Focus Framework: Tracking Prototypes' Back-Talk

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ABSTRACT
This paper presents an analytical approach that we call the focus framework. The framework aids the analysis of the intended and unintended design attributes that emerge within a project's design process. The framework helps to reveal how prototypes and decision making interact together to shape the final design features and make visible the trajectory of central design attributes and unexplored alternatives. In this paper, we report on the framework and its development by way of a retrospective analysis of a tangible light installation we designed known as the Urban Data Posts. We see the potential for designers to use the focus framework as a post-mortem tool to retrospectively analyze their own work and thus inform their design practice. The knowledge gained through the analysis can then be applied in future projects more generatively.

Author Keywords
Research through Design; Design; Prototyping; Theory; Annotated Portfolio; Public Display; Installation; Sensing

INTRODUCTION
Prototyping is ubiquitous in nearly all design projects and prototypes are well understood and used, both in interaction design and design research. As a result, various kinds of prototyping tools, methods, and techniques exist [3,4,7,15,23,26]. But is there more to learn about prototypes, especially if we pay closer attention to the interplay between iterative forms, computation, materials and their impact on design decisions? While the TEI community heavily relies on prototypes to develop novel outcomes in tangible and embodied computing, considerably less attention has been paid to the roles of prototypes in this process. There is growing interest in more closely attending to design research processes in the broader interaction design community [19] and there exists an opportunity for conducting more in-depth designerly investigations of the role of prototypes in the tangible computing design process.

Figure 1. One of the three data posts during the installation.

This work reports on the retrospective analysis of the design process behind the Urban Data Posts project. The Urban Data Posts project is a tangible light installation that aims to explore novel and unobtrusive ways of displaying urban renewable energy data in a public setting. It consists of three street bollard like shapes, each reading environmental data and emitting light through thin cracks (see Figure 1) based on the data. In this paper, we examine the series of prototypes we made that led to the final design of the Urban Data Posts. After completing the project, members of the design team wanted to better understand the tacit recognition of a reoccurring unintended design attribute or what we even saw as a "design flaw" and how it transformed into a central design attribute that altered the project's final outcome. The design feature in question are cracks of light (see Figure 1). This feature appeared in earlier prototypes, but, at the time, it was considered as a "design flaw" and was largely neglected. Yet, it re-emerged as the dominant attribute of the final design. This prompted us to critically reflect on our design process and inquire into the design moves and issues that catalyzed the transformation of this feature from unintentional to an intentional and central design feature.

Our retrospective analysis of the Urban Data Posts project evolved into a two-step process. In the first step, we gained a higher level understanding of our design process through the use of annotated portfolios [12], a method proposed by Gaver and Bowers to communicate knowledge developed in research through design. After applying and iterating on our project's annotated portfolio, an analytical framework

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emerged that we came to call the focus framework. The focus framework consists of 4 "lenses" – *in focus*, *out of focus*, *neglected* and *not present* – each describing the state of a design's attribute over the course of the design process. In the second step of our analysis, the prototypes in our design process were analyzed again, but this time through the lens of the focus framework. Examining the series of prototypes through this lens enabled us to illustrate what Schön [30] describes as a reflective conversation between designer and design object. The focus framework helps to bring to light the "back-talk" of individual prototypes, thus illustrating how a designer responds to (and neglects) the feedback of her prototypes.

The core contribution of this work is the focus framework, which enabled us to better analyze and synthesize the intricacies of our own design process. It revealed to us how our prototypes and decision making shaped the ultimate outcome of the Urban Data Posts project as well as unexplored alternatives. Designers can use the focus framework to retrospectively analyze their own work and thus inform their design practice, as well as better structure the documentation of their own design process to other design researchers and practitioners. The collective knowledge gained through the analysis can then be applied in future projects more generatively. This could be especially useful for the TEI community, which rarely relies on well-established design patterns or social norms, to design novel ways of interaction and interaction technologies.

In what follows, we provide a brief overview of related works and then provide a summary of the Urban Data Post project. We then move to the analysis of our design process to report on the focus framework and how it was developed. Lastly, we discuss the potential of the focus framework to analyze other design projects as a post-mortem tool and in the process inform future design practice.

BACKGROUND AND RELATED WORK

Related work falls into two areas: (i) design as a reflective practice to create tangible and embodied systems, and (ii) prototypes and prototyping in the design process.

Design as a reflective practice

While researchers such as Alexander [1], Simon [33] and many others have articulated definitions of design, Schön's work [30] is most centrally aligned with our approach because of his characterization of design as a reflective practice. In particular, Schön argues that a designer: "*shapes the situation, in accordance with his initial appreciation of it, the situation "talks back", and he [the designer] responds to the situations back-talk.*" [30:79]. Schön and Bennet [31] compare the designer's ability to think about what she is doing to influence further doing to jazz improvisation – players listen to oneself and one-another while still playing and reacting to each other's actions. The same can be said about prototyping. Any act of prototyping prompts the prototype to provide feedback which influences further doing by the designer and so on. The focus framework aims to leverage and extend the notion of back-talk by providing a lens for attending to the complex and, at times, unnoticed or unintended roles that prototypes play across the process of designing tangible and embodied computational systems.

Tangibility and Embodiment TEI

After the introduction of TUIs [17], tangibility and embodiment received growing attention in design and design research. Early contributions provide frameworks and taxonomies to better articulate the field (e.g. [10],[16], and [18]), with more recent work exploring novel interactive artifacts [32] and extending existing physical artifacts and landscapes through interactivity [13]. Prototyping and prototypes play a special role in the field of tangible and embodied systems, simply because of the physical nature of the design artifacts themselves. The TEI community increasingly become concerned with investigating new ways of prototyping [14,24,29,39] and inquiring into materials used when prototyping tangible interfaces [2]. While there is growing interest in attending to the rich and nuanced details of creating radically new forms of interaction and interaction technologies in the broader interaction design community (e.g., [12,19,35]), the role(s) that prototypes play in and across different stages of the tangible interaction design process have retrieved less attention. Our work contributes a framework that can be retrospectively applied to the process of designing tangible systems that aids in better revealing how prototypes shape key design decisions that led to the ultimate design outcome.

Prototypes & prototyping

The understanding of what a prototype is and the various ways it can operate has evolved over the years in the design research community. Researchers have discussed how prototypes can function as tools for design exploration or concept validation [7,20,34], and forms of rhetorical argumentation [11]. Based on a comprehensive review of these works and many others related to prototypes in design, Lim et al. [20] proposes that prototypes are rich resources for manifesting design ideas as well as filtering and exploring specific qualities of emerging concepts. They describe how prototypes operate as externalizations of design ideas that are materialized across three dimensions: material, resolution, and scope. For example, a designer can filter certain parts of a prototype (appearance, data, functionality, interactivity, and spatial structure) to only work on attributes that are currently of importance or that she wants to focus on. This enables the designer to traverse the design space and make decisions without resolving the other attributes. We aim to build on this research by offering a concrete framework that better brings into focus and improves the roles that prototyping and prototypes play across the process of designing tangible and embodied computational systems.

Prototypes within the design process

Dove et. al [9] argue for the importance of design space reflection, concluding that it can be highly beneficial for the designer to retrospectively look at a project's design process. They argue that becoming better attuned to how artifacts and

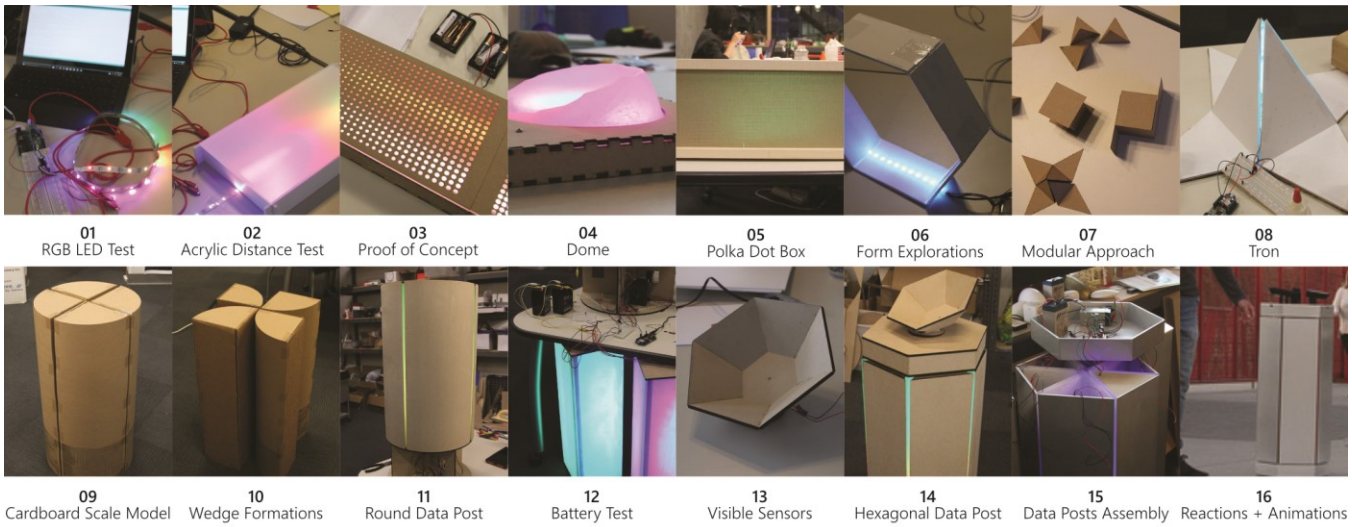

Figure 2. Overview of all prototpyes in the Urban Data Posts project in chronological order.

activities shape the conceptualization of the design space can encourage designers to reconsider valuable alternatives disregarded earlier in the process. Recent research has also emerged that aims to help better capture a project's design process [8,9,22]. For example, Yen et. al [40] explored how reflection can be best combined with the review of feedback during the design process instead of retrospectively. Wakkary et. al [38] reveal the value of reporting on first-hand insights and the lessons learned from building bespoke design artifacts. Boucher [5] unpacks how seemingly trivial design concerns during a design research project are ultimately integral to the nature of research questions manifested by design artifacts themselves. Our work builds on and extends this nascent and growing body of research by contributing the focus framework to better structure first-hand accounts and insights across the process of designing tangibles. The focus framework enables design teams to gain a better understanding of a project's design process and can provide guidance when designing novel tangible objects and interactions.

URBAN DATA POSTS

This section provides a brief overview of the Urban Data Posts project with a focus on its design process. Our aim here is to provide sufficient background information on the project for the reader to follow the analysis of the Urban Data Posts that follows later in the paper.

Overview

The Urban Data Posts project is a tangible light installation deployed in public at Telus World of Science that displays urban renewable energy data. The installation consisted of three street bollard like shapes, called *data posts* (see Figure 1). Each post sensed the energy level of a current (wind and solar) or potential future energy resource (walking) in that urban area. Based on the sensing, the data posts would emit different light animations. The installation was developed over the course of one year and deployed over the course of three weeks. The first author led this entire process, supported by two members of our design studio. While every member brought different abilities to the project (design, woodworking, project management, etc.), all three took part in the concept, design, prototyping, and deployment stages of the Urban Data Posts project.

The goal of the *Urban Data Posts* project is to explore novel and unobtrusive ways of displaying situated data in a public setting, thus aiming to avoid the use of more traditional graphs and charts as well as common displays and screens. Despite the novelty of the display, we wanted the data posts to blend in with the public environment, which required finding a subtle way to display the data. Our intended audience were neighborhood residents and cyclists and pedestrians commuting back and forth to work. Given this, we felt it should take time and multiple interactions for someone to develop a growing understanding and appreciation for our project.

Design Process

The early conceptual work of the design process led to the agreement to develop a tangible light installation with RGB LED strips. The main factors were feasibility and flexibility in designing the final forms of the installation. After that, the design team started to work on one of the main challenges: designing a novel form of display using RGB LED strips.

Various ideas and their respective prototypes looked promising, but were dismissed upon closer investigation due to the lack of visibility, scalability, or visual appearance (see prototypes 2-6 in Figure 2). After a wide variety of prototypes were built the design team tacitly realized the reoccurrence of a "design flaw" in almost all of the prototypes built so far: cracks with light leaking through. These cracks were the result of the tools we used, the time we spent building the prototypes, or our own competencies. However, almost intuitively, this "design flaw", the cracks, were then investigated, iterated and established as a form of display meeting our requirements. While this sounds

straightforward, in the midst of the messiness in a design process, the emergence of the cracks as a design feature seemed a surprise and to come out of nowhere. It was unclear to us where exactly this idea emerged from, which is why we refer to this event as a tacit recognition. After more iterations of prototypes, we established the cracks as a form of display. We then improved the design both technically and aesthetically, and professionally manufactured parts for the final installation.

Final Design

The Urban Data Posts project consists of three street hexagonal prisms (i.e. *data posts* – see Figure 1). Each data post consists of three parts: base, wedges, and visible sensor. The base is the short hexagonal prism on the bottom acting as a pedestal. The heart of each artifact are the wedges – six triangular prisms which form a hexagon. Each of the wedge hosts a RGB LED strip which illuminates the space in between the wedges, referred to as cracks. The visible sensor is the top part of each data post. Much like the base, it is a hexagonal prism but with a small model of a sensor attached to it. It also hosts the remaining electronics such as sensors, batteries, circuit and an Arduino Uno.

Deployment and Results

While it is not the aim of this paper to report on the results of the project (forthcoming), we saw it as a success. During our 3 week deployment at Telus World of Science (a science museum situated in a large open urban setting), the data posts fulfilled our goals mentioned previously. They (1) blended in well with their environment due to their similarity with street posts, (2) displayed subtle, yet distinct animations depending on the current readings of renewable energy resources, and (3) evoked curiosity about their nature and playful interactions from many pedestrians during our deployment. This informal evaluation of the project is based on our observations and interactions with pedestrians during the deployment of the three Urban Data Posts, and our own expectations towards a novel display for environmental data.

DEVELOPING THE FOCUS FRAMEWORK: ANNOTATED PORTFOLIO OF THE URBAN DATA POSTS

This section describes our first step in the retrospective analysis of the Urban Data Posts project, during which the focus framework emerged. Our aim here is to give a methodological account for how we approached our analysis from which the framework was developed despite that not being the intention at the outset. It is also important to us to emphasize that the focus framework did not exist *a priori* to the analysis of the project. Rather, it emerged from the analysis of design process. We first used annotated portfolio as an analytical approach. However, it unintentionally resulted in another analytical tool (our focus framework), rather than a satisfactory account of our design process. We do not view this unexpected emergence as problematic. It makes clear the inductive (or 'bottom up') approach to making sense of an ultimate design in which the concrete details and particulars of a design process need to be contended with first. In this way, knowledge is emergent rather than predicted through a top-down theoretical approach. Further, our experience demonstrates the flexibility and strength of annotated portfolios as a means to analyze at the level of design particulars and intermediate theory [21].

Annotated portfolios

After the Urban Data Posts project was complete, members of the design team wanted to understand the various prototypes and their influence in the project's trajectory in the bigger picture. Especially, since a specific design attribute (cracks with light) transitioned from being a "design flaw" in earlier prototypes, to a central idea in the final design. We wanted to understand how the design team came to realize the potential of the cracks in the midst of the design process, how the cracks transitioned from being an unintentional attribute to being an intentional and central feature, and how other design decisions and prototypes may have influenced our ultimate design.

The analysis of the Urban Data Posts project was a group effort. While the first author was in charge of the analysis, the remaining design team members provided frequent feedback and input towards the analysis in form of regular meetings. Decisions affecting the analysis (e.g. choosing criteria, interpretation, etc.) were made through discussions and by mutual consent. The analysis itself was conducted shortly after the project had been deployed, roughly three weeks after the final prototypes were build. The analysis took approximately one week.

To start our analysis, we chose annotated portfolio as a way to dissect our design process and gain a better understanding of how our prototypes and decision making shaped the project's final design. Annotated portfolios was introduced by Gaver and Bower [12] as a way to communicate research through design. An annotated portfolio is a collection of designed artifacts (a portfolio) represented in a suitable medium (images, videos, etc.) and commented with short texts (annotations). A portfolio, as Bowers [6] writes "*can be annotated in several different ways reflecting different purposes and interests.*" (p. 72). Löwgren [21] sees annotated portfolios as a form of intermediate level knowledge. It elicits key ideas, structures and considerations from the actual artifacts it represents, which can then be used in a generative and aspirational way. Thus, annotated portfolios show close resemblance to other forms of intermediate-level knowledge, like strong concepts [15] and design patterns [4].

We chose annotated portfolio as a starting point in our analysis, because it allowed us to take two positions at once: (1) as researchers investigating the design and prototyping process of the Urban Data Posts project and (2) as the designers of that said project and that had access to intimate, first-hand knowledge about it [21]. By utilizing our "first person" account of this research through design project we could draw on our own knowledge and experiences instead of someone else's, in order to gain a more holistic

understanding of the prototypes and how they influenced our final design.

Preparation

As a first step in our analysis, all prototypes were identified and chronologically ordered. We also gave every prototype a name to clearly identify them. As a means to represent the single prototypes, we chose to use images because we documented the Urban Data Posts project with roughly 500 images and 40 videos. 2-5 pictures were selected for each prototype that illustrated it from different angles, different stages of completion, and highlighted different features. Printed copies were assembled on a whiteboard, and we began to create categories for our annotated portfolio.

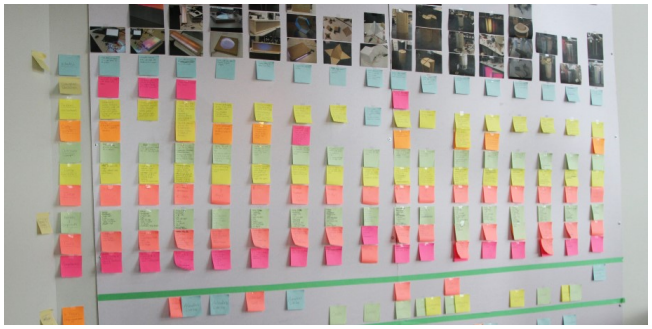

Figure 3. Annotated Portfolio of the Urban Data Posts project.

Guided by our aim to understand the roles of the cracks across the design process and their attendant influence, we created the following points for our annotated portfolio: prototype intention, problems encountered, outcome, time, material and components, tools, and competencies.

Data Collection and Data Wrangling

After the categories were added to the white board, we then started to annotate each prototype. The annotated portfolio then went through several iterations in our attempt to better understand the project's design process. During this back and forth in analysis we deployed several strategies such as: (1) trying to find a correlation between different annotation points (e.g., the tools we used and the outcome of the prototype), (2) gradually adding new annotation points (i.e., conceptual decisions, design insights, design decisions) to elicit more details about the prototype, and (3) clustering annotation points into bigger categories. This process prompted us to rethink our labeling of the cracks of earlier prototypes as "design flaws". We realized they were merely the result of the tools and materials we used, and our own competencies when building the prototypes. Rather than "design flaws", we came to think of them as design attributes, even if unintentional and, at times, unwanted.

Emergence of the Focus Framework

This thinking of "design flaws" as unintentional design attributes helped us to construct the focus framework out or our project annotated portfolio. We realized that in order to better understand the development of the Urban Data Posts, we have to capture both, our intentions building the single prototypes, as well as any unintentional side effects. Furthermore, we cannot look at prototypes in isolation, but need to look at them as part of a bigger process. To help capture our prototypes' intentional and unintentional design aspects over time, we came up with two conceptual lenses, called "in focus" and "out of focus". The idea behind these lenses is to describe a prototypes intention (e.g., why the prototype was built, materials and tools used, etc.), as well as unintentional side effects (e.g., unwanted or unexpected side-effects, problems, etc.). After a few smaller iterations, our work with the project's annotated portfolio yielded what we came to call the *focus framework.* The focus framework is a timeline of prototypes in the design process, which lists each prototype's intention or purpose (*in focus*) and its "back-talk" (*out of focus*). It can be understood as a discrete analytical tool which emerged through the combination of higher level categories created while iterating the on annotated portfolio and attaching elements of it to a timeline.

Although the focus framework emerged through the annotated portfolio of our project, the two are distinct. Annotated portfolios are meant as a way to communicate design research by eliciting key ideas and structures of the final design. The focus framework on the other hand is not concerned with communicating the intent or underlying conceptual thinking of a final design. It is concerned with process, especially how each prototype shaped the designer's decision making that led to the final design. Thus, the focus framework appeared better suited for retrospectively analyzing our design process.

FOCUS FRAMEWORK ANALYSIS

The following section introduces the focus framework and offers an in-depth analysis of the Urban Data Posts project's design process through the framework. Our aim is to describe and demonstrate concisely but concretely the focus framework in a way that is clear and can be seen to be transferable and usable for other design projects.

The focus framework

The focus framework consists of four lenses, called *in focus*, *out of focus*, *neglected* and *not present. In focus* and *out of focus* describe a prototypes intentional and unintentional design attributes. They capture a prototypes "back-talk" [30] and help to understand the interplay between designer and her prototypes throughout the design process, bringing to light the underlying decision making. The lenses *neglected* and *not present* are used to round out the framework. After the focus framework had emerged from the annotated portfolio, we moved the framework to a spreadsheet, arranging the prototypes horizontally in chronological order and the 4 lenses vertically. Design attributes were then added with colored boxes and traced through the single prototypes. The spreadsheet was then digitized and brought into an easier to read visualization which shows resemblance to a transit map (see Figure 4).

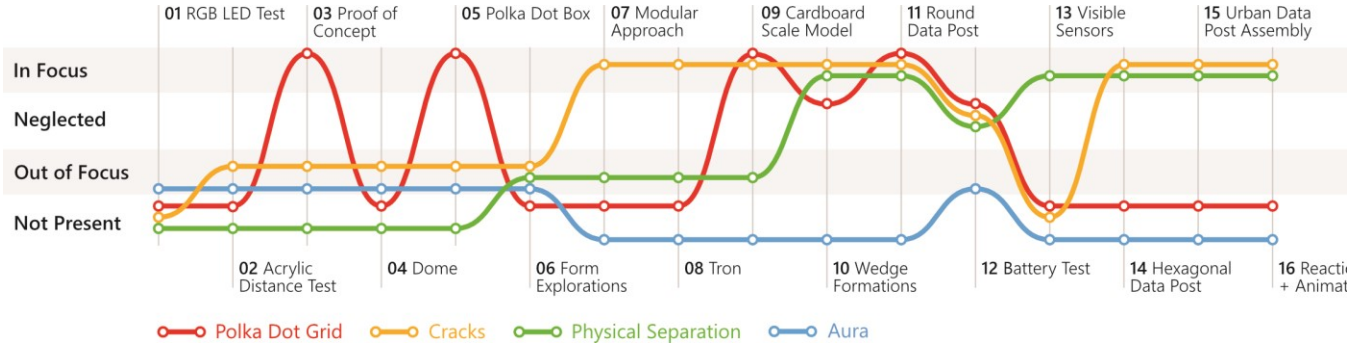

Figure 4. The focus framework showing 4 major threads: Polka Dot Grid (red), Cracks (orange), Physical Separation (green), and Aura (blue).

In focus

In focus describes intentional design attributes in prototypes. Design attributes the designer is *consciously and intentionally* building into the prototype. *In focus* shows resemblance to the filtering dimensions described in the anatomy framework by Lim et al. [20]. Both frameworks describe the intentionality of a designer to build a prototype to explore a specific attribute of her designs. The focus framework uses actual attributes and features of the design. For instance, in our design we were visually separating the data posts, building using a physical model of a sensor which would be needed to read the energy resource this specific data post is representing. The focus was the physical model of a sensor, which we named "Visible Sensor". The design attributes *in focus* obviously differ from project to project, making the focus framework more practice-oriented at the expense of more generalizable theory.

Out of focus

Out of focus describes *unintentional design attributes* in prototypes. Design attributes the designer is *unconsciously and unintentionally* building into the prototype. They are the result of *accidental circumstances* during the build. Before building a prototype, a designer usually visualizes what she wants to build, which can take many forms, such as a mental image, renderings, sketches, and so on. In most cases the actual prototype does not match with the one visualized due to various factors (e.g. materials used, tools, time spent, own competencies, etc.). Any attribute in the actual prototype that differs from the designer's visualization (the intended design), is here referred to as an unintentional design attribute. They are deviations from the 'intended' but are never "big enough" to interfere with a prototype's purpose. Because of that, the designer is unaware of their presence, as her focus is elsewhere. As soon as unintentional design attributes interfere with a prototype's purpose, the designer will likely address them by removing them altogether or altering their appearance.

Neglected and not present

The notions of *neglected* and *not present* help to round out the concept of the focus framework by providing lenses for design attributes that are neither *in focus* nor *out of focus*. *Neglected* are design attributes which are part of a prototype but they aren't *in focus* (because the designer's attention is elsewhere) nor can they be *out of focus* (because the attribute was *in focus* in earlier prototypes). *Not present* simply means a design attribute can't be found in the current prototype. Although these lenses are not fundamental to the framework, they help to keep track of all design attributes during the analysis as we will show when applying the focus framework to analyze the Urban Data Posts project.

Focus Framework Analysis of the Urban Data Posts

Through applying the *focus framework* to examine the prototypes in the Urban Data Posts project's design process, we identified four design attributes that had (or could have had) a major impact on our design. For brevity, only one thread (we refer to the serial occurrences of a design attribute as a *thread)* is described in detail and a quick summary will be given for the remaining three. Figure 4 shows the four different design attributes (colored lines) and their respective status (vertical axis) throughout the design process with its prototypes (horizontal axis).

The Cracks Thread

This thread follows the design attribute called *Cracks*, which are narrow spaces with light leaking through. The idea to work with cracks came from a tacit recognition of their presence in early prototypes (see Figure 5).

Cracks were part of our prototypes as soon as we started to give our prototypes a physical form. Much to our surprise, they appeared in 5 out of the 6 prototypes we built early in the design process. Looking closer at the prototypes, the cracks were the result of the materials and tools we used, how much time we spent building the prototypes and our own competencies. For instance, in one case we had to split our design into two parts, because the laser cutter we were working with couldn't fit the whole piece of our intended design. As a result, we had to "stitch" the two parts together afterwards, resulting in a crack. In another case, we were not able to completely close the lid of our prototype. As a result, some of the finger joints remained open as small cracks, causing light leaking through. However, none of these "issues" interfered with our prototype's purpose and our focus was elsewhere. As a result, the *cracks* in these prototypes were *out of focus*.

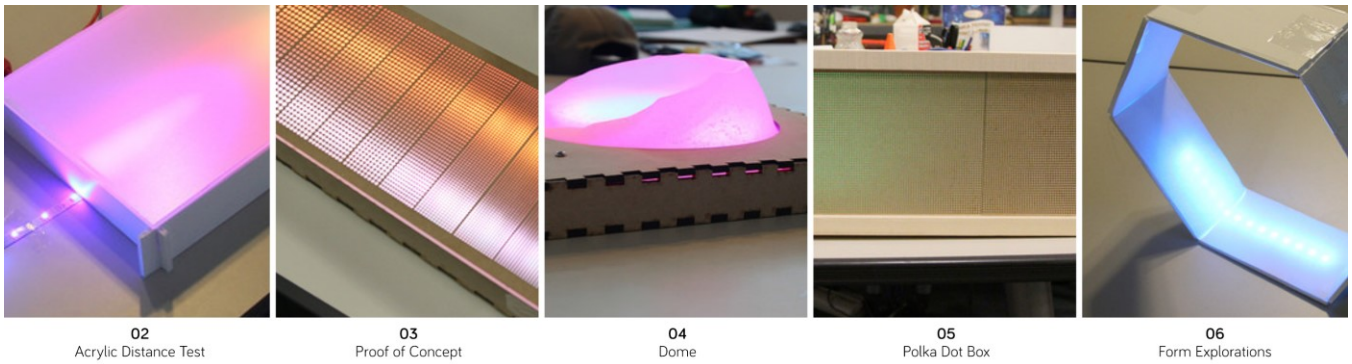

Figure 5. Cracks appeared in early prototypes but were *out of focus.*

After the cracks reappeared in another prototype (this time due to the material we used), we tacitly realized their potential use for conscious implementation in our design. Our focus shifted and we no longer saw them as a "design flaw" but as an opportunity. We then decided to explore *Cracks* as a form of display and moved them *in focus*.

After we established the *crack's* visibility and utility in the following prototypes, they stayed *in focus* for almost the rest of the design process because they transformed into an integral part of the design. *Cracks* were only once *neglected* and *not present*. While *not present* is rather self-explanatory, they were *neglected* once because we repurposed parts of an earlier prototype in which the *cracks* appeared, but our focus in the prototype was elsewhere (i.e. the circuitry). They couldn't be *out of focus* since we knew about their existence and were working with them. This shows the minor roles *not present* and *neglected* play in the framework and how they help to keep track of all attributes.

Our analysis using the focus framework revealed that the *Cracks* were part of our design process much earlier than we had anticipated. We could now see how the *Cracks* appeared in our prototypes way before we had recognized them in our actual design process. This in turn allowed us to understand *how* they had appeared. Reasons for their appearance include the tools we used, the materials we chose, the time we spent building prototypes, and our own competencies. However, for several prototypes, the *Cracks* were always seen as a "design flaw" and thus *out of focus*. They did not interfere with our prototype's purpose and our attention was elsewhere. This changed when we suddenly became aware of their presence and saw their possible utility. We then started to consciously explore *Cracks* as a form of display and turned them into an integral part of the final design, as the focus framework reveals the *Cracks* stay *in focus*.

Summary of remaining threads

The focus framework also revealed other insights of our design process through the other threads.

The *Polka Dot Grid* is a form of display which uses a polka dot pattern cut into an opaque material to cover an illuminated surface (see Figure 5, prototypes 3 and 5). Following the erratic path of the *Polka Dot Grid* (see Figure 4), one can see how the design attribute appeared and disappeared throughout the design process. This jumping back and forth can be explained by the fact, that we were fond of this design idea and tried to recycle it throughout the design process. However, it never met our requirements, which is why it is not part of the final design.

Physical Separation describes the idea to visually separate the single *data posts* from each other. This design attribute also moved *in focus* after a tacit recognition of their presence and possible utility. After this design attribute had appeared midway through the design process, it moved *in focus* and stayed there (with just one exception) as it became another key attribute in our design. *Physical Separation* follows a very similar, yet delayed, path to the *cracks,* something we were not aware before our analysis.

Aura is a design attribute which was recognized during our analysis. It describes the appearance of a very subtle halo around an artifact, without a noticeable light source. As can be seen in the overview (see Figure 4), it appeared almost at the same time as *Physical Separation*, yet never moved *in focus*. Aura is a very interesting design attribute, as it represents a missed and unexplored design opportunity which was discovered through the framework.

Summary of the focus framework

As seen in the Urban Data Posts project, unintentional design attributes can have a major impact on the design process, but it is up to the designer to capitalize on them. She needs to engage in a reflective conversation with her prototypes and closely listen to their "back-talk" [30]. The focus framework allows one to better understand the reflective conversation between design and her prototypes, as it captures each prototypes intentional and unintentional design attributes. Although simplified, the focus framework shows the reality of prototyping from a designer's perspective – constantly gauging which design attributes she wants to explore, while at the same time looking for new opportunities, combining ideas and making decisions for the final design.

DISCUSSION

The goal of this research is to motivate and develop the focus framework as a post mortem analytical tool to better

understand and articulate the process of designing tangible and embodied computational artifacts.

The *focus framework* helped us to bring clarity to our design process in the Urban Data Posts project. Specifically, it enabled us to better articulate and critically reflect on when and why *Cracks* appeared in our prototypes, and how they ultimately influenced the final design. It also enabled us to better identify other design attributes that dramatically shaped our design (Polka Dot Grid and Physical Separation). While *Physical Separation* explains the distinct visual appearance of each *data post*, the *Polka Dot Grid* is an example of a failed attempt to shape the design in a certain way. Conversely, *Aura* represents a missed opportunity in our design process. In this way, the focus framework provided a structure that we could productively scaffold to better understand how our final design came to be, and how competing influences of different prototypes and their attributes shaped the trajectory of our design process. This is valuable knowledge to the designer, in order to better understand her own process to advance her practice. In our case, prior to our retrospective analysis, the design process, particularly the appearance and influence of the *Cracks*, was described as a tacit recognition that was largely mysterious. The insights distilled through the focus framework, enabled us to acutely see that the *Cracks* were actually part of our design for quite some time. We, as designers, were just not sensitive enough to their existence, utility, and generative potential. Or as Schön [30] would put it, we were not receptive enough to the prototype's "back-talk" because it was obscured by so many other design elements and attribute form the various prototypes we created.

After establishing the focus framework, its application to the design processes of other projects in our design research studio became apparent. We could see how in several cases design attributes transitioned from being unintentional (*out of focus*) to being intentional (*in focus*). For example, in case of the *table-non-table* [25,27,36,37]—a material speculation investigation into ideas of unselfconscious interaction [37] and unawareness [25]—we could better see and understand how *sound* transitioned from *out of focus* to *in focus*. The table-non-table is a stack of paper supported by a motorized aluminum chassis that infrequently moves. At first, it was very important to us that the table-non-table was as quiet as possible. We therefore looked into different ways of building the table-non-table, and specifically how we could soundproof the casing for the actuators. However, as the project progressed we came to realize that sound is very important to the experience of the table-non-table, as it is one of the key attributes that gives away the object's otherwise barely visible movement. We then focused on refining and integrating sound as a key design feature.

This application of the focus framework outside the Urban Data Posts project, is a promising sign that the framework has value as a post mortem analytical tool to better understand the development of a tangible design artifacts. It can help to unpack how a final design came to be and where specific design attributes originated and trace their influence. This helps a designer to grow her understanding of a design process, and develop a sensibility and repertoire for designing novel tangible objects in future projects.

The focus framework could also be used in a generative way. The design attributes distilled through the focus framework in one project, might be useful in other projects. For instance, the design attribute *Aura*, which we discovered in the Urban Data Posts project, might be applicable in future design situations. In this way, the focus framework thus could act as an archive of design attributes and can be used to gain inspiration for other projects.

LIMITATIONS

There are two main limitations to this research. One, the findings of this research are based on a single design case. We can see the framework's utility after informally applying it to the design process of other projects that came out of our studio, but future research is needed to verify and refine the focus framework. Second, the Urban Data Posts project was conducted in an academic research context – and not in a professional design context. There are clear differences between the two when it comes to the execution of a design project [28]. Projects in a professional design context tend to have different constraints than projects in an academic setting. Projects in an academic research setting also tend to be paced differently and have more flexible timeframes.

FUTURE RESEARCH OPPORTUNITIES

Based on one of the limitations, future research opportunities include the application of the focus framework to other projects, both in academia and in industry. In the practice of interaction design, it would be interesting to see the framework applied to projects in software design or projects with faceless interaction (e.g., gestural or audio-based interfaces). We see the focus framework to be specifically useful within a field such as TEI. There is an opportunity to leverage the focus framework in future work in the TEI community to better communicate the design processes of novel tangible objects and, in doing so, to extend the framework itself further.

CONCLUSION

This work introduced the *focus framework,* which was used to retrospectively examine the prototypes in the design process of the Urban Data Posts project. The focus framework allowed us to gain a better understanding of the emergence and transformation of important design attributes in our project. We propose the focus framework as a post mortem analytical tool for designers in the TEI community to better articulate their own design projects and inquiries into creating novel tangible objects and systems. Better capturing and communicating this knowledge will increase our collective understanding of the intricacies in the process of designing novel tangible objects and systems, and will enable designers in our community to grow and mature as it influences their future decision making.

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