



# Me, the Hill and My Browser – Investigating the Role of Time in Posthuman Interaction

Patricia Ciobanu

patricia@dsv.su.se

Department of Computer and Systems Sciences,  
Stockholm University  
Kista, Sweden

## ABSTRACT

Despite the growing concerns related to environmental disruptions, such as forest fires and floods, our interaction with nature has become increasingly distant. The belief is that this is due to human attunement to quick changes over short periods, while natural changes seem slow-paced over the long term. We argue that rather than the problem lying with the pace of time, humans should further attune to the various temporalities within nature. To unpack this topic, we follow a two-fold process: Research through Design and Autobiographical Design. The resulting prototype takes environmental sensor data and visualises the changes happening over a short time. We complement this IT-supported process with think-aloud walks, a practice that is embodied and devoid of technology, for a plural perspective on time. We offer insights into how noticing the various temporalities in nature was enabled, finally arguing for designs that support progressive adjustments that sustain human-nonhuman mutualism.

## CCS CONCEPTS

- Human-centered computing → Interaction design; Empirical studies in interaction design;

## KEYWORDS

time, nature, more-than-human design, posthuman interaction

### ACM Reference Format:

Patricia Ciobanu and Oskar Juhlin. 2022. Me, the Hill and My Browser – Investigating the Role of Time in Posthuman Interaction. In *Nordic Human-Computer Interaction Conference (NordiCHI '22), October 8–12, 2022, Aarhus, Denmark*. ACM, New York, NY, USA, 12 pages. <https://doi.org/10.1145/3546155.3546651>

## 1 INTRODUCTION

In recent years, there have been growing concerns with environmental disruptions that affect humans, such as forest fires, floods, and heatwaves, whilst our interaction with nature is becoming increasingly distant. It has been argued that this disharmony is influenced by how humans and nonhumans operate on different timescales [55]. Humans, supported by digital technologies, are



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*NordiCHI '22, October 8–12, 2022, Aarhus, Denmark*

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ACM ISBN 978-1-4503-9699-8/22/10.

<https://doi.org/10.1145/3546155.3546651>

Oskar Juhlin

oskarj@dsv.su.se

Department of Computer and Systems Sciences,  
Stockholm University  
Kista, Sweden

increasingly attuned to quick and immediate events over short periods, while nature is seen as long-term, with changes occurring at a slow pace. This argued perspective has, for example, informed artistic design explorations [47, 52], resulting in various works that convey the idea of compacting the long-term changes that occur in nature into a human time scale. In this study, we instead investigate the proposition that the lack of human attunement to the various temporalities within nature generates the distancing between humans and nonhumans. Constrained by existing human conventions of time, e.g. clock time, ecological transformations escape our comprehension [9]. Thus, the idea of time seems unaffected by more-than-human experiences. This perspective refers to the position of *tempus nullius* seen as "*nobody's time*", "*an unclaimed territory that is similarly devoid of inhabitants*" [36]. If that is the case, we need to acknowledge the role of nonhuman temporalities and design for interaction with nonhumans along many time dimensions.

As nature operates outside the recognized human conventions of time, this creates the illusion of nature being without agency [8]. Puig de la Bellacasa [70] exposes how the treatment of soil is entangled with the time of capitalism, seeking maximum value and productivity, which contradicts the time of the soil that requires pauses for regeneration. The misalignment between clock-time and other time dimensions is particularly noticeable in two research areas, i.e. enabling interaction with the environment that allows for sustainable living and designing research on user-friendly nonhuman computer interaction, such as the field of Animal-Computer Interaction (ACI). First, clock time disconnects us from the transformations occurring within natural environments. As nature becomes more unpredictable due to the climate crisis, humans need to reconnect to nature. Reductive frameworks of time, such as clocks and calendars, are limited in their ability to portray long-term phenomena and thus, distances humans from engaging with these transformations. Second, the field of ACI takes the nonhuman as the user in focus to develop information technologies that satisfy their needs. While identifying those needs is an important issue to solve, the role of time in interacting with a nonhuman is similarly impacting. Aspling [5] p.86 argues for prolonging the interaction supported by design since nonhumans operate over a longer term timescale than humans. That perspective is specifically evident when developing interaction design for plants [6, 66], where prolonging the interaction can span over decades and centuries.

Thus, in specific, we ask *how can we, through design, present the discrete environmental changes occurring over time within human time dimensions in a way that adds to human's relation to nonhumans?* We argue for the need to investigate how a design system can call attention to short-term natural changes, such as

those repeatedly occurring in social life, that would encourage a switch from human attention to culture to a better attunement to nonhumans and a better relationship with nature. While ideas of time in HCI continue developing [27, 40, 60, 75, 83], the absence of perspectives that explore human-nonhuman time is noticeable. Within these spaces, while notions and representations of time have been rethought [16, 69], these have been primarily human-centred, with Lee et al.'s interactive object LUNE used to investigate how moon phases can represent time [38] among the exception. With the argument of current time-keeping technologies giving us a false sense of control [9] by generating an illusion kept away from environmental impact, we need to consider both our human time and nature time concurrently. Such a holistic approach aligns with the heterogeneous perspective of Posthumanism, in which we decenter the human from the assemblage. In research, time is further conceived as an experience and a social relation. It is an experience since change is situated, embodied and differs from one person to another, creating that discrepancy between the flow of time shown on clocks and the one we feel and experience in our bodies. Social time is a feature of how practices and tasks are synchronised, sequenced, and paced in order to support collaboration. In this broader perspective, we suggest investigating how to attune human time with nonhuman time, specifically time and nature as a co-experience as well as a human-nonhuman relational time.

For achieving this, we use the methods of Research through Design (RtD) [94], and Autobiographical Design [57]. We created a physical and digital prototype that depicts in a browser the subtle environmental changes resulting over time in the research site - an observational spot where the First Author, further referred to as FA, has been engaging with through walks since March 2020. We based these changes on four sensor data: light, temperature, humidity, and soil moisture. Each set of environmental data determines an aspect of how we think of time and is visualised on a web page through a graphic filter. For example, a light change affects the brightness level of the web page. We complemented the daily use of the system with think-aloud walks in the surroundings of where the prototype was installed. FA underwent both these practices. Following this process, we learned that an important aspect of living with nonhumans is uncovering their various temporal aspects. Living within two cultures of time, human and nonhuman, required adjustments and more active engagement from FA. Having the reporting of short-term events in nature presented as graphic distortions on the browser made FA imagine the physical research site in her mind's eye, especially when these events occurred in a tempo that fitted with her own culture of time. Having said that, the abundance of events occurring on the research site intruded on her well-timed life as a researcher. The technology also introduced a new element between the human and the nonhuman in the same way humans can come between a person and their interaction with nature. In the following, we explore the diverse categorisations of time within social sciences, humanities and HCI. It allows for a more inclusive discussion on the struggles with bringing together two distinct time cultures within design. We open up the space for this discussion by exploring artistic work that engages with the topic of time within more-than-human worlds.

## 2 RELATED WORK

Since we address time in human-nonhuman interaction, we first address previous conceptualisations of *time* in human culture. We visit theoretical discussions in social sciences, humanities, and HCI. Additionally, we address the topic of *time and nature* and recount diverse projects that aim to topicalise ways to interact beyond clock times in relations that include nature in areas related to design and art. Previous art and design investigations have become stepping stones to address the gap in investigations of our topic within design-led research.

### 2.1 Research on Time

There are many ways to categorise time [3, 4, 17]. The most common approaches discuss time as a measurable concept, an experience, or a social relation.

**2.1.1 Clock Time.** Clock time can be defined as linear episodes with a beginning, middle and end. It is quantitative, measurable and logical. Time as linear aligns with the Greek time concept of *chronos* [30]. Within this aspect of time, actions are quantitative, ordered, decontextualised, and constrained by clock time units. Time is seemingly unaffected by external factors such as context [2] or human emotions [8]. This particular form of time has co-evolved together with different time-keeping technologies [41], usually represented through the figure of a clock.

**2.1.2 Existential Time.** The idea of 'existential time', often referred to as *kairos* is the living time of experiences and intentions [26] p.33. It is subjective, connects to the perception of change, how not all types of changes are equally considered and depends on who registers the change [9]. Although personally and individually felt, existential time is affected by others, which makes it easy for more dominant expressions of time to take space. For example, certain events distort our sense of time, such as a global pandemic affecting our felt rhythms. Similarly, this aspect of time can also be fabricated by digital technologies through their design and our use [41]. We see existential time represented through plastic and digital time within design-led research. Plastic time was introduced by Rattenbury et al. [76], depicting the *empty time spaces* within technology use [92], such as when scrolling through social media. Whereas digital time, examined by Tomlinson [87] and Rushkoff [79], points to the aspect of constant connectivity and the condition of immediacy with digital technologies [41]. Recent design-oriented research engages with ideas of time that challenge the tradition of time as linear (i.e. rational, predictive, manageable) [8]. They explore forms of slow technologies [25, 59, 64] to contrast with fast technologies created to save time, be efficient and have a high-performance [41]. These design inquiries related to finding new ways of representing time [92] and personal perceptions of time [49].

**2.1.3 Time as Social Relations.** Social time is fundamentally a feature of the ways through which practices and tasks are synchronised with each other, and it is an expression of the need for social collaboration. It is "*the change or movement of social phenomena in terms of other social phenomena taken as points of reference*" [26] p.58. Social time has three features: synchronisation, sequence and rate. Synchronisation relates to the requirement for simultaneous

actions. Sequence refers to a demand for a specific ordering. Finally, rate points to the importance of the frequency of events in a time-frame. Within design research, scholars have unpacked perceptions of social time, i.e. *right time* and *collective time* [92]. Right time or the *situational when* was proposed by Taylor et al. [82] as a concept that describes the various *converging circumstances* that make an event take place, evocative of a combination of temporal attributes such as synchronisation and timing. Followed by collective time, discussed by Lindley [41] on time as entangled within social relations. The plurality of perceptions of time combine with the idea of social time, in which the rhythms of different actors synchronise, follow a certain order and thus, create an experience in time [39]. As a socially-situated experience, "*it is not that we have or do not have time, but that we make it through practices*" [70]. Differentiating between measuring systems should be about understanding how change occurs rather than how time 'flows,' acknowledging the various agency distribution between human and nonhuman actors [8, 24].

**2.1.4 Time and Nature.** Human conceptions of time have historically been linked to natural events, such as tracking the sun's position. Such features, however, are challenging to coordinate with when needing more precision, such as when scheduling a meeting. As a clock depends on its material functionalities and thus, might not apply to other contexts [9], each mode of telling time affords specific interactions. The dominant understanding of time as linear and measurable is most often represented by time-keeping technologies such as the figure of a clock. However, this orientation away from natural phenomenon, has been criticized for "*obscuring more complex understandings of time*" [10] such as relations that pertain to ecological changes [9]. This is ineffective to our understanding and perception of changes in the natural world [93]. Regarding the figure of the clock, Michelle Bastian proposes a broader definition: clocks involve choices on what aspects of our world are most significant to us and worth keeping time. It thus becomes "*a device that signals change in order for its users to maintain an awareness of, and thus be able to coordinate themselves with, what is significant to them*" [9]. An important issue with current clock time tools is that they obstruct and constrain explorations of time that require a set of diverse perspectives [68]. Taking the example of clocks, the problem with this modality is the lack of possibility to move from quantitative to qualitative time expressions [9].

As discussed in [93], "*the clock does not measure time; it produces it.*" It has been argued that a cyclical notion of time that relates to noticing recurring patterns, constituted of relationships and more-than-human interdependence [15], shows a more subjective and embodied perception of time. Anna Tsing's *collaborative survival* depicted through the relationship formed between matsutake mushrooms, human-disturbed forests, and foragers is one example of when multiple timescales unify and constantly reoccur [88]. In this form, humans have the ability to respond to environmental changes. Puig de la Bellacasa argues for *care time* as a form of making time that reveals the multiple more-than-human temporalities that unite in cycles of soil growth and decay [70]. This aspect of time and care includes an advocacy for slowness that goes against the dominant fast-paced always-on, always-connected and always available that characterise today's digitally-mediated societies. By disregarding

the pluralistic quality of time, humans contribute to "*the exclusion of certain practices, individuals, and natures, and supports the dominance of others*" [67]. Tsing's use of polyphony expresses the notion of being attuned to the simultaneous melodies and noticing the moments of harmony and dissonance, the melodies becoming an analogy for "*multiple temporal rhythms and trajectories of the assemblage*" [88] p.24. Within environmental humanities, scholars have engaged with rethinking time in a more-than-human world. Michelle Bastian's work reflects on the correlation between time and agency, defining time in relation to change and as enacted by both human and other-than-human beings [8].

In sum, related research establishes that there is more to time than linear and measurable. It also states that such a broader understanding is particularly relevant when it comes to interaction between humans and nonhumans. We also note that although this challenge is made clear and explicit in research, there is a lack of concrete design research that addresses the topic.

## 2.2 Artistic Explorations of Nature, Time and Technology

In our attempt to account for time in interaction with nonhumans, we also take inspiration from artistic explorations that address time ideas from a more-than-human perspective, i.e. compressing nature's long duration of change into a small graphic representation or when challenging the clock metaphor.

**2.2.1 Compressing Time.** Projects such as *Deep Time Walk* [89], *The Room of Change* [52] and *Keeping Time* [13] address how a long-term change in nature, which defies standard clock technology, should be visualized. The encompassing expression in this type of work is to present a compressed time scale graphically. They do so, for example, through an immersive guided and narrated walk that recounts the Earth's history throughout its 4.6bn years of existence in *Deep Time Walk* (for visual reference, see [90]). Similarly, through an installation of *30-meters-long hand-crafted data tapestry* [52] of changes in our environment that happened, are happening, and will possibly happen in *The Room of Change* (for visual reference, see [53]). These projects also refer to a specific understanding of time, such as the concept of *deep time* related to the magnitude of the Earth's age. Duarte et al. explain this difficult-to-grasp concept as follows: "*in a 12-hour analogy of Earth's estimated age, humans have existed approximately only for the last 19 seconds*" [19]. With *The Room of Change* and *Keeping Time*, we notice a weaving of stories and relationships between humans and different environment levels, from technology to the animal or plant kingdom. *The Room of Change* expresses time through this kind of all-encompassing display because we usually experience changes "*from far away and high above*" [52]. Thus, the work depicts change through these various scales and dimensions represented in the form of a data-driven wallpaper. While *Keeping Time* uses photos to represent human experiences of nonhumans (for visual reference, see [14]), pointing to how plants become visible to humans only in particular moments of their life cycle, usually in spring when they flower or autumn when their life cycle ends. The goal of this design case is to show different "*seasonal and cultural correlations*" in visualization-based work, and more so the rising interest in phenology studies due to environmental disruptions in this age of the Anthropocene [56].

**2.2.2 Redefining the Clock.** Another type of expression in this genre, while maintaining the circular figure of the clock, looks into different ideas and notions of time. The clock expressions range from representations of time and nature, such as in *The Present* [85] and *Circa* [28] where the clock units are defined by the current appearance of the sun from sunrise to sunset (for visual reference, see [86] and [29] respectively), to representations that span life cycles, such as the evolution of life on Earth displayed in one of the clocks in *Allochronic Cycles* or of different species from a certain ecosystem in *The Phenology Clock* [31] (for visual reference, see [48] and [32] respectively). As with the previous projects, there are articulations of new notions of time. *Allochronic Cycles* refers to "being out of step with a geological epoch" [47], while *The Phenology Clock* points to the science of phenology: "the study of patterns, rhythms, and evolved temporal interdependencies between multiple lifeforms" [15]. The work of *Unequal Hours* [77] combines all these different expressions of time, the clocks moving at different rates according to "various natural, human and technological timescales, for example tides and eclipse cycles, rhythms of the human body, and local transport schedules" [11]. This variety of temporalities would allow the ribbons to entangle and potentially stop the clocks, showing how natural time cycles are affected by environmental disruptions and how as a result, they fall out of sync (for visual reference, see [78]). Thus, through this installation, the artist explores the intersection between natural cycles and human frameworks of time, pointing back to a period before time was coordinated and synchronized.

In sum, although constrained by the clock metaphor, we find the artistic design expressions above inspiring since they address the time dimension in nature while supporting human's direct involvement in the interaction. However, they all focus on visualizing change over a long duration of time, which differs from the approach taken in our study that targets short-term natural changes, encouraging a change from human attention to culture to a noticing and an improved understanding of nonhumans.

### 3 METHODS & DESIGN PROCESS

We follow a design-led approach, which combines Research through Design (RtD) [94], and Autobiographical Design [57]. In RtD, the

design process is used as a resource to reveal learnings and support transgressive thinking [7]. It has already been used to investigate posthuman topics [22, 42, 44]. Autobiographical Design is the second method used. It is defined as "*design research drawing on extensive, genuine usage by those creating or building the system*" [57]. Autobiographical Design is a form of autoethnography within design and HCI, focusing on the individual experience with a technical system. This type of first-person inquiry is increasingly visible in HCI [18, 23, 45, 51] with works that follow posthuman epistemologies using it as well [12, 42, 72]. In this study, rather than creating a prototype for FA's personal use, we were motivated to explore the topic of time restructured from a more-than-human perspective. This included FA's own embodied experiences of this time governed by environmental changes. We thus focused on the "*unique experiential dimensions*" [57] that arose throughout the design process. In the following, we will describe the subtleties of the IT-supported aspect of the process - the prototype, and how we conceptualized time through four different sensor readings. The prototype was supplemented by the think-aloud walks, further describing an embodied practice devoid of technology.

#### 3.1 Constructing the Prototype

We created a physical and digital prototype that visualises various short-term changes over time on the current web page based on the received environmental sensor data (see Figure 1). Similarly to [1], our prototype depends on different environmental changes detected through sensors that collect light, temperature, humidity, and soil moisture data. We use clock time units, such as seconds, to determine whether a change has occurred. Every 300 seconds, there were sensor readings between 9 AM and 10 PM. What determines if we consider the sensor reading is if there is a difference of more than 1% from the last reading. The 1% is different for each environmental data, based on predetermined values or the minimum and maximum values recorded for that period. For example, humidity is calculated in percentage, and thus the value is in itself 1%. Whereas temperature, the 1% was calculated based on the month's min and max recorded values in the prototype installation site. The sensor data that does account for a change is saved



**Figure 1:** The figure depicts the research site and the setup of the prototype. Picture a presents the observational point where the prototype was placed and through which FA passed during her think-aloud walks. The prototype was placed between two trees (b), with the soil moisture sensor placed in the soil between those trees (c), and the other three sensors (humidity, temperature and light) remaining in the box (d). The phone provided the wireless connection to a cloud-hosted database, which triggered the browser extension to make changes to the active web page and a power bank that kept the phone charged.

in a cloud-hosted database, triggering different modifications to the current web page through a browser extension. Thus, when a change was registered, the browser extension applied a specific graphic filter on whichever web page FA was actively on at that moment. When it was more humid at the installation site, the web page was more opaque, while outdoor light determined the brightness level of the web page. For example, after sunset, the web page would have a darker brightness level, making it hard to see what is on the page. Temperature changes were shown through the web page's background colour, ranging from red in high temperatures (e.g. 30°C) to blue in low temperatures (e.g. -10°C). Finally, soil moisture changes regulated the text-based information shown on the page. The lower the soil moisture was, the more text-based information on the page was missing. FA built and installed the prototype at the top of Hagakullen, also known as Frösundatoppen, in Stockholm, Sweden (see Figure 2).

### 3.2 Living with the Prototype

FA used the prototype daily over 20 days, from July 12 to July 31, 2021. She installed the browser extension on her computer, which she used daily and thus interacted with throughout the day. The device worked regardless of FA's task, which meant it was part of her work and leisure digital time. The use of the prototype was complemented with think-aloud [58] p.195 walks through the research site where FA installed the prototype. The place is a green area that FA has, incidentally, been engaging with since March 2020. The hill (see Figure 2) was originally 50 meters high above sea level. Then, it was used as a gravel pit, which reduced it to half its size. Later, it was decided to restore it to its previous height by adding demolition remains. The walks resulted in eleven think-aloud accounts, i.e. recorded voice notes, which FA collected during July 2021, in parallel with the use of the prototype. Each walk took around one hour, with about thirty minutes of voice notes. Gathering data by walking is an established methodology in social sciences and humanities [81], used in this case as a situated and embodied practice of engaging with nature. As thinking about time and conceptualising time perspectives that include two different cultures is an intricate challenge, FA performed these two parallel practices to have a dual perspective of being attuned to the changes happening in nature. The prototype provided the IT-supported modality of visualising the changes, while the walks were the practice of interacting with nature undisturbed by technology.

### 3.3 Data Collection and Coding

Both parts of the study have sizeable qualitative data. First are FA's daily diary entries, where she wrote her thoughts and reflections that occurred throughout the day related to the topic and the prototype use. Second are the transcribed accounts from the think-aloud walks during which FA described what she saw in the research site, the changes that she noticed over time of different nonhumans (e.g. plants, animals, or other objects encountered) along with her felt experience of walking. We used qualitative content analysis to code the diary entries and transcripts. It is a research method to systematically analyse and identify patterns and structures in different types of content [35]. This method has foremost been used in HCI to categorise and analyse user-generated content (e.g. [33]). As autobiographical work emphasises descriptive details, such coding is suitable for interpreting the meaning behind the written, and spoken experiences [80] p. 88. The data passed four joint analytic inductive sessions between the authors to conceptualise underlying categories. It resulted in conceptualising seven main themes derived from combinations of six to thirty-four subcategories.

## 4 FINDINGS

This section presents the results of how nature was experienced by FA when presented in a human-paced time dimension. In the following, when we refer to the concept of *disruption* we designate an event that unsettles human clock time through external environmental triggers. This stems from ideas and events of environmental disruptions. While when referring to *pause(d)* we point to a state similar to before, seemingly devoid of change.

### 4.1 Nature's Fickle Temporality

During this project, the walks revealed the heterogeneity of the time perspective when engaging with nature. It seems like a one-time walk makes time appear almost fixed, with changes over time remaining hidden. However, the re-occurring walks made FA see what had changed since the last visit and made her more sensitive to the traces of change within the nonhuman temporality. Noticing the multiple variations became a key element in experiencing that environment. Notably, this is very similar to the accounts of Henry David Thoreau and his long-term stay at the Walden Pond, where he describes such traces of change in detail [84].

*"You can already see some leaves, some yellowish leaves from the trees. [...] a wild rose bush that has some flowers*

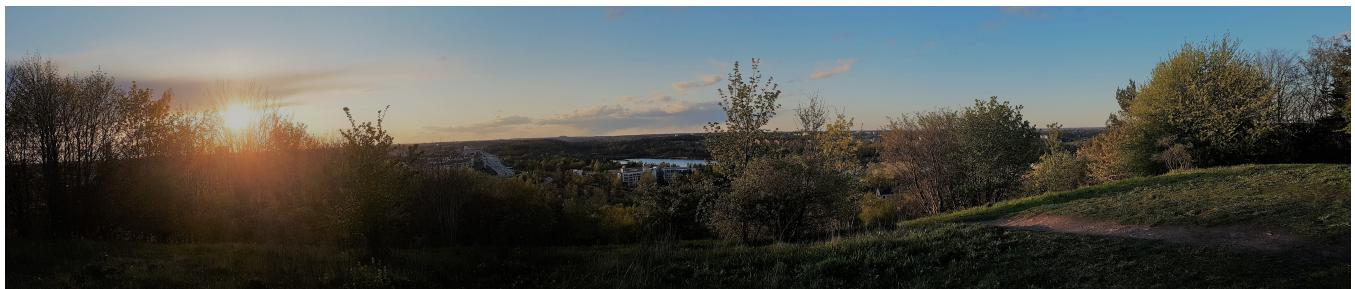


Figure 2: Image of Frösundatoppen in Stockholm, Sweden, at sunset.

*bloomed, but some of the leaves are turning yellow [...] And here is the patch of the white flowers. They now turned pinker, actually, and there are a lot of bees as well. [...] The tree with the yellow flowers that now has the beans, you can see that they are drying up as well, turning yellow. [...] You can also see some of the leaves turning yellow, for the wild rose bush [...] And also the apple tree, some of the apples are turning red, a little bit red. [...] And I like how this tree with the aeroplane-like seeds, the seeds have turned some kind of dark pink, reddish kind of colour. A brighter red than what I saw before. [...] Different snails. Different shapes and sizes. Different shell colours. Maybe you can also see the slugs, but it's harder. [...] It's definitely snail season. Very hard to see them because they are quite small."*

FA also noticed how many natural elements did not seem to change during the think-aloud walking practice. Devoid of change, these elements were seemingly paused at a particular stage of their evolution. Whilst this state was undoubtedly temporary, there was a sense that nature has periods during which time seems constant, an uninterrupted flow with no ramifications. This sense of stillness is imposed by the limits of our human senses, as FA could not visually experience or trace any noticeable changes, even compared to previous visits. This experience is, in a sense, a description of a time frame during which nature is unfluctuating. This concept of time frame connects with the idea of timing, defined as specific moments in which a particular experience is possible. This form of existential time is uncertain and unrelated to the quantifiable time of the clock. The ideas of time frame and timing illustrate the shift from control to indeterminacy that describes the more-than-human turn [20], affected by the "*unplanned nature of time*" [88] p.20. Thus, addressing time is a fickle target, where nature will not easily give us the answers to our design-related questions.

## 4.2 Nature in the Mind's Eye

On certain occasions, the remote short-term interactions broke FA's human practice barriers. FA remarked how the prototype was a way of grounding oneself with the natural world. A change in the environment that happened 'out there,' represented through a graphic filter, created the image of that change in FA's mind's eye. These visuals allowed FA to experience an aesthetic enjoyment of the visualisation while also envisioning being in that environment at that moment. Each disruption was a regular reminder of things that happened in the other world, the outdoor nature, which acted as a prompt to look out the window and pause FA's immersion in task-dependent clock time:

*"What would happen sometimes is that only when I saw the light change shown as a disruption did I realise that it started getting darker. When you are concentrated on a task, and you are getting tired, but you do not really notice it, in this case, it kind of "wakes you up" back to reality. It grounds you in the "real" or "natural" world."*

This experience instilled the wish for FA to be outdoors in 'real time' and have an embodied experience of the changes. As there

were sometimes dissonances or misalignment with what FA perceived from the place of the experience, i.e. indoors, being in nature was perceived as a solution.

## 4.3 Active Engagement as Invaluable for Noticing

Temporal changes in nature were more fully experienced by FA in situations when the pace of her way of life fell in sync with the changes.

*"It was really nice this day because while there were disruptions, they didn't happen that frequently and successively, so I really could take my time to see them and understand that this is a temperature change and this is a humidity change and even take the time to check, if it didn't show properly on the page, to see what colour it is exactly as I wanted to see the change and see if it got warmer or colder."*

This case entailed a need to pause and focus or circle back and notice again but differently. FA remarked that there seems to be more time to notice nature during her think-aloud practice than with the prototype. Natural changes give space and time for when and what to notice as there is room to decide how long to pay attention. Nevertheless, with the prototype, when there were fewer disruptions, there was time to appreciate and understand the changes, with the frequency and variety of changes significant to noticing. Pauses gave space to restart the overloaded senses for a fuller experience and better appreciation. Noticing, however, does not imply that one can be aware of everything happening at a point in time. There were always changes that FA missed, whether unintentionally or consciously. Thus, FA felt there was more of a need to engage with the prototype than with the environment. FA believed that the missed changes resulted from her not being present or attentive. This sentiment, in turn, instilled in FA a feeling of missing out and thus a requirement of always staying connected to be 'in the know', which could be applied both to the digital technology as well as to the think-aloud walking practice. With the disruptions, their intrusiveness was a factor that contributed to a more active engagement in order to come back to human clock time. Once the disruption passed, the chance to experience it was gone. Considering that human clock time, which FA categorized into work time and leisure time, was at times more critical and at other times less, there was a personal decision included into which changes FA noticed and which were *consciously neglected* [71] p.149.

## 4.4 Noticing Mediated and Unmediated Changes in Nature

As stated in section 4.1, the temporal changes experienced during recurring visits to a location in nature are of various durations. The visitor engages with many traces to discern what has been happening. What differentiated FA's experience of natural and digital changes was that changes within an outdoor natural environment were easier to pinpoint and remember later on. On the one hand, while nature does have subtle changes with some usually unperceivable, being in nature is an embodied experience. Thus, it was

more memorable to recall the changes than the prototype unless there was a pattern to detect.

*"Comparing this to the walks/think-aloud, when you go on these walks, you can notice the changes, and since you've been in these places before, you can compare and notice the differences and the results of these differences. With the device, I wouldn't be able to say precisely what happened the day or days before as there were many more changes simultaneously. Only situations like this one, when there were different changes one after the other, is something that can be memorable. However, with the walks, something about the embodied experience makes it more memorable. I could still recall and retrace my walks and the changes I saw weeks after."*

On the other hand, changes within human clock time tasks were easier to detect and quantify. At the same time, usually, it was the drastic natural changes that were detected, with only the result of the change over time that was perceived.

*"With human tasks, such as in this case, work-wise, there is usually a quantitative way to measure progress and change. With nature, it's usually extreme changes that we as humans can detect. But there is meaning in "seeing" small changes and evolution, which is what I experience with the walks. You could really see these small changes in that environment."*

FA also felt more inclined to check through technology whether a particular change happened rather than entirely relying on the senses. This disposition created a discrepancy between the embodied/felt data and the sensor-generated data, as sometimes these did not align. This inconsistency, in turn, underlined the trouble of the experimenter's regress which FA solved in two ways. Firstly, through local visits, i.e. being in the environment and seeing for oneself, becoming a human sensor through the senses, comparing the data with her own experience, and continuous device maintenance. Secondly, through pattern recognition, i.e. focusing on the data and seeing the different combinations of natural changes detected by the sensors.

With the prototype, the particularities of web page design created differences in visually seeing a change and understanding its components, which affected FA's experience in visually seeing the change and caused her to find other ways to compensate for the missing information. Translating the sensors' detections to a visual representation was a way to perceive when a window opened between human clock time and nature time. FA's usual human practice had to adapt to allow nature changes to be seen. By seeing the disruptions on her browser, the different combinations and building a certain pattern recognition in the sensor data, the experience slowly moved from technology-focused to nature-focused. Some easily identifiable and circular changes, such as the passing from dusk to dawn, were more easily followed along with FA's clock time. The prototype provided a 'walk-through-data', whether physical through the think-aloud walks or digital through the prototype.

This practice of the walking think-aloud and the use of the prototype, going in and out of human clock time, became a reinterpretation of transhumant practice, a cyclical pattern between

living within and remotely to nature time. The recurring environmental elements noticeable to FA stimulated a sensorial experience of change, whether auditory or visually, which further instilled the noticing of specific phenological patterns in nature. However, these recurring changes lost a sense of newness with time, making FA lose interest in seeing these similar changes. This predictability created the challenge of keeping noticing.

#### 4.5 From Disruption to Synchronization

The experience of clock time events in nature started as disruptions but ended as synchronized with human life. The continuous visualization of the events happening on the research site was sometimes experienced as an inconvenience. The many changes that happened in nature disrupted FA in her daily habits.

*"[M]ore occurrences of changes happened in the second half of the day, closer to the evening, which is usually when you want to end the day and get into leisure time or rest time, and then one disruption after the other happens and feels like you cannot really appreciate it because that is when it feels like nature is doing its changes. So then it seems that my own human time and nature's time are asynchronous in terms of what and when I would "accept" for her to disrupt my time."*

The interaction with nature is experienced as a continuous intrusion. The incoming notifications of events happening on the research site made her think about how they diverted her attention away from her tasks. She considered that the notification of events should be synchronized with her daily routines. Human activities, synched with the clock time, should then regulate when nature events are allowed. The environmental changes decided when there was a need to pay attention. The prototype became a mere vessel that transported a change and showed it in a digital form. This property, in turn, asked for the practice of human activities, supported by clock time, to adapt their social time to acknowledge the natural changes. As FA perceived these changes within digitally active human clock time, she found herself extending this *active digital time* for more opportunities for nature time to blend in. While natural blending was preferred, sometimes it felt more like a switch between a stream of events than blending human affairs with nature's affairs. When it felt like a switch, nature time felt invasive, even if it was possible to anticipate. Eventually, this experience changed. As the study advanced, FA started anticipating nature interrupting her human clock time. This sense of anticipation, while seemingly inherent in the experience, was more of a skill formed over time and thus resulted out of habit. When FA noticed specific natural changes outdoors, she anticipated future events, which made her more alert and attuned to the following interventions of nature time.

#### 4.6 When Technology Gets in the Way

The challenge of this study is to design for short-term nonhuman interaction with humans in a way that adds to formers' relation to the latter. In other words, to make humans notice nature. However, the design adds technology between the two parts in ways that guide or filter that relation. Natural elements such as temperature, light and humidity have been interpreted as graphic filters, such as

opacity. FA noticed that differences between these filters guided her attention, such as when events included several of them. Then her attention was drawn to one of them on behalf of the other. Certain changes were more dominant, which obfuscated other changes:

*"when the before and after disruption contains a predominant element, such as temperature, that is the first one to catch the attention. It does not seem like a change, even if the light or humidity also changed, because you cannot really notice it as well as the change is subtle."*

All these factors, in turn, transformed the experience along with concealing other elements in the environment. In a sense, the FA noticed the design rather than nature. Considering this as a disturbance and following the idea that disturbances are a matter of perspective [62], in an interesting turn, the FA tried to cope with this by going for walks, almost like a calibration. In order to bring forth less dominant elements or changes in the environment, FA would switch the perspective by pausing and noticing the less dominant environmental queues, triggering a peripheral awareness:

*"I was looking up, which actually is something that I haven't really been doing, and I don't, you know, I haven't been looking up that much.."*

This type of awareness, in turn, highlighted the rare occurrence of natural elements that were not noticed otherwise or engaged the noticing of recurrent elements. FA received new information that was otherwise concealed when she was attuned to less dominant elements, natural or otherwise, and by further changing the perspective of noticing. FA also highlighted the aspect of noticing different elements as they are in time without needing to identify them. She wondered if identifying a particular species in the environment or having quantifiable information on a change causes more attuned noticing. FA considered valuable enough to acknowledge what she was seeing without being able to name it.

#### 4.7 When Humans Get in the Way

Interestingly, the way that technology goes in the way of nature, as described above, mirrors how humans got in the way of experiencing the research site during the walks. The design was intended to enable interaction between human and nature in new ways. However, it required her to handle unwanted human activities to sneak into the interaction. FA felt a lack of possibility of fully immersing in the experience of being in nature, as she felt interrupted by the so-called 'out-of-nature elements'. These interruptions mainly were the noise of the nearby highway or interference from elements passing through the environment, such as other humans walking or biking, which caused a change from the initially decided action. These distractions from FA's 'noticing time' were overpowering, which caused FA to be more alert and envision making changes to the environment which would cause fewer interruptions to the experience of being immersed in nature.

*"I think this view, this mountain hill, is very nice if it weren't for the highway. Because it's kind of, you feel like you are in the forest, but then the sound of the cars really makes you not fully immerse yourself in the experience of being in nature."*

Despite these dominant and sometimes unpleasant elements, FA still had an aesthetic experience of being in that environment. The interruptions were location and time-specific, as in the time of day, week or season, and would increase or decrease in intensity, influencing the noticing of the wild nature and its aesthetically pleasing parts.

## 5 DISCUSSION

In this section, we discuss how the prototype enables an extended relationship between humans and nonhumans with its specific short time dimension. We also examine the potential of further developing devices that incrementally attune us to nature, leading to adapting to interdependent human-nonhuman temporalities and eventually causing behavioural transformations for a more relational interaction with nature.

### 5.1 Attuning to the Short-Term Temporalities in Nature

We were interested in learning whether a system that reported short-term events in nature, i.e. such as those constantly occurring in social life, would be able to compete with human attention to culture. In some sense, it did. The prototype helped FA notice ongoing changes on the research site. It accentuated nature's property as constantly changing, which challenged FA's experience during the initial walk, during which she experienced nature as stable and fixed. Thus, the system's reporting of such events, presented as graphic distortions on the browser page, made the user imagine the location in her mind's eye, especially when these events occurred in a tempo that fit with her way of life. At the same time, the various things that happened out there intruded on her well-timed life as a researcher. The technology also introduced a new element between the human and the nonhuman in the same way humans can come between a person and her interaction with nature. In sum, it seems like nature designing for various temporalities, not just long-term change, matter as a way to increase our interaction with nature.

### 5.2 The Role of Context and a Plural Temporal View

Within the topic of time, space is an important component. As Adam claims, "[s]pace and time constitute the context and context matters" [3]. We see the role of context with the two various practices of using the prototype and doing the think-aloud walks. Each showed different expressions of nature's temporalities. FA experienced a slower, more uniform view of nature through the walks, with changes happening slowly over longer periods. It was also easier to remember the changes, construct patterns and compare with previous visits. With the prototype, the FA experienced a constant flow of changes occurring over the day, these representing the often unnoticeable subtle changes that occur in nature. These were also harder to remember since the flow of information was much greater, entangling the understanding of nature time. Thus, the technology disrupted FA's clock time, allowing nature to take space and FA to adjust to a new set of temporalities. This variety of experiences of time was possible by combining an IT-supported practice with one that is devoid of technology. We conceptualise the notion of time as multiple rather than singular by using clock

time units and visual representations understandable by and used in human culture to translate notions of nature's time that are usually elusive. The work of Pschetz and Bastian [68] maintain this belief by proposing *temporal design* as a pluralist alternative. This concept presents time as emerging out of complex relations which would help designers create artefacts that would "*disclose this variety, also revealing the intricacies of temporal relationships and negotiations that take place.*" With nature defining time, we observed the 'struggles' with maintaining focus on human clock time tasks whilst attuning to natural temporalities. We considered time "*as emerging out of relations between cultural, social, economic and political forces*" [68] by living with a prototype that extends the reach of time to natural rhythms.

### 5.3 Design Considerations for Exploring Time in Posthuman Interaction

As the experience with the prototype was affected by an outpour of changes, future development of technologies such as these is finding a balance between being *in touch* with the processes in nature whilst maintaining some form of human clock time. With the artistic explorations we previously presented, the users initiated interactions with the installations and mobile applications. The human was deciding when to engage, how and for how long. With the prototype, there is a form of pull between forces that govern FA's clock time and the multitude of human and nonhuman actors involved in creating nature time. FA's accounts are "*not just from knowledge, but from familiarity*" [34]. The combination of the think-aloud walks and the daily use of the prototype cultivated a sense of nature as is. By intimately knowing and becoming familiar with a particular place, the everyday closeness of an 'other' grows.

We noticed that FA was inclined to use technology to check information regarding the state of nature rather than entirely relying on her senses. The technology became the main modality of verifying if the assumption was valid. This suggests how we become more dependent on technologies to perceive change rather than use our senses to establish that. This idea corresponds to our reliance on clocks, to the point that they govern our circadian rhythms and social interactions, "*a perilous distraction from an authentic engagement with this temporality*" [10]. This struggle between the urge to quantify and abstain from it is noticeable within a world driven by data and becoming more and more quantifiable, such as the movement of the *quantified self* that seeks "*self-knowledge through numbers*" [91]. Following the example of the *quantified pets*, one critical perspective around such type of design is that there is a risk that the guardian will be less understanding of the behaviour of their animal companion, obstructing the human-nonhuman relationship [37]. Thus, instead of being attuned to the environmental change, we focus on the quantified representation of that change. The prototype helped FA ground herself back to the natural world's rhythm, becoming an alternative to the strict units of clock time. Similarly, seeing the visually abstract representation of the changes was sufficient for understanding that the change happened without knowing the exact number. The prototype reinforced the view of noticing the change without feeling the need for concrete numbers, becoming a bridge between relying on technology for noticing

changes within our surroundings and focusing on the senses to perceive the change. As it is argued in *The Tree*, [21], rather than solely following conventional meaning-making by focusing on "*identifying, measuring, photographing*" we should practice and cultivate attunement [46] to nature that is unguided.

Following the daily use of the prototype, FA experienced a sense of anticipation of future changes. This quality seems to have resulted from habit rather than inherent to nature or the design. Within HCI research, the experience of anticipation surfaced out of slow technologies over time [61]. As McCarthy and Wright explain, anticipation occurs in two temporal phases, before the beginning of the experience and during the experience, which is the time for reflecting on whether the expectation was met, unmet or exceeded [54] p.64. With the prototype, we see anticipation when FA noticed a change in the environment and then waited for that change to be visualised in the browser. With each expectation met, this contributed to her being more attuned to the future interventions of nature time. This is also what contributed to the periodical dissonance, or *temporal confusion* [9] between nature's temporalities and FA's clock time, as the expectations of a change were left unmet.

The natural temporalities occurred, disregarding whether it was convenient for FA. This resulted in FA adapting to the experience and changing the usual practice of her clock time to actually be able to notice and engage with the visualised changes. This adaptive response, or transformation, is increasingly discussed in the climate crisis discourse [63]. It can either forcibly result when a system fails, such as a drought causing migration, or as a response to anticipating a collapse, such as rising sea levels prompting resettlement [65]. Our prototype exemplifies how incremental adjustment leads to adapting to living within the intersection of two different time cultures. Having similar devices that show small changes occurring in the environment that actively engage the user can produce a sense of anticipation and predict future happenings. Seeing and interpreting these patterns in adaptation could, in turn, build towards a multiple timescale sensibility that would reveal "*long-term consequences of lifestyles and materialities*" [74]. This would thus create opportunities for implementing systems that help prevent future events that are harmful to more-than-human worlds.

### 5.4 Reflections on Autobiographical Explorations of Time in Posthuman Interaction

Neustaedter and Sengers [57] describe ethical issues regarding designs for self-use, specifically questioning if there is an inherent bias. We were transparent with the study process, and its boundaries [50], such as the duration, location and motivation, to reduce the idea of bias and acknowledge the subjective nature of the study. We thus consider these investigations valuable to expand the design space for further explorations in the growing subfield of Posthuman Interaction Design [43] in HCI, and we encourage future research and explorations in this topic for others and provide our work as a resource. Autobiographical Design has with additional limitations related to the generalisation of results [57]. However, works such as these are usually appropriated in unexpected ways, whether the design process, method combination or artefact. We thus envision continuing this project by further developing the prototype in a

less disruptive device but with similar functionalities that would be installed in people's homes. Following Bastian's appeal to *liberate clocks* [10] and Jörgen Rahm-Skågeby and Lina Rahm's call to acknowledge the *deep entanglements* of materiality and temporality [73], we envision redesigning the clock into an artefact that is responsive to the short-term natural changes and accounts for the various human and nonhuman interconnections.

## 6 CONCLUSION

This project offers a design-led exploration of how to attune to the multitude of temporalities within nature and whether this encourages a more unified human-nature mutualism through technology. In this case, the need to investigate alternatives to the clock-oriented time perspective in designing interactive systems is important to coordinate ourselves and our designs with environmental changes and nonhuman needs. Time as a concept is broad, messy and heterogeneous. It can relate to both a quantitative measure and an embodied experience. Thus, to tackle the topic of time, we first looked into the different understandings of time within human culture as explored in social science, humanities and HCI in general but also regarding nature. Then, as a second step, we recounted the diverse projects that depict the assemblage of time, nature and humans in new ways. We use these deep dives to support our goal to address the gap in investigations on time that include more-than-human temporalities within design-led research. Then, through a process of Research through Design and Autobiographical Design supplemented by a practice of think-aloud walks, we describe the digital and physical prototype that seeks to support an experience of time through which human clock time accommodates nature time. We then report on how we noticed temporal changes in nature with the support of our prototype. The findings outline the 'struggles' with living within two various cultures of time and being torn between noticing the multitude of temporalities. This, in turn, prompted a need for adjusting to these new temporalities and more active engagement as changes in time were perceived differently during the practice of the think-aloud walks and while using the prototype. This process revealed how a technology-mediated practice adds new understandings to the interdependence of human-nonhuman time compared with the more usual practice of a felt experience of being in nature. Within such plural time perspectives, there is potential in designing interactions that facilitate humans to attune to nature through gradual adjustments. These tools should prompt an unguided intimate exploration of an ecosystem, growing our familiarity with the place and the nonhumans living within, and eventually lead towards structural changes that foster more-than-human interdependence.

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