

Light Bodies:

Exploring Interactions with Responsive Lights

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ABSTRACT

“Light bodies” are mobile and portable, hand-held lights that respond to audio and vibration input. The motivation to build these devices is grounded in a historical reinterpretation of street lighting. Before fixed infrastructure illuminated cities at night, people carried lanterns with them to make their presence known. Using this as our starting point, we asked how we might engage people in more actively shaping the lightscapes which surround them. We prototyped a first iteration of sound and vibration responsive, LED-based coloured lights that we placed in three different settings including a choreographed dance performance, an outdoor public installation and an audio-visual event. We report on our experiences with these preliminary investigations.

Author Keywords

Interactive installation, responsive lighting, physical pixels, ambient displays

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI):
Miscellaneous.

General Terms

Installation, Design, Lighting, Responsive Lighting, Technology and Society, Urban Infrastructures

INTRODUCTION

In “light bodies,” we invited people to actively engage with their lightscape in different performance settings. Our aim was to enable people to shape lighting as well as explore their physical and social context under different lighting conditions.

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TEI'10, January 25–27, 2010, Cambridge, Massachusetts, USA.
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Figure 1. Light bodies on view at Electrovision. Photograph:
<http://www.flickr.com/photos/tentacles/3751218213/>,
<http://creativecommons.org/licenses/by-nc-sa/2.0/>

Some of the questions we are beginning to investigate in this problem space include: How can people explore their environment with mobile light bodies? Can a portable responsive light enable a more active relationship between people and lighting? How can this approach allow us to revisit the communicative aspects of lighting and their potential role in public spaces?

BACKGROUND AND RELATED WORK

Lights-on-Bodies to Fixed Infrastructure: A Historical Perspective

Urban street lighting today is a networked, fixed infrastructure that relies on the electrical grid. We take this system for granted and expect it to function reliably and automatically. However, street lighting originated as a personal, mobile technology for self-identification during the night in cities. People were required by law to carry lanterns after curfew in medieval European cities to mark their presence and signal that they were not engaging in nefarious activities: “Anyone who is found at an unusual hour in an unusual place without a light must submit to the strictest investigation.” [10]

These mobile systems lost much of their early communicative function as they evolved into the fixed infrastructure that we use today. For example, as a first step in the move away from handheld lighting, city governments required citizens to affix lanterns on their buildings. [10] These elevated lanterns slowly became lighting poles maintained not by individuals, but by the state. Indeed, their association with the state often meant they were targets for revolutionaries in Europe from the end of the 18th century throughout the 19th century.

Schivelbusch's European history can be augmented by observing lanterns around the world, especially in Asia where rice-paper lanterns were used as slow, asynchronous messaging systems or in connection with festivals.¹ As in the history of European cities, the emphasis was thus on the responsiveness and mobility of lighting rather than persistent illumination.

Visions for Mobile Lights: A Futuristic Perspective

Efforts to revive such historical ideas have played a large role in shaping futuristic visions of urban lighting. For instance, images from an exploratory design exercise about the future of lighting sponsored by Philips revitalise aspects of lantern use in Asia. In the report, the editors write: "Personalization will meet dematerialization. It is a natural evolution cycle for technology to move from public to personal and to shift from fixed to mobile domains." [4] They go so far as to speculate on how much longer we will have fixed infrastructures for lighting and suggest, in the near future, we will be surrounded by very tiny pixels or share mobile light objects for temporary appropriation.

Of course, Philips has its own motivations for envisioning supplemental forms of street lighting and, consequently, any "natural evolution" from public to personal should not be taken for granted. Again, historical precedents are instructive; the transition from lantern-carrying to fixed-in-place reflector lanterns in 17th century Paris demonstrates how specific decisions by Louis the XIV's administration were a driving force behind the implementation.

We gain some sense of the interplay of shaping forces in an allegorical representation on a Louis XIV medallion from 1667 commemorating the introduction of fixed street lighting (Fig. 2a). A figure holds out a lantern illuminating the night, ostensibly for the public's benefit. A similar gesture means something very different in a Philips scenario sketch (Fig. 2b). A person reaches for a mobile

¹ For some examples of festivals and practices see the following links and references: 2. *Mid-Autumn Lantern Festival*, China, <http://www.c-c-c.org/chineseculture/festival/lantern/lantern.html>, 3. *Nara To-kae*, Japan, http://www.toukae.jp/tokae_e/index.html, 13. Siu, K. W. M. *Lanterns of the Mid-Autumn Festival: A Reflection of Hong Kong Cultural Change*. *Journal of Popular Culture*, 33, 2 1999), 67-86.



Figure 2a. Louis XIV Medallion (1667). D'Allemagne, *Histoire du luminaire*. [10]: p.86.



Figure 2b. Visions for mobile street lighting. Philips, *city.people.light-Future Urban Lighting Concept*, 2007: p.37.

light object that will enable him to move freely about the city at night. The juxtaposition of visions reveals the associations made with lighting in each period: collective liberty on the one hand and individual independence on the other. Whether in the past or in the future, we discover lighting schemes emerge from a complex assemblage of "sociomaterial reconfigurations" [14] that is by no means predetermined by any intrinsic or "natural" characteristics of a technology.

Related Contemporary Projects: A Critical Perspective

Contemporary projects on urban and mobile lighting have intentionally exploited and examined the taken for granted, sociomaterial configurations. Interventions have been inspired, for example, by stage lighting design and the established ways of using theatrical lights to support meaning making. Using light, Sester has created an elegant juxtaposition of the stage and urban setting. In ACCESS [12], she programs a spotlight to follow people, and, in doing so, demonstrates how a personal "limelight" can impact the sense of being in a place, as well as provocatively questioning modern systems of surveillance. At a much larger scale, Rafael Lozano-Hemmer's *Voz Alta* allowed the public in Mexico City to control the direction and brightness of spotlights across the cityscape by speaking into a megaphone [9]. Commissioned as a memorial to the 1968 student massacre in Tlatelolco, the project used the lighting to draw attention to specific political monuments.

"EXCUSE ME MISS, YOUR BAG IS ON FIRE"

The title for this section stems from a passerby who commented on the glowing bag of lights that one of the authors was carrying to an installation site (Fig. 3). It demonstrates how eye-catching an illuminated object can be. The playful comment also reiterates, the serious concerns involved in deploying experimental lights in public space. Giving people a conspicuous, brightly-lit prototype can bring unwanted attention and contribute to a feeling of unease at night. Such a scenario would invariably lead to a focus on safety which already dominates debates around urban lighting.



Figure 3. Bag for transporting light bodies to installation site.
Photograph: Authors.

In this work, we sought to move beyond discourses of safety and enable people to actively engage with spaces and each other using light. We thus selected secure, open-ended settings that would allow us to explore the more communicative, social, and playful aspects of hand-held lights.

Our emphasis on the less functional qualities of mobile lights introduced another parameter: the range between performance and everyday life. In the city, unpredictable lighting conditions present a challenge for deploying point sources of low-intensity light. While the cumulative effect of multiple natural and artificial lights is interesting, the impact of a particular light source becomes difficult to pinpoint. At the other extreme, stage lighting provides control over every aspect of an environment. We worked to strike a balance between the high degree of control afforded by stage settings and the unpredictable nature of everyday environments. In doing so, we aimed to blend exceptional with mundane and bring aspects of performance into everyday life.

Lastly, our interests were not only in how lighting influences contextual cues by modulating the appearance of the environment, but also how it shapes the relationship between observer and observed or audience and performer. Contemporary theatre often subverts the 19th century tradition of hiding the audience in the dark. This practice relates to the important role lanterns once played in signalling a person's presence in public spaces at night. In exploring different settings, we intended to further examine the dynamic relationship between observer and observed.

DESCRIPTION OF THE TECHNICAL SYSTEM

To investigate the open-ended objectives described above, we built a modular prototype. In order to conduct our research in the chosen settings, we used sound and vibration as the primary environmental inputs. As a consequence, our work builds on a number of inspiring installations that use sound together with light as input and output respectively.²

Hardware

We used the Arduino-compatible Funnel board as our primary input-output module. The benefits of this platform include an integrated lithium-polymer battery charging circuit, an expansion socket for XBee® wireless modules, and a sufficient number of accessible digital output and analog input pins. [1, 8] We designed a custom expansion module for the Funnel to provide to provide audio input and visible outputs for the performances which we needed for the performances.

Each expansion module was fitted with 20 LEDs in four clusters of five colours each: red, green, blue, (RGB) amber (A) and white (W). It was important to include more than just the standard RGB configuration to support a larger colour palette. We used 120° wide-angle, super-bright LEDs manufactured by CREE.

A Kobitone electret condenser microphone served as the primary analog input. The audio signal was amplified and filtered with a high-pass (above 3kHz) and low-pass (below 100Hz) Sallen-Key filter configuration using a TLV2374ID quad operational amplifier. Each output of the op-amp was connected to an analog-to-digital converter (ADC) pin on the Funnel board. In addition, each unit included a MSI piezo vibration tab which was amplified and also connected to one of the Funnel's ADCs.

The Funnel and LED breakout board were powered separately to maintain modularity and isolate the power usage of the lighting element. The Funnel board was powered with its own 3.3V 900mAh li-polymer cell, while the LEDs were powered with a detachable, rechargeable 1850 lithium-ion 3.7V 2600mAh cell.

Casings

For these preliminary explorations, we bought translucent acrylic cases (soap dishes) with bevelled edges that afforded a smooth and pleasing tactile experience. Two additional diffusion layers were necessary to evenly distribute the light. First, we positioned a sheet of Mylar above each board on 2mm nylon screws. Then, we placed a thin layer of upholstery stuffing in the lid.

² For example, Meejin Yoon's White Noise White Light, Usman Haque's Burble or a series of works by Achim Wollscheid like polyson and intersite. These projects could also be considered subcategories of a broader area recently entitled as "sonic interaction design" which includes many projects about urban soundscapes in general, e.g., the mobile system Ambient Addition or the architectural-scale Gamelan Playtime. [5,6,16,17]

Software

The first version of the light bodies software used the amplitude measured by the unfiltered audio signal to determine the collective brightness of the red, amber and white LEDs. This simple relationship and restricted colour palette resulted in an “audio-candle” effect designed to match the choreography and costumes in the first performance described below.

In the next revision, we added support for more interactive scenarios. The updated program continuously responds to all sensor inputs and uses a larger palette. The high and low frequency signals trigger different colours as shown in Table 1. The thresholds for triggering these colours were dynamically updated by averaging the ADC values separately for each of the two filtered audio signals over 64 cycles. The overall amplitude determined both brightness and drop-off speed—when the audio level was louder, the lights faded more quickly. Tapping and low vibrations elicited a markedly different blue-green colour to distinguish this response from the automatic and more-frequent audio responses.

Candle Mode (Enhanced Responsiveness)					
Intensity	Normal Mode			Random Fades	
	> 3KHz	< 100Hz	Vibration		
Amber	Amber	Blue	Blue	Blue	
Red	Red	Red	Green	Green	
			White	White	

Table 1. Colour mappings for response modes and triggers.

We also added an ambient candle mode based on a modification of the previous version’s software to bridge long periods of inactivity in the musical score. Green, blue and white LEDs faded up or down at random while amber and red LEDs responded directly to the unfiltered amplitude levels. The colours used in the candle provided a visible link between the two modes, as in all cases, the audio signal response uses red as its base colour. The sum-total effect was to create a slightly individualized—but still consistent—response pattern in each unit.

EXPLORATIONS

As a preliminary step towards exploring the problem space outlined above, we opportunistically integrated light bodies into three public settings. Through personal connections and by chance we were able to formally and informally experiment with the prototypes in three very distinct explorations. As a result, our observations remain speculative, but they will guide us towards future implementations and designs.

Klang.Körper and Licht.Körper³

The Wiener Musikfreunde Orchester celebrated its 150th Anniversary with a special community-building project inspired by Sir Simon Rattle’s “Rhythm Is It!” project performed in a new concert space at the Vienna Technical University. Two dance companies consisting of amateur dancers were recruited in a school and through a community centre to dance in the Romeo and Juliet Overture by Tchaikovsky as well as in the first and last movements of Symphony No. 1 by Brahms. Through a personal connection with the orchestra, we were able to develop the first version of light bodies as a stage prop for the performance.

We used the audio-candle mode (the first software version described above) to provide a subtle, ambient effect that would not distract from the music, enhance the choreography and blend well with the dancers’ costumes. The choreographers incorporated light bodies into the entire performance which lasted approximately one hour. At the beginning of the show, the dancers carried the lights on stage and placed them around the perimeter of the dance floor. The stage was not elevated, positioning the dancers and the audience at approximately the same level.

Throughout the piece there were several notable moments when light bodies were an important component of the choreography. Three instances illustrate how they contributed to the performance. First, in the Brahms symphony, each teenage dancer (24 in total) brought a personal artifact like a hair brush or a cell phone on stage that he or she placed next to one of the light bodies on the perimeter of the dance floor. At the climax of the first movement, each dancer picked up a light instead of a personal object and used it in a vigorous shadow boxing sequence before sinking to the ground with the light colour washing his or her white costume. The lights symbolically replaced the worldly artifacts on a search for identity, which is one of the themes in this piece. Second, at the end of the first movement, the dancers left the stage and the lights remained sprinkled across the stage as a ghostly reminder of their presence. Third, midway through the last movement, the dancers returned in shorter solo sequences. As they leapt across the stage, they left a trail of deep red and amber light.

Before the closing sequence, the dancers handed the light bodies to audience members. This moment proved the most interesting because audience members who had been sitting in the dark suddenly became an extension of the stage. Like in our subsequent observations, we saw that people quickly started to play with the small devices. The unlit audience

³ Klang.Körper means body of sound in German and inspired the equivalent Licht.Körper which we then translated into English as light bodies. The choreographer chose this term to describe the effect of being engulfed by a cloud of music, dance and also light that amounts to more than a sequence of musical notes.



Figure 4. Light bodies placed on the stage next to the dancers' personal objects. Photograph: TU Wien.

area also made the attractive colours of light bodies more visible.

Play Me, I'm Yours

For the second of our explorations, we made use of a project entitled “Play Me, I'm Yours” by the artist Luke Jerram. Run for three weeks, Jerram's project installed thirty “street pianos” in public spaces such as streets, parks, train stations and markets around London. The pianos were purposefully arranged so that bystanders and passersby would be encouraged to play them. As the project's website explains: “Questioning the ownership and rules of public space “Play Me, I'm Yours” is a provocation, inviting the public to engage with, activate and take ownership of their urban environment.” [7]

Choosing one of the pianos installed in a public square, we were curious how the light bodies might further augment the public's interaction with the surrounding space. As the devices responded to sound, we hoped they might introduce an additional medium of engagement, enabling interplay between sound, light and space. The “Play Me, I'm Yours” project also conveniently offered a contrast to the more choreographed dance/orchestral performance in Vienna. It afforded an exploration of the relationship between performance and audience, creatively juxtaposing and confounding the roles of performer and participant. Furthermore, it situated the interactions in an urban setting, something that resonated with our interest in the antecedents of state-controlled, city lighting.

For our exploration, we placed eight of the lights, each programmed to respond to different elements of sound, around the piano and allowed members of the public to

continue playing. This unfortunately only lasted for one hour, between 7:30 and 8:30pm, as we were constrained by the closing of the square. Also, we never quite reached nighttime darkness because of the extended hours of summer daylight in London. Nevertheless, we observed what we felt to be two noteworthy results. One we found people interacting with the light bodies directly, tapping, shaking and re-orienting them to trigger the lights. Their holdable size and form, and importantly the ambiguity of their relationship to different sounds appeared to prompt this. Moreover, the dynamic quality and obvious responsiveness of the lights served to prolong people's engagements—there was an observable curiosity about the lights' behaviours and to what they might be responding.

The second and perhaps more unexpected result was that the light bodies provoked different ways of experimenting with the music and the piano. For instance, people standing around and listening to someone playing experimented with placing the light bodies on different parts of the piano. They were placed on the keys, beside the sheet music, and by the open lid of the instrument—near the strings and hammers. In effect, the lights were being used to explore the piano's structure and the relationship it had to the music being played. At the risk of reading too much into people's casual and off-hand experimentations, it seemed the lights afforded a means to explore the intersection of form and sound, re-experiencing space-in-the-small, so to speak.

Something we didn't see was the use of the lights to investigate the wider environment. We will discuss this in further detail in the discussion section. A possible explanation for this was the localised impact of the light bodies. The effects of the lights were really only detectable



Figure 5. Play Me, I'm Yours. Photograph: Abigail Durrant. Reprinted here with permission.

when standing around the piano, whereas we had hoped they might be noticed by the many people passing through and sitting around the square. On a practical level, we felt the draw of the lights was diminished by the ambient light levels and that they probably would have worked better in darker conditions.

Electrovision

In the third of our explorations we incorporated light bodies into an audiovisual event, Electrovision, also in London. [11] Electrovision, held every two months, offers a small collective of VJs (video jockeys) a place to showcase their work in a bar purposefully arranged to view video and film. Projectors display content on three of the bar's large walls and visitors to the bar sit at tables and in couches surrounded by the projections. The bar is dimly lit and music is played alongside the visuals. We distributed twenty of the lights across the tables for the entire evening (approximately six hours). Again, the lights were programmed to respond to a combination of sound and vibration in a variety of ways. We used the revised software with enhanced audio and vibration responses that produced more distinctive outputs across light and colour.

Our interest here was to further explore the relationships between performance, public space, and light and sound. We saw Electrovision as somewhere between the Klang.Körper/Licht.Körper performance and "Play Me, I'm Yours" Installation; the visual performances were clearly in the control of the VJs, but the audience had the freedom to talk, interact and freely move around the informal performance space. Thus, in the case of the light bodies, we hoped that people would freely interact with them and treat them as adjuncts to the visual performances. In short, we

were interested to see if the lights might impact how the bar-goers experienced the space and engaged with the performance.

In a number of respects, the exploration revealed commonalities with the previous exercises. Again, people interacted with the objects to explore them further and also appeared to use them to investigate particular elements of space and form (Fig. 1). Several features of the interactions warrant remark. In addition to tapping and shaking the lights, people appeared to be interested in the subtleties of interaction in that they made efforts to purposefully control the different effects with sounds and voice. For instance, we observed people blowing on the devices and, in one case, repeatedly singing to them. Some tried to control the lights' colours suggesting that they understood the lighting schemes were mapped to specific sound ranges. These interventions also, in several instances, evolved to incorporate multiple light bodies. We saw people gathering groups of light bodies from around the bar onto their own tables and subsequently stacking and organizing them. They explained how they wanted the lights to interact with one another, and how one might be set off to then trigger others, causing a relay effect.

What we found particularly interesting were people's playful experiments with physical forms and the performance space. On a number of occasions, we observed people using the lights to augment their own bodies and movements. Several put lights under their shirts, using the bass of the music to mimic their heart beats. Others used the lights as props, simulating birds, ear phones, soap bars, etc. Those collecting the lights sometimes organised them into patterns on the tables, drawing attention to certain areas of the bar. For example, one pattern depicted a large arrow pointing towards one of the wall projections. The lights were then simultaneously triggered, at maximum brightness, by vigorously knocking on the table. Some seemed equally happy to let the devices perform in an ambient way. Some people even turned the light upside down to colour wash the table. We saw one group of people bring their light body with them as they moved from a smaller table to a bigger one. They appeared content to simply let it respond to the ambient sounds near their seating area.

Of course, we are well aware of the particular kinds of audiences that attend events like Electrovision and their likely enthusiasm for devices such as light bodies. However, we were encouraged to see people engaging with the lights in the ways they did. Overall, our impression was that this experience set out trajectories for further thought and investigation. Specifically, as we will go on to discuss, they highlighted a number of design possibilities worth exploring.

DISCUSSION AND CONCLUSIONS

Drawing inspiration from historical developments in urban lighting, we have presented preliminary work investigating the relationships between (urban) spaces, light and responsive, hand-held lights. We designed and built a prototype system enabling people to directly and indirectly influence their personal lightscape. Though the designs were very preliminary, we opportunistically introduced light bodies into a series of performance-like settings which are summarized in the following diagram (Fig. 6). The diversity of the settings provided us with some starting points for imagining future theoretical, technical and design trajectories. In conclusion, we reflect on the central themes we have drawn from this work and how we hope to further pursue it.

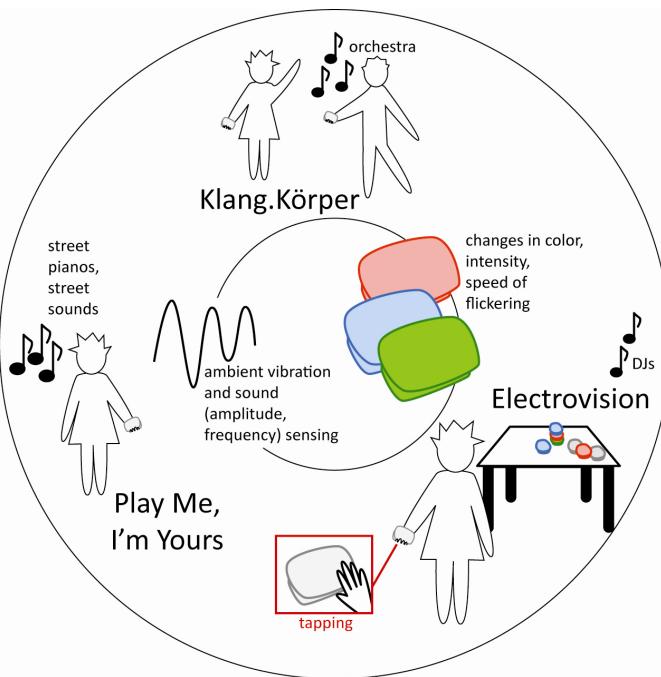


Figure 6. Diagram summarizing the interactions with light bodies.

Unexpected Affordances

In all three explorations, we used off-the-shelf casings for the lights. We selected them because of the translucent shell and rounded edges that felt good to touch. Moreover, their easy availability allowed us to prototype the devices early in the design process, and, in doing so, invite feedback and speculation. As we have suggested, we were encouraged by the many playful interactions with the lights and, to some extent, felt the simple form of the cases provided an open-ended platform that encouraged exploration. Many of the interactions, however, were directed at either the lights themselves or the objects and furniture they were placed on. Although there were a few promising exceptions (especially at Electrovision), we saw little evidence of the lights being used to re-experience the surroundings. In this sense, at

least, they appeared to be far more ambient in their behaviour than we had intended.

Our current design work has been influenced by these observations. To expand the repertoire of the mobile lights and specifically to encourage people to use them to engage differently with space, we are working on more evocative cases. For example, we are experimenting with handles and hooks on the casings that might allow the responsive lights to be worn on coats, bags or bicycles and thus be visible while moving through public spaces (Fig. 7).

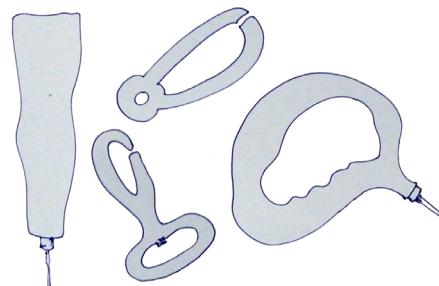


Figure 7. Design sketches for connectors

Also, we are considering how different forms might suggest the orientation of the microphone in relation to the direction of the light, and how simple buttons or rings could adjust colours, beam angle and response patterns. We are also exploring designs for groupings of light bodies that would impact each other, prompting interaction across distances and between people.

Reflections on Open-ended Explorations

The three chosen venues provided a valuable platform for studying light bodies. By observing their use in performance settings, we found ourselves looking beyond the technical features of the light bodies, drawn more to how they integrated with and occasionally disrupted people's behaviours. Pursuing the new designs, we've been struck by the impact this has had on all levels of implementation, from the form of the lights to their programming.

For example, our observations of people repeatedly tapping and shaking the lights or knocking on objects around them to extend the responses, led to us programming the dynamically changing thresholds (e.g. increasing brightness of a light pattern to staccato sounds, or increasing the trigger thresholds as overall audio levels increased). This, in turn, has helped us with re-designing the lights' casings and how they might work with directionality of audio. In future design scenarios, for example, we imagine the lights to decrease in brightness as one orients the device towards the sound (Fig. 8). The counter-intuitive relationship might encourage, we hope, a rethinking of regions of relative quiet.

Whatever the case, we've found the interjection of the bodies into the live, open-ended and choreographed events has provoked us to think imaginatively about the interleaving of the computational workings, form, and usage of the lights; the observations have very much promoted reflections on the intersections between these layers.

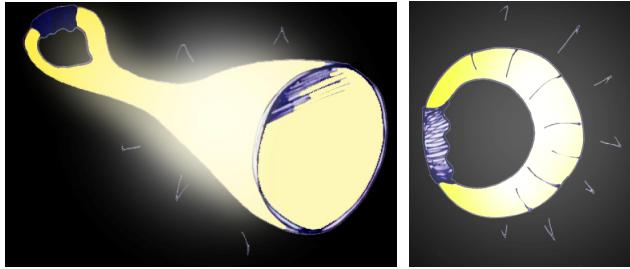


Figure 8. Design sketches for funnel-shaped light body (left) or ring-shaped light body (right).

Performative Space through Light

Our explorations all revolved around purposeful performances, even if the degree of preplanning and orchestration varied. The range of performances allowed us to witness very different audience-performer arrangements. For example, in Klang.Körper the explicit separation between audience and stage made the act of handing the light bodies to audience members symbolically significant. In the other explorations, people engaged with light bodies and became performers as a result. Inevitably, light bodies became part of the performance and people treated them as stage props or ambient artefacts rather than as mundane, everyday objects (e.g., lanterns).

Consequently, in our next explorations, the hope is to focus on (urban) environments that are not explicitly bound to performances. Rather than situating the lights in events where they are clearly intended to be experienced in unusual and unexpected ways, we want to examine their use in everyday, mundane settings, settings where the purpose of their advanced functions may be far more ambiguous. Many urban theorists have explored the performativity of urban spaces in reflecting upon the meaning of the public realm [15]. By focusing on light with the specific contextual ground work laid out at the beginning of the paper, we hope to develop our work in this direction. In particular, our aim is to build on the examples we saw of people casually exploring the dynamic relationship between space, light and social interactions. As with the illuminated arrow and simulated heartbeats, we hope to see the designs we are working on provoke impromptu actions that alter the relations people have with their spaces and one another. In the long term, we intend to explore the interesting ways in which interactive, mobile lights can become a more mundane feature of our urban environments.

ACKNOWLEDGMENTS

We would like to thank Mark Feldmeier for his help with the audio circuit. We are grateful to Mo Seeger for inviting us to Electrovision and the Roxy Bar and Screen for hosting us. Our participation in Klang.Körper was made possible by Georgine Zabrina of the Wiener Musikfreunde Orchestra. We would also like to thank Eberhard Papesch of the Wiener Musikfreunde Orchestra and Martin Atzwanger of the Technical University, Vienna. We are extremely grateful to Daniela Heissl, an extraordinary choreographer and dancer who managed to integrate light bodies into her pieces at a distance. Finally, we'd like to express our gratitude to the performers and bystanders who engaged with light bodies at the various performances! This paper was written while Susanne Seitinger and Daniel Taub were employed as interns in the Socio-Digital Systems Group at Microsoft Research Cambridge, UK.

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