Attending to Slowness and Temporality with Olly and Slow Game: A Design Inquiry into Supporting Longer-Term Relations with Everyday Computational Objects

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ABSTRACT
Slowness has emerged as a rich lens to frame HCI investigations into supporting longer-term human-technology relations. Yet, there is a need to further address how we design for slowness on conceptual and practical levels. Drawing on the concepts of *unawareness*, *intersections*, and *ensembles,* we contribute an investigation into designing for slowness and temporality grounded in design practice through two cases: Olly and Slow Game. We designed these artifacts over two and a half years with careful attention to how the set of concepts influenced key design decisions in terms of their form, materials, and computational qualities. Our designer-researcher approach revealed that, when put into practice, the concepts helped generatively grapple with slowness and temporality, but are in need of further development to be mobilized for design. We critically reflect on insights emerging across our practice-based research to reflexively refine the concepts and better support future HCI research and practice.

Author Keywords
Slow Technology; Temporality; Research through Design.

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

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 shape and structure people's everyday lives. In their seminal article on *Slow Technology*, Hallnäs and Redström argue that the increasing availability of technology outside of the workplace requires the HCI community to expand its 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*" [19:161]. These authors outline a design research agenda aimed at inverting values of optimized performance and creating technologies that support moments of self-reflection as well as critical reflection on technology itself. Building on the slow technology philosophy, Vallgårda and colleagues [64,65] have argued it is imperative for designers to critically attend to the *temporal form* of digital artifacts, and how their temporal expression shapes the possibilities, relations, and perceptions that people form with them over time.

Figure 1. Olly (top) is a music player that slowly surfaces songs from its owner's past. Slow Game's (bottom) gameplay slowly unfolds over long time periods.

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Notions such as slowness and temporal form offer promising lenses to frame the question of how ongoing and longer-term relations could be enabled with computational objects. While the HCI community has seen a resurgence of interest in this area, tensions have also surfaced. Early articulations of designing for slowness and temporality are somewhat abstract, and researchers and designers have struggled to varying extents with creating technologies that manifest slower temporal expressions, and sustain long-term human-technology relations over time [4,11,22,39,40].

Our particular position and approach to these matters originates with and concerns design research in HCI. This designer-researcher position 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*" [37:33]. Designer-researchers often function as a small but multi-disciplinary team that is reflexively focused on the experimental and novel outcomes of the design process that are critically and reflectively arrived at through design practice. Thus, design research in HCI can contribute a highly insightful, first-hand, and reflexive view of practices of making design artifacts in relation to higher-level concepts framing key decisions in the design process and in light of attendant materials, tools, methods, and competencies.

The overarching goal of this paper is to contribute a conceptually informed perspective on designing for slowness and temporality through design practice. Recent research [42,67] has proposed *unawareness*, *intersections*, and *ensembles* as related conceptual terms that are united in an emphasis on moving beyond solely focusing on interaction to account for the implicit, incremental, and, at times, unknowing encounters that emerge among people, things, and the environments they inhabit. These terms offer a potentially rich generative lens to frame initiatives aimed at designing for slowness and temporality. Yet, little work has applied these concepts in the creation of new artifacts to scaffold and explore their potential for design practice.

Our paper contributes a detailed case study of how these three concepts shaped key decisions in our process of making two design artifacts: Olly and Slow Game (see Figure 1). Olly is a music player that occasionally, yet perpetually surfaces songs from its owner's past. Slow Game is a simple game whose gameplay slowly unfolds over long time periods. Our process of making these artifacts unfolded over the course of two and a half years. The research aim of both Olly and Slow Game is to investigate the nature and design qualities of computational objects that can be given meaning by people in a slower, emergent, and longer-term manner as they are lived with.

This paper makes two contributions. First, it offers a reflective account of how we adapted the sensitizing concepts to grapple with slowness and temporality through our practice of designing two highly resolved design artifacts with attention to their materiality, form, and computational qualities. Second, it critically reflects on insights revealed through decisions in our design process to reflexively develop the concepts to better support HCI initiatives aimed at designing for slowness and temporality.

BACKGROUND AND RELATED WORK

Temporality—the state of existing within time—shapes virtually all aspects of how we experience and construct the world around us. There is extensive literature exploring the concept of time from many perspectives in the humanities and social sciences [c.f., 6,38]. 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 dialogue between a human and computer begins, unfolds, and resolves. Early proposals such as Calm Technology [69] and the ambientROOM [23] 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 [34].

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*" [35:11]. This argument echoes Hallnas and Redstrom's [19] seminal call for design initiatives to amplify and stretch *time presence* in everyday life, and reveal an expression of present time that is slower. These issues remain important for the 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 [7,29,54], pause [32,66], and solitude [15].

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 [14], Grosse-Hering et al. [18] designed a series of juicers that aimed to support meaningful interactions by slowing down key parts of the juicing process. Slowness has been applied as a frame to explore strategies for extending object lifespans. For example, The Long Living Chair [50] captures and displays the amount of times people have sat over its lifetime. Slowness has also been applied in design efforts to support experiences of anticipation [61,62] and social connection [21,25,43,60] over long time periods.

More broadly, HCI researchers have started to turn their attention to examining different perspectives of time. Lindley [31], Pschetz et al. [49,51], and Sengers [53]

envision time as socially entangled and relational, highlighting the need for alternative expressions of temporality in design. Taylor et al. [58] offer a rare account of a cross-cultural design project that emphasizes time from an Australian Aboriginal community's perspective. Across several works [e.g., 12,13], Friedman and colleagues sought to expand initiatives in HCI to consider multiple lifespans. 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 [27], narrative time [3], sequential time [33], and ephemerality [8], as resources for design.

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 [22,39]. The infrequent yet ongoing computational action of slow technologies can make it difficult to establish a sensibility for when the temporal pacing is 'right' [40]. Others have reported difficulties in aesthetically manifesting subtly changing computational actions in a resolved physical form [4,11,52].

These tensions highlight the complexity of designing technologies that deviate from enacting normative conceptions of time. This resonates with the work of Vallgårda et al. [15], 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*" [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 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 of design artifacts as a form of inquiry in and of itself [16,45]. Our work aims to precisely contribute to this area. We describe and reflect on insights that emerged through our process of designing Olly and Slow Game. Our goal is to materially ground a conceptually-informed approach to designing for slowness and temporality with attention to key design decisions shaping the materiality, form, and computational qualities of our design artifacts.

SENSITIZING CONCEPTS

The concepts of *unawareness*, *intersections*, and *ensembles* originated in two recent works [42,67] that analyzed existing design artifacts including Photobox [41], table-non-table [67], Indoor Weather Stations [17], and Discovery-Driven Prototypes [30]. The three concepts were originally envisioned to analytically capture key qualities in these design artifacts in order to develop the higher-level notions of unremarkable creativity [42] and unselfconscious interaction [67]. The three concepts have not previously been mobilized in generative efforts to design for slowness and temporality, or in design practice more generally.

Key to unawareness, intersections, and ensembles is a united emphasis on moving beyond a sole focus on *interaction* to better account for the implicit, incremental, and, at times, unknowing encounters that emerge among people, things, and the environments they inhabit. In our view, these concepts could be valuable for design because they offer a lens to attend to and anticipate the temporal qualities of this notably broad set of human-technology-environmental relations. Yet, no work has applied these concepts in the crafting of new design artifacts to explore how they could be scaffolded in designing for slowness. Next, we summarize the concepts to preface our reporting on how they shaped key decisions in the process of designing Olly and Slow Game.

Unawareness refers to designing computational objects that do not require or rely on the attention of their owner to operate. Unaware objects are open to be engaged with, but are not dependent on a person interacting with them in order to perform computational behaviors. They execute preset computational processes and, in this sense, operate entirely 'unaware' of their owner's presence or actions. They also have no explicit output functions based on interaction with them and they lack traditional 'interface' or control mechanisms. This approach is a counter exploration to the idea of 'smart' technologies that are always available, and may infer or anticipate our behaviors.

Intersections refer to people's implicit and ongoing encounters with a design artifact in which a direct modification may or may not occur. While interaction often involves direct manipulation, intersections can range from being mindful of the artifact, to subtle uses of it, to piecemeal re-situations of it in its physical context. Intersections can be treated as complementary to interaction, but are more general in their aim to account for the range of known and unknown encounters that unfold with computational and analog objects alike.

Ensembles manifest through cumulative intersections. As intersections accumulate, qualities emerge that go beyond an individual artifact; it often becomes experienced among a holistic ensemble of things and people in a local environment. For example, consider the interrelations that exist among the different things we have on display in our homes, how they uniquely reflect us, and how they subtly, yet continually change. Similarly, an ensemble is a dynamic collection of social and material elements in an everyday setting that become unique and nuanced over time.

Figure 2. Olly. Top (Left to Right): **T1.** An early functional MDF prototype; **T2.** Rich veneer wood grains move in and out of alignment as the internal disc rotates; **T3.** A pending song is played by spinning the rotating disc; **T4.** Olly can operate lying flat (or in any other orientation). Bottom (Left to Right): **B1.** MDF chassis with low-wear timing belt driving Olly's rotation; **B2.** 5mm aluminum plate with boat-grade veneer epoxied to it; **B3.** Three Olly research products; **B4.** Design team member (Odom) living with Olly during testing.

DESIGN RESEARCH CASES: OLLY AND SLOW GAME

Olly and Slow Game are two cases in which we drew on unawareness, intersections, and ensembles as sensitizing concepts across our inquiry. Our goal in this paper is to interweave a critical reflective dialogue on slowness and the three concepts, and to account for their influence on very specific design decisions related to the materials, form, and computational qualities of our design artifacts; and, to discuss these decisions to reflexively consider the concepts in relation to slowness and inform future design practice.

On a general level, our methodological approach is influenced by the range of works in HCI that are united in their emphasis on the importance of creating design artifacts as a means to uncover new knowledge that could not have been arrived at otherwise [e.g.,1,2,9,10,24,48,56,70]. Specifically, we position our work within a designer-researcher stance; we aim to contribute a first-hand account of key insights emerging through our process of arriving at two highly resolved design artifacts. With this in mind, we frame our research through the related methodological approaches of *material speculation* [68] and *research products* [44]. Material speculation is the crafting of a counterfactual artifact to carefully inquire into research questions. A counterfactual artifact is a fully realized system that in a use context may contradict what would normally be considered logical given the norms of design and design products, and may seem to have only an ostensible or weak purpose. This, in turn, requires intentional design with a design goal that is manifested through careful attention to the crafting of a design artifact. Crucial to material speculation is the creation of a quality design artifact that can fit among other everyday objects despite having a weak functional purpose.

Olly and Slow Game are designed to exacting requirements with only the weak purposes of listening to music or playing a game. We also see Olly and Slow Game as research products [44]—artifacts designed to drive a research inquiry and that have a high quality of finish such that people engage with them as is, rather than what they might become; and, that operate independently in everyday settings over time. The combined requirements of material speculation and research products set the confines of our design goals and set the goals of our design process. These related methodological approaches required us to create highly robust and finished design artifacts that could operate in actual everyday domestic contexts. We produced low-volume batches of Olly (3 total) and Slow Game (14 total) to conduct long-term field studies in the future.

Our design processes for Olly and Slow Game occurred in parallel over the course of two and a half years. Olly was initially developed by Hol, Naus, Verburg, Odom, and Wakkary at Eindhoven University of Technology (Netherlands) and later completed at Simon Fraser University (Canada). Inspired by initial ideas by Bertran [5] (United States), Slow Game was collaborative developed with Odom, Lin, Tan, and Wakkary at Simon Fraser University and Hertz and Harkness at Emily Carr University (Canada). We documented each design process as it progressed, and annotated key design choices and decisions in light of the sensitizing concepts as we moved towards highly robust and finished artifacts. This paper offers a collective account by the research team; however, it does not aim to report on each and every design decision. We offer a postmortem accounting that attends to specific design decisions that were productively shaped by the sensitizing concepts, as well as cases in which frictions emerged. Next, we introduce Olly and Slow Game, and then offer a synthesized account of key design decisions and instances.

Olly

People now accumulate massive digital records associated with their personal experiences, which can be valuable resources for reflecting on one's own life. Yet, as digital archives grow larger and are more distributed, they become

Figure 3. Slow Game. Top (Left to Right): **T1.** Log felled during a windstorm; recovered by design team; **T2.** Recovered log treated with beeswax and dried over months, then cut and planed; **T3.** CNC milled batch production of enclosures; **T4.** Early form exploration; elongated cube-like form with exposed bark and moss where mini USB power cable is inserted; **T5.** Affixing hand cut and then laser cut veneer to front face of final 5cm cube design. Bottom (Left to Right): **B1.** Custom design 3D-Printed chassis with tight integration of all components; **B2.+ B3.** Several Slow Game research products; **B4**. Design team member (Odom) living with Slow Game during testing.

less visible, lacking the material presence that might enable people to engage with them over time [46]. Olly takes up these issues in the context of digital music consumption, which is exhibiting a global shift toward digital streaming services [36]. This change has enabled people to access more music than ever before and produced extensive metadata records that capture each unique instance in which a song was listened to—offering a potentially rich design material. Music also offers an inherently temporal medium: it structures time to be performed and can only be experienced through the time in which it is listened to.

Olly is a slow music player that enables people to experience digital music they have listened to in the past. Olly is linked with its owner's Last.FM [71] online account. Last.FM is an application that runs across a user's music listening devices to archives records of music listening histories. In existence since 2002, Last.FM offers unusually rare access to its users' extensive music listening histories (when a user profile is public), which Olly uses to occasionally surface a song from from its owner's past.

Olly's central feature is the internal wooden disc encircled in aluminum (see Figure 2). When a song is surfaced from the past, it is not immediately played. First, the disc begins rotating to subtly indicate a song has been selected and is available to be played if desired. During this time, the speed of the rotation is based on how deep into the past the song was listened to (e.g., the deeper into the past, the slower the rotational speed and vice versa). To play the song, the owner must tangibly spin the rotating disc. The disc continues rotating until the song has completed playing. Each time Olly surfaces a song, the disc will make 224 total rotations. If the song is not played during this time window, it will abandon it and stop spinning until another song is eventually surfaced; the process continues indefinitely. The owner has no control over when a song will play or what it will be. The disc rotates on both sides of Olly, enabling it to be played and functionally exist in any physical orientation.

The final version of Olly consists of the following. We implemented a Java application on a Raspberry PI 3 embedded inside Olly's enclosure. It generates a database from Olly's user's Last.FM account, and uses the temporal metadata of each unique listening instance to control the level of voltage supplied to the motor driving the internal disc to alter its speed. The application randomly selects each listening instance; an updated Last.FM metadata archive is stored locally on the Raspberry PI weekly. Songs are played via another Raspberry Pi implemented with the Mopidy music server that plays music via a unique Spotify account independent from Olly's user. This Raspberry PI is implemented with a high-fidelity audio shield that communicates with Olly via WIFI to enable the user to easily listen to the audio playback in their home.

Slow Game

Slow Game's design is inspired in part by correspondence chess; a game in which players send their next move to a remote opponent via postal mail. The game requires players to both directly interact and simply live with their chessboard over long time periods. We wanted to inquire into how we could apply these slower-paced qualities to the design of a computational game. After developing high fidelity mock-ups of several games (e.g., Tetris, Pong, etc.), our design research team selected 'Snake' as a compelling game to craft into a research product.

Snake is a simple game in which a player manoeuvres 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 game over. Snake was popularized worldwide when it was included as a pre-loaded game on Nokia mobile phones in 1997 [19]. Snake's familiarity and rapid pacing made it a good candidate to augment with a slower pacing.

The final version of Slow Game expresses a low frequency of action in the Snake game: it advances one pixel forward (i.e., one move) every 18 hours. It is embodied in the form of a small wooden cube with a display consisting of 64 LEDs that are warmly muted behind a thin wooden veneer (see Figure 3). The cube offers a familiar form that can easily fit into the palm of one's hand and maps to the simple act of rotation from one flat slide onto another. The Snake's movement is bound by gravity. For example, if it is pointing 'down', it will continue to move down one pixel on the plane every 18 hours. The snake's orientation can be changed by rotating the cube 90 degrees clockwise or counter-clockwise. To 'win' the game, the snake must grow to a length of 17 pixels. If the user reaches 17 pixels—which can take several months (or longer)—Slow Game will enter into a 'win' mode, emitting a warm glow that slowly fades in and out. If the user loses, it will create a negative image of 'game over' plane (i.e., all pixels unlit will become lit and vice versa). In either case, after 18 hours the game starts again from the beginning. Slow Game cannot be paused or restarted. If it loses power (and the battery dies), it will always remember its place in the game.

The final version of Slow Game consists of the following: a 3V Adafruit Arduino trinket (which runs the Snake application); an Adafruit 8x8 white LED matrix with driver backpack; a mini-USB LiPO charger and battery; and, a 3D compass and accelerometer (with integrated voltage regulator). These components are mounted onto a 3D-printed chassis that we custom designed to ensure the components remain in place and tightly fit the spatial constraints of the wooden cube enclosure.

Attending to form and materials: evoking and anticipating time

On a general level, early visions of slow, calm, and ambient technology collectively advocate for designing systems that can easily fade between foreground and background of everyday life. This work certainly influenced our approach. Yet, unawareness, intersections and ensembles gave us a more specific set of constraints to conceptually ground our design practice. The design artifacts needed to be open to people's brief encounters, fleeting reflections, and piecemeal reconfigurations to other things, in addition to direct manipulations and interactions. These combined concepts highly influenced decisions related to the form and materials of our design artifacts, which we turn to next.

Reflecting on the form and materials of Slow Game

We initially considered several forms for Slow Game (e.g., a sphere, cylinder, pyramid), but decided on a cube because it enabled us to leverage the simple affordance of rotating it from one side to another as the primary input for the game. This meant we did not have to include buttons or interface control mechanisms – a key constraint in crafting unaware objects. We anticipated this small, recognizable form would enable it to easily fit in relation other things and places in a home (e.g., on a mantle, bedside table, etc.). We speculated this form could catalyze intersections and emerge in ensembles over time precisely because it is so simple, easily configurable, and left it up to the user to decide where it should go in her home.

After considering numerous materials including silicone, leather, and metal, wood emerged as the best choice on both practical and conceptual levels. The material qualities of wood can project a sense of warmth and endurance that resonate with long-lasting domestic objects. Conceptually, wood itself is bound up in time; its natural fibres are developed over years, often forming 'growth rings' that express its age. Wood presented a flexible material that itself requires long time periods to grow and it was an ideal material to produce a sturdy enclosure for the electronics. Because wood can also be worked down to a thin veneer, it also offered a rich way to mute the brightness of the LEDs such that the display remained persistent, while not demanding attention—a quality important for intersections.

We sourced the wood for Slow Game from a cherry tree felled during a windstorm in Vancouver, Canada. This choice did not provide the easiest or most efficient path forward. It was motivated by our desire to engage with the temporal qualities of the material. After treating it with beeswax and drying it over several months, we cut and planed several pieces, and conducted experimental form studies by fabricating small batches of different cube-like forms with a large format CNC mill. We created enclosures that situated the exposed tree bark on the cube's backside where the charging cable is inserted to evoke a poetic contrast between the natural and artificial. Yet, this design choice made it feel like an artistic showpiece and required it to be deeper (i.e., it was no longer a cube). These issues made Slow Game feel too extraordinary and complicated the subtle, mundane quality needed for an object to settle in ensembles of other things, spaces, and people.

The final design of the 5-centimeter wooden cube evokes a warm, minimal aesthetic. We produced a small batch of 14 cubes; each of which has an open face to front-load the electronics and a small slot for the micro-USB power connector. We hand-cut paper-thin sheets of veneer from the same log, laser cut the veneer to conform to the cube's front face, affixed the veneer to the front of each cube, and sanded and oiled the cubes to produce a quality finish.

Reflecting on the form and materials of Olly

Olly introduced different challenges compared to Slow Game due to sound being a temporal and immaterial matter. Creating a music player that was completely 'unaware' and played a song immediately when selected would be

disruptive and demanding of one's attention. We needed to create a design artifact that manifested songs in a way that was momentarily present, subtle, and invited intersections over time. We began our process by exploring qualities of earlier music listening technologies designed for the home. After reviewing numerous radios, record and tape players, we were inspired by the minimal, yet rich experience of 'pick and play' turntables. We were drawn to the experience of picking up the needle arm and seeing the turntable then spring to life as it began rotating. The slight shimmer of the rotating aluminum disc on the turntable bed in our view was a rich metaphor to draw on; it prompted us to consider how we could use physical rotation as a motif to indicate when a new song has been selected in an unobtrusive way.

Keeping in mind intersections and ensembles, we wanted to create a form that could be easily configured and re-configured in and to everyday settings. Our team initially considered a purely circular form, but this alternative was too limited because it could only operate on a flat surface (e.g., on a table or wall). Through further iterations, we found that a teardrop-like shape with an internal rotating disc visible from both sides could generated an unfamiliar, yet inviting design. It exhibited an easily readable area for output and interaction in a form that could operate and firmly stand in any orientation (i.e., on its side or lying flat). This decision was highly influenced by the concept of ensembles; by creating an artifact that could operate in any orientation, we anticipated this would naturally open it up to other objects being situated on and around it over time.

We began exploring Olly's material aesthetics by affixing different paper patterns of wood grain and metal rings to the MDF prototype. This exploration revealed unexpected possibilities in using wood veneer—by layering veneer cut from the same sheet across each disc and each corresponding side, we found that this could very subtly represent changes over time. Each time Olly stops rotating, the orientation of the wood grain on the disc in relation to the body is, in all likelihood, different from the prior orientation. This subtle tracing of change seemed apt to stimulate intersections. For example, it prompted us to speculate on the range of intersections (and eventual ensembles) that could be triggered: e.g., briefly contemplating what Olly might have selected when one was away, placing a trinket on the disc to make unseen rotations more visible, or perhaps moving it to a more visible place in the home. Changes in the wood grain alignments could easily go unnoticed too. These decisions enabled Olly to subtly express temporal changes that could lead to accumulation of intersections, in addition to the interaction of spinning the disc to play momentarily surfaced songs.

To raise Olly to research product quality, we created an external enclosure with reinforced veneer and aluminum. We anodized the aluminum to protect it from scratches and selected a fine oak veneer traditionally used in boat cabins due to its long-lasting quality. We waterjet-cut 5-millimeter thick aluminum plates, and epoxied the veneer onto the plates to prevent mutations that could result from long-term exposure to fluctuating temperature and humidity levels.

We reinforced the internal chassis with steel pins, and integrated a low-wear timing belt connected to a set of two 90 degree gears attached to the motor to actuate the disc. Springs were also integrated to anticipate changes in tension when a user spins the disc to ensure it will hold up over long-term use; multiple coats of beeswax and oil were applied to the veneer to bring out a warm shimmer in the disc as it reflected light while rotating. We produced three Olly research products through these processes.

Similarities of form and materials in Olly and Slow Game

Collectively, Olly and Slow Game share several important similarities in terms of design decisions in their form and materials, which were highly shaped by the concepts of intersections and ensembles. Both are embodied in forms that remain open and flexible; they invite owners to determine where they ought to fit in their home and what ought to be configured around them. Indeed, the 'proper' way a thing may fit in our life is a dynamic point of reference that naturally shifts and changes over time. Material choices in our design artifacts were selected to evoke time and anticipate longer-term relations. Olly's pairing of reinforced veneer with an aluminum circle subtly captures traces of change over time as the circular wood grain comes in and out of alignment with the remaining unmoving veneer. Slow Game's hardwood enclosure dovetails with maple veneer that reveals flat grain lines developed over the tree's growth; it subtly expresses the temporality of the material in a robust physical enclosure.

Attending to computational and temporal form: structuring and expressing time

Next, we attend to key insights and tensions emerging through our design practice that helped balance the concept of unawareness with the need for design artifacts to remain intriguing in the long-term. The process of arriving at the research product versions of Slow Game and Olly required over six months of testing to develop their respective software and hardware. Speeding up the pace of either design artifact would not provide an authentic sense of the felt experiences of slowness and unawareness. As a result, some design team members lived with prototypes of each design artifact as a part of our design process, which we describe in further detail next.

Reflecting on computation and temporal form of Slow Game

Over a six-month period, Odom, Hertz, and Lin lived with Slow Game prototypes, which yielded insights related to its pacing and intelligibility. We initially implemented Slow Game with a pacing of one move per day; an unwavering cycle that started exactly when it first powered on. Over time, we found this choice produced a methodical, 'clock-like' quality. If the next move transpired during a time period when a user might readily notice this change (e.g., daily at 8am), it was thrilling at first, but became predictable. It was equally unideal if the next move always

occurred at a time that a user was unlikely to notice for long time periods (e.g., several days). These collective experiences made us critically re-think Slow Game's pacing and highlighted the need for it to depart from a 24-hour cycle and indeterminately phase in and out of sync with the temporal rhythms of people's everyday routines.

Through iterative experiments, we also 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 forgotten. We found that an interval of one move per 18 hours created a dynamic, yet balanced quality of experience. This pacing enabled Slow Game to operate on its 'own time', while remaining inviting and intriguing.

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. This ultimately produced experiences of frustration and disengagement across design team members. We desired to make Slow Game unaware such that it did not require a user's attention to operate. Yet, it was clear some type of feedback had to be integrated to sustain intelligible and enjoyable experiences with it. This prompted us to re-think our application of unawareness and adapt the concept in a more flexible way. We included 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, or 'set' the 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 move, and becomes inactive for the remaining cycle. Whether manipulated or not, Slow Game indefinitely continues to move through time.

Reflecting on computation and temporal form of Olly

Our practice of designing Olly also required attending reconciling the connection between pacing and unawareness. It came with the added challenge of designing a technique that selected songs and subtly expressed their availability to be played in a brief temporal window. We decided to develop a random selection algorithm that was in part inspired by prior work demonstrating that randomness can help sustain ongoing experiences of curiosity [28,62].

Over the course of a six-month period, Hol, Naus, Verburg, and Odom lived with Olly prototypes during intervals that ranged from a few days to several weeks. These prototypes exhibited higher (e.g., ~1 song per hour) and lower averages (e.g., ~1 song per week) of randomly surfaced sounds. Through these experiences and discussions of them among the design team, we collaboratively arrived at a selection of roughly 8 songs per week to represent a frequency that struck a balance between enabling a user to notice a surfaced music selection once or a few times a week, while enabling Olly to remain unobtrusive and undemanding. On a technical level, Olly conducts a 'dice roll' every six minutes that has a 1/200 chance of success; this equates to an average weekly selection of 8.4 songs. When a success occurs, Olly randomly selects a specific listening history instance from the user's entire Last.FM library (i.e., a specific song with metadata indicating precisely when it was listened to in the past). Olly then enters a 'pending' state in which it makes the song temporarily available to be played by rotating; the user can spin the disc in the direction it is already rotating to trigger the song to play. During the pending state, Olly will complete a maximum of 224 rotations. If the user does play the song, it is abandoned and returns to a dormant state until another success occurs. This process continues indefinitely.

While we considered alternative modalities such as sound and light to communicate the brief temporal windows in which Olly has surfaced a song, we found actuated motion to be the most compelling. It was the most unobtrusive compared to sound and light, and it also enabled us to use Olly's rotational speed as a technique to subtly encode how old or new the selected listening instance is in the user's archive. For example, a metadata instance in which the user played the song long ago will exhibit a slower rate of rotation compared to an instance that is more recent. On a technical level, supplying different voltage levels to the motor enabled us to change the speed of rotation. 4.4V is the lowest functional amount of voltage, which represents the oldest song in a user's library, which requires about ten minutes to complete 224 rotations, and 12V is the highest, completing the 224 rotations in about 4 minutes. The rotational speed related to specific music selections will take time to interpret and contemplate. Over time these subtle differences may become more discernible and personally meaningful. For example, when a new owner of Olly would notice the first handful of selected and rotating songs, she would not have a baseline for considering when in her life she had previously listened to them. Yet, over the years as hundreds or thousands of songs are noticed and possibly played, she may develop a sensibility for anticipating or reflecting on when in her life the surfaced song was associated with.

Our implementation of 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 (i.e., not relative to the oldest and most recent listening instance). For example, the absolute fastest rotation could only be triggered if Olly selected an instance of a song that the user had listened to that week. If new entries ceased to appear in a user's Last.FM account, all of the songs in the Olly database will continue to grow older irrespective of the actions of its

owner. In this way, our choice to use rotation to subtly communicate Olly's oscillations between awareness and unawareness also enabled us to encode an added layer of temporal expression into the design.

Similarities of computation and temporal form

The design decisions we highlighted in both Olly and Slow Game illustrate how their temporal qualities are directly shaped by their perpetual performance of actions over time, which are mostly unaware of user engagement. This enabled us to structure time in ways that are humanly understandable, but which productively depart modulate in and out of alignment with people's everyday rhythms bound to clock-time. Precisely because the computational expression of these design artifacts manifests the movement of time through them, they open up possibilities for sustaining ongoing and indeterminate experiences; experiences in which 'interaction' in a traditional sense remains extremely minimal.

DISCUSSION AND IMPLICATIONS

Through a critical reflective accounting of key design decisions in our RtD process, we aimed to extend a conceptually-informed approach to designing for slowness and temporality. While there is growing interest in and outside of the HCI community in designing technologies that invite slower, longer-term relations, there is a lack of design artifacts and situated accounts of design practice in this research space. The central contributions of our paper take a step toward addressing this gap.

Our designer-research approach was guided by the sensitizing concepts of *unawareness*, *intersections*, and *ensembles*, which we drew on to frame, grapple with, and closely attend to our inquiry into designing longer-term relations with everyday computational objects. Prior research had developed this set of concepts to analyze pre-existing design artifacts, such as the Photobox [41] and table-non-table [42,67]. Here we move beyond analytical use of the concepts to a generative use. Our approach allowed for a deeper understanding of these sensitizing concepts by revealing how they can be applied in design practice and where frictions emerge. We found that they productively supported working through slowness and temporality in the interweaving of design decisions across the computation, form, and materials of our design artifacts. Insights from our RtD process also revealed limitations in these concepts and highlighted the need for them to be further developed and to be better utilized on a practical, concrete level for design. Next, we critically reflect on how unawareness, intersections, and ensembles generatively worked together in the designing of Olly and Slow Game, and discuss implications that these insights suggest for the original articulation of the concepts. Our goal is to extend these concepts as an approach that can support the HCI community in designing for slowness and temporality with added precision and nuance.

Working with unawareness to open a design space

From a conceptual level, unawareness opened a design space for us to better attend to temporality by displacing the human-centered focus on interactivity as the main concern of our design inquiry. It required us to carefully think through how we could craft design artifacts that remained open to engagement, yet operated largely irrespective of human involvement. On a basic computational level, Olly will select songs indefinitely, regardless of whether they are listened to; Slow Game will perpetually advance one move every eighteen-hour interval and can never be restarted. We found that this independence enabled both design artifacts to evoke a unique temporal pacing and trajectory. These same general qualities were similarly embodied by the earlier design artifacts Photobox and table-non-table. Each operated completely unaware of and largely unaffected by their local environment or owner(s). Computationally, their state changed on their own time in parallel to and, at times, intersecting with people's everyday rhythms, and routines.

While unawareness fundamentally framed our RtD process, over time it became clear that this concept could not be too literally applied in design practice. We found that integrating "moments" of awareness in Olly and Slow Game was crucial to evoking a pacing and degree of intelligibility that could lead to ongoing relations and experiences with them. For Slow Game, this meant including feedback that communicated the status of its current place in time, but did not enable the user to advance to the next move. For Olly, this required using rotational motion to subtly signify when a brief temporal window of 'awareness' opened in which a user could trigger a song to be played (if desired). These design decisions evoke a computational quality and character that substantially differ from Photobox and table-non-table, both of which offered no insight to end-users on their status or state.

Conceptually, unawareness reveals how independence is critically important to expressing a distinct and ongoing computational pacing—a quality that appears central to supporting relations and experiences that unfold over a longer temporal trajectory. Insights from our RtD process highlight the importance of subtly balancing independence with the ability to still remain open to human engagement. These insights suggest that the concept of unawareness should be treated with less rigidity in design practice. Designing artifacts that do not require or rely on attention from their owner to perform their behavior proved to be highly valuable for designing for slowness and temporality. Yet, our work also revealed that it may be important, perhaps essential, to integrate subtle output functions to communicate their temporal status or state. In this way, unawareness advances how designers can conceptually approach designing for slowness by providing a lens to explore how the computational actions of a design artifact can be structured ways that evoke rich, yet relatively minimal interactions and operate independently, while still remaining intelligible for end users over time.

Intersections and ensembles: foregrounding manipulability and lived-with quality over interactivity

Across our design inquiry, intersections and ensembles worked together to ground our form and material design decisions in the conceptual space that unawareness opened up. Intersections prompted us to closely work through how we could craft and situate design artifacts in relation to people in ways that expand beyond a focus on interactivity. Ensembles guided us to see how design artifacts can invite and form relations among other things in a local environment. While from a purely conceptual perspective ensembles might emerge from intersections that accumulate around a design artifact over time. In practice, we found that the two concepts mutually inform each other and the boundaries between them should be seen less rigidly.

Our RtD process also made clear that leveraging intersections and ensembles to attend to slowness and temporality was both subtle and complex. We needed to create design artifacts that could invite simple engagements, and achieve a high quality of fit among the things and places populating mundane everyday settings. These conceptual constraints pushed us to tightly bring together form and materials in our design decisions to foreground the manipulability and lived-with quality of each design artifact over interactivity. As a result of attending to these concerns, the final forms of both design artifacts explicitly aimed to not over-determine how and where in people's dwellings the artifacts may be situated. For Olly, this catalyzed our move to design a teardrop-like form factor that could operate in any orientation, which, if laid flat, produced a sizeable flat surface that other things could intuitively accumulate on and around. Slow Game's simple, familiar handheld form enables it to be integrated among many things in any domestic space. The form decisions across both artifacts intend to subtly open up a space for people to consider not only their own relation to the design artifact, but to configure, manipulate, and resituate it in relation to other things in their home over time.

In both cases, the form was tightly paired with carefully thinking through material decisions. The anodized aluminum encasing of Olly evokes a robust character that is resistant to wear as it is moved around and across a home (or homes) over time. The reinforced fine veneer on Olly's dominant sides amplifies its temporal texture; even if in a dormant state, the differing alignments of wood grain between Olly's disc and body express subtle traces of action that may trigger fleeting reflective moments if noticed. The warmth and glow evoked by Slow Game's wood veneer face and the uniformity of its smooth wooden finish projects an enduring quality that will hold up.

Collectively, these insights help conceptually advance designing for slowness and temporality by illustrating the importance of giving prominence to form and materials in relation to their ongoing (and largely unaware) computational expression of a design artifact. Closely attending to form and materials opens a continuum where the manipulability and lived-with quality of a design artifact operates as a bridge between intersections and rich, yet highly minimal interactions. In this way, intersections and ensembles offer added clarity on how to grapple with crafting computational objects that, by design, aim to slowly acquire situated meaning as their place in one's life is developed cumulatively and incrementally by virtue of their formal affordances, material qualities, and indeterminate, yet perpetual computational behavior.

CONCLUSION AND FUTURE WORK

We have described and critically reflected on our collective practice of designing and making Olly and Slow Game. Our aim was to generatively inquire into how unawareness, intersections, and ensembles could offer conceptual scaffolding for grappling with slowness and temporality in design. We closely attended to how this set of concepts influenced key design decisions that structured and expressed time across the materiality, form, and computational qualities of our design artifacts. Through a reflexive designer-researcher approach, our work provides insights into how the quality of independence generated through unawareness could enable design artifacts to evoke a rich and unique slower temporal expression. Intersections and ensembles helped operationalize unawareness through refocusing our attention beyond interactivity toward subtle design qualities that, over time, could give rise to a wider range of relations among people, things, and environments. Insights from our research revealed that these concepts need not be treated so rigidly when applied in practice.

In summary, the more flexible, revised vision of these concepts offer promise to be scaffolded in future efforts to design for slowness and temporality by shifting the primacy of what we attend to in design: (i) for materials, focus shifts to how they evoke and will persist through time beyond how they feel 'now'; (ii) for physical form, prominence is given to decisions that explicitly invite encounters with other things as well as other people; (iii) for computation, emphasis expands beyond immediate response time to crafting a temporal pacing that is distinct, indeterminate, and ongoing.

Importantly, our aim is not to be prescriptive or conclusive. A multiplicity of approaches is needed to open up new ways of conceptualizing and designing diverse expressions of time as technology increasingly becomes embedded in everyday life. We hope our work will inspire future HCI research and practice initiatives into designing for slowness and temporality. More generally, we hope the critical reflective reporting of our designer-researcher approach can be appreciated as an effort to better support design-oriented forms of knowledge production in the HCI community.

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