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ARTICLE

Extending a Theory of Slow Technology for Design through Artifact Analysis

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1. Introduction

People's daily experiences and the environments they inhabit have become saturated with digital devices and systems. With this shift, new concerns have emerged across the HCI community over the role, place, and pace of new technologies, and how they mediate people's experiences in their everyday lives. Hallnäs and Redström's foundational article on slow technology argues 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*" (2001, p. 201). They call for new design initiatives that amplify and stretch *time presence* in everyday life, and reveal an expression of present time that is slower. Hallnäs and Redström outline a design research agenda aimed at challenging values of optimized performance and creating technologies that support moments of self-reflection as well as critical reflection on technology itself, known as "slow technology."

The slow technology design philosophy offers a critical and generative vision to frame investigations into how longer-term human-technology relations could be supported with computational objects. Lately, the HCI community has seen a resurgence of interest in this area. Tensions have also surfaced. The proposal of slow technology is visionary, yet also abstract. Several international workshops have revealed that designers and researchers have struggled to put conceptual ideas of slowness into practice (Lindley et al., 2013; Odom, Banks et al., 2012; Odom, Lindley et al., 2018). Tensions have emerged from a lack of guidance in designing technologies that present slower temporal expressions and are capable of sustaining longer-term experiences. Researchers have also critiqued the 'fast/slow' dichotomy that appears in the foundational slow technology article and challenged the dominant focus on treating 'slowness' as solely a matter of speed (Lindley, 2015; Pschetz, 2015; Pschetz & Bastian, 2018).

A primary goal of our article is to contribute to these emerging calls by extending a theory of slow technology for design through conceptual development by using an artifact analysis approach. The design-orientation of our work has made it possible to contribute a set of conceptual qualities that designers can work with. In this way, the primary goal of our work is to extend the design theory of the original slow technology vision. Along with numerous colleagues, over the past eight years we have adopted a reflexive designer-researcher approach in creating and studying slow technology design artifacts. For our artifact analysis, we selected one artifact proposed in the original slow technology article – *Slow Doorbell* – and six slow technology design artifacts from our prior research – *Photobox, Olly, Slow Game, CrescendoMessage, Olo Radio*, and *Chronoscope*.

Adopting a designer-researcher position gives prominence to first-hand insights emerging through the creation of things that materially ground conceptual ideas through their existence.

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Designer-researchers often function as a small, often multi-disciplinary team that is critically focused on the experimental and novel outcomes of the design process that are arrived at through practice. Thus, this approach can contribute a first-hand and reflexive view of practices of making design artifacts in relation to higher-level theoretical concepts.

In what follows, we review works related to slow technology and temporality in HCI. We then detail our artifact analysis approach in relation to slow technology. For readability and to preface our artifact analysis, we briefly outline the conceptual terms that emerged through it. Then, we describe and analyze each design artifact in our collection. We conclude with a discussion that reflects on the extended concepts and terms that emerged through our artifact analysis and further detail how they might be mobilized in future research.

2. Related Work

Temporality – the state of existing within time – shapes virtually all aspects of how we experience and construct the world around us. Time is fundamental to our existence. It is omnipresent. Thus, 'time' is a highly familiar phenomenon, yet challenging to pin down to a single definition. Scholarly inquiry into time itself comes with a complex dilemma: "time is both one of the broadest and richest topics, but also one of the most elusive" (Martineau, 2012, p. 6). It is no surprise that there exists extensive literature exploring the concept of time from many perspectives across disciplines and fields including the humanities, social sciences, and physical sciences (c.f., (Adam, 2013; Birth, 2012; Nowotny, 2018; Price, 1997; Rovelli, 2018; Wittmann, 2016)). In light of our specific focus on slow technology and design theory, an exhaustive review of differing theories of time is beyond the scope of inquiry for this article. It is nonetheless important to acknowledge a key sample of contemporary works that offer insights into some ways that time has been conceptualized and debated. In this, we touch on clock-time and digital-time as two key conceptualizations of time (among many) to modestly situate our review of HCI and design research to broader ongoing discourse.

People's everyday lives are often surrounded and influenced by artifacts of clock-time – clocks, calendars, watches, and so on. These mundane temporal artifacts have long helped people to structure and coordinate their interactions and activities. However, scholars have argued that to 'know' the exact time, as measured and dictated by clock-time, is not inherently organic nor natural (Landes, 1984). People's subjective felt experiences of time and the way in which they are objectified and segmented through clock-time, can differ substantially; and, this tension has received attention by researchers across numerous fields (c.f., (Nowotny, 1992; Pschetz & Bastian, 2018; Wittmann, 2016)). Critiques of this tension have foregrounded the need to conceptualize time in more diverse ways outside of the 'hegemony of the clock.'[1] Through historical analysis, Glennie and Thrift (2009) offer a salient critique of clock-time that situate it not as mechanistic and deterministic, but rather as a set of practices that evolve and change depending on the people, communities, and places within which it is situated. This shift toward viewing time as socially constructed and enacted is also explored through Birth's (2012) connection of social practices with environmental and biological rhythms to account for the diverse nature of subjective lived experiences of time.

There also exist many works that have explored relations among digital media, technology and time. Douglas Rushkoff's (2013) well-known concept of "present shock" explores how the need for constant connectivity ushered in by digital technologies has amplified the reification of time by the clock and, in so doing, further diminished the availability of 'organic time.' This line of scholarly work is extended to further differentiate digital-time from clock-time through the always available and evolving information flow embodied in digital networked technology. People's exposure to rapidly expanding information that comes with digital connectivity can lead to lack of adherence to and abstraction from chronological clock-time. Through constant

[1]Deeper philosophical discussions on felt experiential or phenomenological time can be found in the works of Heidegger, Bergson, Husserl, and Ricoeur. See Martineau (2015) for an in depth review of these philosophical lines of thought and their relation to earlier influential philosophical positions on time from Aristotle and Augustine.

digital availability the present has ‘caught up’ with the future and this produces significant implications for how people perceive and identify time. Consequences from such digital availability can generate an abstraction of digital information flows existing “outside of time, a sort of Dorian Grey existence, suspended in a continuous present” (Hayward, 2016, p. 2). The consequences of digitally mediated immediacy and availability, resulting temporal inequities, and their respective entanglements in the cultural politics of power relations continue to be major areas of scholarly inquiry and debate (c.f. (Bastian, 2017; Crary, 2013; Mazmanian & Erickson, 2014; Sharma, 2014; Tomlinson, 2007; Van Hinte, 1997; Wajcman, 2015)).

The development and formalization of theories of time is extensive; they go far back to beyond the time of Aristotle and contemporary theories are continuing to emerge in our lived present. From a high level, it is clear that time is situated, relational, and entangled; it cannot be treated reductively, and a diversity of perspectives are needed to conceptualize it. The connection among time and technology will continue to be the subject of ongoing discourse across many disciplines.

Naturally, time also touches on many core aspects of HCI research and practice. Interaction and graphical user interfaces are fundamentally temporal. Time is the medium through which an interactive dialog between a human and computer begins, unfolds, and resolves. Early proposals such as Calm Technology (Weiser & Brown, 1997) and the ambientROOM (Ishii et al., 1998) ushered in interest in the HCI community around designing ambient displays – devices and applications that began to explore time in relation to peripheral information visualizations (Mankoff et al., 2003).

As focus in HCI expanded outside of the workplace, the need to more seriously consider the temporal dimensions of technologies in everyday life steadily emerged. This is summed up well by Mazé and Redström’s assertion that creating objects embedded with “computational material” requires designers to “*investigate what it means to design a relationship with a computational thing that will last and develop over time – in effect, an object whose form is fundamentally constituted by its temporal manifestation*” (Mazé & Redström, 2005, p. 11). This argument echoes Hallnäs and Redström (2001) earlier call for design initiatives to amplify and stretch *time presence* in everyday life, and reveal an expression of present time that is slower and, in this way, more subjective and socially situated. These issues remain important for the HCI 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 slowness can be an outcome resulting from technology use. Works in this area have focused on supporting experiences of mental rest (Cheng et al., 2011; Leshed, 2012; Sengers et al., 2005), pause (Vidyarthi et al., 2012), and solitude (Fullerton, 2010).

Another area of work has investigated slowness as a frame for the design of interactive systems themselves. Drawing on Strauss & Fuad-Luke’s principles of Slow Design (Strauss & Fuad-Luke, 2008), Grosse-Hering and colleagues (Grosse-Hering et al., 2013) designed a series of juicers that aimed to support meaningful interactions by slowing down key parts of the juicing process. A study of the slow juicers found that participants preferred slow, mindful juicing activities *sometimes* – slow interaction was not perceived as appropriate during busy weekdays, but it was suitable on the weekend when causal time was more available. Slowness has been applied as a frame to explore strategies for extending object lifespans. For example, The Long Living Chair captures and displays the number of times people have sat in it over its lifetime. The Long Living Chair design raises questions around the role that a subtle yet explicit accumulation of one’s history of use with a thing might invite care and maintenance over time (Pschetz & Banks, 2013).

Slowness has also been applied in a range of design efforts to support experiences of social connection over long time periods. For example, the Reflexive Printer (Tsai et al., 2014) is a wooden thermal printer that randomly prints out black and white halftone pictures from the user’s mobile photo album, and deletes the digital copy if the user does not scan the barcode of the picture. The researchers propose “perceived drawback” as a design quality to reframe technology-mediated reminiscence and build anticipation as an inter-subjective dialog between people and technology develops over time. Slowness has also been adopted in the design of social messaging technologies to build anticipation in the communication experience. FutureMe Labs (2020) is an online messaging service that enables its users to send delayed messages by up to 60 years to their future selves or others via e-mail. A study of FutureMe revealed that long-term time-delay between when a user wrote a message and when it was delivered prompted careful contemplation and intentionality in writing the message and led to range of emotional valences when messages were received – from the profound to the unsettling (Odom, 2015). Similar to FutureMe, Postulator is a personal web-based application that sends photos or video clips to the users themselves or others via e-mail after a time-delayed period (Hawkins et al., 2015). Postulator explored how a slow, time-delayed pacing can stimulate reflective experiences such as the "perceived butterfly effect" where users intentionally tied together different periods from their past and contemplated how they might affect future social interactions with others. FamilyStories is a collection of tangible devices that explore how time-delayed asynchronous audio messages can support storytelling among family members living in different time zones share (Heshmat et al., 2020). A study of the FamilyStories system revealed that mapping time-delayed messages to different time zones that family members lived in often led to intimate and valuable interactions. Taken together, these works offer insights into potential benefits and challenges of the long-term use of a socially situated experiences of slowness and anticipation.

More broadly, HCI researchers have started to turn their attention to examining different perspectives of time. Lindley (2015), Pschetz and Bastian (2018), and Sengers (2011) envision time as socially entangled and relational, highlighting the need for alternative expressions of temporality in design. Giaccardi (2011) proposes *extended temporality* as combined cycles of pause and duration that, over time, lead to the accumulative development of shared social heritage. Taylor et al. (2017) offer a rare account of a cross-cultural design project that emphasizes time from an Australian Aboriginal community's perspective. This work proposes an approach that moves away from treating time not as a discrete point on a digital clock or calendar, but rather as a socially shaped "set of converging circumstances that constitute 'the time' for happenings to take place" (Taylor et al., 2017, p. 6461). Across several works, Friedman and colleagues sought to expand initiatives in HCI to consider multiple lifespans (Friedman & Nathan, 2010; Friedman & Yoo, 2017). They highlight the need for new design methods to better engage with the challenge of designing in timeframes that may expand beyond the lifetime of the design team itself. In parallel, researchers have proposed different themes, such as biological time (Kuznetsov et al., 2013), narrative time (Benford & Giannachi, 2008), sequential time (Lundgren, 2013), time as social coordination (Pschetz et al., 2016) and ephemerality (Döring et al., 2013) as resources for design. While broad, 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.

The recent emergence of works in HCI related to temporality and slowness 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 (Huh et al., 2007; Lindley et al., 2013; Odom, Banks et al., 2012; Odom, Lindley et al., 2018). The infrequent yet ongoing computational action of slow technologies can make it difficult to establish a sensibility for when the temporal pacing is 'right' (Odom, Selby et al., 2012). Others have reported difficulties in esthetically manifesting subtly changing computational actions in a resolved physical form (Bennett & Fraser, 2012; Fass, 2012) and in anticipating how qualities of slow technologies might change over time in, and beyond, the design process (Regan, 2012). These tensions highlight the complexity of designing technologies that deviate from enacting normative conceptions of time. This resonates with the work of Vallgårda and colleagues, who argue for designing the *temporal form* of computational objects, in addition to their physical form and interaction gestalt. They describe the need 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*" (Vallgarda et al., 2015, p. 14).

Collectively, these circumscribed areas of work trace a trajectory of perspectives on time, temporality, and slowness in HCI and illustrate their continued evolution. They also highlight a relative shortage of research into slowness and temporality grounded in design practice. We see this issue as reflective of a growing concern in the HCI community on the lack of research that centers on the creation and analysis of design artifacts as a form of inquiry in and of itself. Our work aims to contribute to this area. We describe and reflect on theoretical insights that emerged through our artifact analysis of slow technology design artifacts. Next, we describe our artifact analysis approach.

3. The Artifact Analysis Approach

Each of the design artifacts in our collection for analysis was designed with an aim to apply a framing of slowness as a critical lens to explore how longer-term relations could be better supported among humans and technologies. By primarily selecting artifacts from our prior research, we are able to report on first-hand insights in and across our collection. We situate the artifact analysis approach in the context of Research through Design (c.f., (Gaver, 2012; Zimmerman et al., 2007)) practice that contributes new knowledge in ways inherent to design methods, materials, tools, competencies that are essential in the making of design artifacts. This approach foregrounds the significance of the *reflexive practice of design* as being integral and essential to the potentiality of design to create research knowledge. This further extends a view of research from the perspective of design practice that provides the opportunity to describe and reflect on accounts of the messy interplay among theoretical ideas, design artifacts, and the first-person experiences of them. Thus, adopting an artifact analysis approach gives prominence to first-hand insights emerging through the creation of real things that materially ground conceptual ideas through their actual existence – "*a process of moving from the particular, general and universal to the ultimate particular – the specific design*" (Nelson & Stolterman, 2003, p. 33).

In our case, this approach can contribute a reflexive view of design artifacts in relation to higher-level theoretical ideas that frame the creation of design propositions which, in turn, connect to specific, domain-level research questions. The goal of this process is ultimately to produce new concepts that can support new practices within an expanded design-oriented theoretical frame. We see this approach as being most closely aligned with HCI research that inquire into a type of design knowledge that lies between design theory and concrete design exemplars. Stolterman and Wiberg (2010) see concept-driven interaction design research as research that addresses gaps in *design theory* between practical guidelines and established theories imported from other disciplines. Gaver and Bowers (2012) and Löwgren (2013) frame annotated portfolios as offering design knowledge that is situated within an intermediate-level knowledge in design research. We see our application of the artifact analysis approach to a case of slow technology as situated within intermediate-level knowledge (Höök & Löwgren, 2012). We aim to extend a design theory of slow technology through an ongoing, piecemeal approach that leads to cumulative knowledge that, taken together, can further develop this program of design research (Redström, 2017).

We chose an artifact analysis approach as a way to establish a deeper understanding of slow technology and how it is represented in design artifacts and their intrinsic qualities.[2]Artifact analysis is an approach that supports a structured close examination of artifact examples to help facilitate conceptual development. It is a research tool that is primarily useful to develop, experiment with, and refine definitions of usable terms and concepts that can serve as a design-oriented theoretical foundation for determining and defining classes of artifacts and their intrinsic qualities.

The way we understand artifact analysis comes with some challenges. For instance, the notion of intrinsic qualities is problematic. Our way of dealing with this problem is to approach our analysis

[2]Following Lewis (1983), our use of the term "intrinsic" is in the philosophical sense — a quality that a thing has in-and-of-itself, independent of other things.

and the properties of the artifacts in the same way as a designer thinks about the artifact (see Janlert & Stolterman, 2017). To a designer, the artifact is a thing that will be shaped and given certain properties and qualities. The properties and qualities that the designer *can control* can be seen as *intrinsic* to the designed artifact. That is, when we analyze an artifact and its potential 'slowness' in relation to the theorization of slow technology, we only investigate qualities that can be shaped by the designer, and not qualities that are solely based on an end user's experience of or reaction to a design artifact.

Through its application, artifact analysis can iteratively lead to stable and well-formed definitions of artifact qualities that can inform the design of new artifacts. The outcome of an artifact analysis is critical and theoretical but it also has a practical purpose. It is *critical* in the sense that it intentionally challenges intuitive or everyday understandings of artifacts and their qualities, and makes it possible to ask new questions. It is *theoretical* in the sense that it leads to conceptual constructs that make it possible to more precisely define artifact qualities, their relationships and trade-offs. Our treatment of the term 'theory' is aligned with Gaver (2012) and Redström's (2017) related arguments that design theory should not be seen as conclusive and fixed, but rather as unfolding and transitional. We do not aim to create a comprehensive theory of design but rather view theory as "an annotation of realised design examples, and particularly portfolios of related pieces" (W. Gaver, 2012, p. 937). By drawing on basic terms and definitions of slow technology as formulated in Hallnäs and Redström (2001) original visionary work, we aim to work toward more complex concepts through first-hand insights of design practice. Artifact analysis offers a structured approach to supporting this process.

For the purpose of our research, our artifact analysis approach took the following form:

(1) We started with a tentative definition of the notion 'slow technology' (primarily based on earlier research and literature, as presented in the 'existing definition' section detailed next)
(2) We selected our set of artifacts to be part of the analysis (detailed in the following sections).
(3) We carefully examined potentially 'slow' properties of each artifact in relation to the tentative definition.
(4) We updated our definition based on the insights from each artifact analysis.
(5) We repeated steps 3–4 until new insights from each analysis slowed down.
(6) We critically revisited the initial theory (see revisiting the theory section) and extended it with our findings.

This approach occurred over the course of one year with the authors performing the analysis (as detailed in the steps above) and holding monthly meetings to discuss the relative stability and precision of the emergent conceptual terms. The approach looks simple and straightforward. However, it requires effort and a sincere ambition to be open-minded when it comes to recognizing and identifying new aspects of the theory that an artifact may bring. Careful investigation into the details of an artifact is necessary, and our process was shaped by iteratively oscillating back and forth between the conceptual and the actual, between definitions and manifestations. This required a detailed understanding of the theoretical concepts as well as of the material and functional aspects of the design artifacts in our collection. The artifacts each have a specificity to their performative and material arrangements and the qualities that are intrinsic to them. This is why we have primarily chosen artifacts that have been involved in our prior research. We already had an intimate and embodied situated knowledge about their designs and rationale. They are not the 'only' design artifacts that could be analyzed and there are clear areas for future research to explore other design artifacts in relation to the design philosophy and theory of slow technology.

As a preface to what is to come, the design artifacts selected for our analysis are the following. *Slow Doorbell* is a doorbell that plays a short musical phrase of a much longer musical score each time it is pressed (Hallnäs & Redström, 2001). *Photobox* is a wooden chest that is connected to its owner's online Flickr photo collection that occasionally selects and prints a photo from the photo archive (Odom, Selby et al., 2012; Odom et al., 2014). *CrescendoMessage* is a messaging application that lets the user send a photo to another person; however, the photo is initially visually obscured and, over time, it becomes clearer until it is fully revealed (Chen, 2015; Tsai & Chen, 2015). *Olly* is a music player that occasionally selects and offers the possibility to play a song that its owner had previously listened to at a specific point in time in the past (Odom & Duel, 2018; Odom, Wakkary et al., 2019). *Slow Game* is a simple game embodied in the form of a small cube where the player can 'set' the next move but it will only be made every 18 hours (Odom, Bertran et al., 2019; Odom, Wakkary et al., 2018). *Olo Radio* is a music player that enables its owner to re-listen to music they have played previously through three different ways of temporally organizing the archive (Odom et al., 2020; Odom & Duel, 2018). *Chronoscope* is a tangible, hand-held digital photo viewer synced with its owner's digital photo collection that allows them to explore and tune into possible known and unknown connections across their photos through different timeframe modes (Chen et al., 2019).

In our view, the artifact analysis approach was appropriate for our ambition to extend a theory of slow technology for design. Next, we offer a more detailed account of key propositions and qualities that formulate the initial vision of slow technology which is taken primarily from the foundational article where the theory was first presented. This is important because it primes the reader with the theoretical backdrop that is at the core of our analysis and which we aim to build on and extend through our work.

4. Slow Technology: Existing Definition

In this section, we distil how slow technology is understood and defined. We then return to this definition when revisiting how our proposed design qualities help to extend the original conceptual vision of slow technology as described below.

Core to Hallnäs and Redström (2001) argument is that, beyond designing 'calm' or ubiquitous technology that merely makes it easier to integrate technology into our everyday lives, design practice needs to change to actively promote moments of reflection and mental rest in the environments people inhabit. Slow technology aims to conceptualize technology in a way that invites people to critically consider and reflect on it in the context of their everyday lives. Against this backdrop, they raise the question: "*what are the characteristics of information and computing technology that initiate changes toward a more reflective environment?*" (2001, p. 202) and propose that the answer, in part, may involve adopting *slowness* as a core conceptual commitment in the design of technology. The conceptual idea of 'slowness' is situated in contrast to 'fast' technologies that are designed with efficiency and usability in mind. In Hallnäs & Redström's view, when people are able to complete tasks more quickly and efficiently, it takes time away "*both in terms of making the user more efficient when working (the task taking less time) and making the artefact as fast and easy to use as possible*" (2001, p. 203).

In contrast, slow technologies may *require time* to understand how they work and why they are designed in such a way. For example, consider the conceptual propositions outlined by Hallnäs & Redström: "*technology can be slow in various ways as it takes time to: i) learn how it works, ii) understand why it works the way it works, iii) apply it, iv) see what it is*, [and] *v) find out the consequences of using it*" (2001, p. 203). Such *slow expressions* manifested by a slow technology may invite reflective experiences. When an invitation to directly experience or interact with a slow technology is accepted the "time presence" of the artifact may become amplified as experiences of reflection unfold and one develops interpretations of the phenomena that they are encountering. In this way, slow technology has an accumulative quality – its character is not necessarily defined by a single interaction, but rather through the ongoing collation of experiences with it. Building on this foundation, Hallnäs and Redström (2001) articulate three interrelated conceptual themes that support the *core vision of slow technology* and *what it aims to achieve*, which we summarize below.

Reflective Technology: designing technology that both invites reflection and, at the same time, is reflective in its expression. This means that a slow technology needs to support reflective and interpretive experiences while also asking questions about its existences as a technology. "*Here, the call for slow technology is to use slow design expression as an instrument to make room for and invite reflection; to use a slow presence of elementary technology as a tool for making reflection inherent in design expression*" (2001, p. 204). The aim is to leverage the slow, evolving qualities of a technology as a strategy to open a space for reflection, both experientially and critically.

Time Technology: designing technology that "*amplifies the presence of time*" (p. 204) and "*stretches time and slows things down*" (2001, p. 205). This means creating technology that frees up time for particular kinds of things and experiences (e.g., reflecting on the past, critical interpretation, curiosity, prospective thought, and so on). Here, "*the call for slow technology is to design technology that in true use reveals a slow expression of present time*" (2001, p. 205). The aim is to create technology that elongates time and, in doing so, makes space for pause and reflection as a key quality in design.

Amplified Environments: designing technology that amplifies the presence of things to make them into something more than merely a silent tool for fast access to something else. "*The call for slow technology is to use slow design expression to amplify given environments in time*" (2001, p. 205). This speaks to the need to balance *presence* and *use* when crafting a design artifact and to carefully attend to the subtle integration of its expression within an everyday environment.

Hallnäs & Redström's original proposal of slow technology is a kind of "leitmotif" for interaction design. The three propositions above help conceptualize a vision of the design style, form, and expression of slow technologies. Slow technology offers an important theoretical frame for questioning and expanding the role of technology in people's everyday lives. It offers a pathway toward transforming design practice beyond a sole focus on designing efficient, optimized, and easy-to-use tools toward creating technology that invites reflection as well as open-ended and ongoing engagements across long time periods. It critically positions people living with slow technology, and the technologies themselves, as co-shaping each other while more is learned and revealed through the accumulation of experiences over time.

While the initial vision of slow technology is inspirational and generative, it is worth revisiting and exploring how it might be extended with additional terms and definitions in light of more recent design artifacts that have been created since the original article. Challenges are also emerging among the design research community in creating slow technologies. Numerous international workshops have revealed that designers and researchers have struggled to put ideas of slowness into design practice (Lindley et al., 2013; Odom, Banks et al., 2012). Researchers have also critiqued the fast/slow dichotomy articulated in the original slow technology article, arguing it may be limiting and more diverse perspectives on temporality are needed (e.g., (Odom, Lindley et al., 2018; Pschetz & Bastian, 2018; Pschetz et al., 2016)).

Next, we briefly detail terms that help capture key qualities that emerged through our artifact analysis in order to prime the reader for the analysis that follows in the subsequent sections.

5. Key Qualities Emerging From Our Analysis

A set of key qualities of slow technology have emerged through our artifact analysis. Importantly, *these qualities did not surface a priori*. Before we move into our analysis, we want to briefly present these qualities since we believe that makes the reading of the analysis easier to follow. There are key connections and, in some cases, dependency across these qualities. They are not mutually exclusive, and it is not required that a design artifact exhibit all of them in order to be considered a slow technology. They are also not conclusive – more qualities may exist or emerge through the creation of new design artifacts. These qualities are closely aligned with Gaver's (2012) articulation of Research through Design as a research activity that produces knowledge that is provisional, contingent, and aspirational. The qualities preserve and respect the ultimate particularity of each design artifact, while articulating theoretical concepts that can connect and differentiate them. We believe they can help extend the existing understanding of slow technology because they offer terms that can further support the conceptualizing, designing and making of slow technologies. Before we move on we will define these key qualities. We are aware that these definitions may be difficult to comprehend without examples, but it is useful to have them presented before we move into our artifact analysis. The eight key qualities we have identified are:

Implicit Slowness: a quality of a slow technology where end-user control has been intentionally designed into the artifact to enable direct modulation of its pace – one can 'speed it up' if so desired. Yet, by virtue of the design artifact's affordances, form and composition, it is unlikely this would happen and, thus, it retains a 'slow' character. In simple terms, this means the slow pacing of the design artifact is not enforced and can be freely controlled, but other qualities of the design artifact make speeding up the pacing less desirable, appealing, or intuitive.

Explicit Slowness: a quality of slow technology where the designer has highly restricted end-user control over the design artifact. Its pacing and speed cannot be changed and, thus, the design artifact operates on its 'own time.' Explicit slowness manifests an unpredictable quality in the design artifact and can be used as a technique to design for cycles of anticipation and release.

Ongoingness: the perpetual movement of time through an artifact that is subtle and gradual. The quality of ongoingness can have both explicit and implicit dimensions. Explicit 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 and never ending. Explicit ongoingness is an important part of offering an invitation for engagement or interaction. There is less pressure or demand to accept the invitation because one can trust that eventually another invitation will emerge again in the future, although the specific point in time that this will happen may be unpredictable and unknown. Implicit ongoingness captures the 'aging' and cumulative change of a design artifact over time. It refers to the ongoing, perpetual behavior of an artifact that may not be immediately perceivable, but which plays an important role in shaping evolving relations to and perceptions of the artifact.

Temporal Drift: this quality refers to the temporal pacing of a design artifact's behavior that makes it drift in and out of alignment with the cyclical rhythms and routines of a person's everyday life. Manifesting a temporal pacing that is different from an objectively recognizable form of time (e.g., the 24-hour cycle that makes up clock-time) creates an ongoing convergence and divergence of the actions of a slow technology and the actions of those that also inhabit the same shared environment. To achieve temporal drift, the artifact must have the *ongoingness* design quality. Temporal drift 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: a quality that explicitly emphasizes designing for the time and space prior to the moment that a design artifact is directly interacted with. This pre-interaction temporal space 'primes' the experience that one might have with the artifact, where the actual direct interaction may be quite minimal. Pre-interaction experiences can also be experienced entirely on their own and do not require direct interaction with the artifact for them to occur.

Temporal Modality: the application of different forms of time, linear and non-linear, as a central and defining quality of an artifact's interaction design.

Temporal Interconnectedness: the integration of two or more *temporal modalities* in a design artifact creates the possibility for temporal interconnectedness to emerge. This quality refers to the capacity to create a set of connections across different temporal dimensions simultaneously among different elements of digital media or data by virtue of the artifact's design.

Temporal Granularity: a quality that enables the end user to 'tune' the amount of time that they move through when interacting with a slow technology that represents a digital media or data archive. Temporal granularity can be applied to address a friction (or frictions) that can emerge where temporal qualities of a design artifact create a dense time-related barrier that makes it difficult, if not impossible, to engage with a key aspect of the design itself over time. Tuning the temporal granularity of a slow technology opens 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 interaction pacing can be designed into slow technology.

In our analysis below, we will examine in more detail how these qualities can be understood. Some artifacts will relate to several qualities while others only to one or two. These qualities are real, particular, and unfalsifiable; they aim to embrace design theory's provisional nature and diversity through grounding a specific set of design examples, while still remaining open for further theoretical ambitions to emerge from strings of design exemplars in the future (c.f., (Gaver, 2012; Redström, 2017)). Thus, the qualities we detail are not the 'only' design qualities that can extend the original theoretical concept of slow technology. The purpose of our analysis is to extend the current understanding of slow technology, and how to surface and define a set of design qualities that can better support the creation of new slow technology design artifacts. Our aim is less to give complete and comprehensive descriptions of each artifact.

6. Artifact Analysis

In what follows, we describe each design artifact in our collection and attend to key insights that surfaced through our artifact analysis. For each artifact, we offer an overview of what it does and a detailed analysis of how it negotiates and attends to slowness. Throughout this section, we make reference to the concepts described above and further unpack them by connecting these terms to the actual qualities of the design artifacts in our collection. Yet, before proceeding, it is important to acknowledge the inclusion of the Slow Doorbell in our analysis which is a concept is taken from the original slow technology article. It was one of the first examples of slow technology and can be seen as the starting point for the theory of slow technology. This concept is highly inspirational and clear as a slow technology design exemplar, and, in our view, it is worthy to be included.

The slow doorbell was never designed in practice in the sense that it was never made into a 'real' working prototype or product. Rather, it is a *design proposal* – something that does not yet materially exist and, in this case, was depicted through only verbal description. There is important value in design proposals precisely because they are somewhat open to interpretation and, as such, "allow for [their] consideration, discussion, and debate [where] the intended audience or users of design proposals are often [other] researchers and designers" (Pierce, 2014, p. 739). We aim to consider and extend the Slow Doorbell design proposal within our analysis because its existence as a conceptual design proposal makes it more malleable to our own judgment and practice-based perspective on slow technology. The slow doorbell has also been highly influential in our design practice because, as we will unpack, it makes clear that slow technologies need not solely ascribe to the fast/slow dichotomy, but rather can also be more openly manipulatable and continuous while still retaining the original visionary qualities of slow technology.

6.1. *Slow Doorbell*

In the original slow technology article, Hallnäs and Redström verbally present the "slow doorbell" as a conceptual design proposal (2001, p. 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 it can be assumed 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. As noted, the slow doorbell was never designed in a 'real' sense and exists as a design proposal; however, in our interpretation it offers a compelling early example of what the form, presence, and accumulative quality of a slow technology might be like. As an early example, slow doorbell illustrates how a slow technology can operate outside of the oppositional fast/slow juxtaposition and offer the home dweller direct control. That the slow doorbell exists as a conceptual design proposal has enabled us to think about it from our own interpretation and, in this way, flexibly extend it into our analysis. Thus, we decided to include it in our collection of design artifacts. It is an example of how slow technology was originally envisioned and, in this, offers the possibility to bridge our own work with an initial design exemplar that is open to interpretation and conceptual development.

The slow doorbell is 'slow' in the sense that it augments the somewhat infrequent activity of having one's doorbell pressed with a relatively brief snippet of a longer musical score. It *takes time to understand* what the musical score is. For example, we can imagine that if a five minute song played occasionally in 5 second increments when one's doorbell is pressed, then it would take a notable amount of time for the song to play in its entirety. It is also slow in the sense that it may take a substantial amount of time for a home dweller to understand or become familiar with the song. This could require a five minute song to be played through the doorbell in its entirety several times before a home dweller is able to recognize what the song is and where 'in time' the song is whenever the doorbell is pressed. Finally, the slow doorbell is emblematic of the original slow technology vision because it augments a common activity in a way that is "time productive" – it does not make the notification of a visitor to one's home more efficient (or less efficient). Rather, slow doorbell augments this mundane activity to explore how it could be realized in a way that takes time, interpretation, and reflection to understand.

In our view, the Slow Doorbell can be seen as exemplifying the quality of *implicit slowness* because it is directly interactive yet assumed to be used only occasionally. This quality is in contrast to *explicit slowness* where technologies actively enforce a slow pacing and do not give the user control over changing it. One could imagine going to the doorbell and pressing it many times rapidly. As a result, in a relatively short time, one would know the song's entire melody, thematic movements, and score. It is *implicitly slow* because its pacing could be easily modulated through user interaction and control. Initially, the musical score will be unfamiliar and unpredictable. The frequency of when musical fragments of the score will be played is also unpredictable as it relies on the recurrent, yet somewhat unpredictable return of visitors to one's home. Thus, it changes over time as experiences with it accumulate and the musical score becomes more familiar to home dwellers (and perhaps to frequent visitors as well).

6.2. *Photobox*

Photobox is a networked device that is connected to its owner's online Flickr photo archive that is embodied in the form of an antique chest (see Odom, Selby et al., 2012; Odom et al., 2014). 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 (see Figure 1). 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 (although 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.

Photobox uses 'slowness' to engage with the abundance of digital photos that a person has accumulated and to make them scarce in printed form. It manifests an *explicit slowness* because it has a pacing that cannot be modulated (i.e., it cannot be sped up or slowed down). Photobox combines a slow printing rate with multiple layers of randomness to make its behavior persistent, yet unpredictable. When these qualities are combined, they aim to manifest tension and trigger experiences of anticipation as the user will not know when a photo will print, where it will be from in their past, what will print next, and when it will come. Photobox continues its behavior indefinitely and, in this sense, manifests qualities of *ongoingness*. Photobox demonstrates *explicit 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. Photobox offers an early example of *implicit ongoingness* because it is continually updated to reflect the most up-to-date index of the owner's Flickr archive; and, thus, each time it is encountered, it represents the slowly expanding totality of the user's digital photo archive. In other words, it captures the aging, cumulatively changing quality of one's digital photo

Figure 1. The Photobox occasionally prints randomly selected photos from the user's Flickr collection. It can be opened to see whether or not a photo from the past is there.

collection each time one considers Photobox and decides to open it (whether one's photo collection is expanding or if it becomes diminished through personal deletion, data loss, or otherwise). On a technical level, it would be possible to open the Photobox and find a printed photo that the user had taken that same day or from many years ago. This quality of implicit ongoingness seen in Photobox helps capture how an artifact can manifest slow change over time that may not be immediately perceivable, while still viably evoking a feeling of continual evolution alongside the user through time.

Additionally, the extremely reduced 'interactivity' with Photobox (i.e., simply opening up the chest to look inside and see if a photo of one's past is waiting for you) was an initial attempt at creating a slow technology that foregrounds *pre-interaction* experiences. Pre-interaction is explored through intentionally requiring the user to open the chest and look inside while not providing any contextual clues as to whether a photo has been printed. In light of this design quality, prior to directly interacting with the Photobox, the user may anticipate or prospectively contemplate where in their life a photo might be coming from (if one has indeed been printed). This example helps start to show that the conceptual space *prior to interaction* with a slow technology can be a highly important area to attend to through design because it can open up rich possibilities to amplify time and prime critically reflective experiences with the artifact. Pre-interaction is explored and conceptually developed further through other design artifacts that follow Photobox in our collection.

6.3. *Olly*

Olly is a networked music player that is connected to its owner's digital music listening history account data via the Last.FM service.[3] Similar to Photobox, Olly uses randomness as a design quality

[3]Olly (and also our Olo Radio design artifact) works by linking to a user's Last.FM account. Last.FM is a free web-based application that runs across a user's personal computer, smartphone, and peripherals to generate precise records of each song they have listened to in terms of the time, date, artist, song, and album (e.g., if listened through Spotify, iTunes, etc.). In existence since 2002, Last.FM offers unprecedented access to its users' listening histories. We also decided to use Last.FM data because it is a relatively open platform which makes it easier to work with listening history data (e.g., as opposed to Spotify or other listening services that do not allow end users to download or access their entire listening history data in a raw form).

paired with a slow pacing to catalyze experiences of anticipation, interpretation, and reflection (see Odom, Bertran et al., 2019; Odom, Wakkary et al., 2018). Each week, Olly randomly selects approximately 9 songs that were previously listened to by the user (see Figure 2). The user does not have any control over what song from their past is selected or when. Importantly, when Olly selects a song, it does not immediately play it. Rather, it goes into a 'pending' state where the internal disc of the device begins to rotate. The rate of rotational speed of the disc is based on how deep into the past that specific listening instance of the song was originally listened to. For example, if a listening instance was selected that is from deep in the user's past (e.g., many years ago), Olly will exhibit a slow rate of rotation compared to a listening instance that had been played much more recently. Supplying different voltage levels to the motor enabled us to change the speed of rotation. 4.4 V is the lowest functional amount of voltage, which is used to represent the oldest instance in a user's database; it requires about 10 minutes to complete 224 rotations. 12 V is the highest (and represents the most recent instance of a song previously listened to); it takes about 4 minutes to complete the 224 rotations (see Figure 3). Understanding the rotational speed relative to each specific music listening instance will likely require the user to take time to interpret and make sense of. Over time, these subtle differences may become more discernible and personally meaningful.

Olly also causes all instances in a user's database to slowly age over time because their 'age' is relative to today's current date. For example, Olly's absolute fastest rotation could only be triggered if it selected a song that the user had listened to in the past week. If new entries stopped appearing in a user's listening history archive, all of the songs in the Olly database would still continue to slowly grow older through the inevitable passage of time and irrespective of the actions of the user. Beyond the speed of rotation, no other information is offered about the specific listening instance when it is surfaced and made available to be played. This design decision was motivated by our desire to support a range of experiences with Olly that can evolve as one develops a sensibility for 'reading', interacting, and living with it over time. When a song is selected and if the user wants to play it, they then need to spin the disc and the song will begin playing momentarily. After the song finishes playing, the disc stops spinning and Olly shifts back into a static, passive state until another song is randomly selected. The process continues indefinitely.

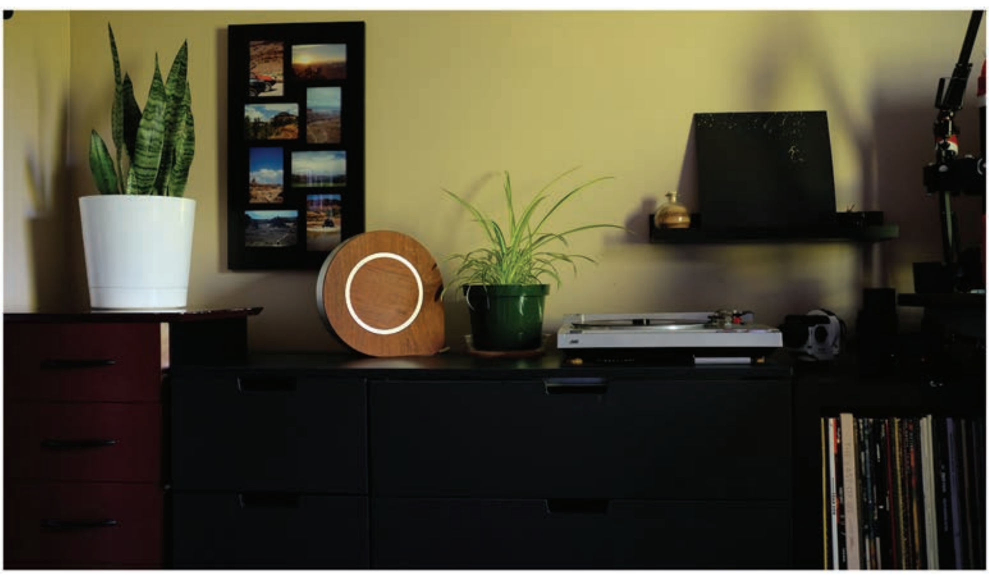

Figure 2. Olly is a music player that slowly surfaces songs that its user has listened to previously to be revisited and makes them available to be listened to again.

Figure 3. Left to Right. Olly can operate standing up (or lying flat); A pending song is played by gently spinning the rotating disc (pictured here when lying flat); Woodgrains move in and out of alignment as the disc rotates; Three Olly design artifacts.

Similar to Photobox, Olly uses 'slowness' to engage with the abundance of digital listening history data that a person has accumulated in their life by making situations in which they resurfaced and presented to be played through the artifact relatively scarce. Olly manifests an *explicit slowness* because it has a pacing that cannot be modulated. It also combines this slower rate of selecting songs with randomness to make its behavior persistent, yet unpredictable. When these qualities are combined, they aim to manifest tension and trigger experiences of anticipation because the user will not know what song from their past will play if they trigger the rotating disc.

However, different from Photobox, Olly aims to extend the *pre-interaction* experience by leveraging the actuated rotation of the internal disc to project a temporal expression associated with the specific listening instance that is being surfaced. This quality draws attention to how anticipation can be better primed and supported with a slow technology through *pre-interaction* (e.g., prior to when a song is played and one contemplates when in their life the song is coming from based on the subtle clue in the rotational speed). Photobox largely left it up to the user to wager a guess on if a printed photo from their past would be waiting for them by virtue of the enclosed, chest-like form. In contrast, Olly signals when a song from the user's past has been selected and subtly projects a temporal encoding through this signaling to open an invitation for the user to contemplate where in their past the rotational speed is associated with, prior to the song being actively listened to (should the user decide to accept the invitation in the first place). Olly demonstrates how *pre-interaction* can be a valuable quality for priming and supporting ongoing interactions with and experiences around slow technologies.

Olly also extended the temporal frame of interaction through expressing the relative 'age' of a listening instance through rotational movement that was continuous, interpretative and gradually shifting; and, which itself aged over time. The 'aging' of the listening history archive was expressed by the rotational speed for each unique instance becoming subtly slower as it grew older day by day.[4] As a material form, Olly was designed and built robustly, not as a matter of permanence per se, but as a way to age and adapt to the passage of time; for example, the mahogany veneer gracefully ages and acquires a patina over time. These techniques of digital and material adaptation, combined with its unpredictable yet indefinite behavior, generate a sense of 'aliveness' in Olly whose combined physical materials and digital expression can slowly age alongside its user. Olly represented an up-to-date reflection of the totality of digital music listened to in its owner's life whenever it is encountered. Thus, the slow and gradual, yet consistent change through time amplified a sense of both *explicit* and *implicit ongoingness* as it continued to evolve.

Collectively, Olly represented a conceptual advance for slow technology that built on the Photobox in three key ways. First, it illustrated how a small degree of control could be extended to the user in a slow

[4]Although Olly randomly selects instances of songs listened to previously in its user's life and this data ages over time, the system structures the listening history archive chronologically. For example, when the user listens to music in their everyday life (outside of using Olly) and it is recorded in their listening history archive, these instances are simply the 'newest' ones introduced into the archive along a linear timeline. They do not form temporal connections to other songs in the archive except in relation to how old or recent they are to relation each other. The concept of *temporal interconnectedness* – where digital media or data form connections across multiple dimensions chronological and non-chronological time simultaneously – is motivated and exemplified later through the Olo Radio and Chronoscope projects.

technology while still maintaining the quality of *explicit slowness* (i.e., the user could not change the pacing but could decide whether or not to play the song after it was selected and the rotation began). Second, it demonstrated how encoding the relative age of a listening instance, represented through its unique rotational speed, can be mobilized as a technique to support *pre-interaction* experiences that amplify Olly's time presence and can trigger reflective experiences. Third, it shows how integrating a slowly changing temporal expression, in this case an expression that is relative to today's date, can work as a resource to support the quality of ongoingness in slow technologies.

6.4. *Slow Game*

Slow Game's design inspired by and adapted from the Slow Games, an original art project by Ishac Bertran.[5] Bertran's project explored how a slow pacing could be applied to three different games: Pong, Tetris, and Snake. With this project, we initially aimed to produce a small batch of Slow Game research products to further inquire into slower-paced, yet ongoing temporal qualities and what might be revealed through applying them to a computational game that could operate over long periods of time. Out of the three initial games Bertran explored we decided Snake was the best fit for this project particularly because it does not require any additional interface controls or features (e.g., external knobs or buttons) which would enable us to craft an entirely uniform, embedded, and finished design artifact. The original snake game is a simple game in which a player maneuvers a fast-moving 'snake' (a thin line of pixels) that roams around on a 2D-plane with the goal of picking up 'food' (a single pixel). The user controls the direction the snake is heading. When the snake reaches a food pixel, its tail grows one pixel longer and another food pixel appears elsewhere. The player cannot stop the snake from moving while the game is in progress. The challenge is to make the snake avoid running into its own body or the perimeter of the 2D-plane; either case results in the game being over. Snake was popularized worldwide when it was included as a pre-loaded game on Nokia mobile phones in 1997.

The Slow Game research product is embodied in the form of a 5 cm wooden cube (see Odom, Bertran et al., 2019; Odom, Wakkary et al., 2018). It persistently displays the 'place' that the user is within a simple slowed down version of the snake game (see Figure 4). The user navigates a 8 × 8 (64 pixel) matrix where the goal is for the Snake to reach 17 pixels long in order to win. The orientation of the slow game physical cube dictates where the next 'move' will go. However, the move is only made after an 18 hour period passes. Through iterative experiments, we lived with versions of Slow Game to explore different pacing cycles (e.g., 10, 14, 18, 28, 30, 50 hours, etc.). These experiences revealed that shorter phases (e.g., 10–14 hours) seemed to be too fast and multiple moves could easily occur before we noticed, while longer phases (28–50 hours) tended to feel 'too long' and, over time, caused the artifact to not be attended to for days, or to be largely forgotten. We found that an interval of one move per 18 hours created a dynamic, yet balanced quality of experience.

These experiences also revealed new tensions. We found that as Slow Game's snake grew longer and more visually complex, it became difficult to interpret which direction the next move would advance. It was clear some type of feedback had to be integrated to sustain intelligible, if not enjoyable, experiences with it. This prompted us to include a subtle feature in the design to clarify the cube's orientation: when it is rotated, the snake retraces itself pixel by pixel (one second per pixel), beginning at the tail and moving to the head. After reaching the head, it will blink three times in the pixel representing where the snake would move next. In this way, Slow Game communicates when it is tangibly manipulated to invite the user to check in on where the next move will go (i.e., effectively 'setting' the next move).

Yet, the user has no control over making the move actually happen. Slow Game becomes 'aware' at the precise moment when 18 hours have passed; it then senses its orientation, advances the next

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

Figure 4. Slow Game's gameplay unfolds slowly over time.

move, and becomes inactive for the remaining cycle. In some instances in the game, the 'best' or most optimal series of moves to win the game in the most direct and shortest duration will require the user to simply leave the cube undisturbed for a series of days before another simple tangible manipulation of the cube is required. If the game does 'end' and the user loses, Slow Game goes into a 'mourning' state for 1 day (24 hours) and then the game restarts. If the user wins by making the Snake grow to 17 pixels long, then the game displays a visually pleasing, warm and slowly pulsing glow for 1 day and then the game restarts. In either case, this process continues indefinitely no matter whether or not there is any user interaction. In this way, Slow Game exhibits an explicit form of *ongoingness* because time is always perpetually moving through it.

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.' However, different from Photobox, it does offer some control in the design. The user may interact with Slow Game by tangibly manipulating it to explore different options for their next move as it re-traces its steps up to where the next move would land. However, the move will only be made after an extended duration of time has passed (i.e., 18 hours). This design decision builds in support for *pre-interaction* by enabling the user to explore and contemplate where they might 'set' their next move by manipulating the cube's orientation without knowing precisely when that move will be made.

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. This concept contrasts the *explicit slowness* of Photobox and Olly, both of which operate in an unpredictable way where their 'action' is only momentarily present in the printing of a photo or the rotation of the disc when a song is selected, and then they withdraw into a passive state in the background of daily life.

Through its warm LED display diffused through maple veneer and the capacity for a user to manipulate it at any time to explore where their future move would land, Slow Game persistently manifests a subtle presence. Because Slow Game operates on a different timescale outside of 24-hour clock time, the point at which the user would need to check to see if their move has been made is drifting in and out of the unique temporal rhythms of their everyday life.

In summary, Slow Game mobilizes qualities of *explicit slowness* and *ongoingness* in ways similar to Photobox and Olly. However, it differs by illustrating how *pre-interaction* can be a persistent, even interactive, quality through enabling the user to explore where their desired move may land as the snake retraces its path each time the cube is manipulated. The interaction makes clear to the user where the snake will make its next move, yet only through time and patience will the move be made, whether or not it is intentionally set by the user. 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.

6.5. *CrescendoMessage*

CrescendoMessage is a digital messaging application that allows people to pick one photo and send it through one of its three obscuring lenses – *Gaussian Blurred, Crystallized*, or *Pixelate*(see Figure 5) – to another person (Chen, 2015; see Tsai & Chen, 2015). In the original concept, the sender can select any temporal duration between one day to one year for the photo to slowly reveal its true unaltered form as it gradually becomes less obscured and more visible until it is fully revealed on the date and time selected by the sender. The user receiving the photo has no control over speeding up this process. The photo simply stays in their messaging application, visible at any time although its form may be obscured. Through time changing gradations slowly increase in fidelity, potentially prompting the user receiving the photo to prospectively reflect on what the photo content would be until the actual photo is eventually revealed (see Figure 6).

CrescendoMessage offers a constructive contrast to the Photobox, which uses time delay as the expression of *explicit slowness*. After the sender sets the time-delay period and selects the desired obscuring lens, only through an enforced amount of time will the photo be revealed. In this way, it demonstrates a ‘crescendo’ expression of *explicit slowness* that also supports *pre-interaction* through the receiving user not being able to control the photo but having the option to view the slowly changing gradational exposure of the photo as it becomes clearer over time. As an analogy to concepts for structuring time in music theory, Photobox’s quality of *explicit slowness* can be seen as similar to *staccato* – indicating a sudden appearance in a short duration. In this view, Photobox occasionally prints a photo and then after an unknown, potentially significant amount of time delay occurs until the next one prints. Our messaging application gradually reveals a photo over time representing a *crescendo* form of explicit slowness that contrasts the examples of Photobox, Olly, and Slow Game.

In this way, CrescendoMessage highlights how gradational change can produce a gradual revealing temporal expression and alternative form of explicit slowness. CrescendoMessage also opens up new ways of approaching designing for *pre-interaction* and the role it can play in priming experiences with slow technologies, where direct interaction is a secondary concern. Photobox’s capacity to support pre-interaction is highly restricted and solely relies on its form of a chest – an enclosure that must be opened to see what is inside – to potentially support pre-interaction. Olly supports pre-interaction explicitly but does so within a limited time window (4–10 mins). Slow Game also explores pre-interaction through direct interaction where the user can manipulate the cube to explore where the next move may go, but only through time (e.g., 18 hours) will the move actually be made. CrescendoMessage offers an example of how pre-interaction can be considered over much longer time periods (e.g., from one day to one year).

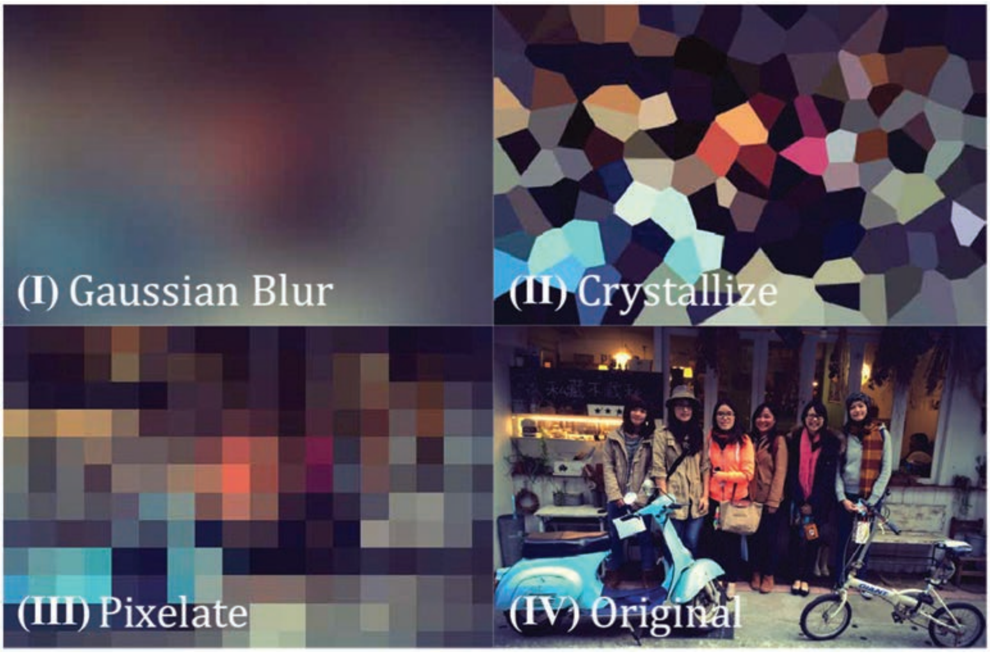

Figure 5. Different types of obscuring lenses that can be applied to a photo via CrescendoMessage which will then slowly resolve to reveal the original image.

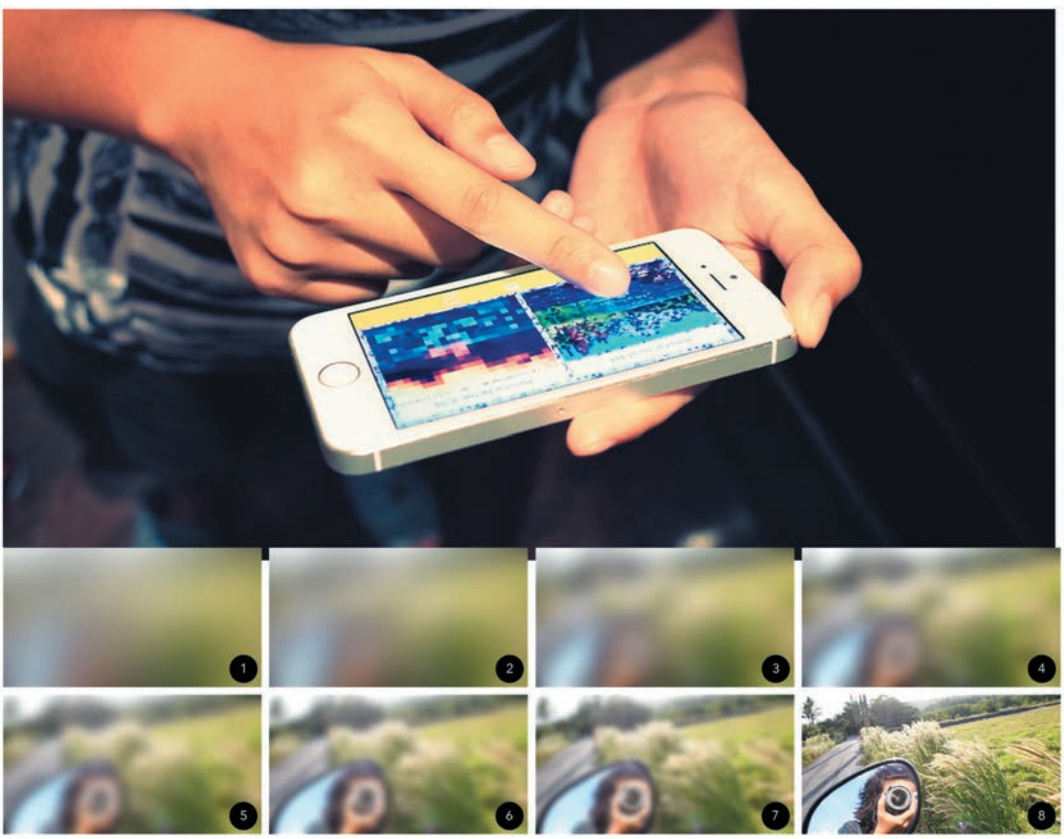

Figure 6. A scenario of the CrescendoMessage application in use and one example of gradual change over time when Gaussian Blur is applied to a photo.

6.6. *Olo Radio*

Olo Radio is a music player that draws on a user's personal music listening history archive (via Last.FM) to embody the lifetime of digital music they have listened to (see Odom & Duel, 2018). Different from Olly, Olo Radio enables the user to have a high degree of control over the system (see Figure 7). The two main points of interaction are the motorized linear slider and the timeframe knob (see the illustration in Figure 8). The timeframe knob offers the user three different *temporal modalities* that can be used to explore their listening history archive. The decision to make the timeframe knob a central feature in Olo Radio's interaction design enables the user to interact with music from their past through both chronological (Life) and non-chronological (Day, Year) *temporal modalities*. Different modes can be selected and toggled by the knob next to the motorized linear 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 actuated 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 all listening instances surrounding it have been reorganized based on the newly selected mode. Olo Radio offers direct control to the user to change the timeframe modes and the position 'in time' that the slider represents whenever desired. This design decision creates an opportunity for the user to explore a range of possible connections across different songs listened to at different points in time in their past. Yet, Olo Radio's design is intentionally minimal. It takes time to understand, recognize, and interpret memories bound up in one's personal history.

In our original design, we ensured that Olo Radio made daily updates to its database to capture new listening instances and then to evenly distribute all listening instances across 64 'containers' across the linear slider so that the same number of listening instances of songs were in each container. However, we found that even with a modestly sized listening history archive caused initial frictions in our design. For example, an archive of 50,000 unique listening history instances would take approximately 45 hours of music continuously playing to make it through just one single container. While songs at the 'front' of each container might shift around to some degree when new data was added from the updated Last.FM archive, eventually a pattern in a specific 'point in time' that had been listened to several times previously would become quite recognizable. Practically, this meant that it was improbable that large amounts of music in the 'middle' and 'end' of the containers would ever be able to heard again. Conceptually, this meant that Olo Radio precise points in one's past would only be available to be engaged with through a significant amount of time and patience. We anticipated that Olo Radio would take time to understand, but we did not expect that frictions related to the temporal organization or each timeframe mode would be a point of friction.

These experiences prompted us to revisit Olo Radio's design. We did not want to offer more end user control because we anticipated that this would detract too much from Olo Radio's agency and, in this, comprise the qualities of unpredictability and change over time that are important for a slow technology. Yet, we needed to develop a technique to move through time in each container in a way that resurrected the many listening instances that were largely out of reach in the deeper temporal recesses of each container. We also needed to ensure that the unique sequential pattern was preserved from one song to the next. We eventually arrived an algorithm that applied a random selection to the where 'in time' music would begin playing from within a container. This only happened when the slider was tangibly manipulated by the user and moved to a new location. Each time a new container is actively selected, Olo Radio will randomly determine where in time in the container it should begin playing from, effectively preserving the uniqueness of the temporal sequence, while avoiding being predictable.

Figure 7. Drawing on a user's archive of digital music listening history, Olo Radio embodies the lifetime of music a user has listened to. The motorized linear slider and 3-switch knob exhibited on the left cabinet enable the user to explore, interact, and listen to music from their past across different timeframe modes; the rightmost knob controls on/off and volume.

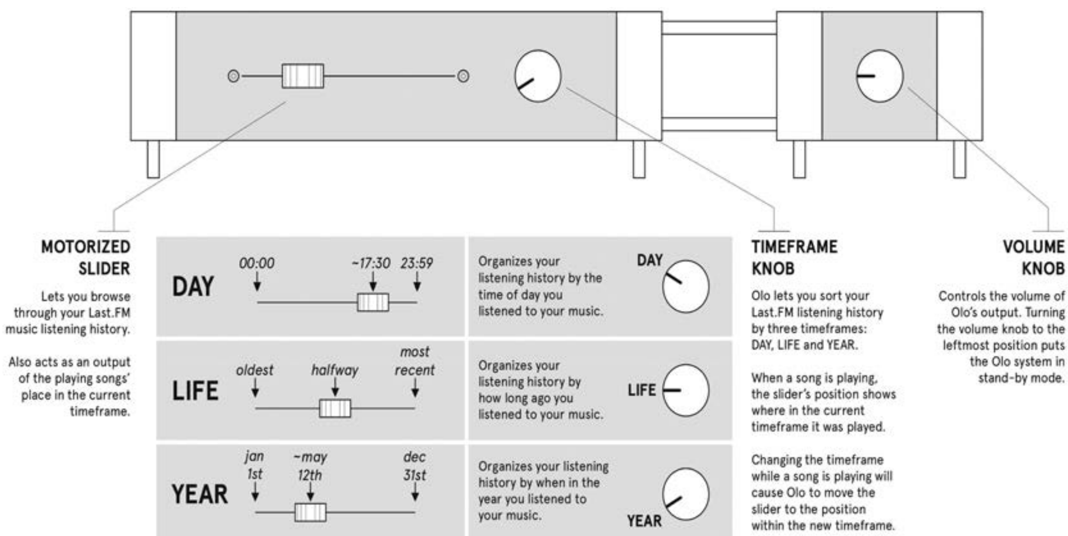

Figure 8. Explanation of the features, timeframe modes, and interaction design of Olo Radio.

As a design artifact, Olo Radio both builds on and departs from the design artifacts reviewed thus far in our collection. Photobox, Olly, Slow Game, and CrescendoMessage leverage *explicit slowness* to generate a pacing that is ongoing and offer differing degrees of restricted end-user control. In contrast, 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, we carefully designed Olo Radio with conceptual propositions of the slow technology design philosophy in mind. It *embodies* *different forms of time* and makes them more present in everyday life through the Life, Year, and Day temporal modalities. It also *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. These design decisions aim to use minimal feedback to catalyze a range of experiences that can evolve as one develops a sensibility for 'reading' and exploring Olo radio over time.

Olo Radio's *temporal modalities* combined with its quality of *ongoingness* together open possibilities for one's relation to grow with it over time. It slowly evolves through updating daily to capture the historical traces of a user's music listening history. This means that Olo Radio always represents the totality of a user's listening history which effectively bridges it from the present moment when it is encountered to the past in an *ongoing* way. Olo Radio also subtly changes as the granularity of its slider gradually decreases as listening history data slowly stacks up across it. This, in turn, leads to a perpetual re-sorting of the sequential order of all listening instances which generates a quality of unpredictability that is uniquely tied to patterns produced from a user's own listening practices and accounts for the temporal density of the archive. The timeframe modes enable *temporal interconnections* to form and expand across all instances in a user's listening history simultaneously. For example, when a new listening instance is introduced into Olo Radio, it not only forms a relational connection to the other 'most recent' entries, but also to other music that was listened to previously at that specific time of the day as well as that time of the year. This quality of *temporal interconnectedness* may lead to relations forming among memories, experiences, and life stages that are bound up in the user's life history in chronological and non-chronological ways. This generates possibilities to explore alternative perspectives on one's personal history from various temporal vantage points and to manifest a cumulative sense of change across time.

Collectively, the design qualities of Olo Radio resonate with the original vision of slow technology, while offering new theoretical insights that can extend how we can approach it from a design perspective. Manifesting historical qualities of a personal archive through different temporal modalities can evoke a type of agency that is uniquely reflective of the user, that takes time to interpret, and that can scale and change over time. Due to digital music being an immaterial and temporal media, Olo Radio takes advantage of the time a user needs to 'spend' to listen, absorb, and interpret music being played back from their past. The minimal interface design and actuated feedback can offer a quick 'glance' at where one might roughly be in time without demanding attention or the need for interaction. Next, we discuss Chronoscope which aims to adopt a similar approach used with Olo Radio and apply it to personal digital photo archives.

6.7. Chronoscope

Chronoscope is a tangible photo viewer that embodies the lifetime of digital photos a person has accumulated over their lifetime (see Chen et al., 2019). Chronoscope is synced with the user's online photo storage archive (e.g., Google Photos, Dropbox) and enables the user to interact with their photo archive through three separate rotational controls: temporal viewing direction, timeframe modes, and viewing granularity. When peering into Chronoscope, a single photo tied to the specific time that it was taken, based on its timestamp metadata, is visible (see Figures 9 and 10). A rotating wheel, as the scope's main feature, controls two temporal viewing directions through a rotational movement (clockwise to move forward in time and counterclockwise to move backward). We selected physical rotation for this input as a subtle analogy to the circular shape of clocks and the temporal flow evoked by their movement. By rotating either direction, the user sees each photo in relation to a wide spectrum of other photos in the archive.

When the user stops the rotation, Chronoscope settles on the specific photo associated with where 'in time' the position is in relation to the selected timeframe mode. When switching the bigger knob on the side of the scope, users can seamlessly toggle among different organizations of their archive through three *temporal modalities: linear, date*, and *time*. *Linear* organizes all photos in the archive in a linear timeline, from oldest to most recently taken. *Date* structures all photos in a temporal ordering based on the Month and Day they were taken irrespective of the year, potentially offering a more 'seasonal' way of exploring photos in one's archive. *Time* organizes all photos based on the specific time of the day they were taken irrespective of date or year, opening a space to explore the rhythms and qualities of past experiences captured in photos bound to parts of a user's 24-hour daily cycle.

A cornerstone decision in the design of Chronoscope consists of the following. When the user changes the *temporal modality*, the specific photo that is currently viewable does not change; rather, the organization of all of the photos around it changes in relation to its specific timestamp metadata. 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. We judged this to be an important and valuable design decision because it creates a space of possibilities for people to experience known or unknown connections among different photos and open possibilities to trigger experiences of interpretation, reflection, curiosity, or serendipity over time.

While the decisions described above reflect design qualities similar to Olo Radio, we encountered new tensions when grappling with the static and persistent qualities of digital photos displayed on a screen. For example, if a user has 20,000 photos and they aim to navigate to a specific time at the

Figure 9. Chronoscope is an interactive photo viewer that enables the user to re-visit and explore their digital photo archive *through* and *across* time.

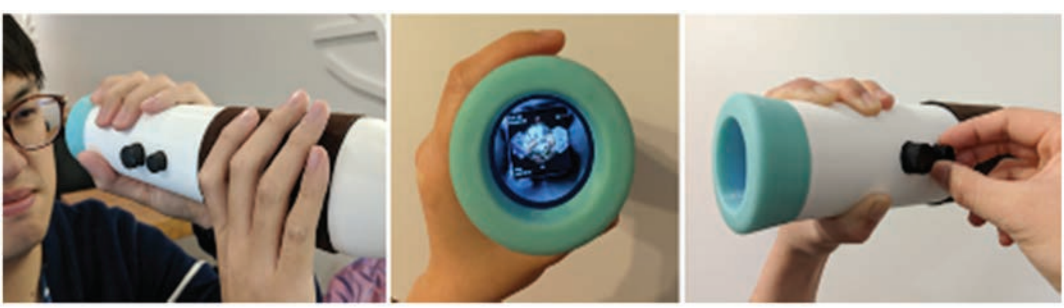

Figure 10. Left: Using his right hand the user manipulates a fully rotational black silicon surface (rotating clockwise moves 'forward' in time and rotating counter-clockwise goes deeper into the past). Middle: Peering into the eye piece through a magnification lens, the user views photos from his past. Right: The user manipulates a black metal knob that 'tunes' the granularity of photos that moved through in each rotation; the untouched knob toggles between timeframe modes.

'other end' of the photo collection, it would take approximately 2.77 hours to get there since each rotation moves through the photo archive by only one photo as a unit (and it takes about 0.5 second per rotation). With a larger archive, such as 200,000 photos the scenario is much worse (about 27.7 hours of continuous rotation).

This design issue revealed to us that we would need to build in a support for 'tuning' the number of photos that one moved through per each rotation. Different from how we grappled with the density of temporal metadata in the Olo Radio project, we could not rely on randomness or automatically 'shuffling' to a different point in time because it would be disorienting. Thus, we needed to enable people to move through their photo archives in very slow, precise, meticulous, and considered ways if, for example, they encountered a set of photos that triggered deep reflection or required critical examination. Equally, we needed to provide quick movement across vast amounts of photos without an excessive amount of rotations, while retaining a subtle awareness of what had been passed over. In this way, Chronoscope demonstrates the quality of *temporal granularity*. With added control over the number of photos to be moved across in each degree of rotation, people would be able to 'tune' the pacing and speed through time that they move across their photo archive. The 'tuning' design element opens up more freedom and flexibility for the user to move through photos from minutes in a day to years of one's life, making it easy to slow down or speed up in real time. Ultimately, we found this design decision to be valuable in that it supports both movement across time (both the chronological and non-chronological modes) as well as movement through time in a combined and extended way.

Similar to Olo Radio, Chronoscope's design is highly resolved, while the user experience is largely undetermined and unstructured. It does not suggest where one ought to look in their past when deciding to engage with it. The design is relatively minimal and constrained, while it may give rise to various open-ended experiences – moments of curiosity, contemplation, and exploration. As a design artifact, Chronoscope makes use of *temporal modalities* to embody different forms of time and makes them more present in everyday life through the Linear, Date, and Time timeframes. It also leverages the combination of multiple *temporal modalities* with the quality of *ongoingness* to open up new possibilities for both chronological and non-chronological *temporal interconnections* to simultaneously emerge among digital photos in the archive through and across time. Chronoscope builds in support for tuning *temporal granularity* to open up added control and flexibility for the user to navigate possible *temporal interconnections* through and across time.

Chronoscope offers a complementary case to Olo Radio. Both design artifacts illustrate an extended way that slow technologies could be designed while also resonating with conceptual propositions core to the original slow technology design philosophy. They take time to understand, manifest change through time, and amplify time presence through their use, and reflection upon their place, in everyday life. They build on and help extend these propositions by manifesting different and multiple forms of time in ways that break down the dichotomy between slowness and fastness. In this way, they offer examples of how slow technology can be conceptualized beyond solely matters of interaction speed, tempo, and pacing. Chronoscope and Olo Radio offer a high degree of control over the system paired with the capacity to develop cumulative change as temporal interconnections form across multiple dimensions of time, while still retaining the reflective, critical, and ongoing design qualities emblematic of slow technology's conceptual proposal and vision.

7. Revisiting the Theory

The contributions of this research offer an extension of the existing theory of slow technology as well as a number of design artifacts that each represent some key dimensions of the theory. These contributions are closely related and interdependent. Artifact analysis requires a detailed understanding of theoretical concepts as well as the design artifacts themselves. The selection of artifacts is crucial and this is why we primarily selected design artifacts that we had first-hand knowledge about. If other artifacts were selected, other design qualities may emerge and this suggests clear opportunities for future research. We do not see this as problematic since our aim is not to present our extension of the theory as conclusive or finalized. Our goal is to derive theoretical insights that can support, extend, and further diversify the conceptualization and design of slow technology. We see our work as an invitation to others to conduct similar research that explores the value of the theoretical concepts and to potentially develop other forms of extensions.

Based on previous work in the field, we summarized the theory of slow technology as consisting of three interrelated conceptual themes that together support a core vision. This vision defines slow technology as:

Reflective Technology: designing technology that both invites reflection and is equally critically reflective on technology through its expression.

Time Technology: designing technology that makes space for reflection through embracing different forms of temporality as a key quality in design.

Amplified Environments: designing technology that amplifies the presence of things to make them into something more than merely a silent tool for fast access to something else.

Based on our research, we still find the core vision of slow technology as relevant, generative, and theoretically stable. From a high-level, the new qualities inspire a different way of viewing design and influencing a designer's attitude. Through our research, we have extracted eight artifact qualities that can contribute to and extend this core vision. These qualities are different from the visionary themes; they are *design qualities* since they can be controlled by a designer to be more or less present and explicit in an artifact. The eight qualities are as follows: *implicit slowness, explicit slowness, ongoingness, temporal drift, pre-interaction, temporal modality, temporal interconnectedness*, and *temporal granularity*.

We believe that extending the initial theory, which is quite abstract and mostly on the level of intention and ambition, with our more concrete, design-oriented qualities makes the overall design theory of slow technology more robust and useful. The theory becomes more robust through connecting an abstract vision with concrete examples and by exposing the theory to a number of artifacts. Through this process, we get a clearer sense of what are key core aspects of the theory and also what might constitute weaker aspects of it. The extension also makes the theory more useful simply because it relates abstract concepts and ideas to qualities that can be controlled and worked with by designers. Next, we revisit and reflect on proposed qualities in light of our artifact analysis and the core vision of slow technology.

Implicit slowness shows that, on a general level, slow technologies can be freely controllable and that slow interaction is not merely a matter of speed. It foregrounds the need for designers to consider how a design artifact's affordances, form, composition, and presence holistically come together to support an accumulation of interactions that gradually reveal its character over time. Implicit slowness opens a space for designers to explore how artifacts can be designed that may not be interacted with every day, week, month, or even year, but which are open to direct interaction at any time and which are continually returned to over time through sustained and recurrent experiences.

Explicit slowness offers a contrasting quality where slow technologies are designed to intentionally restrict end-user control as they operate on their 'own time' irrespective of user interaction (or even the presence of others). It offers a framing that designers can scaffold to expand beyond designing for immediate response time and to explore crafting a temporal pacing that is distinct and indeterminate. Explicit slowness emphasizes the co-habitational aspect of slow technology where an artifact oscillates in and out of perceptual view in everyday life through moments of action and sustained periods of inaction. As this process unfolds, relations to and perceptions of the slow technology may change and grow richer as experiences accumulate around it. Explicit slowness also prompts designers to closely attend to how they surface and balance unpredictability in the artifact as it signals and enacts its slowly paced behavior.

Ongoingness brings attention to the movement of time through an artifact and how this, in turn, shapes the artifact's design and evolving expression. Ongoingness is closely linked with artifacts that exhibit *explicit slowness* because it speaks to the subtle, yet perpetual and never-ending nature of their behavior. This quality is important for creating slow technology because it can evoke a recognition by the user that the artifact is continually changing alongside them, albeit at its own pace. While greatly restricted user control is often exhibited in artifacts that are explicitly slow, over time the quality of ongoingness may help generate a deeper understanding of an artifact and alleviate tensions that may initially emerge from a lack of end-user control. Ongoingness also extends to artifacts that are not explicitly slow by prompting designers to develop techniques to project the co-evolving, aging quality of an artifact through time even if this subtle cumulative change is not always immediately perceivable.

Temporal drift leverages qualities of *ongoingness* and *explicit slowness* to explore the relationality among cyclical forms of time that operate on different tempos (e.g., the 24-hour clock-time that many people organize their everyday lives around contrasted with a different yet stable tempo). Such juxtapositions can productively generate a sense of ongoing change in a design artifact as it drifts in and out of alignment with periods of times when the user is in its proximity. Designing a different, yet stable temporal pacing in relation to clock-time into an artifact offers an alternative approach to supporting an ongoing cycle of anticipation compared to using randomness to generate unpredictability in a slow technology.

Pre-interaction refocuses attention to the expanded set of experiences that could be considered and designed for prior to interaction with the artifact itself. For example, anticipation is often characterized as two temporal phases: the first, before an experience happens as tension builds, and the second during the experience as one reflects on what has been revealed through interaction. However, the first temporal phase of anticipation has often been overlooked in HCI and design, and remains underexplored. The extended temporal frame offered by pre-interaction points to how design artifacts, through different temporal expressions, can catalyze a rich range of experiences prior to interaction and that lie outside of direct interaction.

Temporal modality foregrounds the integration of one or multiple different forms of time as the cornerstone of an artifact's interaction design. For example, temporal modalities can be applied to organize digital media or data in ways that are not random but may still be unpredictable and apt to catalyze anticipatory, reflective, and interpretive experiences. Integrating temporal modalities as a defining quality of interaction opens up another alternative way for designers to conceptualize slow technologies that moves away from treating slowness as simply a matter of speed in opposition to fastness. Chronological timescales such as time of day, month, or year and other non-linear forms of time, such as lunar, biological, geological or deep time can be explored as generative resources for crafting and applying diverse kinds of temporal modalities in designing slow technologies.

Temporal interconnectedness arises as a quality that can be explored and manipulated when two or more temporal modalities are integrated into a design artifact. This situation opens the possibility for interconnections to form and expand across all instances of digital media or data embodied by a design artifact across multiple dimensions of time. The simultaneous and ongoing formation of interconnections across time can project a co-evolving quality that is unique and distinct to the user, that takes time to interpret, and that can scale to evoke cumulative change over time.

Temporal granularity extends control to the user to 'tune' the relative amount of time that they move through when performing an interaction with a slow technology. Particularly in the case of design artifacts that embody large, dense archives of digital media or data, this quality enables users to tune down the granularity of the interaction to slowly explore and attend to very specific time periods represented in the archive. Equally, it enables the user to tune up the granularity to fluidly navigate across vast time periods. As experiences accumulate with tuning temporal granularity and a user becomes more familiar with this quality, they may develop a sensibility for their own desired interaction pacing when moving through time periods and across interconnections stitched together through multiple temporal modalities.

In summary, the theoretical contribution that we offer directly builds on the three original visionary themes of slow technology and extends this foundation through eight design qualities. Each of the eight qualities relate to one or more of the visionary themes. Additionally, each of the design qualities relate to each other in complex ways. As an initial step, the goal of this article is to describe and unpack each of the eight qualities in relation to a key set of design artifacts. Future research can further investigate what the interdependencies and relations may look like among the qualities, but we anticipate that there are many combinations and that there are potentially serious tradeoffs involved. For instance, combining and exemplifying all qualities in a single design artifact likely is not possible; certain combinations or strengths of qualities might even be counterproductive or cancel each other out. Additionally, we have not yet examined what might not be covered with these eight qualities. There is an opportunity to investigate this question through selecting a new set of artifacts for analysis and to explore comparative conceptual connections and differences. One approach could involve selecting a collection of different slow technology design artifacts. Another approach could consist of selecting a set of artifacts that do not exhibit any signs of slow technology, or that might be contrary to slow technology. Such artifact analyses could challenge and explore the stability and extensibility of the eight design qualities, and may lead to further insights about them as well as new theoretical concepts that our analysis may not have captured. There are clear opportunities for future research to both build on and challenge our findings.

8. Conclusions and Future Work

We have offered an extension to the design theory of slow technology. Our aim was to build on the original theory of slow technology and the core vision that its visionary conceptual themes mobilize. A key goal of our research is to articulate new qualities that help extend this vision and enable the theory to be more robust and useful by making it more practically accessible to designers and design researchers. To achieve this goal, we have developed and refined eight design qualities through a careful artifact analysis approach and presented a detailed analysis of seven artifacts that exemplify key aspects of the extended theory.

So, what does an extended and more detailed design theory of slow technology mean to the field?

First, it helps further open up and develop the slow technology design space. The foundational themes of Reflective Technology, Time Technology, and Amplified Environments are highly generative, and they are also highly abstract. Design researchers and practitioners have encountered difficulties in translating these themes into the particularities of design practice in the crafting of new design artifacts. The eight qualities developed and articulated through our research aimed to be a more design-oriented extension of the slow technology vision. Importantly, it is not required for all qualities or a finite number of qualities to be represented in a design artifact for it to be considered “slow technology.” Rather, designers and design teams can use this extended theory to raise certain questions about whether a particular quality exists in an artifact that they are designing and the extent to which it should or should not be emphasized. This will help support various stages of the design process by assisting design decision-making earlier in the design process when assessing possible design alternatives and variations in the divergence phase. This extended theory will also help later in the convergence phase when assessing specific design qualities as slow technology artifacts move toward finished form.

Second, we believe that our work will better support academic researchers and creative practitioners to analyze design artifacts based on the expanded theory. It provides a foundation for considering what a theory of slow technology might be, might be missing, or how it can be further developed. We have worked under the assumption that when a theory is extended – made more precise and concrete – it also opens it up for critique. We believe clear concepts and definitions are easier to analyze and critique than broad abstract intentions. We see our work as a piecemeal advance in a longer-term process toward conceptual clarity and invite others to engage with it. We hope that the original design theory with its extension will be seen as a contribution to the field that needs further examinations and analysis.

We also believe that engaging with the artifact analysis method was the appropriate methodological fit for this kind of research. We selected this method because we needed an approach to develop conceptual insights from a range of artifacts with the purpose to develop a theoretical understanding across these artifacts. The artifact analysis method enabled us to reexamine designs that we already knew intimately and to inspect the artifacts through a theoretical lens that led to further refinement of the design theory and the emergence of new concepts. In a field like HCI, where research deals primarily with designed artifacts, there is a need for an approach that can support theoretical and conceptual development through an investigation of a category of designs by careful examination of individual artifacts. Outside of slow technology, we believe HCI research has a number of 'theoretical' candidates that would be suitable to approach using an artifact analysis method. We hope the artifact analysis approach can be appreciated as an effort to better support reflective forms of knowledge production in the HCI community.

In conclusion, our proposal for an extended theory of slow technology is an invitation to others to further build on, extend or challenge the theory. HCI research is a field that is about the new, the next, the future, and has arguably engaged less in cumulative knowledge building. Our research is an attempt to build theoretically on what has already been done in the field to extend previous work. We hope that our work will entice others to do the same.

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