Defamiliarization, Representation Granularity, and User Experience: a Qualitative Study with Two Situated Visualizations

Luiz Augusto de Macêdo Morais*
Federal University of Campina Grande

Nazareno Andrade†
Federal University of Campina Grande

Dandara Maria Costa de Sousa‡
Federal University of Campina Grande

Lesandro Ponciano§
Pontifical Catholic University of Minas Gerais

ABSTRACT

This work explores the user experience with two situated visualizations that lie on different points of design space. The first visualization — the Activity Clock — displays the aggregate presence of laboratory members into a wall clock. The second — Personal Activities — represents the same persons individually, in a conventional poster media. We interviewed 17 participants and leverage a theoretical lens of Continuous Engagement and Sense-Making to study how design decisions impact the user experience with respect to (1) which design factors attract users, (2) how design features affect users' understanding of the visualization, and (3) what kind of reflections are evoked by design. We discuss how the defamiliarizing effect of the Activity Clock plays a dual role in attracting users while also hindering their understanding of the data. We also consider the evidence that fine representation granularity in the Personal Activities evokes deeper reflections.

Keywords: Situated visualization; user experience; defamiliarization; representation granularity.

Index Terms: H.5.m [Information Interfaces and Presentation (e.g. HCI)]: Miscellaneous—

1 INTRODUCTION

Situated visualizations are data representations located close to the objects or in the space to which data refers [41]. Recent work on situated visualization has, for example, explored the display demographic data about the residents of a street in the signs of the street itself [5], data about the activity of a café on its wallpaper [33], and the degree of popular support in a neighborhood for municipality measures on the public spaces of the neighbourhood [36]. For this study, we designed two situated visualizations that display the presence of people near a research laboratory in the cafeteria of the laboratory. While there is a significant amount of previous research indicating the potential of situated visualizations, there is limited work exploring the trade-offs in the design space of such visualizations.

The contribution of this work is contrasting two dimensions of design space of situated visualizations by exploring the user experience with two data representations. One of the visualizations displays the aggregated presence of individuals and is designed to provoke a sense of defamiliarization for being embedded in a modified but seemingly ordinary wall clock. The second visualization is presented in a conventional printed and framed poster, but shows data from each person with an individual glyph as an attempt to lead readers to connect with the personal nature of the data. These two designs allow us to compare the effects of different features along the dimensions of (i) familiar vs. defamiliarized physical presentations, and (ii) individual-level vs. group-level situated data representations. The analysis of user experience with the two visualizations explores the trade-offs and opportunities of different design dimensions and helps to inform future practitioners and scholars.

The first dimension we consider is physical presentation familiarity. A *physical presentation* is the frame that makes the visualization observable (e.g., public displays, posters, 3D printout) [41]. The term *defamiliarization* comes from art and means "*presenting common things in an unfamiliar or strange way in order to enhance perception of the familiar*" [7]. Our first visualization causes defamiliarization because it has a familiar format (a wall clock) with a different function (being a data visualization). Previous literature in HCI discusses the role of defamiliarization and ambiguity as a way to foster engagement [10] and critical reflections [2]. In this study, we explore how defamiliarization affects engagement and reflections in the context of situated data representations.

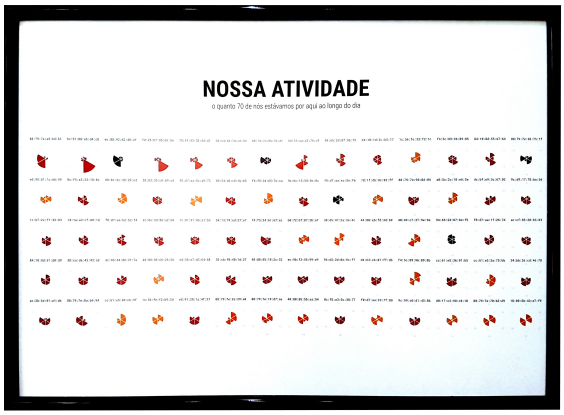
The second dimension we consider is concerned with *representation granularity*, which we define as the level of correspondence between entities in the data (e.g., people) and marks, given an entity of interest. On one end of the continuum of this dimension, there are visualizations with a coarse representation granularity, where each visual mark represents a group of entities. Our first visualization is a group-level visualization with respect to lab attendees, as each visual mark in this design represents the aggregated level of presence of all people in the laboratory. On the other end of the representation granularity continuum, there are individual-level visualizations: in which each mark representing a single entity. InfoVis literature has recently started to investigate the effects of representation granularity on people's empathy and prosocial behavior [3]. In this work, we investigate the effects of representation granularity on user experience in the context of situated visualizations in semi-public spaces, where readers are data referents.

Considering these two dimensions of the design space, we examine user experience with our two visualizations based on McCarthy and Wright's Process of Engagement and Sense-Making [23]. This examination is guided by three research questions: (1) Which design features attract users to the experience? (2) How do design features affect users' understanding of the visualization during the experience? (3) What kind of reflections are evoked by design features during the experience?

Our results demonstrate that physical presentation familiarity, representation granularity, and the situated nature of visualizations play a significant role in user experience. Evidence shows defamiliarization and the interplay between data and place contribute to engagement. On the other hand, defamiliarization is also responsible for hampering understanding in some circumstances. Finally, results indicate individual-level visualizations can promote more profound levels of reflection, compared to group-level data representations.

*e-mail: luizaugustomm@lsd.ufcg.edu.br
†e-mail: nazareno@computacao.ufcg.edu.br
‡e-mail: dandara.sousa@ccc.ufcg.edu.br
§e-mail: lesandrop@pucminas.br

(a) Activity Clock



(b) Personal Activities

Figure 1: Visualizations deployed in the laboratory cafeteria

2 Situated Visualizations

One spectrum in the design space of data representations which has been gaining attention in academia is that between situated and non-situated data representations. Willet et al. [41] conceptualize a non-situated representation as a physical presentation which is not located in the physical space or near the physical object to which data refers – the *physical referents*. Conversely, situated data representations are close to the data's physical referent, allowing analyses to leverage the experience of readers in the data context.

Because of this relationship with context, situated data representations take the opposite direction of decoupling data representations from the physical world that many data analysis tools seek. Situated representations are necessarily more coupled with the context and with the physical world in which they are deployed. Leveraging this coupling has been reported as a means to increase meaning and enriching data value [5, 36], to raise awareness [37], to provoke discussion and reflection about local concerns [19], and to keep spatial experience tangible and multimodal [26], among other possibilities.

Situated data representations can also be seen on a continuum between situated physicalizations and situated visualizations [41]. Physicalizations are physical artifacts encoding data in their geometry or material properties [17], such as centuries-old Inca Quipus, or physical bar charts reflecting polling data [22]. Situated visualization is a term which has been used to differentiate situated representations where data is encoded in a virtual representation that uses visual marks and perceptual channels but does not use an object's geometry or materials [17, 41]. Examples of situated visualizations include street signs displaying data about residents in the street [5], a wallpaper showing activity patterns in a cafe [33], and digital screens in public spaces showing quantitative data about these spaces [8, 35].

3 Related Work

This study contrasts two designs of situated visualizations using a qualitative and holistic approach to explore user experience. In this section, we discuss related work on HCI and InfoVis that explore user experience and situated visualizations.

3.1 User Experience with Data Visualizations

An interesting work that explores user experience is the one of Hogan, Hinrichs and Hornecker [16]. They qualitatively contrasted the "lived" experiences of users that interacted with three different types of representation modalities — auditory, haptic and visual. The authors describe and discuss in detail the process of sense-making of participants during their interaction. Our work differ from theirs because they ground their data collection and analysis in the Micro-phenomenology. In our case, we grounded our work on McCarthy and Wright's Process of Engagement and Sense-Making [23].

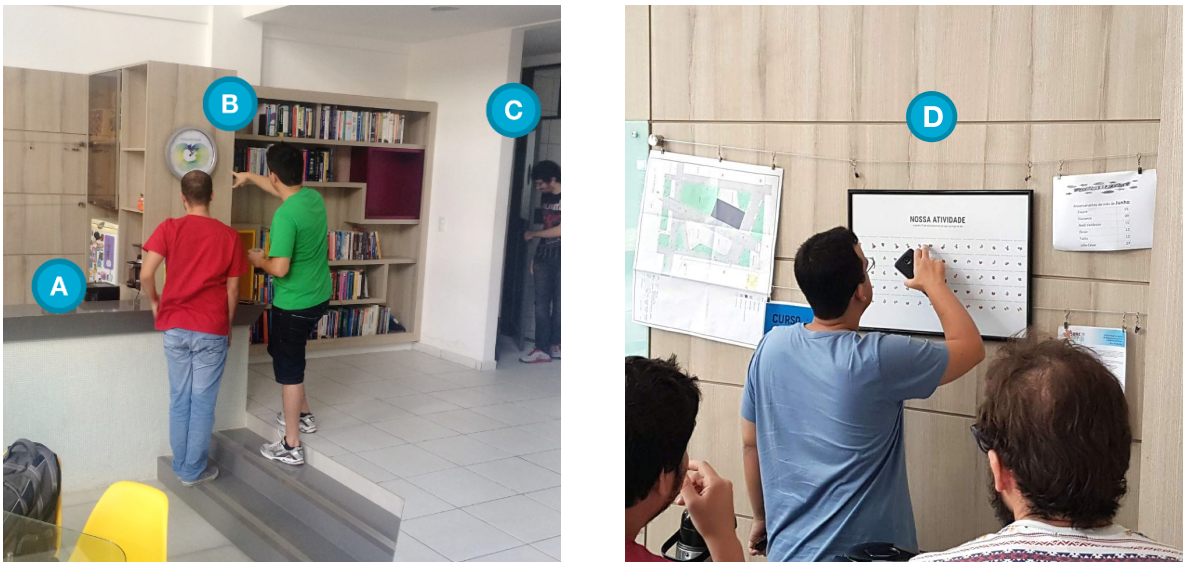
With regard to studies that address user experience, the literature [20, 32] affirms that most work investigates user experience using utilitarian and quantitative approaches. Several researchers focus on measuring factors such as usability or attitude, which are important but do not reflect user experience as a whole. In this study, we use a qualitative and holistic approach to investigate the overall experience of users when interacting with situated visualizations.

3.2 Engagement with Situated Visualizations

Engagement is defined by O'Brien and Toms [28] as a quality of user experience. There have been limited studies focusing specifically on the process of engagement with situated visualizations. Koeman and colleagues [11, 18] conducted multiple works with situated visualizations in the urban space that explored types of engagement in this setting. Among the design factors of the visualizations that stimulate engagement, Koeman cites the attractiveness of the devices, which promotes engagement through attention-getting and curiosity.

With respect to the context, the active participation of shopkeepers to invite shoppers to interact with a visualization deployed in their street and the reflections of participants about the meaning of results are reported to have increased engagement. The former seems related mostly with the social connectedness of those in the physical context of the visualization, while the latter is associated with both this connectedness and a sense of mattering with respect to the data visualized. Koeman et al.'s results are corroborated by Claes and Moere [5] in a case study with visualizations conveyed in street signs. Moreover, Claes find that the context may interfere with the visualization to have it misinterpreted. In their case, a street sign about the number of immigrants residing in a street was sometimes interpreted as propaganda.

Another strand of work relevant for understanding engagement with situated visualizations is that of engagement with public displays, which sometimes present situated data visualizations. The literature on public displays most often focuses on digital displays and on interactive visualizations, but offers relevant insights. A consistent result is that curiosity aroused by the public display is major element to initiate engagement. Visual encoding decisions that result in aesthetically pleasing and intriguing experiences often cause curiosity and engage the audience [14, 29, 37, 40]. A sense of mattering with the data chosen to be visualized also seems to



(a) Interaction with the Activity Clock

(b) Interaction with the Personal Activities

Figure 2: Space where visualizations were deployed. Details: (A) kitchen counter, (B) watercooler and (C) bathroom and (D) mural

foster curiosity and thus engagement [36–38]. The positioning of the visualization is a contextual factor that can also cause curiosity and help get the attention of passers-by [1, 4, 37]. Whether the place where the display sits is more socially engaging or has a higher flux of people also affects the number of passers-by that will engage [29].

Regarding results about the period of engagement with public displays, a major element that shapes activities is that visualizations are on a social space. Social interactions, mediated by the degree of social connectedness of the context, often lead to social learning about how the visualization works [24, 38]. Also, the physicality of visualizations has been reported to increase social engagement [6], and the positioning has been found to facilitate incidental interaction with the device [1]. In our context, we explore the role of the situated nature of the visualizations and the hyperlocal quality of the data on engagement.

4 Space and Audience

The two visualizations used in this study were deployed in a cafeteria of a research laboratory. This laboratory is situated in a dedicated building at a Brazilian University and hosts approximately 60 people who work in topics related to Data Science, Information Security, and Distributed Systems. Members of other nearby laboratories and students of the University also routinely use the cafeteria, which is used by over 100 people on a typical day. The cafeteria is located in the laboratory's entrance hall, where there are a fridge, a coffee machine, and a dining table. It is also in the way to the toilets and the offices.

As such, the cafeteria is a semi-public space with a captive audience that routinely attends to it. Most often, attendees stop by for water, coffee or snacks, and use the opportunity for socialization before coming back to work (see Fig. 2a for example). We chose the cafeteria as the space for this work due to our familiarity with it and its users, and due to the opportunity to motivate engagement with visualizations of data which refers to the captive and regular audience of the space.

5 Visualization Design

Our case study examines and contrasts two visualizations that share the same dataset and were deployed in the same space. Both visualizations were presented in the cafeteria for two weeks, each in a different period, with the second deployed 10 months after the first. They were deployed in adjacent positions in the cafeteria, one less than two meters away from the other. The two visualizations are called Activity Clock and Personal Activities, and visualize data about user presence in the laboratory where the cafeteria is located.

5.1 Dataset

The data was obtained from a dedicated sensor built with a TP-Link 3020 commercial Wi-Fi access point. This sensor runs a modified firmware to collect probe requests from devices searching for Wi-Fi networks near the cafeteria. The MAC address and timestamp associated with each probe request are stored over time. The dataset in each visualization comprises observations in weekdays of a 3-year period.

We use the presence of probe requests from a mobile phone with a given MAC address in a period as a proxy for the presence the owner of that phone in the laboratory. Although it is apparent that this approach incurs in some imprecision, we have validated that aggregate patterns observed over time match the common sense of those reading the visualizations. Moreover, we also reduced noise by filtering out of the data MAC addresses that only appear once or from network printers, notebooks and devices which are always present during the early hours.

5.2 Visualization 1: Activity Clock

The Activity Clock is a visualization that allows a passer-by to examine the typical number of people over the course of a day in the space where the clock is situated. The clock is depicted in Fig. 1a. It was designed by two of the authors as an intervention for the cafeteria in the hall of the research laboratory. The clock was initially conceived during a hackathon with the goal of leading people to reflect about their collective and social behavior in their workplace. The present research was designed after the clock was created.

The clock displays statistical summaries of the typical number of people in the space between 8:00 AM to 8:00 PM. For the visualization, this period is divided in 15-minute bins, and summaries for each bin are displayed with bars and dots distributed in the body of

the clock following a radial axis according to the clock's dial. Dots encode the median number of people in the corresponding period of the day; each bar represents the range between the 10th and the 90th percentile for the number of people in that bin on different days. The color redundantly encodes the median using a Viridis color scale [39]. There are light gray grid lines that indicate reference points for the distance of bars and points to the center of the plot – the zero in this axis. Fig. 3 details a part of the visualization in the clock.

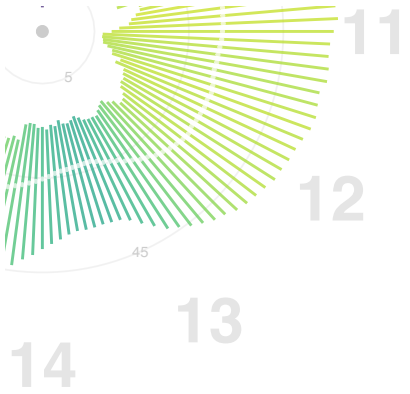


Figure 3: Detail of the bottom right quadrant of the Activity Clock, with the hour hand omitted. There is more variation and a higher median in the number of people in the cafeteria at 11-12am than 1-2pm.

The plot described so far is printed on paper and mounted on the body of a plastic wall clock. This clock is also modified to have only the hour hand, working similarly to a normal clock. With this design, the hour hand dynamically points to the 15-minute bin corresponding to the present. The aim of removing the minutes and seconds hands was to have an unequivocal pointer to the bin that allows the reader to compare historical data with the current moment in the cafeteria.

Because of range of hours for which we intend to show data, the clock has a 12-hour dial that starts at 8:00 AM (in the position of the usual 12) and goes until 7:59 PM. On the one hand, this allows the visualization to display the 12 hours we are interested in examining. On the other hand, it implies that no data is shown for the period after 8:00 PM and before 8:00 AM. Hours are shown in the 24-hour notation (thus ranging from 8 to 19) to communicate to readers that for example 9:00 PM is not represented in the visualization.

Finally, the clock has a written title which reads "Our activity: people near this space during the day" in Portuguese. This title has the goal of hinting readers about the data used while also communicating that the visualization is about "us", in a tentative to make readers empathize with the data.

It is relevant to mention that although the visual encoding of the visualization is familiar to the cafeteria audience, there are no explicit instructions in the clock about how to read it or a description of its data source. This deliberate absence is meant to provoke a puzzling sentiment and encourage engagement, likely at the cost of turning away some readers unable to understand the visualization. Nevertheless, our subsequent observation and interviews suggest most readers were able to make sense of the visualization.

5.3 Visualization 2: Personal Activities

Our second visualization, called Personal Activities (Fig. 1b), has the similar general purpose of the Activity Clock of displaying patterns of presence in the laboratory.

In contrast with the Activity Clock, this visualization concerns the daily activity of the 70 MAC addresses that are most often seen in the laboratory and are from mobile phones after our data inspection. One glyph is shown for each of these MAC addresses next to the address itself. This glyph is a radial bar chart with six bars of the same size: the radial position of the bar encodes which 2-hour bin between 8:00 AM and 10:00 PM the var represents. The height of the bar represents the proportion of observations of that MAC address that happen in that period of the day. Each glyph is also colored according to the proportion of the observations of that MAC address that happen in the morning, redundantly signaling whether each person observed is predominantly diurnal or nocturnal. Fig. 4 shows four of the 70 glyphs in the visualization in detail.

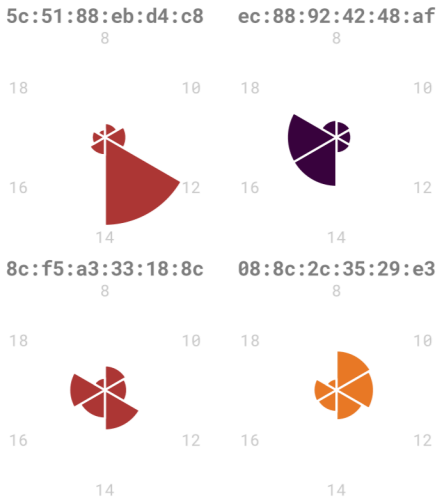


Figure 4: Four of the glyphs shown in the Personal Activities visualization, with their corresponding MAC addresses. The top right chart shows a person predominantly present in the afternoons; bottom-right someone mostly present in the mornings.

Also differently from the Activity Clock, Personal Activities was deployed in the cafeteria in a more conventional form: a paper print in a rectangular frame. The subtitle of the visualization reads "How much 70 of us were here during the day". Similarly to the Activity Clock, our design limits the help provided to the reader in interpreting the visualization. There is no clear vertical axis stating what is the unit of measure or absolute value that the height of the bars represents, and although it is possible to deduce it, there is no legend for the color scale.

Finally, displaying the MAC address corresponding to each glyph has an interesting identification effect. This happens because MAC addresses are complex for a human to memorize, and we typically do not know the address of our mobile phone. Thus, the addresses in our visualization allow one to identify him/herself in the data with some effort, but do not allow a reader to identify the identity of others without their participation.

5.4 Similarities

The two visualizations share similarities in their visual encodings and overall design. Both use polar coordinates to create round-shaped marks, have the same pattern of 8:00 to 20:00 on the radial axis, and share the same title, "Our Activity". Additionally, both designs have a minimalist style and limited instructions to encourage engagement with the visualization and with others through discussion.

5.5 Contrasts

With respect to representation granularity, the Activity Clock represents group information at each period of time. As such, it aggregates group data, considering cafeteria users as the entity of interest. In contrast, the Personal Activities presents patterns of 70 lab members by using a glyph to represent each person. Even if data is still aggregated in the time dimension, it is not aggregated considering persons.

With this difference of representation, the Activity Clock is more suitable to explore and compare collective activity, and guides readers for interpretations that relate to group identity. Personal Activities makes it difficult to identify collective patterns, but allows users to dive in the perception of individualized patterns, even if these are stories of coworkers whose precise identity is for the most part unknown.

A second distinction between the visualizations is the familiarity of their physical presentation. The Activity Clock is a visualization embedded in a familiar wall clock that causes defamiliarization through an unusual function of presenting summaries of past activity in the cafeteria. Its unconventional dial, missing hands, and body create an enigmatic nature to the visualization, which was designed to encourage engagement. The design of Personal Activities uses a rectangular framed poster format that is more familiar to most readers of data visualizations.

6 METHOD

Our case study consists of investigating how the design decisions of the visualizations deployed in the laboratory cafeteria impact the experience of users. Each visualization was deployed for one week in the same space, with the two deployments ten months apart. During each deployment, one of the authors observed individuals that engaged with the visualizations either through security cameras or in-loco. Afterwards, some of these individuals were recruited for participating in a semi-structured interview.

An important note is that this study does not aim at producing a generalized model of the effect of design choices in the visualizations. Instead, it aims for an in-depth qualitative exploration of two points in the design space of situated visualizations with respect to representation granularity and physical presentation familiarity.

6.1 Participants

Individuals who visibly engaged with the visualizations during our observation period were recruited by email or face to face communication. The recruitment stated that the research is related to data visualization, but did not disclose the research is associated to experience, engagement, or visualization's situatedness. Finally, seventeen participants were interviewed: eight who only engaged with the Activity Clock, two who only engaged with the Personal Activities, and seven who interacted with both visualizations.

Participants are most often students – both undergraduate (5) and graduate (3) – or software engineers (6), but also include a cleaning worker, a designer, and a secretary. Three of the 17 participants are female, a gender imbalance that reflects the overall gender distribution in the Computer Science Department of the University. Hereafter, all participants' quotes will be identified by an acronym for the visualization that s/he mentioned (i.e., AC, for Activity Clock; PA, for Personal Activities or AC+PA for both) followed by an alias.

6.2 Making Sense of the Experience

We adopt the approach proposed by McCarthy and Wright [23] to study user experience when interacting with technology. More specifically, we grounded our interview in the process of sense-making proposed by the authors. This qualitative and holistic perspective suits our interest to comprehensively explore the user narrative, from motives to engage with the data representations to the reflections it evoked during and after the experience.

This sense-making process is divided into six stages [23]. *Anticipating* is a continuous process that happens when people bring expectations, possibilities, and ways of making sense of the experience. Anticipation may occur when users encounter the visualization and make assumptions about that. *Connecting* refers to the pre-conceptual and pre-linguistic sense of the situation; when people are attracted by a design quality, for example. *Interpreting* occurs when users explore the narrative structure, the agents and possibilities in the experience. In our context, interpretation is related to the process of understanding and exploring the visualizations. *Reflecting* is when people make judgments about the experience as it develops. Reflection may happen when people think about the impact of data in their routine, for instance. *Appropriating* is making the experience unique and meaningful, as when users change their attitudes about data. *Recounting* is telling the experience to others or ourselves, and arises for example when people discuss together the data.

6.3 Interview Protocol

The interview protocol was designed to elicit participants' engagement and sense-making regarding the experience of interacting with the situated visualizations. The interview roadmap addressed all stages of sense-making described in Sect. 6.2. During interviews concerning the Personal Activities chart, the roadmap had additional questions to explore the differences between the two visualizations with participants that interacted with both.

The semi-structured interviews were conducted by the first author. They occurred in the participant's work or study place. The dialogues were audio recorded and lasted on average 20 minutes (SD 8 min.). The author asked questions and probes to lead participants to describe what attracted them to the visualization, how they understood it, whether and how they interacted with others, what were their reflections about the data, and whether they have interacted multiple times with the visualization.

Concerns over possible post-rationalization were addressed by using techniques based on the Elicitation Interview Method [15]. (1) The time between the interaction and the interview was as short as possible (three days at most) to avoid participants forgetting the details from the experience, (2) questions were asked in the present tense to make participants re-experience the situation as if they were there, and (3) participants' sentences that explicitly start with "I think that", "let's say", or equivalent were discarded from the analysis.

6.4 Analysis of Transcriptions

All interviews were transcribed and coded through multiple iterations of coding and discussion between the first two authors. As recommended by Miles and Huberman [25], our analysis combines an initial set of codes informed by theory with codes that were not initially foreseen but emerged from the analysis.

After deciding on an initial set of codes, internal validity was strengthened by having two of the authors coding a subset of the interviews and discussing a common understanding of the codes. Following the initial coding, axial coding was used to group codes into categories. Finally, selective coding was used to aggregate concepts and categories into a single model. Diagramming techniques [25] were used throughout the analysis to facilitate selective coding.

Although we have captured all stages of sense-making during the interviews, the responses regarding recounting were not sufficient to produce consistent theories about the theme. The resulting model for analysis is based on five sense-making stages extracted from McCarthy and Wright's framework: anticipating, connecting, interpreting, reflecting and appropriating. After the coding process, the most salient quotes from each category were extracted and organized according to the research questions.

7 Enticing Factors

The first part of our interviews explores user anticipation and connection with the experience. In our results, enticing factors are related to design and contextual aspects of the situated visualizations, which we discuss in turn.

7.1 Defamiliarization

For the Activity Clock, the defamiliarization produced by an object initially recognized as a clock but that is not serving the usual function or form of a clock is mentioned by multiple participants. This sentiment was reported to provoke engagement:

> You recognize it's a clock. It's not that distinct from a clock, but you can see it's unusual. The clock is displaying something else besides time. — AC - Heitor

> As I told you on that occasion [the last interview] "is this showing the time? It's not the time; it's something else.". This is the unique part of the visualization that caught my attention. That was not showing the time, but it's a clock, so "what is it?". — AC - Sandro

As detailed in Sect. 5.2, decisions such as adapting the range of numbers in the clock's dial are meant to simplify the design of the visualization. However, these characteristics reinforced the defamiliarization and were cited by multiple participants as source for a puzzling effect that led to curiosity. For example:

> [The clock caught my attention] because we expect two hands and there was just one [...] If it was a clock with two hands, a clock with numbers from 1 to 12, it wouldn't have caught my attention. But as it was a strange object, it caught my attention. — AC - Gustavo

> The clock draws our attention first when we look at the numbers. They are not conventional. Because it goes from 8 to 7 and we are used to have from one to twelve, right? — AC - Rita

Removing the minutes and seconds hands was initially meant to improve the visualization's readability. However, leaving only the hour hand also provoked curiosity in Maria:

> I felt curiosity exactly because of that, because it is not a normal clock as we are used to see. [...] What attracted me was just this thing with the [hour] hand. — AC - Maria

Sometimes, curiosity was also referred to as a result from a first feeling of confusion due to the unmet expectation that the clock behaves according to its affordances:

> I got curious, stared at it and realized that minute and second hands were missing. I thought the clock was broken — AC - Leandro

As expected, there were no reports with regard to defamiliarization in the engagement with Personal Activities.

7.2 Aesthetic Elements

Aesthetic elements resulting from visual encoding were prominently mentioned by participants as promoting engagement. Although the visualizations have contrasting dimensions in design space, they share several similarities in design, and were described similarly by participants.

One of the aesthetic elements alluded to by multiple participants is the asymmetric shapes created by the combination of marks. Participants indicated that finding visualizations with such shape made them curious to understand what they mean:

> If you see it, the form kind of creates a wave [...] It got a lot of my attention when I saw that. — AC - Leandro

> [It led to a feeling of] curiosity, really. The forms of the plots. When I saw several circles, each with a different shape, I got curious to see what was it. I wanted to understand what that meant. — PA - Jair

Another enticing factor is color. Participants described that the colors (or their interaction with shape) provoked curiosity and motivated them to explore the visualizations:

> It really stands out, this yellow and green thing: a wheel that has no symmetry. — AC - Klaudio

> The colors also got my attention. You try to find out what the reddish thing means, and what is the yellowish one. — PA - Daniel

7.3 Hyperlocal Personal Data and Place Attachment

The two visualizations present hyperlocal personal data in the place the data refers, which evokes a sense of belonging and curiosity in the members of the laboratory. People seem tempted to engage with the visualizations because they are motivated to find themselves in the data.

The title was one of the major factors to make people feel part of the data. In both visualizations, the sentence "Our Activity" played an important role to promote engagement. This is evident in Daniel's quotation:

> The fact of [the Activity Clock] having "Our Activity" [in the title] makes me think there is something mine in the chart. It's the idea that I am part of that thing. — Daniel - AC

Particular to the Personal Activities, the fine representation granularity also contributed to increase the motivation of users to find themselves in the visualization. When asked why they were attracted to explore the visualization, Wagner and Felipe said the following:

> What caught my eye was a series of plots. From a distance, you already have the feeling that those plots represent a person and this arouses the curiosity because most probably I was one of those people. — PA - Wagner

> The feeling was whether I was in that visualization. I was curious about this: to see if I was there. Since there were only 70 people, I wanted to know if I was there because there are over 100 people here. — PA - Felipe

Nonetheless, sense of belonging only seems to emerge when users have an emotional bond with the place. This bond is known in psychology literature as *place attachment* [21]. Thus, sense of belonging seems to be evoked from the interplay between the situated nature of the visualization, the hyperlocal and personal qualities of data, and place attachment.

During the interviews with participants that were attracted because of their sense of belonging, we realized that place attachment plays a pivotal role on that. Rafael, for example, declares he is not as interested in charts placed elsewhere as he is for the one positioned in the laboratory — a place where he works everyday:

> I find charts in other places over the day [and he is not interested]. But that [Personal Activities] was presented in a space where I spend a large part of my time — AC - Rafael

Another participant reinforces the validity of the effect when he states the importance of being attached to the place in order to be attracted to explore the visualization:

> I don't know if it's the importance of the place, but maybe it's the connection of the place with my work. – PA - Daniel

> If it [the Personal Activities] was placed in the DSC [other department building], which is a place I don't visit often, it would be unlikely I have stopped to exploit it. — PA - Daniel

8 Experience of Understanding

We also explored the experience reported by participants in understanding the visualizations. Evidence shows that defamiliarization and lack of instructions may hinder the understanding of the displays. On the other hand, socialization is pointed as an effective strategy for understanding.

8.1 The Role of Familiarity in Understanding

Although Sect. 7.1 describes a positive effect defamiliarization causes on the engagement with a situated visualization, defamiliarized physical presentations may also provoke confusion or deter understanding of the visualization. Sandro summarizes the trade-off of presenting an enticing visualization that is hard to understand:

> The clock was the most unique way, a more prominent means of showing the person's data. But at the moment the person stares [it's difficult to understand]... that indeed seemed more like art. — AC+PA - Sandro

Some of the participants reported the hour hand or the dials of the Activity Clock confused them so they could not understand how the visualization works appropriately. The same absence of some hands in the clock that provoked curiosity also deterred understanding of some of our interviewees:

> At one point I went and thought it was broken. [...] the pointer being represented by the hour hand confused me a lot. And since there is no minute hand, then it is slower. Then I thought it was broken. — AC - Leandro

> I felt curiosity exactly because it is not a normal clock as we are used to seeing. I was interested in the clock but I couldn't understand it, actually. — AC - Maria

As the Personal Activities chart followed a more conventional format, people understood at first sight that its visual components correspond to a data visualization. The following quotations make evident that the Personal Activities is more intuitive than the Activity Clock:

> This other graphic that you generated [Personal Activities], when I looked at it with attention, I understood what it was. I did not need to guess what that was. — PA - Sandro

> I can see from a distance and say it's a data visualization. [...] Because it [Personal Activities] is more intuitive. The way things were arranged was more intuitive. Look, there are 70 people and here's their activity in the lab. It was more intuitive than the clock chart. — AC+PA - Ana

8.2 Lack of Instructions and Comprehension

When we designed the visualizations, one of our aims was creating casual visualizations [31] with as few instructions as possible. We were interested in exploring the role of the contextual information and the fact the visualizations are situated and presented in a hyperlocal and convivial environment.

As expected, the absence of detailed instructions hindered the comprehension of the visualization in some cases. A couple of users report that elements of visual encoding in the Activity Clock and Personal Activities are enticing yet tricky to understand without a legend:

> The second thing I looked at was the bars [of the chart], I wanted to know what the bars were, and the third thing I tried to figure out was the color. Why is there blue over there, green, turning yellow, turning blue again? — AC - Daniel

> I did not understand the color part [on the Personal Activities chart] because it has no legend.— PA - Sandro

Another aspect of design in the Personal Activities chart that was hard to decipher was using MAC addresses to identify people. Some users reported they had trouble understanding that the identifiers were MAC addresses and that they correspond to the smartphones of the laboratory's members.

> I was trying to understand what was the visualization about and especially the MAC address. I did not realize it was the MAC of each person at first. — PA - Jair

> Everything the visualization had to tell me I understood. I just ran into this difficulty of identifying who I was. [...] I knew it was a MAC address, but I did not know if it was the phone, the notebook, the computer, I don't know ... Anyway, I didn't go back. I expected something easier. — PA - Wagner

8.3 Strategies for Understanding

When dealing with the difficulties of understanding the visualizations, two aspects of the experience of a situated visualization were prominent in the discourse of respondents: the ease of socializing to discuss the difficulties, and the ability of directly observing the space and people that the data refers while analyzing the visualization.

Socialization played a significant role in the experience of understanding the visualizations. It happens mainly because of the ambient nature of the visualization and it usually arises from opportunistic conversations:

> Usually, it [the socialization] started from a doubt. There was someone looking at the clock and saying "that clock, I'm not quite understanding what's going on", "what are these bars here?" — AC - Daniel

After socialization takes place, users combine their individual experiences about the place to create a collective mental model about the visualization and the data it represents. This was mentioned for example by Gustavo:

> After some time with the guys analyzing there with me they made me realize that it is from 8AM to 7PM, which made me think about the work hours. It is the period we are at work. — AC - Gustavo

Individual users also take advantage of the fact that they can use contextual information to understand the visualization. Daniel, for example, described how relating the data in the clock to the reality he can observe was helpful in his experience of understanding the visualization:

> After I discovered that the axis pointing there to the 9 really points to 9h, even though it is not at 12h, but it is rotated, then I started to pay attention to the bars and see that it really made sense to my reality. Looking at 12h, which is a time I am usually here, if this data reflect with my [routine]. — AC - Gustavo

9 Types of Reflection

Next, we focus on the process of reflecting and appropriating in the experience. Our results indicate that people reflect on their routine when interacting with both data representations. However, deeper levels of reflection are only reported when interaction occurs with the individual-level visualization. In the following, we list types of reflection according to their depth of reasoning and appropriation.

9.1 Reflection on Routine

A first and shallower type of reflection was reported during the experience with both visualizations. The sense of belonging users develop during the initial contact with the visualizations leads them to search for themselves in data and reflect about their routine in the laboratory. Participants compare data presented in the visualization with the routine they experience in everyday life. For example:

> After I realized what that was [a visualization], I checked if it [the data] was right. Because I know the time I'm usually here. So I went to see "my [routine] matches with the one here [in the visualization]?". Then I realized it matches and I went to search other people's [routine]. — PA - Bruno

> The time I use it [the cafeteria] the most matches with the time it is most used. So I kind of tried to make a retrospective and see if my experience with the hall matched with the plot — AC - Heitor

Due to the situated nature of the visualizations, users reported sometimes taking advantage of direct observation of the environment to compare it with the data. The placement in a convivial space also allowed socialization to take place during moments of reflection about the routine. Finally, the captive audience of the place facilitated socialization, as most people a reader would meet and engage in conversations about the visualization were the ones whose data were also portrayed in the visualization. Sandro's quote illustrates these points:

> I arrived and found members from another project. Then I said: "Look, it [data from visualization] matches your schedule here". At lunchtime there's hardly anyone here, actually. Or the other way round: "It's already 3:00 PM and everyone is already back here". It's matching what is presented on the clock. — AC - Sandro

9.2 Reflection on Oneself

The fine representation granularity of the Personal Activities led participants to have more personal and deeper reflections compared to the Activity Clock. Bruno described the difference between experiencing the two visualizations:

> I saw myself there [in the Personal Activities]. I can see my everyday life there. I couldn't see myself in the [Activity] Clock. I could perceive that my routine matches the pattern in the clock, that it makes sense, but that's it. — AC+PA - Bruno

After exploring their own glyphs, some participants reflected about personal facts the data allowed them to remember:

> I kept thinking of things like "oh, I really spend too much time here, I'm always here... if you want to find me, I'm right there in my room" — PA - Ana

> I knew I always left earlier, but seeing it there, I say "oops". Even if the person does not know it is me, but someone... or something knows that I leave earlier. — PA - Felipe

9.3 Reflection on Behavior Change

In addition to reflecting on facts about themselves, participants also questioned their routines and considered changing behavior because of the personal data represented in the Personal Activities. For example:

> I reflected on my productivity, my schedules... it made me question [my routine]. I'll try to procrastinate less during the day so I do not need to stay here after 6PM. — PA - Rafael

Representing people through situated individual-level visualizations in a hyperlocal context allows users to opportunistically find themselves in data. It can arouse reflections on behavior change, as described by Ana:

> One thing I realized was kind of pondering a bit more about the moments I'm here. Because as I end up spending more time than I should. [...] There is a visualization showing "look, you've really been here for a long time." So let's make it better. — PA - Ana

No interviewee that interacted only with the Activity Clock mentioned reflections about changing their behavior, while this was clearly mentioned by four of the participants that interacted with the Personal Activities.

10 Discussion

Overall, our case study contrasting the two visualizations unveils a number of design and contextual factors related to the situated nature of our visualizations that affect user experience.

10.1 Defamiliarization, Enticement and Interpretation

Defamiliarization seems to facilitate the anticipation and connection with the experience at the cost of making interpretation more difficult. The unusual design of the clock evoked curiosity and motivated participants to connect with it and to think about the role of the device in a different perspective. The attribute in the clock that was most often mentioned as motivating engagement is the false affordance caused by the defamiliarized object. Technology affordances [9] are usually used to guide the usage of a device, and therefore false affordances are commonly seen as something to be avoided. A false affordance is perceived as a cause for user mistakes. Our case study, however, points that the sensual experience of false affordances in a familiar device may trigger engagement by causing curiosity.

The fact the design of both visualizations left it open for the reader to infer precisely what is encoded in the visual marks and channels had a negative effect on understanding, but a positive side effect on engagement. At the same time this design characteristic turned away some interviewees, the challenge in general motivated participants to connect and interpret the visualizations both cognitively and socially. In some sense, the positive response of participants to the demand of an extra time to understand the clock puts it as a successful slow technology [12] for these participants. Also, akin to previous studies [24, 38], the challenging nature of understanding the visualization gave room for social interactions to arise around

learning how the visualizations work, particularly the Activity Clock. In our context, the fact the visualizations are situated and portrait the captive audience of their physical location seems to facilitate social interaction around interpreting, as participants seem to easily identify themselves and others in the data.

10.2 Representation Granularity and Reflection

In our contrast of the two designs, the fine representation granularity seems to make it easier for users to have more meaningful reflections and appropriations in their experience. Individually representing personal data in a situated context sparks curiosity because people become motivated to find themselves in data, find others, and discuss insights face to face. Furthermore, users of the individual-level visualization appropriated the experience by reflecting on their routine and considering to change their habits. This effect is promising and should be studied in more detail in the future.

A concept that seems relevant to articulate this discussion is that of mattering. Taylor et al. [36] leverage Wilson's [42] conceptualization of data mattering to discuss how the awareness of the connection between data and its effect on space enables a more profound understanding of the analysis process. Our results suggest that a perception of one's affective relationship with the data also has an effect on different aspects of user experience. In particular, it facilitates more meaningful reflections among those reading the visualizations. And although the choice of the data to be visualized is a design factor, the context of the situated visualization next to the physical referent seems to play a role in catalyzing the sense of belonging participants had with the data. Moreover, the experience of connecting and reflecting seem to have been facilitated by the fact that the people who are the data referents are also knowledgeable to the audience of the place.

10.3 Personal, Hyperlocal Data and Situatedness

The positioning of our visualizations in a familiar context and in a space with a use other than data analysis surfaced interesting engagement activities and points of engagement and re-engagement. As a modified clock put in a plausible place for a wall clock, and a poster hanging on a wall, our visualizations leveraged both incidental encounters with it and discussions with others.

Such discussions, besides the aforementioned social learning, were also fostered by recognizing others in the data. Opportunistically meeting such others created the opportunity for discussions, and data observations were used as conversation initiators. On one hand, the fact that both visualizations are relatively small displays did not allow for conversations or discussions to a scale besides a handful of participants. On the other hand, the material nature of the visualizations seems to have made participants comfortable with getting close to them and engaging in discussions with others.

Several of the respondents mentioned explicitly that the use of the *Our* pronoun in both visualization titles encouraged anticipation and connection with them. The very simple message seems to have resounded with group identity and motivated enticement.

10.4 Aesthetics and Engagement

A less novel but nevertheless design aspect of the visualizations that motivated both cognitive and social engagement is the aesthetically pleasing experience resulting from their design. This is in line with previous work which has highlighted the role of aesthetics for engagement with situated public displays [14, 29, 37, 40] and with web interfaces [28].

It seems relevant to highlight that the aesthetically pleasing experience has played a significant role in the context of our situated visualizations. This is so because visualization design manuals and research have often focused on the perceptual efficiency of a visualization, with aesthetics as a secondary consideration. Indeed, the visual appeal of the visualizations seems to be in great part a side effect of using a color scale whose chief design concern is to be perceptually efficient and efficacious [39]. In a different direction, our results support arguments that aesthetics should not be an afterthought in interactive systems [30, 34, 43] and recent results which argue the same for online data visualizations [13, 27].

11 Limitations and Future Work

This work has a number of limitations that foster future work. Our findings are based on two deployments of situated visualizations in the same University. As such, our participants are a sample of individuals with specific characteristics, and a captive audience to the visualizations in the space we used. It is necessary to reproduce similar experiments in different settings to test the generalizability of our observations. We suspect our results might be reproduced in other hyperlocal, semi-public and situated spaces. On the other hand, we are not convinced the same effects can take place in public places, where passers-by cannot develop a sense of belonging with the data-in-place.

Besides context, our research design also explores coarse variations in two design dimensions of situated visualizations simultaneously. Although our results show that there are some relevant effects related to defamiliarization and representation granularity on user experience, future work should disentangle these effects and deepen our analysis of each individually. More controlled and large scale experiments may allow us to devise design guidelines for leveraging these dimensions in diverse settings and with diverse audiences.

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