit together like a puzzle. Natural organic forms, such as a kidney, pear, peanut, or bubbles, also guided us. We prototyped these shapes from Styrofoam to evaluate them, having project members kicked and pushed the new objects back and forth as well as exhibiting them at an Open Day and observing visitors. They all can be tilted and flipped easily, but do not roll on, and due to their irregular shapes, move in very individual ways.

3.1.2 Character Design

The Light Fragments not only have different shapes, but were also assigned personalities, nicknamed: Mom, Dad, daughter Tanya, Paul, teacher and retiree (figure 6). For example, Tanja and Paul like each other, and align their behavior when they see each other. Mom and Dad behave in a similar way. Paul wants to be cool, and Dad is easily annoyed with him. The retiree is slow to react. These characters were then translated into technical attributes, sensor and actuator levels and patterns. Each device has a sleep mode, three staggered reactions when being manipulated, and notices the vicinity of another device. For example, Mom and Dad then adopt the same colour blinking pattern. Staggering reactions is important for the behavior to be understandable by users. Otherwise, a device would jump from sleep mode into its maximum activation level after having been kicked heavily once. This proved somewhat cumbersome, because each sensor needed to be calibrated for the specific shape of the device. Learning algorithms could simplify this calibration procedure. Due to time and financial constraints, we created only three objects, selecting Mom, Dad, and Paul as a minimal set.

Figure 6. 'Family' with different roll characteristics.

3.1.3 Product Design

Constraints on material choices were that the hull needed to be translucent, robust, and lightweight. After consulting with professional product designers and our University workshops, and testing different materials, we chose Vivak PET 1.5 mm sheets to vacuum-form the objects from our Styrofoam shape prototypes. This resulted in two halves that then were re-connected with a zipper. To achieve a translucent effect, the hulls were sandpapered and colour-sprayed. To hold the hardware in place, a cardboard grid was built, with the added benefit of strengthening the devices' stability as well as separating LEDs into compartments (see figure 5). This had to distribute weight equally, so the objects could flip over, as well as making sure they light up uniformly.

3.2 A Wireless Modular Approach

The prototyping of novel interfaces for urban scenarios is still a difficult process, due to the need for robustness. Another problem is how to match architectural and urban scale, as well as wiring of sensors and actuators. Scaling up could be achieved by having more light fragments that distribute over space. For moveable objects, communication is best realized via a wireless connection. A wireless modular approach can furthermore help to bridge over distances. We thus aimed for a system architecture that supports ad-hoc configuration, and is based on a central orchestration server. This also lowers the costs for each individual module, supports Wizard of Oz control and fast prototyping, reduces integration time/cost, allows for ad-hoc configuration and adding of further devices, and easy integration into existing media architecture.

To simplify the devices, we divided each light fragment into sensor and actuator modules, each controlled by a transceiver micro-controller combination (a panStamp). In this architecture, the server module receives data from sensor modules, which register movement and each other's vicinity. It then determines how each device is to react based on its personality, and broadcasts instructions to the actuator modules. The server furthermore provides a user interface that allows the ad-hoc configuration of devices' personalities. We utilized accelerometers to sense movement, as this sensor can at once sense user input as well as the devices' inertial movement. To detect vicinity of devices we took advantage of the RSSI (radio signal strength indicator) of the panStamps' broadcast messages. As precision was not a critical factor, RSSI measurements were sufficient. Output was provided via a multicolour LED band where each LED can be controlled individually, as light patterns attract attention, especially at night. Each device furthermore has its own 12V LiPo battery for power supply.

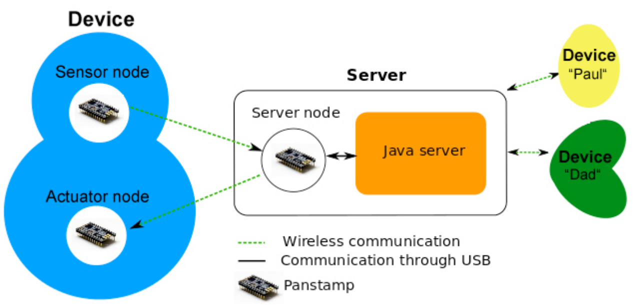

Figure 7 Device structure.

The orchestration server has a lookup table determining how each personality responds to stimuli based on its current state. A personality's behavior has four elements: a light pattern (blink, fade, rainbow, etc.) two colours used by the pattern and the pattern duration. After a first interaction (being moved), the state will be "first contact", which then moves on to "played" and "played hard". After a period of silence, the level goes down again. The devices furthermore report battery status to the server if this falls below a threshold. When starting the server, one can customize a personality or select from the predefined. Hence, different devices may be associated with different characters, and new colours, light patterns or even states can be added by editing the table.

4. EXPLORATORY EVALUATION IN THE WILD

For a first deployment we chose a highly frequented area in a pedestrian area (approx. 15m wide, with an inner main path of ca. 7m width) constituting a major connection path. A lot of people move through this area and many take some time to linger, with several benches installed at the sides. As the light patterns work best in the dark, we began our small in-situ study in late October at dusk (6:30pm), on a cloudy but comparatively warm (16-17°C) evening in dry weather, until the pedestrian zone became quiet. We had set up just as stores began to close, putting the light fragments into the middle of the street. At this time, the area was used by people passing through, hanging out, or waiting for friends. Around half an hour into the deployment, stores closed, which affected pedestrian flow, with far less people around, and shoppers being replaced by people going to the pub or for dinner.

The project team distributed itself at some distance in the area surrounding the devices, trying to overhear conversations, while pretending to just pass the time (e.g. as a pair sitting on a bench), taking notes and a few photos. One team member documented the events on video from a distance (due to distance and low light levels, individuals cannot be identified).

4.1 Observations

We analyzed the video to get an overview of typical interaction duration and patterns. The total study time was approximately 75 minutes, in which around 307 people passed by and 10 groups interacted with the objects. Overall 16 people interacted actively while another 10 observed. This amounts to around 5% of passers-by interacting with the light fragments. Solitary individuals did not interact with the light fragments at all, but sometimes made a small detour towards them to inspect them, or only observed from a distance. People took care to not step on the objects, often coming surprisingly close to them, but never accidentally touched them, much as one would avoid a puddle or stone. Bicyclists were often observed to slightly swerve in order to make sure to avoid hitting the light fragments.

While 5% does not sound like much, we still feel this to be a success, given many pedestrians were on their way to another destination and the weather was fairly cool. Also, our system seemed to suffer a rather common issue for novel interfaces that people did not know what to do and expect. When there was a long break in activity, we thus began to kick the devices around, hoping to lower the threshold for interaction creating an intentional honey pot effect [6]. This was usually successful: as soon as our team members left, somebody who had been watching approached the light fragments and began to play with them. This 'follow-up' effect (frequently reported in the literature for e.g. touchscreen installations) also happened naturally. For example; two women had been standing a couple of meters away, observing another group that played with the objects. Once the group left, the two approached the light fragments, one saying to the other: "I`ve watched this the whole time, now I also want to have a go"!

4.1.1 Interaction Durations

From the 16 people who interacted, there were 3 children (with their mothers) interacting with the devices (2 of them doing return visits), two teenagers (one with mother doing a return visit, one alone with bike waiting for others to catch up), three couples (one adult only tapped the object, a younger couple played for 50 seconds, and a young couple playing extensively), a middle-aged couple, a group of teenagers and a group of young adults.

Figure 8. People interacting with the light objects.

The typical interaction duration ranged from just a few seconds to two minutes, with most people spending either just a few, or between 10 and 34 seconds, and a few people spending 1 or 2 minutes (resembling a fairly typical exponential usage curve with a long tail). A young couple (the last group of users) was at the extreme, spending 13 minutes playing with the light fragments. The overall usage time was 20:38 (7½ minutes without the last group). It is noticeable that children, teenagers or young adults were the most likely to touch the objects, even though a lot of older people stopped to at least briefly inspect the devices.

4.1.2 Sense-Making

From observation and overheard utterances, it is evident that people felt compelled to sense-making – if they took more than a passing glance, they commented on and described the objects to each other. Some, especially if they only had a short look and then left again, quickly labeled the objects as 'art' (an art university is in town and inhabitants thus frequently see all kinds of art projects on the street). The comment 'This is art.', indicates that passersby struggled to see a purpose for the object, but 'art' provides an easy label which then allows them to move on. Interestingly, the mother of a small boy used this in trying to call her child away: "This is art, don`t touch!" Many people who had a closer look began to describe the shape or behavior of the objects to their companions, "It`s an egg" (teenager), or "potato", and "luminescent orb", or commented on the aesthetics: "nice colourful" (small boy).

People also clearly wanted to understand whether the objects were reacting to manipulation and often commented aloud when they noticed a change, or verbalized their hypothesis. They often realized that the light fragments react to jolts, and some noticed that bringing them together would usually result in a change of light patterns. Some people picked up the light fragments and shook them to see if this elicits a response. However, they found it difficult to understand how the objects work exactly. For example, after a young couple kicked them around in an improvised football game, the man asked his girlfriend "wait - does this change the colour from the movement or like, or does it just do it anyway"?

Actions and utterances by those that interacted for a longer time indicate that they began to imaginatively engage with the light fragments. For example, a young man suggested to his friends "Imagine the ball in American Football would glow like this." A couple which played for 13 minutes with the light fragments, sang a children's song 'I'm walking with my hand lantern', associating the objects with pre-technology hand-carried illumination devices.

4.1.3 Interaction Patterns

Overall, in the observed period, we saw many different behavior patterns and some outright performances. A little boy accompanied by his mother was the first user. He knelt, watched the light patterns, and touched the objects. Unfortunately his mother soon pulled him away, but they came back after a while and he played more. The boy called out the different flashing colors of the LEDs and commented: "beautifully colorful". He also brought one of the three prototypes, which was a little further away from the other two, back to the others so it completed the group. Other groups behaved similarly. The light fragments were often laid out to form a group and brought together again, in case one had moved further away. We were rather surprised how caring the light fragments were handled by most people (although this may be influenced by the awareness that this was some sort of art project, with the creators probably nearby). This 'caring' is reflected in users bringing the light fragments together again before leaving them, in people telling each other to take care, in a girl holding the smallest light object in her arm, saying "my baby", and in rather cautious first attempts at interaction – only once they had the impression the objects were fairly robust, did people kick them stronger.

In designing public interfaces, a core design question and tradeoff is whether these should serve as many groups as possible, or be used longer by one group. For a shared encounter it is probably better if people stay longer, so a sense of mediated experience can develop. However, some people (especially children) might 'hog' the device and not let others access it. With three objects, we had hoped to avoid this problem. This worked for a group, but not across groups, as others rather waited to have a turn until the current group left. We have also experienced this in our prior work as an issue, with groups usually staying apart.

Since the light objects had different forms, we were interested in what form attracted the first contact. This happened seven times with "Dad" (the kidney-shaped light fragment), five times with "Paul" and four times with "Mom". The first contact was almost exclusively with the foot. People usually began by having a closer look, tapping the device tentatively with the foot, and then either kicking it gently, or picking it up to then put it down again and use the foot. When people began to kick, it usually was Paul, the smallest and most ball-like object, most likely to roll (whereas the other fragments required more effort to flip over). In a few cases, the object was kicked back and forth between two people. Overall, the devices were successful in making people utilize their feet to interact with them. Almost everybody who moved one light fragment would also interact with another, and often it seemed as if people wanted to tap and move each object at least once. In particular, when leaving, a few people moved them close to each other again. Furthermore we often saw that several members of a group were active in parallel, joining in after one member started to interact – having several light objects thus successfully communicates that these are meant for multi-person interaction.

Some interactions were surprising as people started to use the system in unintended and unexpected ways (see Dalsgaard's challenge No. 8 [8]). For example, while we expected people to pick up the devices for closer inspection, one young man tugged the smallest light object under his t-shirt to create the impression of a big blinking pregnant belly. The last group to play with the objects, a young punk couple, surprised us with the widest range of creative appropriation (from football, volleyball, singing, to putting the devices into the trees). When it was already dark, this couple arrived at the ensemble. As they were waiting for a third person, they passed the time by playing with the light fragments. They kicked them to each other, played a short football game including benches as goals, flipped them into the air and used them to play volleyball. The girl took the biggest device, donned a hat on it, and held it like a baby in her arm, and began to sing a lullaby. It seems she was ascribing a personality to the device, but it is unclear whether this is in reaction to its shape or the light patterns. When the two began to sing a children's song about a lantern, climbing onto one of the benches and holding the device up in the air, they clearly responded to the light effects. Finally, the man took his friend on his shoulders so she could stick the prototypes inside the tree crutches, where they remained hanging and flashing (continuing the lantern theme). As their missing friend arrived, they all left. Unfortunately, one of the devices fell from the tree shortly after being put up, its hull cracking. This thus terminated our in-situ deployment study.

5. DISCUSSION AND CONCLUSION

Overall, the light fragments worked well and this initial study confirmed most of our design decisions. Concerning the choice of shapes and behaviours of the devices, we consider our design a success. The light fragments communicated clearly that foot interaction is expected, as this was the first thing people did actively. Giving them a little tap requires little effort and then invites further interaction when the device reacts. Having three different forms caused the users to move each at least once, bringing them together again, and allowed several people in a group to be active simultaneously. However, no inter-group encounters were achieved as people were cautious of invading into the activity of another group. For future designs we might add additional light fragments at a more distant location (5-8m away). This increases the distance between groups, but still lets them co-experience the system. Also, the distributed architecture approach with separate wirelessly communicating sensor and actuator nodes and a central server proved a viable approach for responsive interaction that we are continuing to use in further urban scenario projects.

We saw various stages of user appropriation and engagement, starting with initial awareness moving on to discovering the devices and making sense of them, towards inventive play and finally extending play to the environment. The process of engagement with the light fragments often started by noticing from afar (approx. 15m), reacting (even just by swerving around them) and overt inspection with a glance. Subsequent sense-making activity moves from pure description, over physical contact and trying to understand the behavior to imaginative use with continued attempts to understand reactions of the light fragments. Longer imaginative use here began to include the environment creatively into play, similarly as observed by Seitinger [23]. This is facilitated through the movability of the light fragments. These observations extend known engagement models such as the audience funnel [16] or [13] with an additional phase: longer engagement leading to a creative inclusion of the environment into the activity, here, using benches as goals and decorating trees with light fragments. Future work on engagement models should investigate the role of group interaction which for installations such as ours plays a potentially larger role than for traditional public displays.

Design characteristics of our system which differentiate them from traditional 'public displays' include that we have explicitly designed for multi-user interaction and made the interaction space as big as possible by having multiple as well as movable interaction objects, similar to Seitingers projects. Furthermore, our design aims to increase the performer display (the user turns into a performer), offering observers something that is worthwhile to watch. We believe, that this is an important design maxim, as people in urban space simply like to watch others (regardless if these are strangers), and a successful performer display thus tends to attract other people, potentially creating a subtle honey pot effect and motivating observers to want to have a go themselves.

Our future work includes creating a more robust shell for the light fragments, redesigning light patterns as well as improving responsiveness. Future studies will focus on deploying the light fragments in different spatial configurations, such as near benches, the edge of pedestrian walkway zones, plazas and walkways. With this we expect to understand the architectural influences better. We would also aim to observe bystander/observer behavior in more detail, seeking to identify how long they tend to observe others, and whether there is a threshold at which they either leave or try to join the action.

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