Illustrating, Annotating & Extending Design Qualities of Slow Technology

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Abstract

Slowness has emerged as a broad, yet rich lens to frame investigations into how temporality can be leveraged as a design material in creating computational objects. The proposal of slow technology is visionary, yet it is also abstract and there is a need to address how we design for slowness and temporality on theoretical and practical levels. The goal of this critical visualization is to build on a recent proposal of new design qualities for slow technology by illustrating and annotating them; and, subsequently unpacking how they are present in the conceptual and practical workings of six tangible design artifacts. Our work visually illustrates key design qualities with attention to precise aspects of designed things to clarify and extend the theory of slow technology in a way that is difficult to achieve through verbal articulation alone. This work concludes with a critical reflection on insights emerging across our research and interprets them to support future design research and practice.

Authors Keywords

Slow Technology; Design Theory; Research through Design.

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CSS Concepts

•Human-centered computing → Interaction design; Interaction design theory, concepts and paradigms.

Introduction & Background

People's daily experiences and the environments they inhabit have become saturated with digital technology. With this shift, new concerns have emerged across the interaction design community over the role, place, and pace of new technologies in people's everyday lives. In their original article on slow technology, Hallnäs and Redström's argue that the increasing availability of technology outside of the workplace requires designers to expand their focus beyond creating tools to make people's lives more efficient to "creating technology that surrounds us and therefore is part of our lives over long periods of time" [37:201]. These authors outline an aspirational design research agenda aimed at extending beyond values of optimized performance and creating technologies that support moments of self-reflection as well as critical reflection on technology itself.

Designing for Slowness & Temporality

Building on the slow technology philosophy, Mazé, Vallgårda and colleagues [59,97] have argued it is imperative for designers to critically attend to the temporal form of digital artifacts "to investigate what it means to design a relationship with a computational thing that will last and develop over time -- in effect, an objects whose form is fundamentally constituted by its temporal manifestation" [97:11]. This argument echoes Hallnas and Redstrom's [35,36,38] call for computational objects to amplify and stretch time presence in everyday life, and reveal an expression of present time that is slower. These issues remain important for the interaction design community, and there has been a resurgence of interest in

connections among slowness, time, and technology. A key strand of research has focused on how the experience of slowness can be an outcome resulting from technology use. Works in this area have focused on supporting experiences of mental rest (e.g., [53]), pause (e.g., [3,98]), solitude (e.g., [18]), and human-nature connection [2,70].

Another area of work has investigated slowness as a frame for interaction design itself. Drawing on Strauss & Fuad-Luke's principles of Slow Design [87], Grosse-Hering et al. [33] designed a series of juicers that aimed to support meaningful physical interactions by slowing down key parts of the juicing process. In other instances, slowness has been applied to explore strategies for extending object lifespans. For example, The Long Living Chair [75] and Movement Crafter [76] both capture and display digital histories of use that people accumulate with these tangible artifacts over their lifetime. Slowness has also been mobilized through the creation of systems that support experiences of anticipation (e.g., [13,48,91]) and social connection over time and space (e.g., [41,90]).

In parallel, design researchers have started to turn their attention to examining different perspectives of time. Lindley [55], Pschetz and Bastian [77], and Galani and Clarke [30] envision time as socially entangled and relational, highlighting the need for alternative expressions of temporality in design. Friedman and colleagues sought to expand initiatives in interaction design to consider multiple lifespans [28,29]. Researchers have proposed different themes, such as biological time [52,72,78,79], deep time [80], sequential time [57], and ephemerality [26,89,92] as resources for design. These works collectively reveal a multiplicity of ways in which time can be viewed in relation to design that move beyond treating it as a matter of merely pace or direction.

Emerging Challenges

The emergence of research related to slowness and temporality is valuable and encouraging. Yet, researchers and designers have also expressed struggles in creating technologies that sustain slower, longer-term experiences. Early works advocating for designing for slowness are somewhat abstract and there is a need to further address how to design for slowness on conceptual and practical levels [2,45,54,61,62]. The infrequent yet ongoing computational action of slow technologies can make it difficult to establish a sensibility for when the temporal pacing is 'right' [14,65,68]. Others have reported difficulties in aesthetically manifesting subtly changing computational actions in a resolved physical form [9,27,83].

These tensions highlight the complexity of designing technologies that deviate from enacting normative conceptions of time. This resonates with the work of Vallgårda et al. [95,96], who argue for designing the temporal form of computational objects, in addition to their physical form and interaction gestalt. They call for design research to develop concrete examples of temporal form through "comprehensive and intricate designs in which the material and physical forms expand beyond two-dimensional glass and plastic surfaces, and the interaction gestalt comprises more than look and point action" [97:14]. Importantly, this passage illustrates that physical computing artifacts may be particularly well poised to further develop the design-oriented theories of slowness and temporality in part due to their embodied, material persistence through time.

Collectively, these areas of work trace a trajectory of perspectives on time, temporality, and slowness in interaction design. They also highlight a relative shortage of research into slowness and temporality grounded in design practice, and tensions emerging around such activities. In an effort to take a step toward addressing these concerns, Odom, Stolterman and Chen [66] conducted an 'artifact analysis' of a collection of design artifacts that led to the proposal of several new qualities that designers can work with in creating slow technologies. Yet, despite the target audience for their research being designers, their work is nearly entirely textual, requiring substantial commitment to absorb and adopt it. The design qualities proposed by these authors are also closely tied to the 'under-the-hood' inner-workings of each artifact, which can be equally difficult to grasp through abstract long-form textual descriptions.

Intertwining the Visual, Material, & Verbal

The challenge of translating and mobilizing verbal academic research to the practices of designers is well known in the HCI and design communities (c.f., [19,31,32,85]). There is often a major disconnect between how design theory and methods are articulated in academia and how they are applied in design practice [84,102]. Yet, theories and methods represented in forms that are easier to explain and visualize may offer powerful pathways toward influencing design practice as well as facilitating communication and reflection about design among different stakeholders [32]. More research is needed which critically investigates different visual forms of design theory and concepts, and how such explorations may not only yield new representations, but also further generatively develop and extend them. This perspective is aligned with research in HCI that situates the "theory-practice gap" as a generative space that can catalyze new insights, ideas, and perspectives [7,20,21] and, more generally, contribute to a growing corpus of "translational resources" for designers and creative practitioners [19,102,103].

Outside of challenges in translating academic research to design practice, there are also growing calls to treat design knowledge less in terms of discrete material things and more as critical "figurations that merge the material and the semiotic or representational'' [74:12]. This call builds on perspectives in Feminist philosophy that recognize the power of treating knowledge as situated, embodied, and plural (e.g., [6,23,39,40]). A concrete implication of these perspectives is to treat different modalities of design research along a flatter ontological hierarchy where there is much generative and inspirational potential in illustrating and unpacking key concepts through an *intertwining of the visual, verbal, and material* (c.f., [10,11,22,73,88,105]).

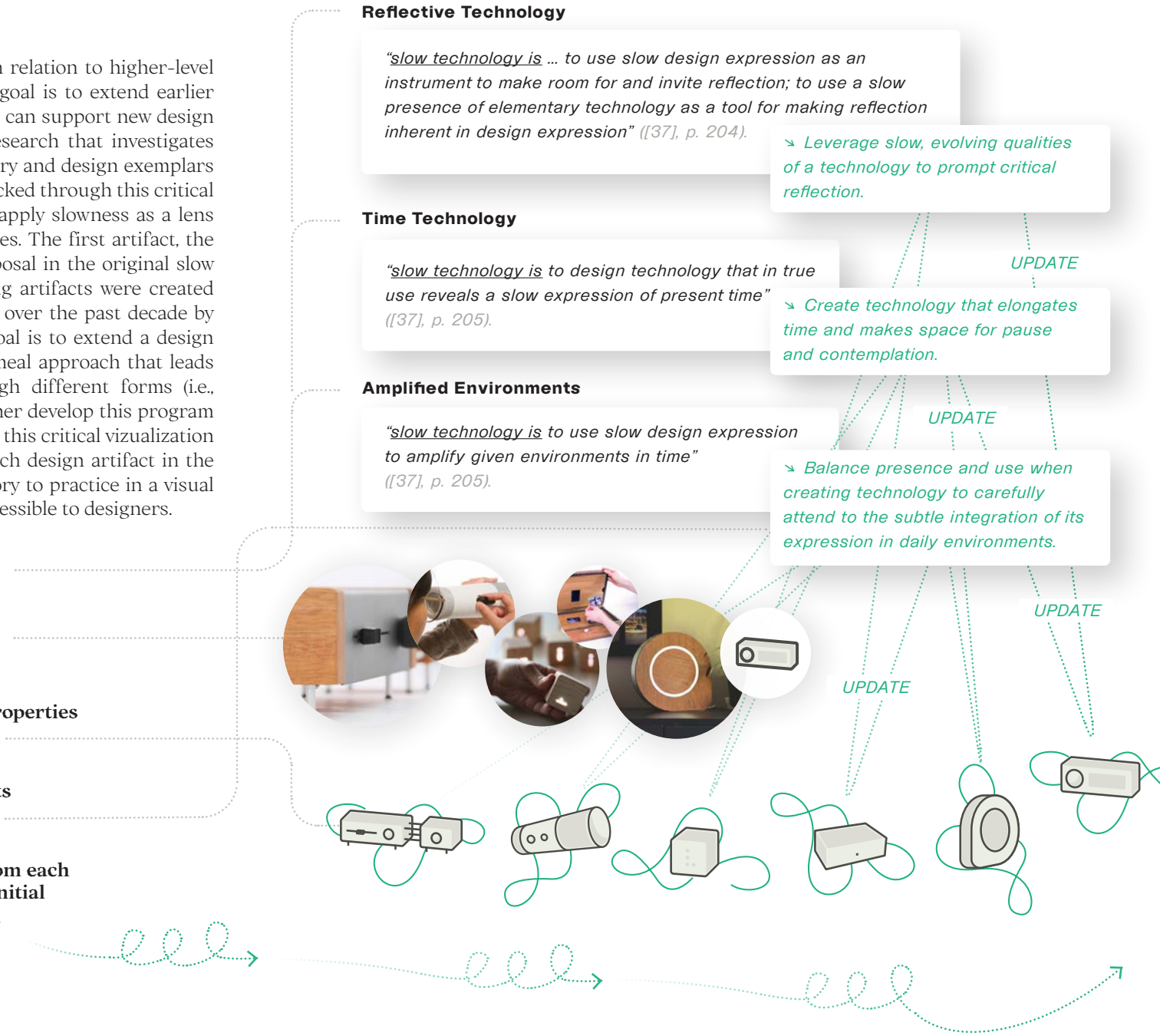
Research Goals & Contributions

Thus, the goal of this critical visualization is to illustrate, annotate, and extend proposed design qualities of slow technology; and to unpack how these qualities are present in six concrete, real working design artifacts. We pursue this goal through visually articulating conceptual design qualities and juxtaposing them to practical and material inner workings of the selected artifacts to clarify and extend them in a way that is difficult to achieve through verbal articulation alone. The remainder of this critical visualization is organized as follows. Next, an overview of the artifact analysis process is presented in relation to the design theory of slow technology. Then, a visual design language for each of the design qualities is developed and introduced to work with them more fluidly in visual form and in annotating design artifacts. Following this, each of the six design artifacts are presented and annotated (one per spread). This critical visualization concludes by critically reflecting on insights emerging across this research process to reflexively refine the concepts and better support future research and practice in the design research community.

Visual Artifact Analysis

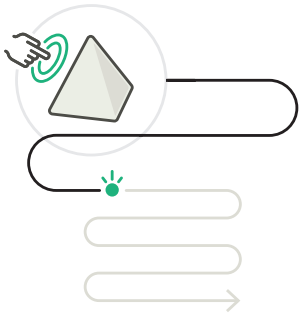
Artifact Analysis situates design artifacts in relation to higher-level design-oriented theoretical ideas [66]. The goal is to extend earlier theoretical ideas through new concepts that can support new design practices. This approach is aligned with research that investigates the knowledge that lies between design theory and design exemplars (e.g., [12,43,44,86]). Each of the artifacts unpacked through this critical visualization were designed with an aim to apply slowness as a lens that framed their respective design processes. The first artifact, the slow doorbell, appears as a conceptual proposal in the original slow technology article ([37] p. 202); all remaining artifacts were created and studied through various collaborations over the past decade by the author. Following Redström [82], our goal is to extend a design theory of slow technology through a piecemeal approach that leads to cumulative knowledge embodied through different forms (i.e., illustrations and annotations,) that can further develop this program for future research and practice. In this way, this critical vizualization aims to illuminate the inner workings of each design artifact in the collection and illustrate connections of theory to practice in a visual form that is pragmatic and more visually accessible to designers.

1. **Start with a tentative definition of slow technology.**
2. **Select a collection of design artifacts to be part of the analysis.**
3. **Carefully examine potentially 'slow' properties in relation to the tentative definition.**
4. **Update the definition based on insights from each artifact analysis.**
5. **Repeat steps 3-4 until new insights from each analysis slowed. Critically revisit the initial theory and extend it with the findings.**

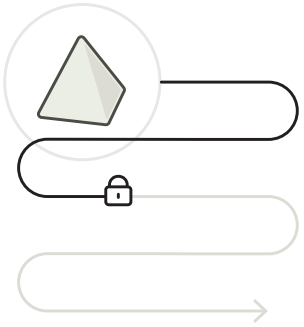


Design Qualities of Slow Technology

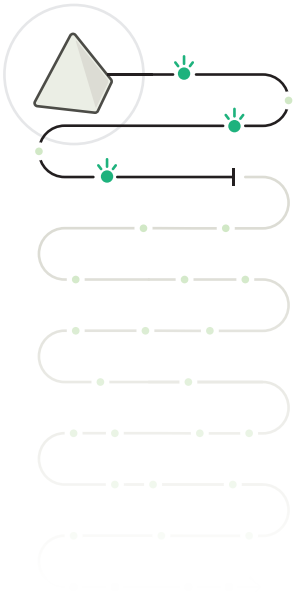
Eight design qualities emerged through the original artifact analysis [66]; this process revealed an opportunity to include an additional 9th quality (temporal density). There are key connections and, in some cases, inter-dependencies across these qualities. The qualities preserve the ultimate particularity of each design artifact, while articulating concepts that can connect and differentiate them. Importantly, these qualities emerged through the analysis and not a priori. But, before unpacking each design artifact, we develop and visualize a design language for illustrating each quality with condensed definitions that were translated and summarized from Odom, Stolterman & Chen's work [66]. This critical visualization mobilizes them in visual form and in annotating key aspects of the design artifacts. For each, the pyramid form represents a design artifact and the accompanying design elements articulate key attributes of the design quality.



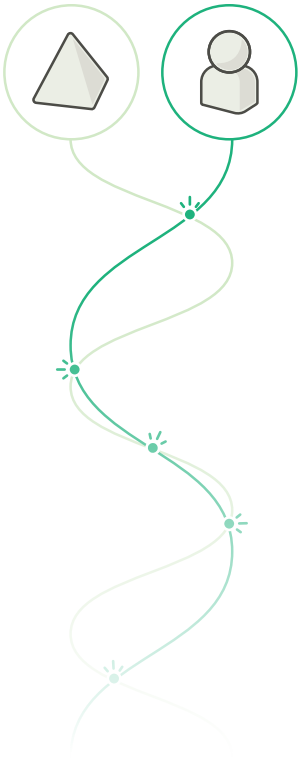
Implicit Slowness is a delicate quality where the slow pacing of the design artifact is not enforced and can be freely controlled, but other qualities of the design artifact (e.g., character and form) make 'speeding up' the pacing less desirable or intuitive. In the illustration, a user enters the interaction space and tangibly manipulates the artifact, but then leaves it (for now) although it remains available for interaction at any time.



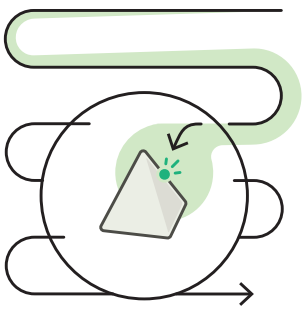
Explicit Slowness emerges when the designer has highly restricted end-user control over the artifact. Its pacing and speed cannot be changed and, thus, the design artifact operates on its 'own time.' This can lead to an artifact having an unpredictable quality which can be leveraged to design for anticipation. In the illustration, we see an upcoming point where the artifact will enact its function or behavior while it remains unavailable for the user until then.



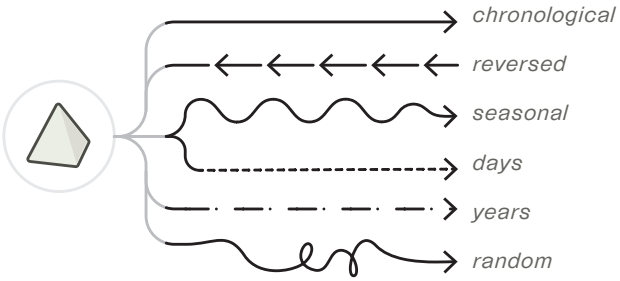
Ongoingness connects to the perpetual movement of time through a slow technology. Ongoingness refers to the need for a period of time to pass for a design artifact to enact its computational behavior in a cycle that is continuous, indeterminite, and never ending. This quality can offer 'invitations' for interaction where there is less pressure to accept the invitation because the user can 'trust' eventually another one will emerge again, even if the specific time when this will happen is unknown. Ongoingness also captures the 'aging' and cumulative change of a design artifact over time, which may not always be immediately perceivable, but nevertheless plays an important role in shaping evolving relations to and perceptions of the artifact. Here, we see the long tail of occasional actions enacted by the artifact that continue indefinitely through time.



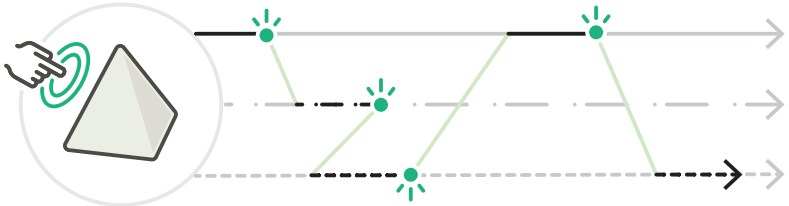
Temporal Drift refers to the pacing of a design artifact's behavior that makes it drift in and out of alignment with the cyclical temporal rhythms of a person's life. Manifesting a temporal pacing that is different from an objectively recognizable form of time (e.g. 24-hour clock-time) creates an ongoing convergence and divergence of the actions of the artifact and the actions of those that also inhabit the same shared environment (as shown in the illustration). To achieve temporal drift, the artifact must have the *ongoingness* design quality and is also related to *explicit slowness* as a quality that can be used to design an artifact that intentionally manifests and operates on its 'own time.'



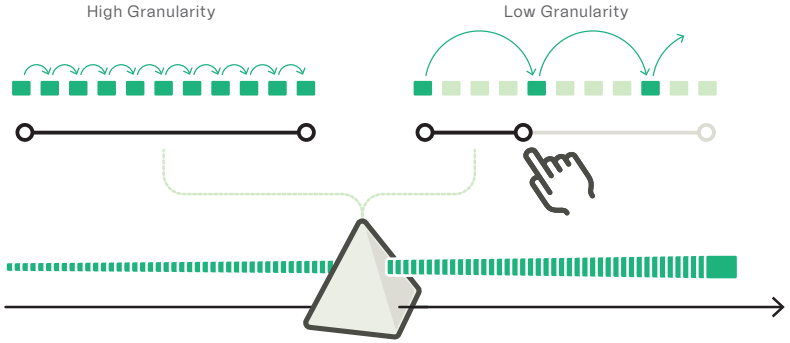
Pre-Interaction emphasizes designing for the time and space prior to the moment that an artifact is directly interacted with. Pre-interaction 'primes' the experience that one might have with the artifact, where the nature of the actual interaction may be quite minimal. Pre-interaction can also be a valuable quality to leverage for building anticipation as intrigue builds. Here, the growing green arc shows the cumulation of interest in the artifact prior to a user entering the interaction space and directly manipulating the artifact.



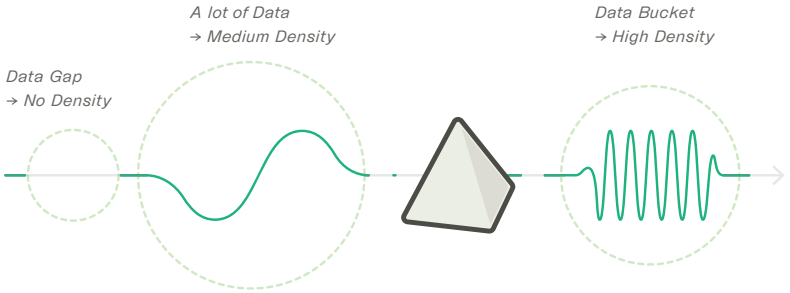
Temporal Modality is the application of different forms of time, linear and non-linear, as a central quality of an artifact's interaction design. Here, we see the artifact manifesting multiple examples of temporal modalities from chronological time to using seasons, days, or years as different timeframes. Thus, different modalities can be used to offer different experiences through interaction.



Temporal Interconnectedness emerges when two or more *temporal modalities* are integrated as central features in an artifact. This opens the possibility to create a set of connections across different temporal dimensions simultaneously among different elements of, for example, digital media or data by virtue of the artifact's design. Here, we see a user interacting with the artifact directly; they are able to move through different connections across temporal modalities (e.g., chronological, years, and days in this case).



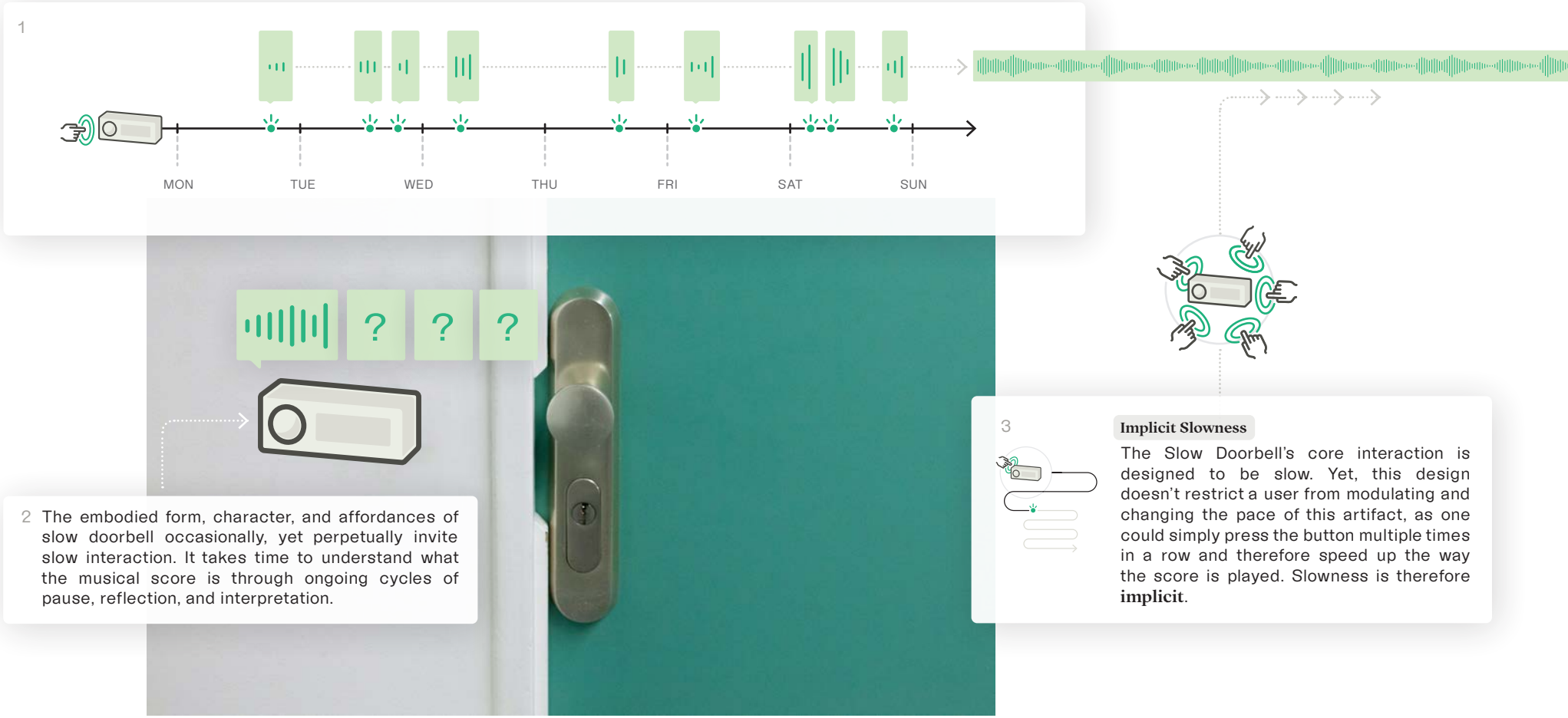
Temporal Granularity enables the end user to manipulate or 'tune' the amount of time that they move through when interacting with a slow technology that represents a digital media or data archive. Tuning the temporal granularity of an artifact can open up more freedom and flexibility for the user to move through large historical archives of digital content across time as 'slow' or 'fast' as desired and, in this way, opens up a different way that the interaction pacing can be designed into slow technology. Here, we see different potential temporal trajectories that a user could move through depending on their granularity setting.



Temporal Density* captures how frictions can emerge when temporal qualities of a design artifact create a time-related barrier that makes it difficult to engage with a key aspect of the artifact itself. Here, we see the movement of time through a digital archive; at low density points in time a user would be able to move quickly through the archive, whereas the high density areas could take considerable time to traverse. Designing in support for *temporal granularity* can help address tensions emerging from temporal density. *in the original article, this quality was embedded within the description of temporal granularity; upon reflection, it is illustrated as its own quality for clarity and distintion.

Slow Doorbell

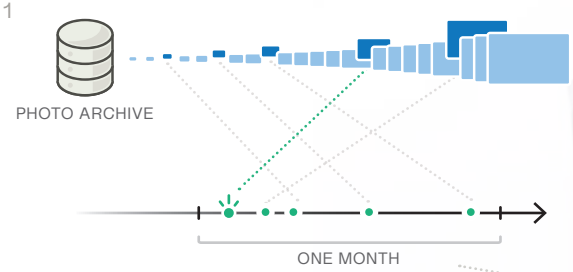
In the original slow technology article, Hallnäs and Redström verbally present the "slow doorbell" as a conceptual design proposal [37:202]. When the doorbell is pressed, it plays part of the melody of a longer musical score for a short duration. Each time it is pressed, more of the musical score is revealed as it advances through the piece. Because the doorbell is pressed somewhat occasionally, then it would take time for a home dweller to understand the melody and the musical score as a whole through the gradual accumulation of experiences with it. Slow Doorbell was included in the collection of analyzed artifacts because it is visionary and offers a compelling early example of what the form, presence, and accumulative quality of a slow technology might be like. In this way, it is an exemplar of the ***implicit slowness*** design quality.



Photobox

Photobox uses ***explicit slowness*** and ***ongoingness*** to engage with the abundance of digital photos that a person has accumulated and to make them scarce in printed form. Photobox is a networked device that is connected to its owner's online photo archive embodied in the form of an antique chest ([67]). Each month it selects and prints 4 or 5 randomly selected photos from its owner's personal photo archive and prints each selected photo at a specific randomly selected time for that month. This process continues indefinitely. The user has no choice of what photos will be selected, when they will be printed, or how many will be printed each month (it is always either 4 or 5 per month). The 'interaction' with the Photobox is simply to open it up and look inside to see whether or not a photo (or multiple photos) from your past are there waiting for you. In this way, Photobox does not demand nor require the user's attention in order to operate.

1



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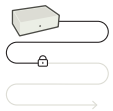
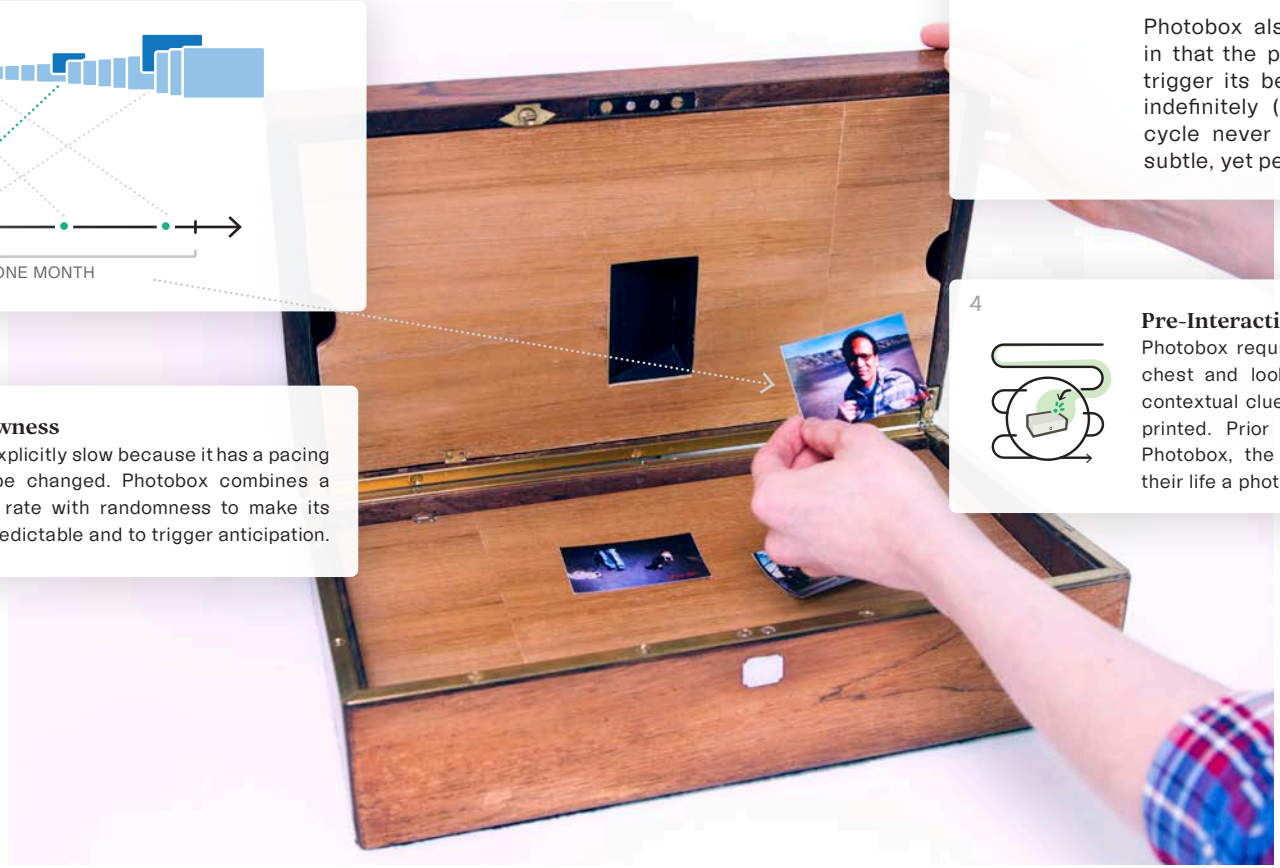


Explicit Slowness
Photobox is explicitly slow because it has a pacing that cannot be changed. Photobox combines a slow printing rate with randomness to make its behavior unpredictable and to trigger anticipation.



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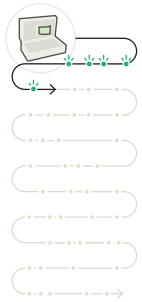


Ongoingness
Photobox manifests **ongoingness** because it is continually updated to reflect the most up-to-date index of the owner's photo archive; and, thus, each time it is encountered, it represents the slowly expanding totality of the user's digital photo archive. While this change 'under the hood' is not perceivable, it evokes a feeling of continual evolution alongside the user through time. For example, one could open a Photobox and find a printed photo that was taken earlier that day or from many years ago.

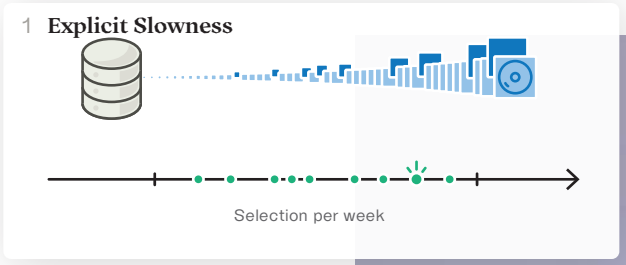
Photobox also demonstrates **ongoingness** in that the passage of time is required to trigger its behavior and, since it operates indefinitely (i.e., this monthly randomized cycle never ends), it manifests a form of subtle, yet perpetual change.

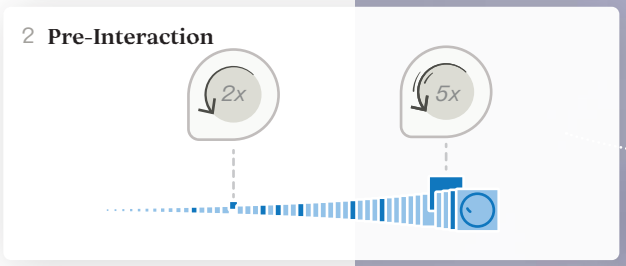
4

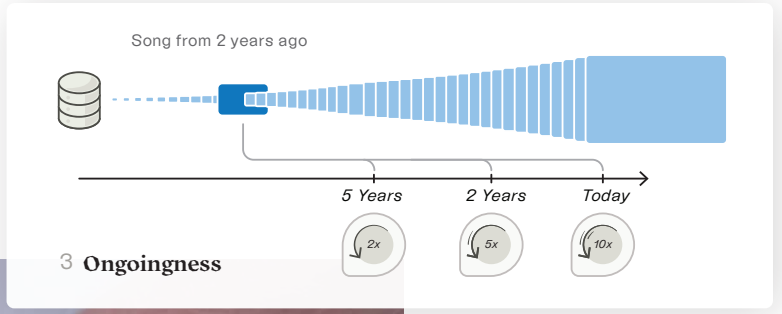
Pre-Interaction
Photobox requires the user to tangibly open the chest and look inside while not providing any contextual clues as to whether a photo has been printed. Prior to directly interacting with the Photobox, the user may contemplate where in their life a photo might be coming from.

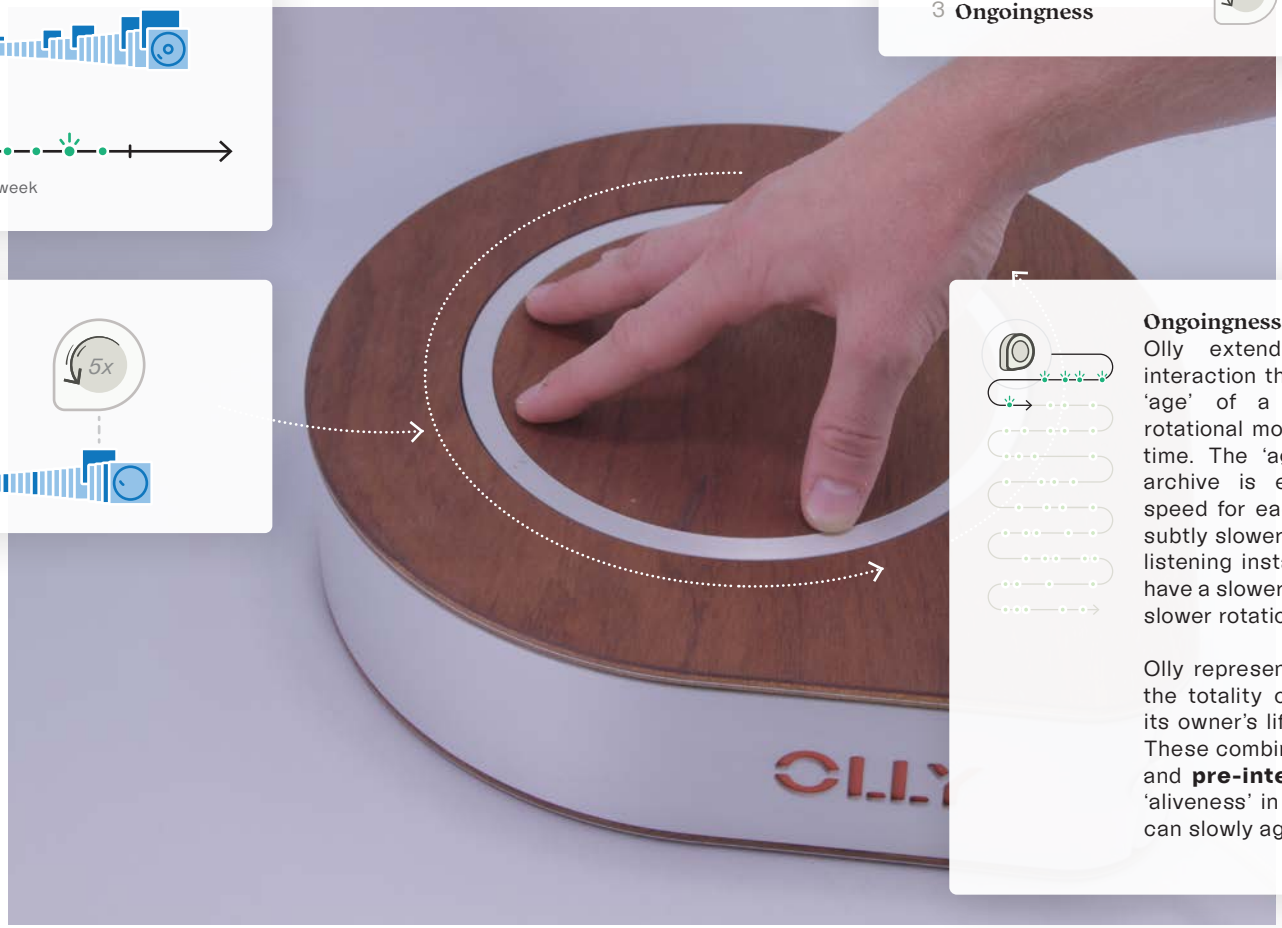
Olly

Olly is a music player that enables people to re-experience digital music they have listened to previously ([68,69]). Olly mobilizes ***explicit slowness*** by making use of its owner's personal music listening history metadata archive (via Last.FM [107]) to occasionally randomly select a song from its owner's past and make it available to be played. Olly's central feature is its internal wooden disc encircled in aluminum. When a song is surfaced from the past, it is not immediately played. Instead, it enacts a key ***pre-interaction*** design quality. First, the disc begins rotating to subtly indicate a song has been selected and is available to be played. The speed of the rotation is relative to how deep into the past the song was listened to by Olly's owner (e.g., the deeper into the past, the slower the rotational speed). To play the song, the owner must tangibly spin the rotating disc. If the song is not played within a brief time window, Olly will abandon it and stop spinning until another song is eventually surfaced; the process enacts ***ongoingness*** by continuing indefinitely.









Ongoingness + Pre-Interaction
Olly extends the temporal frame of interaction through expressing the relative 'age' of a listening instance through rotational movement which itself ages over time. The 'aging' of the listening history archive is expressed by the rotational speed for each unique instance becoming subtly slower as it grew older day by day. A listening instance from the recent past will have a slower rotation in 2 years and a much slower rotation in 5 years (Figure 3).

Olly represents an up-to-date reflection of the totality of digital music listened to in its owner's life whenever it is encountered. These combined qualities of **ongoingness** and **pre-interaction** generate a sense of 'aliveness' in Olly whose digital expression can slowly age alongside its user.

Slow Game

Slow Game expresses a low frequency of action in the Snake game: it advances one pixel forward (i.e., one move) about every 18 hours, generating a ***temporal drift*** as the point when an advance is made moves in and out of 24-hour cycle that encompasses one day. Slow Game is a small wooden cube with a display consisting of 64 LEDs behind a thin wooden veneer ([63,68]). The cube offers a form that can fit into the palm of one's hand and maps to the simple act of rotation from one flat slide onto another. The Snake's movement is bound by gravity. If it is pointing 'down', it will continue to move down one pixel on the plane each 18 hour period. The snake's orientation can be changed by rotating the cube 90 degrees clockwise or counter-clockwise. To 'win' the game, the snake must grow to a length of 17 pixels. If the user reaches 17 pixels— which can take several months (or longer)—Slow Game will enter into a 'win' mode, emitting a warm glow that slowly fades in and out. If the user loses, it will create a negative image of 'game over' plane.

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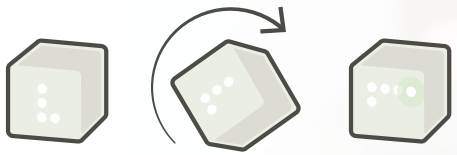
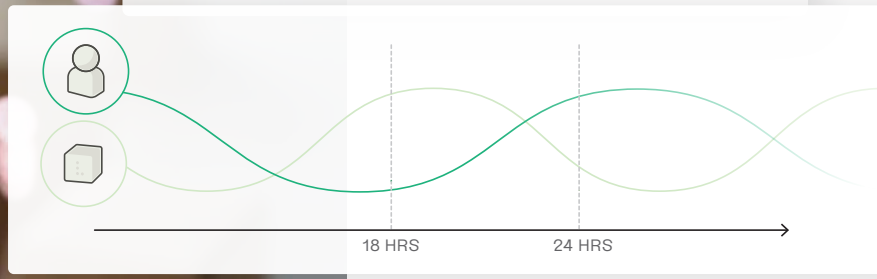


3

Temporal Drift

Slow Game's pacing is intentionally designed to be offset from the 24-hour clock time. This design decision makes Slow Game temporally drift in and out of alignment with the user's everyday rhythms and routines. For example, the moment that Slow Game makes a move – and the clock starts counting down in the time window until the next move is made – might occur in the morning time when the user has recently awoken from a night's sleep. But as the days progress this moment will drift closer to the afternoon, then evening, then late at night, and so on. Thus, this quality creates a temporal drift that moves in and out of the 24-hour cycle of clock-time that people typically organize our lives around. Slow Game exemplifies the quality of **temporal drift** by manifesting its own time, in this case on an 18-hour scale, and perpetually moving in and out of alignment with 24-hour clock-time.



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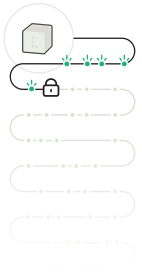


Ongoingnes & **Explicit Slowness**

Slow Game illustrates the quality of **explicit slowness** because it enforces a slow, although relatively predictable and visible pacing. The user cannot 'speed' the game up nor slow it down. It operates on 'its own time' and it operates indefinitely with time perpetually moving through it, no matter whether or not there is any user interaction.

4

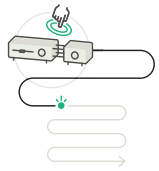
Pre-Interaction

Slow Game shows how **pre-interaction** can be a quality that enables the user to explore where their desired move may land and tangibly orient the artifact in this direction. Yet, only through time and patience will the move be made, whether or not it is intentionally set by the user.

[1]See Betran's website for documentation and description of his original project that precedes the Slow Game research product project described in this critical visualization: http://www.ishback.com/slowgames/index.html.

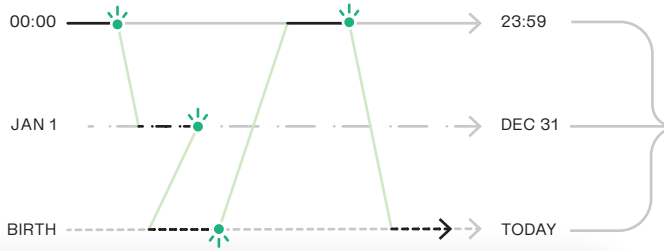
OLO Radio

Olo Radio is an ***implicitly slow*** music player that also uses a user's personal music listening history archive (via Last. FM [107]) to embody the lifetime of digital music they have listened to [64,71]. The two points of interaction are the actuated linear slider and the timeframe knob. The timeframe knob offers the user three different ***temporal modalities*** that can be used to explore their listening history archive through chronological (Life) and non-chronological (Day, Year) modes. Different modes can be toggled by the knob next to the slider. The specific position of the slider is encoded to a specific 'point in time' in the user's past that is relative to the timeframe mode. When Olo Radio is turned on, it begins playing the song queried from the slider's current position. If left untouched Olo Radio will continuously play music, slowly moving forward in the timeframe mode. If the slider is moved, the current song will fade out and the song at the new location 'in time' it arrives at will fade in. If the timeframe mode is changed while a song is playing, it will continue to play as the slider moves to the position in time where that instance is located in the new mode. In effect, the playing song remains unchanged, but the sequence of music surrounding it have been reorganized based on the newly selected mode because the ***temporal modalities*** are ***temporally interconnected***.



Implicit Slowness

Olo Radio offers the user a high degree of direct control and also has no enforced pacing -- the user is free to interact with it as much or as little as they desire. Yet, it *requires time to understand* in important ways: 1) as the archive grows larger, the granularity across the slider timeline will slowly decrease and 2) the interface is highly minimal and offers no explicit information about the specific listening instance of a song that is being played.



3 Temporal Modalities

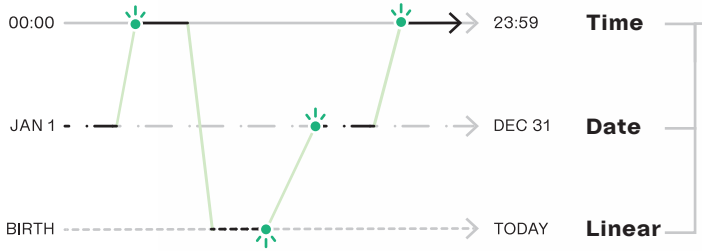
Olo's 3-switch knob allows users to switch between the three different temporal modalities.

Temporal Interconnectedness

Olo's three temporal modes allows users to dynamically switch between timeframes and the 'position in time.' This creates temporal interconnectedness among songs you are listening to, and enables the user to explore a range of possible connections across different songs listened to at different points in time in their past.

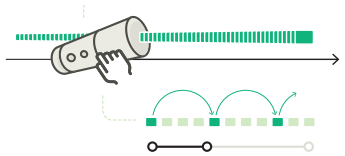
Chronoscope

Chronoscope is a photo viewer that embodies the lifetime of digital photos a person has accumulated over their lifetime ([16,17]). It is synced with the user's online photo storage archive and enables them to interact with their photos through three rotational controls: viewing direction, ***temporal modalities***, and ***temporal granularity***. When peering into Chronoscope, a single photo tied to the specific time that it was taken is visible. A rotation wheel controls two viewing directions through rotating clockwise to move forward in time and counterclockwise to move backward. By rotating either direction, the user sees each photo in relation to a wide spectrum ***temporal interconnections*** across other photos in the archive. The ***temporal granularity*** knob can be manipulated to increase or decrease the amount of photos navigated through in one rotation, enabling one to better grapple with the ***temporal density*** bound up in wayfaring through massive photo archives.



3 Temporal Modalities

Users can toggle among 3 different temporal modalities. This enables the viewable image to act as an 'anchor point' through time and, in effect, empowers the user to explore a wide range of temporal interconnections between different photographs taken at different points in the user's past.



Temporal Granularity

Due to the high **temporal density** that comes with very large and old photo archives, the user needed to be able to move through their photo archive in slow and considered ways if they encountered photos that triggered deep reflection. Equally, they needed to move across vast amounts of photos without an excessive amount of rotations. The **temporal granularity** knob adds control over the number of photos moved across in each degree of rotation. Tuning the granularity creates freedom to move through photos from minutes in a day to years of one's life, making it easy to slow down or speed up.

Rotation wheel, to move forward, or backward in time.

Discussion

The core contribution of this critical visualization is an illustrated and annotated extension of recent proposed design qualities of slow technology. The prior articulation of these qualities was exclusively verbal, making them abstract and dense to engage with. Thus, this work makes an advance by translating and extending prior research through developing an annotative visual design language for nine design qualities and mobilizing them to reveal and attend to key practical, technical, and material workings of a set of slow technologies. Through the intertwining of the visual, material, and verbal, the goal has been to take a step towards creating a generative resource for designers to better supporting gaining a grasp on slowness as a conceptual concern in the design of technology. Next, each design quality is criticaly reflected on to present opportunities for creatively inspiring future design research and practice.

Implicit Slowness illustrates that slow technologies can be open to user control. Designing for implicit slowness pushes designers to closely attend to the physical character, form, and composition of the computational object, and how these attributes can support ongoing, piecemeal interactions over time. This foregrounds the critical need to consider the longer-term place of computational objects in everyday environments from the *start* of the design process. How might computational objects invite occasional, yet recurrent interactions every week, month, or year? As the design research community becomes increasingly interested in designing for ritual interactions [42,58,70,94] – experiences that are intentional and recurrent, but which do not typically occur on a daily basis – there is a key opportunity to explore how implicit slowness might support future investigations in this area.

Explicit Slowness emphasizes highly restricted end-user control. This quality pushes designers to cast the potentiality for interaction along a wider temporal trajectory to craft a distinct slow pacing. It can inspire designers to deeply consider the lived-with qualities of everyday computational objects. This requires designers to equally consider the experience of an artifact when in direct use and when it is simply cohabitating in one's dwelling. Implementing this quality successfully requires developing a sensibility for a pacing that invites enough interactions such that the design artifact is not forgotten while remaining unobtrusive. Indeed, this can be a delicate balance that requires time in the desgin process to tune and refine through lived-with experience. Explicit slowness can extend recent efforts in the design research community exploring strategies for fluidly supporting interactions with computational objects 'sometimes' in everyday life (e.g., [1,53,99,106]).

Ongoingness focuses attention on the perpetual flow of time through a computational object and is tied to the indefinite nature of *explicit slowness*. It also extends to systems that are implicitly slow by emphasizing the cumulative change of the system. In both cases, there is an opportunity to create new techniques for projecting the co-evolving 'aging' quality of computational objects. As evident in several systems in this critical visualization, subtle changes over time are often imperceivable, occurring 'under the hood' (e.g., the slow aging of listening history data in Olly as the rotational speed of each instances becomes slower over time). Future work mobilizing ongoingness could build directly on design that investigates facilitating longer-term use and care of computational objects through inscribing and expressing time through them (e.g., [24,25,51,75,100]).

Temporal Drift leverages *ongoingness* and e*xplicit slowness* to investigate how multiple cyclical forms of time operating on different tempos may drift in and out of alignment. In the example of Slow Game, the object's ongoing slow pacing operates approximately every 18 hours, creating a temporal offset when juxtaposed to 24-hour clock-time. In parallel to Valgarda's discussion of temporal form in shape changing interfaces [97], temporal drift pushes designers to expand their model of interaction beyond the immediate, and to consider it in relation to different forms of time that connect to traces of the past and moments of alignment in the present and future. Temporal drift also offers a strategy for generating unpredictability in a slow technology by using a stable (yet off-set) temporal pacing as opposed to relying on randomness. In this way, we see opportunities for exploring temporal drift in relation to emerging design research exploring lived-with experiences of different forms of biological time beyond purely a human perspective (e.g., [8,46,52,79]).

Pre-interaction can be leveraged as a quality to build anticipation around a computational object that can be created through various techniques. For example, designing systems that require the user to 'open them up' first can be highly effective at building anticipation and opening a space for pre-interaction [4,93,94,101]. As exhibited in Olly and Slow Game, pre-interaction can also consist of mobilizing subtle temporal expressions that prime interactions. There is an opportunity for future work to also explore different forms of material expression to support pre-interaction, which could range from subtle actuation to new shape changing techniques to subtly changing living displays [47,50,72,81,104]).

Temporal Modality and **Temporal Interconnectedness** attend to the integration of form(s) of time as a defining feature of a system. When applied to organize digital media or data, interconnections can form in the archive, enabling the user to interact with multiple dimensions of time. As illustrated in Olo Radio and Chronoscope, these qualities offer an alternative way of mobilizing temporality that does not exclusively rely on explicit slowness or chronological time. Future research can explore how different forms of linear and non-linear time can applied in the interaction design of computational objects. We also see opportunities for building on recent research that explores biological and bio-rhythmic forms of time as design materials [5,8,34,56,104]. The design research community also has a rich history of designing novel systems to support experiences of recollection in ways that are often historical and chronological [15,49,60,62,100]. This research direction can be extended through the design of new systems that investigate the possibilities and limits of mobilizing temporal modalities to trigger different experiences of retrospective reflection by moving through personal data via multiple interconnected forms of time.

Temporal Granularity and **Temporal Density** highlight possibilities related to navigating large digital media or data archives across time. Temporal density shows frictions may emerge when there is a great degree of data associated with a particular point in time, making it challenging to navigate. However, temporal density should not necessarily be viewed as inherently negative. It can be leveraged as a design quality that requires time and commitment to understand and interpret – a key aspirational quality of slow technology. Yet, when tensions do emerge, temporal granularity can guide the design of novel interactions that enable the user to modulate time with precision, whether via large movements or in a slow meticulous manner. There is a clear opportunity to investigate the design of new interaction techniques to negotiate temporal density and fine-tune the temporal granularity of slow technologies.

Conclusion & Future Work

The design qualities extended through this critical visualization are not conclusive. This work represents as an effort to 'open up' the artifact analysis approach and invite others to conduct similar research that explores the value of illustrating and annotating theoretical concepts to generate translational resources for design practice. It helps take a step toward extending prior research as a form of cumulative knowledge building in design that intertwines the visual, material, and verbal. Our hope is it will inspire future research and practice into designing for slowness and temporality and, more generally, into the ongoing cultivation and development of new formats for visual knowledge production.

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