Designing for Extreme Sleepers: Rethinking the Rhythms of Sleep Technology

Kasper Karlgren
kasper@dsv.su.se
Stockholm University
Stockholm, Sweden

Donald McMillan
donald.mcmillan@dsv.su.se
Stockholm University
Stockholm, Sweden

ABSTRACT

Sleep takes one-third of our life and is of increasing technological interest. Yet development has been focused on the traditional notion of 8 hours-per-night schedules of 'good sleep' – overlooking the varied nature of people's sleeping and waking practices. Based on the experiences of Shift Workers, Gamers, and Polyphasic Sleepers, this paper exposes the sleep practices of *extreme sleepers* for the design of technology. This cohort follows sleep patterns outwith those encoded in current technology for work, will and well-being. Through interviews and design workshops, we present three themes emerging from these perspectives on sleep. These themes revolve around the physiological, felt, and social timings of sleep. We explore a design space around these themes through eight different critical design exemplars. In conclusion, this work encourages the design of sleep technology focusing on users' agency over their own life-rhythms rather than pre-built concepts of 'good' sleep.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in collaborative and social computing**; • **Applied computing** → *Health informatics.*

KEYWORDS

Sleep, Self-tracking, Health Informatics, Personal Informatics, Speculative Design, Research Through Design

ACM Reference Format:
Kasper Karlgren and Donald McMillan. 2022. Designing for Extreme Sleepers: Rethinking the Rhythms of Sleep Technology. In *Nordic Human-Computer Interaction Conference (NordiCHI '22), October 8–12, 2022, Aarhus, Denmark.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3546155.3546685

1 INTRODUCTION

When and how we sleep has long been governed by societal development driven by technology. From the rapid introduction of reliable artificial lighting in the 1800s and 1900s to the development of the alarm clock – these technological artefacts changed what it means to sleep and what it means to stay up. More recently, development advances through the dissemination of new sensing technology [5, 21] in wearable and near-bed technology and system features such like Nightshift[1] are designed to either track or influence our sleeping patterns. This influence is often supported through the collection of bio-tracking data that provides users with insights into their sleep.

Yet the development of sleep-influencing technology is still deeply anchored in the embedded cultural values surrounding sleep and productivity, and evident in our language around sleep. We structure time into socially normative categories of *work & leisure*, *weekday & weekend* and *sleep & awake*. Historically, this can be seen from examples of the first alarm clocks and knocker-uppers [14] securing structure of timing of work, to the more recent bedtime reminders and sleep cleanliness scores provided by the Oura ring [42] and Fitbit [18]. Many of these tracking systems are built around normative concepts of 'good' sleep, and productive scheduling [46] – and often fail to support the real agency of users who elect to live outside of these norms. Estimates of the number of people living and working outside of such normative sleep schedules vary by geographical location from around 17% to 38% of the workforce [38]. In this paper, we explore different ways that technology can be designed to engage with sleep for those who do not conform to normative sleep practices by choice or by profession. This work proposes that a new focus on people whose sleep patterns depart from what is considered normal healthy sleep can work as a design inspiration for new sleep designs that focus on the end users' agency over their body rhythms.

We conducted workshops and interviews to explore the experiences of 17 non-normative sleepers. These 'extreme sleepers' [25] – who sleep in various ways outside the cultural norms encoded in the design of current sleep-adjacent technology – provided a varied perspective on sleep, through speculation with caricatures of even more extreme characters based on Reddit forums on sleep [15]. We explore the possibilities of designing sleep technology for *new sleep practices*. In particular, we discuss the implications of designing for those who for varied reasons sleep in other rhythms than the conventional 8 hours at night – shift workers, gamers or *polyphasic sleep hackers*[2]. We also get insight into some of the core problems of how existing technologies conceptualise and visualise sleep.

The relationships between sleep practices, sleep norms, and consumer sleep technologies inspired a set of designs for how we can re-conceptualise the representation of sleep in interaction. First, we present a set of different ways to revision the timing of sleep around different rhythmic bodily processes. These designs place hunger, digital-stimuli influence and sleep debt as the metronomes, showing how our understandings of, experiences of, and decisions

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

ACM ISBN 978-1-4503-9699-8/22/10.
https://doi.org/10.1145/3546155.3546685

[1] A feature to reduce the blue light emitted by screens between certain hours
[2] The practice of sleeping in more that two segments of sleep per day

around sleep are not always bound to the clock. Secondly, we address how sleep rhythms are socially influenced – in two designs for supporting 'night owl' schedules, we present opportunities to design for both choosing to experience social cues that match current rhythmic states and to impart the experience of your own rhythmic state on those around you. Lastly, we address in design the conceptualisation of time in which all hours are 'equal.' Drawing on the experiences of our participants in working or socialising with others on different sleep schedules, we expose the fleeting and changing perception of hours through a scheduler that renders the hours differently depending on their temporal relation to sleep and work. In conclusion, this work encourages the design of sleep technology with a focus on the users' agency over life-rhythm, rather than on pre-built concepts of 'good' sleep. [3]

2 BACKGROUND

2.1 Sleep within society

This work intends, instead of focusing on the standardised view of 'good sleep', to shine light on the many ways sleep fits into life through varied, or even extreme, perspectives on sleep. Historically and culturally, sleep is much more varied than one might think yet the view of sleep routines and practices commonly encoded in design do not reflect this. As such, the positioning here of 'extreme' sleepers is in relation to the prevailing values and expectation in current sleep technology and design.

When we sleep, and when it is socially acceptable for us to sleep, is heavily influenced by the culture in which we find ourselves. As culture changes, so does sleep. Indeed, in many cultures sleep is at times bi-phasic [57]: divided into two segments of sleep separated by an hour or more of time spent awake during the night. Segmented sleep is more often build from naps, such as in the widespread use of nap and siestas [40]. Naps during workdays have been both of social and political significance, such as the right to *xiu xi* (short rests) in Mao's constitution in China [24], the disappearing siesta in Spain [24], or the culturally acceptable *inemuri* (short naps) in Japan [54]. Taking napping further, *polyphasic sleepers* [50] discuss attempts to split all sleep into a series of short naps throughout the day. Other cultures view sleep as a necessary but unwelcome 'dead time' [39], a view that has persisted since well before our industrial society[3], and revolves around the idea that those who are important or highly productive achieve this by sacrificing their sleep [59]. Yet much of our modern life relies heavily on night workers in roles central to society such as blue light personnel, delivery workers or transport personnel, with resultant non-normative sleep schedules. We see different ways in which sleep has been changing over time, and even for those in 9-5 employment there are indications that expectations of availability in the modern workforce encroaches on time for sleep [47]. The participants we study in this paper then may not have been viewed as 'extreme' in all times and places, in reference to the highly normative 9-5 working culture which has taken over western sleep practice, they can be seen as 'extreme sleepers' in relation to the expected uses of sleep-adjacent technology today.

[3] "Uneasy lies the head that wears a crown" King Henry the Fourth, Part Two, William Shakespeare.

2.2 Designing for Sleep

Designing technology for sleep is slightly incongruous given that there is seldom direct interaction while sleeping. Yet this field covers many different technologies, from those aimed at improving the timing of sleep, to gadgets that promise higher quality sleep.

Design research has has an slight, but increasing, interest in sleep technology. Lockton et al's autoethnographic work studied a variety of different sleep technologies, exploring their use from the data visualisations they presented to the bed-time routines they encouraged [36]. SlumberBot explores the way a chatbot can aid reflection on sleep, and the contextual factors influencing it [34]. Somnia explored 'connectedness' between partners through smart pillows, and recommend sleep technology be designed to care for the social aspects of sleep [52]. Nguyen et al. explore the use of tangible probes for sleep tracking [41]. In the Tumble Clock the authors explored embodied interaction at the point in between being asleep and being awake [63]. Wensveeen et al. [58] explored the emotional valence of how the alarm button is pressed.

Other work focused on promotion of awareness of what they deemed good sleep practices, such as in ShutEye's use of a peripheral display [8], or in the creating interactive caring system with unified view of multiple sleep data sources [32], and through the use of games [47]. The work of designing for sleep often branch towards different ways of representing time. The DayClo reinterpreted schedules to aid reflection and planning [31]. The Reverse Alarm Clock was designed in such a way as to reinterpreted time for children to help them to understand when morning begins [43], and the Takt watch [16] focused on the sensory perception of time for those with ADHD which can be seen as an instantiation of Temporal Design - these an attempt to bring the cultural, social and economic aspects of time to the surface [45].

Artistic design has also focused on sleep as an example of a human bodily rhythm to be represented and reinterpreted in ways that provoke or question the norms. The *Artificial Biological Clock* comments on the societal pressure on women derived from the expectations around their biological clocks [51]. The *Vixen™_Circadian Stopwatch System* is speculative artwork consisting of a set of imagined interventions from Cortisone laced sandwiches to automatically administered eye drops exposing the encroachment of societal obligations, and the resultant intentional altering of ones circadian rhythm [53]. The provocative art piece *Perfect Sleep* takes the form of an installation with a 'sleep chair' and a publicly available smartphone app that encourages users to experiment with their extending own sleep cycles, with the aim of reaching a perfect' 24h sleep [10].

2.3 Sensing the body

Many of these recent efforts are built on an understanding of the users' sleep through sensory readings. Sleep sensing as a field has been growing through sleep technology research exploring *how* and *when* people track their sleep, often by looking for less obtrusive ways to bio-track as to minimise disruption to sleep. This has been approached by leveraging smartphone sensors [12, 13], smart textiles [26], personal radar systems [48], or even dreams [9, 11, 23]. While mostly designed for individuals, sleep tracking

has been extended to research on sleep environment tracking [27] and multi-user health tracking [44].

However, earlier work has reported that users fail to see these visualisations as *actionable*; it is hard to know what ones should do to improve one's score [33]. Zhang et al. argues that there is a need for actionable interventions to improve sleep quality and health [64]. Sleep scores and efficiency metrics can also lead users to try to influence variables that are hard to change, such as sleep phases, instead of caring for the influenceable factors of sleep. Ravichandran et al's review criticizes such trackers for rich yet inconsistent data that can sometimes conflict with clinical standards, possibly leading to harm [49]. Woźniak et al. state that the long term health goals of trackers fall short due to the dropping commitment levels of users, finding that transparency on how goals are computed can increase their commitment to these goals [61]. Ko et al. point out that most trackers lack validity studies and that sensory accuracy may be limited, such as when the bed is shared [29]. Yang et al. found that users struggled to assess the accuracy of the results of such systems, and to understand how the values were calculated [62].

Tracking data is presented to users, after processing and aggregation, in 'user friendly' visualisations. For example, the Oura ring [42] provides users with graphs of resting heart rate, sleep stages and values of 'restfulness' and 'sleep efficiency' dependent partly on the number of times they woke up during the night. The choice of data and representation is not neutral, and imposes a particular concept of sleep on the user. Tracking systems are often built around generalisations of the interests, health goals, and other parameters of prospective users, without understanding or adapting to individuals' needs or interests. These reflection have been brought up in discussion through works such as the critical design of fit4life [46].

What we see is that sleep has been, and still is, varied. Historically, the 'traditional' sleep rhythm reflects the cultural values of society around rest, wakefulness and production, and as such might not be as much of a ground truth for 'good' sleep as we may assume. On the other hand the development of current sleep technology relies heavily on tracking the timing, length, and 'quality' of sleep sessions – but has focused less on the social and felt experiences of when one sleeps. Design research has the tools for exploration of felt experiences, and as noted above in § 2.2 through the lens of time and rhythm. This work builds on the existing line of work that renders possibilities of change (or support of) on everyday life through the speculative sketching of future technology.

3 METHOD

To explore the challenges and opportunities around non-normative sleep practices we ran a series of workshops and interviews with a range of participants with differing relationships to sleep. Our participants were recruited to either participate in an interview or to be part of a workshop. The workshops were intended to be held in person, but due to the ongoing pandemic they were moved online using a combination of Discord for voice and video chat, and Miro to provide a shared collaborative online whiteboard. We ran 4 workshops, of which the details of the procedure are presented below. While the workshops were the goal of recruitment, due to the nature of the participants' sleep and work habits for some it was impossible to coordinate a workshop that fitted. In these cases a one-on-one interviews were conducted using the workshop materials and modified versions of the activities, including some of the artefacts created by previous participants, as prompts to discuss up how they sleep, how they relate sleep to technology, what actions they take to plan their sleep, and challenges that their sleep schedule presented for the lifestyle they wanted to lead. These interviews (6 in total) lasted between 21 and 56 minutes and the workshops lasted between 87 and 155 minutes. Here we present the participants, the workshop plan, and the method of analysis.

3.1 The participants

We recruited a total of 17 participants (13 male/4 female with an average age of 28), initial contacts were made to 4 participants through social media (via Facebook), then snowball sampling (through word of mouth, Discord groups and social media) was employed to increase the number and diversity of participants. Our pool of participants included those for whom shift work (including night shifts) was required, 5 bar-personnel and 3 hospital workers, as well as another 3 'gamers' recruited from the online community some of these shift workers participated in after work. We also reached out to the an online community dedicated to polyphasic sleep, and through their internal Discord server recruited another 5 participants. This was not an attempt to achieve saturation or to effectively cover all possible combinations of cultural, social and occupational goals and constraints that impact sleeping habits. Rather, this recruitment was viewed as an opportunity to broaden the conversation around how and when technology can influence our sleeping practices by including those that fall outside the norms encoded in traditional sleep-adjacent design. In the quotes presented below the participant names are redacted and replaced with a letter indicating their cohort (**N** for nurses, **B** for bar-personnel, **P** for polyphasic sleepers, and **G** for gamers) and a number indicating the order of their appearance within this manuscript.

3.2 Designing the workshop

The workshops were constructed around three main sections: first, a group discussion around the participants' sleep; then 'exploring extreme sleepers' and lastly 'imagining magic machines'.

The session opened with a discussion about their sleep. This discussion included an activity where the participants marked out their sleep schedules on a 6 day sleep schedule (as seen in figure 2. This format showed the days from Wednesday to Monday, to cover two transitions from 'workdays' and 'weekend' while avoiding representing a full week. The view functioned both as a way to probe the participants' sleep rhythm while encouraging them to think about their sleep habits outwith the standard 'calendar and clock' framing, but also introducing them to the format before its use in the next activity involving 'extreme sleep characters'.

Through an initial search for sleep and shiftwork related content and 'lurking' [22] on Reddit we identified four subreddits[4], from which we used the practices discussed by the users to constructed four 'extreme characters' [15]. These were constructed to be exaggerated caricatures of the most common reported issues with changing sleep schedules on each subreddit. The characters were

[4] r/nursing, r/polyphasic, r/Biohackers, r/GetOutOfBed

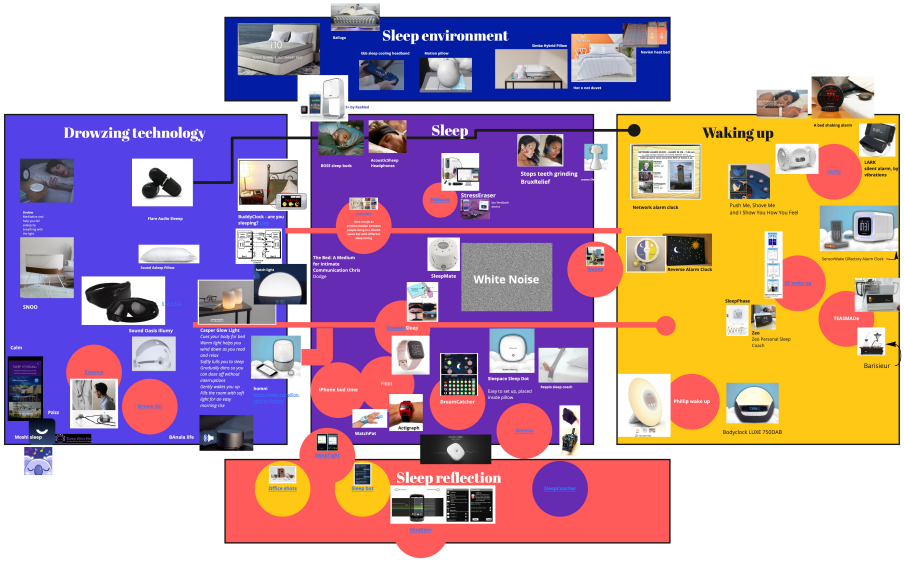

Figure 1: Map of sleep technology

presented on the Miro board as persona cards, including pictures, quotes, and sleep schedules generated from the Reddit postings. They included a permanent night worker, a sleep-focused biohacker, a polyphasic sleeper and someone unable to regulate their sleeping times. Participants were asked to explore and discuss the challenges these four extreme sleepers experienced, building on their real-life experience and attitude towards sleep, through the use of (digital) post-its.

For the last activity, the Miro board was scrolled to a section on 'imagining magic machines'. This section was inspired by the method of creating 'magic machines' [7]. Drawing from Andersen's methodology, participants were asked to envisage machines that would influence sleep practice in some way without having to worry about how it would work and speculate on its embodiment and interface to the sleeper and others in their lives.

To inspire and ground this in current sleep practices we constructed a map of current sleep technology (shown in Figure 1, larger images are available in Appendix A). In this we broadly categorise available sleep technology into five overlapping themes: *onset*; *mid-sleep*; *wake-up*; *environment*; *reflection*. This map was constructed through an open-ended exploration of existing sleep technology and involved the categorisation of over 60 consumer products, community-built tools and designs from research.

The reflections were done in form of an open discussion, pulling challenges from the 'extreme characters' and discussing situations where this problem was solved and how a magic machine bridge the gap between problem and solution. The researcher moderated this discussion and aided through note-taking.

3.3 Data and analysis

All qualitative data were anonymized, and conversations were transcribed, where necessary, translated to English by the first author, and coded following a hybrid coding approach [17]. The analysis was framed around learning from 'marginal practices'[35] to provide new perspectives on the use of technology from outliers or extreme users [25]. The development of the coding scheme was an iterative process involving both authors, drawing upon a conceptual framework developed from prior work on sleep practices (e.g. sleep phases, sleep technology, related bodily processes) and codes that emerged from the data (e.g. conceptualising time, social scheduling). This focused our analysis on different discussions around challenges in fitting *sleep* into the rhythm of *everyday life*.

4 FINDINGS

In our analysis of the interviews and workshops we discovered several different, yet overlapping perspectives on sleep and time. First, we discuss the different schedules of our participants, and then continue with our findings structured into three themes on the temporal aspects of sleep: the physiological, the social, and the experience of felt time.

4.1 Diversity of schedules

Our participants' sleep schedules captured a variety of different sleep practices. Through the collection of self reported sleep schedules we categorised their practices into four categories (as seen in Fig. 2 – blue marks sleep hours and red work hours).

Of our participants, the biggest category (5) was represented by *polyphasic sleepers* (Fig. 2-a). These participants often varied between many different schedules, balancing the desire to explore different patterns of sleep and the challenges inherrent in changing and sticking to such sleep schedules. The most common polyphasic pattern involved a much shorter period of sleep during the night augmented with non-flexible and routinised naps during the day. Another group of participants (4) pushed sleep later due to evening or night shift work (Fig. 2-c). A third group (5) were participants that slept during the day and were primaraly awake at night (2-d).

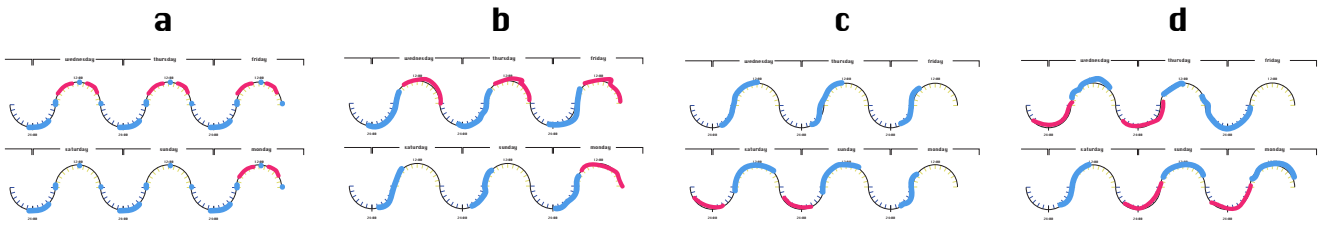

Figure 2: Four different sleep schedules

This included those who chose to stay up after late work, those who alternated between night and day shifts, and those who only worked nights. Lastly, while all of our participants were selected for their experience in shifting their sleep, some (4) were currently keeping close to a traditional sleep schedule (Fig. 2-b). This was for reasons such as not currently being involved in night shift work, or 'recovering' after having explored a new polyphasic sleep pattern.

4.2 Sleeping and the Body

Sleep was not the only bodily rhythm that regulated how our participants lived their lives. However, in changing when they slept there were cascading effects on other bodily practices that had to be planned for, and worked around, if they were to be able to meet their sleep goals.

4.2.1 Biochemical influences on sleep: One such is that of planning for hunger. When working varied and late schedules, ones eating pattern can vary as much as ones sleep – to the point of having hunger influence ones sleep. "*Many times I have to wait until the store is open at 7 in the morning. Then I run down and buy breakfast, eat it and fall asleep. At times I have had to get out from bed because it [hunger] has been so hard that I cannot fall asleep.*" (B3)

Another important bodily rhythm that the participants were discussed as becoming out-of-sync with their sleeping pattern was the ebb and flow of chemical influences. More than half of our participants reported the extra care they had to take in planning how and when to use nicotine and coffee in comparison to when they were on a 'regular' schedule. Caffeine intake was often used to regulate alertness by those that had shifted sleep schedules, but with the more complex patterns of sleep used by the polyphasic sleepers the benefits of alertness from the caffeine intake was often seen as less important than the problems that it could cause by interfering with a scheduled segment of sleep. The more complicated relationship to nicotine had its own rhythms to manage. Ensuring that the timing of a craving would not prevent or interrupt sleep was managed much in the same was as hunger, but shifting the schedules of nicotine to do so was more difficult as was managing its effects on the body. One participant explained that it was easier to get his cortisol down, a chemical elevated by nicotine, in order to sleep by using other supplements. "*A lot easier when I add glycin, or melatonin, or CBD, then I get a lot better cool-down curve.*" (B6) The use of such supplements, which was reported by a number of the people we talked to, resulted in participants conducting self-experimentation with the rhythms of their use and the influence they had on their body.

4.2.2 Cognitive influences on sleep: Participants also discussed being out of sync with sleep through discussions of the felt divide between body and mind – describing that it at times felt as bar work, while physically exhausting, did not always provide enough mental stimuli. This lead often to feeling that the body was more tired than ones mental arousal "*You go a lot on autopilot during the hours, so you don't really think that much during work. you end up not being that mentally exhausted. but your body is out, because you have been running like a maniac*" (B4).

The challenges, and the countermeasures, described here could be seen as viewing cognitive stimulation as something akin to chemical stimulation. Our participants reported similar strategies, such as attempting to move stimulating activities further away from scheduled sleeping times to avoid lengthening their *sleep latency* – the time it took them to get to sleep. Others attempted to directly shorten this latency through certain types of mental exercises, from the expected meditation-adjacent activities to encourage sleep onset to quickly trying to exhaust their mental capacity through puzzles or intensive socialising *"I think that you fall asleep as best when you've had time to vent your thoughts with your colleagues"* (B5)

4.3 Being Socially Off-Beat

One of the greatest challenges for people sleeping at different times was community building and maintaining a social life. Participants who worked night shifts expressed having continuous trouble establishing social connections or maintaining those they had.

4.3.1 Society being awake during your downtime: There are challenges reported in being out of sync with the rest of society. Most of the services and amenities of modern life are scheduled around the expectation that those using it sleep and work on a normative schedule: "*for her it was actually kind of difficult to, you know, find doctors appointments and things because she slept in the middle of the day and then even on her off date she was sleeping that way*" (P1). Even for interactions that could be moved to a time that could work for those with non-normative sleep schedules, participants described it being difficult to communicate their sleep schedule when it was out of sync with those they were meeting, such as in

establishing contact with ones land-lord: "*I have had problems with my landlord, that something is broken in my apartment. And they call only between ten and three. When I am sleeping.*" (N1)

When sleeping after having worked a night, isolation is oftentimes what people want. The participants expressed that many times one can be disturbed by the sounds of neighbours – who in attempting to keep from disturbing others with noisy activities, such as drilling or gardening, during the sleep schedules they expect of their neighbours they perform these tasks while those on nightshift are asleep. Others also reported having their sleep cut short by partners who were not sharing their schedules. "*My sleep, it disappears quite often, as [partner], she wakes up at 7-8 at times, and then I wake up as well, when the nasty Apple alarm starts, it's disgusting. Then you are disturbed and don't get any real sleep. I should have slept at-least another three hours*" (B2).

4.3.2 Being awake during society's downtime: But being too successful in creating a separation between the rhythms of society that didn't fit with their sleep patterns also caused problems for our participants. The actions we plan in coordination with others either explicitly timed such as doctors appointments or implicitly such as arranging to 'meet for lunch' or planning to go to a particular shop before it closes, are important markers of our structuring of the time we spend during a 'day'. Without such temporal events to orientate other activities during their waking hours our participants found it more challenging than simply swapping their day-time and night-time activities when working a reversed schedule: "*And for me it is very much that if you have something planned that forces you up, otherwise it is that you wake up 12 after a night shift and I know I don't have to go up. OR that there is nothing planned, that you're going up and doing something or have a booked doctor's appointment or whatever, then it is easy that you wake up and just 'fuck this shit!' and stay in bed sleeping.*" (N1)

Even having friends that had similar schedules did not always solve this problem, as there was trouble in knowing exactly when other people were free which often put a lot of burden on planning. "*One of the bigger things with working nights, and then you're working very intensively, you are awake very short times, then your tendency to plan things is not as good.*" -N1. One participant described planning his and his wife's sleep schedule around her night shift nurse schedule: *"What we try to do is maximise the time together*" (P1).

Although for some moving their free time to the night could be isolating, it was seen as a benefit for others. Particularly among the people working in bars, there was a culture of like-mindedness and night dwelling which had a significant social value to them. For some this meant going out after closing "*When you work that much, and everyone is working a lot together then it becomes, like when you are up during the nights [gaming], then you spend time with them, and everyone shares the same daily rhythm.*"(G2) — but there was also a culture of staying up on Discord, gaming and talking together after work. Staying up at night, beyond one's work schedule was due to the sense of security and freedom of being awake, and alone, together. Particularly, as one participant explained, the feeling of "*Silence, and that you are not the only one up and gaming. Darkness also, I love when it is dark. There is a completely different aura. That is how I feel*" (B3)

4.4 Felt Time

Connected with the lack of temporal reference points, participants also reported that their experience of time passing changed, with their perception of the lengths of hours contracting and expanding based on where they fell into their sparsely populated daily schedules.

4.4.1 Self-Structuring time: As expressed by a nurse, the hours before work can contract so much they felt as if they disappeared without structure. "*Oh, it is suddenly six o-clock, and I have just left bed and I have no energy. I don't really know what is happening, and then 'well damn, now I have to leave for work again'*" (N1). Without external activities to orient towards, participants were forced to rely on their own will in order to ensure that free time before a shift was something that was made available and felt as such. *"I feel like the hour you have on the day.. it feels like if you don't get anything done precisely at the hours between 13-14, then it won't happen. Then you give up on the day and push it until the day afterwards as much as it is possible.*" (B2)

Another way to combat this contraction of the before-work hours was to more closely follow the pattern of a normative sleep pattern and wake up closer to their working time, pushing the free time late into the night after they had finished their shift. But where time leading up to work was seen to contract, this time stretching out before sleep without activities to orient around was seen to expand and become something *"tedious and drawn-out...to be endured." (N3).*

4.4.2 Changing temporal transitions: Beyond changing how the participants experienced blocks of time within their days, they also reported differences in how they experienced the progression of their days overall.

One participant described sleeping on a segmented schedule, being awake five to six hours during the middle of the night and sleeping in two blocks on either side, as blurring the edges of when the day ends and begins. "*And when I did that schedule, it definitely felt the time dilation like it felt like life was just as a really long day. And that kind of is a little bit mentally taxing, I think, to kind of never feel like the day ends*" (P1).

Even less extreme changes to sleep schedules could change how our participants perceived the day unfolding. A schedule with a siesta-like nap was reported to create a "*break in my day. I feel rested and cognitive alert so..it helps me go through the day*" (P1). Or as another participant stated, it creates a "*reset in the day*" (P5), explaining that if the morning did not go as planned they could 'reset' the day, starting afresh after waking.

Some schedules also opened up new perspectives on the unfolding day. One participant reported their sleep schedule as unlocking time during the night that *"feels like its own mini day" (P5)* where they found themselves referring to *"tomorrow"* as the time after their second schedule sleep, and *"yesterday"* to the time before their first. This resulted in the time in between their two core sleeps as conceptually belonging to neither.

5 DESIGNING FOR ALTERNATIVE SLEEP RHYTHMS

The themes presented above represent a number of challenges that those sleeping at odds with the dominant societal schedule can

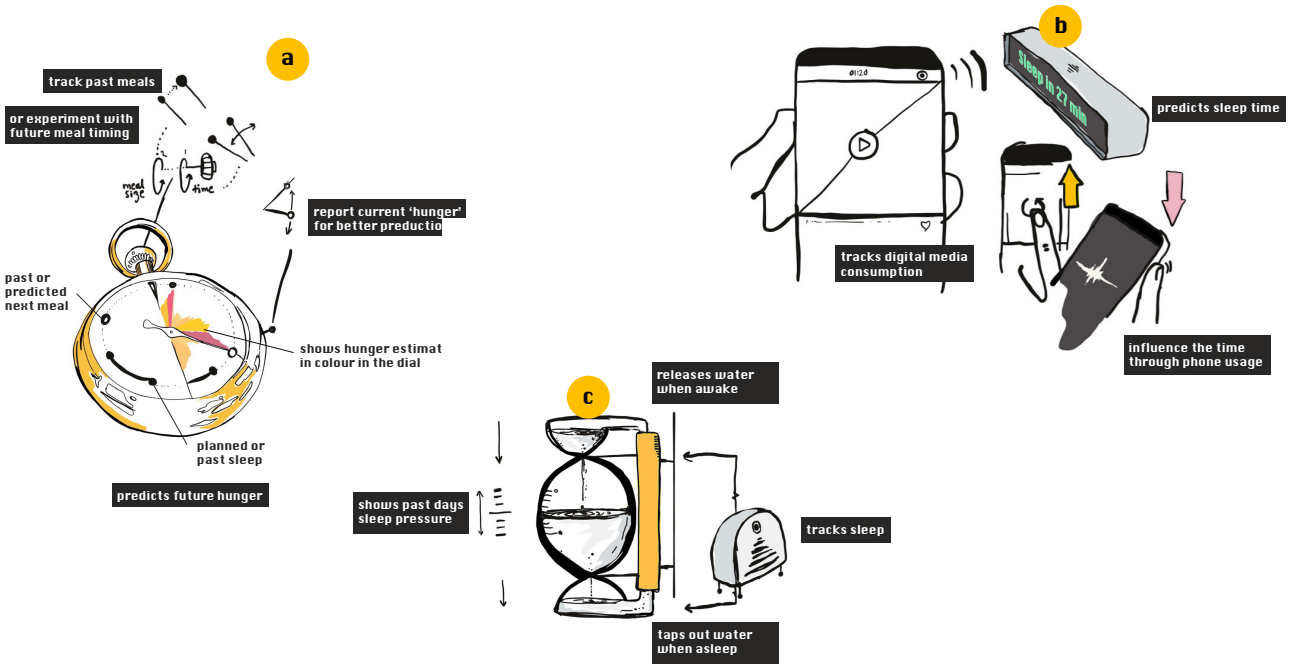

Figure 3: Three different representations of body-time

face. Here we present three families of design concepts, each one representing a possible future direction for research into designing for sleep practices. The first, *Unravelling*, focuses attention on the differing rhythms of bodily processes that must be managed and planned when rearranging sleep schedules. The second, *Re-coupling*, turns towards designing to manage awareness and affect of differing patterns of wakefulness. Our third section, *Re-valuing*, focuses on reflection and scheduling practices that take into account the changing experiential qualities of time when sleep schedules are not fixed or synced.

5.1 Unravelling

From our findings, we found that the de-coupling between a work/sleep schedule and other rhythms of life can create complicated patterns - particularly in the case of one's body (§4.2). We highlight and isolate different aspects of sleep and try to point at the challenge of breaking down the understanding of something as holistic as sleep.

The 'hunger-watch' (Fig. 3-a) is a pocket-sized dial that lets the user follow changes in their hunger, one of the emergent discussions on sleep and the body from the findings above. The watch's face shows the time based on the users' metabolism. On each side of the dial, there are knobs providing the user with ways to input changes to the appetite: One for reporting meals, and one for updating their perceived hunger. Through these two points of measurement, tracked meals and a continuous self-evaluation of hunger provide a metabolism-based view of time instead of industrialised clock time. This view shows the time to next hunger estimation, with each input providing a new time horizon. Pairing the view with the users' sleep schedule, the design encourages exploration of the interplay of food consumption with the pace of work, sleep and life.

Another part of the process to unravel is the multitude of influences on the onset of sleep. We continued on the thread on the varying influence 'mental alertness' or 'exhaustion' had on the participants' sleep. Depending on a number of pre-sleep decisions, each with a rhythm and of its own, the *latency of sleep* (how long it takes to fall asleep) can be influenced. In our 'sleep-train countdown' (Fig 3-b), the display shows the latest estimate of sleep latency based on the user's logged phone activity. Phone activity has been shown to be an accurate predictor of sleep rhythm [3], and this timer continuously updates as the user opens and closes apps of different influence on their sleep. By comparing measured engagement and activity with past sleep data the system predicts the users' mental engagement as a 'latency score' for each application, influencing the display accordingly and providing them the feedback they need to effectively manage device use before sleep. This design critically contrasts the ever-increasing quantitative tracking of our digital activity, and the more qualitative efforts most take to aid sleep onset.

Many of the body's rhythms change much more slowly than the ongoing tracking of every moment of every night's sleep suggests. One aspect that is often overlooked by sleep tracking technology is that sleep debt and homeostatic pressure is carried over from one day to the next. In a step back from continual tracking and feedback,

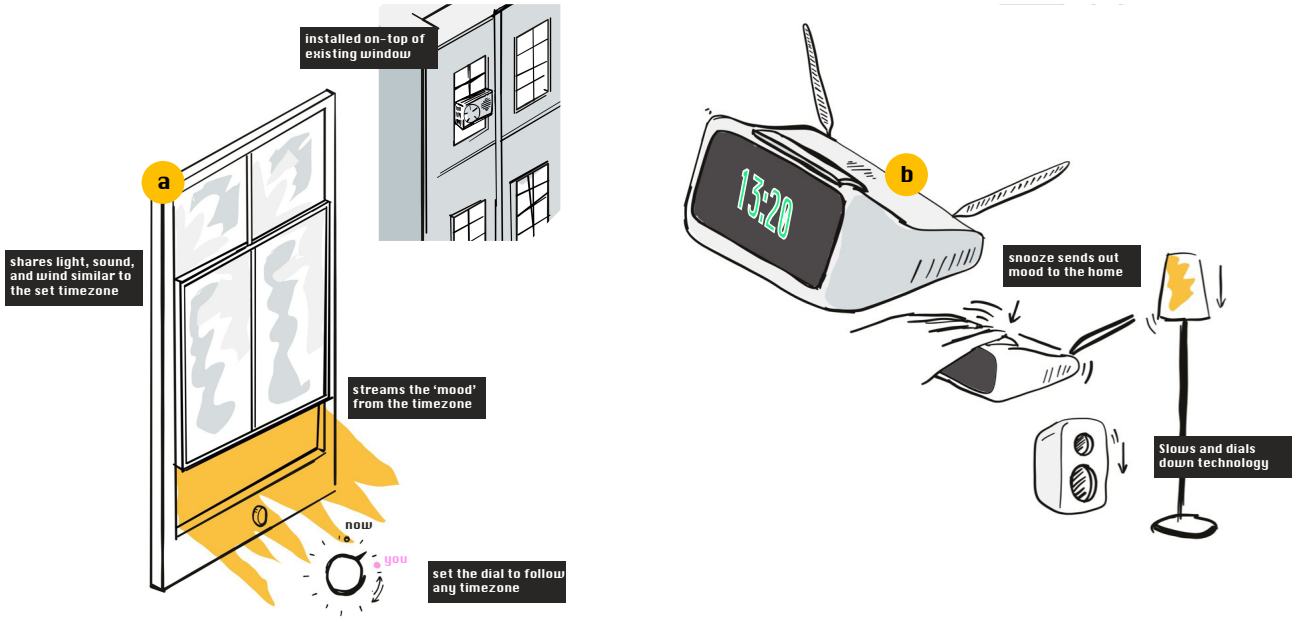

Figure 4: Technology to push and pull mood

the 'wake klepsydra' (Fig. 3-c) encourages slower reflection and action by only providing users with averages of past days. This design is in the shape of an extended hourglass – when the user is sleeping, the pressure is released and water pours out into the reservoir, and when the user is awake the glass slowly fills up representing the pressure to sleep. As such, the device always displays a rolling average of the sleep pressure of an individual.

These designs, through separating perspectives, respond to troubles experienced by our participants due to the irregularity of hunger, differences in mental alertness and schedule, and the build-up of sleep debt. Through unravelling and data-driven predictions of the complex mental and bodily influences on sleep these designs reduce uncertainty[6] and provide the knowledge to exercise their agency and to take action to facilitate a sleep schedule that fits their work and life goals.

5.2 Re-coupling

Another key theme in the findings was how the participants found themselves de-coupled and out of pace and with society, as rendered in the theme in §4.3. We focus on the social aspect of isolation through two design speculation. Through these devices we let users both pull and push social cues that matched their rhythmic state.

The 'atmo-shifter' (Fig. 4-a) is a way for participants to get ambient feedback on how one's body and society are out of sync. It builds in the discussion on temporal cues to orientate the structure of days when sleeping differently. Based on measurements this display, in shape of a real-size window, sends out stimuli to imitate the 'mood' of a time. Through an extension of the window, it expresses an ensemble of sensations of simulated sunlight, wind flow and ambient sound based on live data from locations in those time zones. On the bottom of the window, there is a knob that corresponds to the time of the window, two highlighted dots represents the local time, and the measured time of the user based on body tracking and sleep data. The window is set to follow the rhythm of the user, but can be easily changed by pulling the handle out of sync. The window supports its user by letting the user control the mood of the environment of their bedroom – working as a shifted reference of time of day but also as a sensation of being in-time, a sense of liveness [56], and 'not the only one that just woke up'.

While the 'atmo-shifter' *pulls* a rhythm to the user, the 'snooze-pulse' (Fig. 4-b) *pushes* their rhythms to others. This draws inspirations directly from discussions in the workshops on ways to communicate awareness of ones sleep pattern to those around them. The device is an transposed alarm clock built for a household. Where what wakes up a non-normative sleeper is often not an alarm, but the influence of others in the household going about their daily activities. This snooze button allows the user to broadcast their rhythm throughout the home. On activation, the clock connects with smart devices through the home to lower blinds, dim lamps, reduce the volume on speakers, and even throttle the broadband of the other residents to communicate the slow and quiet state of the rhythm of the primary user. This communication can both explicitly and implicitly convey the mood of the user to those that share their living space.

These designs are two different exemplars of how technology can *recouple* and connect the rhythms – by providing ways of influence – of a person with their social surroundings. The snooze-pulse directly addresses the lack of agency felt by our participants with respect to influencing and communicating their needs and desires for sleep at times when others were awake. The 'atmo-shifter', on the other hand, provides the opportunity to influence their environment with social cues that match the rhythm of their life –

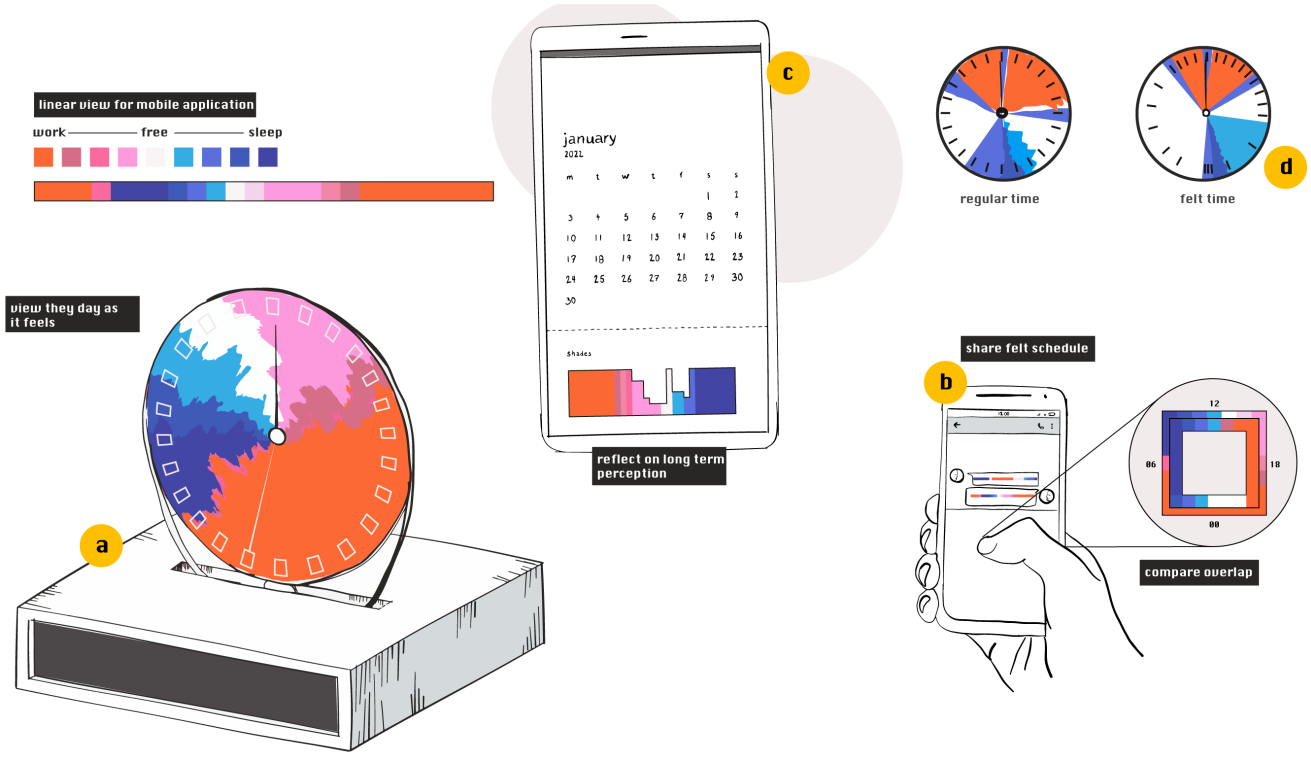

Figure 5: The shade-view family of scheduling designs

rather than forcing them to change how they schedule their time – to experience what they have been missing. But it also opens for an embodiment of ones sleep rhythm, one that also can support the communication between partners and family in different schedules.

5.3 Re-valuing

Not all hours are the same, and different people experience the same clock time as having different opportunities and values as their schedules fall around it. What one feels as a lazy Saturday afternoon, another experiences as hours squeezed between wake-up and work. Here we build on the discussion on felt time presented in §4.4.

Our 'inpendo-view' (Figure 5) presents a way to capture, foresee and plan around these alternative perceptions. It takes the form of an upright glass-disc which rotates as the day progresses. This disc forms a display showing the upcoming hours in relation to scheduled events and past activities, following tracked rhythms over days and weeks. In the representation showing in Figure 5-a the red working hours shade the preceding and subsequent hours, while the blue sleeping hours do the same but with different valence that represents, for example, how upcoming sleep and upcoming work differently influence the time before.

Current calendar representation has implicit shading due to cultural norms, where early morning, afternoon and evening hours have distinct opportunities and meanings attached. Users of this system can track and share the opportunities and meanings attached to the hours in their own daily rhythms. Through aggregating this representation of hours over a month the display 'shade-schedule' in Figure 5-c provides an alternative way to reflect on work schedules. These coloured hour representations can also be shared with friends and family to compare and sync times where their availability matches in meaning and opportunity as well as freedom from other responsibilities (5-b).

Moving beyond the representation of the opportunities and meanings attached to different periods of time, the 'felt-dials' shown in Figure 5-d represent the experiential lengths of different periods of the day as opposed to their cardinal lengths. Although this design provides a simple view of how hours are felt, we speculate that this can be expanded in a series of different representations of perceived and *revalued time*, with other representations such as presenting the predicted alertness, building on research efforts of alertness tracking, [4] or hunger, as discussed in §5.1.

A large proportion of our participants reported struggles with the effective scheduling of shared activities, especially with those on normative schedules. These designs allow for non-normative sleepers to not only understand and reflect upon how their free time may be influenced by things other than the clock, but also the agency to attempt to schedule shared activities at times when the influences on, and perception of, those free hours are also shared.

6 DISCUSSION

In this research, we gathered experiences of sleeping schedules outside of societal norms from different perspectives and sketched three different design concepts to address these. We discuss the

possibility of supporting agency over life rhythms through technological means and the fine line between the support of the agency and 'bad sleep'.

6.1 Technological supported sleep-rhythm design

We shape our everyday rhythms through when we sleep. Whether this is motivated by individual life decisions or the timing of work, as our findings show, life outside of normative rhythms can be unsurprisingly challenging in many ways. Our themes structure these challenges as being out of step with the pace of everyday life, both in terms of one's own body, social and felt terms. These themes restate the influence that shared sleep schedules have on the timing of almost all intricacies of life.

Our three design themes directly relate to how we can, through technology, support the construction of rhythms in times of change and maintenance of non-normative sleep patterns through mitigation strategies for the challenges that provide the most substantial pressure towards the societal mean.

In the designs for unravelling time, we start from the premise that the complexity and intricacies of daily rhythms should be separately understood through the lens of their timing. In understanding daily rhythms, we show that designers of technology should pay attention to both the individual rhythms and the myriad of ways in which they come together, influence each other, and become syncopatic in nature [60]. Informing the design of visualisation and the values inherent in body reflection tools, this focus will allow users to see the consequences of changes that reach across bodily processes.

These design reflect a set of 'slices' of timings, but one substantial finding from the participants which we have not yet discussed is medical influences on these daily rhythms. This remains an important factor of sleep influence, one that has also had very little attention in the research of sleep in HCI. The rhythms of chemical ingestion can also work in consort, or at odds, with the varied bodily rhythms that govern sleep. They can also be used in an attempt to directly influence wakefulness, and the onset of sleep, in order to attempt to mitigate some of the challenges in living at the edges of normal temporal rhythms.

In re-coupling technology, we find that to make sense of life 'during times of disruption' – there is need to establish what the new normal is [20]. Social rhythm cues can be established, both pushed to the people in the surroundings of those living non-normative schedules – but also by providing users with control over their own environmental references for time. However, lastly, and more generally, we encourage a rethinking of our representations of time to include the social and subjective aspects of felt time. In expanding our representations, in design and discussion, beyond linear time we can start to support the various non-normative 'normals' that many in society are forced, or choose, to live with.

As in time, where technology such as the alarm clock and artificial light have allowed for a societal redesign of what time means, and how we conceive of the hours and rhythm of the day. We call for a new perspective on sleep, where technology is built to support and enable personal redesigning of the experienced day through and for our restful hours.

6.2 Agency over bad sleep?

In our designs, we have attempted to support the user's agency in determining their sleep patterns and providing support in managing the challenges that can come with being out of sync with those around them. Much of the technology we see directed at sleep, contrary to this, seem to be about removing agency in some way. The Phonecell [2] in which users physically locked away their devices to meet the designers values around 'good sleep' can be taken as a deliberately provocative and extreme example of this. However, the values encoded in the interactions found in the myriad of successors of Sleep Cycle Alarm Clock [1] show similar attitudes towards personal agency when balanced against sleep hygiene. Given the lack of medical grounding around many of the assumptions encoded into these systems – from the emphasis of sleep stages on sleep quality scores [49] to the validation and lack of standardisation [28, 30], and even sleep times [55] – this can be read as falling into a puritanical value laden encoding of a moral imperative to wake early, practice self-control and be a productive member of society.

With a more generous reading of the design choices made in these systems, it can be seen as erring on the side of caution. Sleep is an important bodily process, one with significant impacts on both mental and physical health [37]. Basing the design of sleep-facing technology on the assumption that people will sleep once a day and that the risks of someone being encouraged by the technology do minimise their sleep to their detriment is greater than the risks of pushing them to prioritise sleep over other areas of their life. There is a challenge in designing for the extreme sleepers we talked to, in that providing support to meet their goals in work and social life could often turn into supporting them to manage various levels of sleep deprivation – a state with both short term and long term mental and physical health consequences [3]. Weighing the relative benefits of any individual user spending time on socialising, working, or exercising vs. sleeping is ethically challenging and technologically even more problematic. The stress of missing a work deadline and becoming unemployed may be much more detrimental to the physical and mental health of a user than getting four hours of sleep a day for a week, yet such sleep deprivation may also result in potentially fatal dangerous driving. In supporting the experimentation with extreme sleep schedules, the designer must make a choice as to *if* to include limits or not, and if they do *where* those limits should be.

7 CONCLUSION

This paper explores the design possibilities of technology for sleep through the lens of extreme users [25] – in this case those who either chose to sleep at odds with societal expectations, or those for whom their professional life forces them to shift or segment their sleep outside of the normative 8-hours-a-night pattern encoded in current sleep-adjacent technology design. Through a series of workshops and interviews with these extreme sleepers, and speculating with caricatures of even more extreme users [19], we presented their experiences of sleeping out of sync with their friends and family and society at large. We also explored how the shifting of sleep timing was interwoven with other bodily processes, such as hunger, and how it changed the felt experience of work and leisure time even when the number of hours of each did not. Based on

this qualitative enquiry we present a series of designs to explore the interactions and contradictions between the different bodily processes governing sleep, ways to reinforce social connections weakened by out-of-sync sleep schedules through pushing and pulling influences, and visualisations to reflect, share, and coordinate around the different experiential qualities of time as it is influenced by events such as waking and working. We advocate for systems that go beyond normative ideas of 'good sleep' and value-laden design geared towards 'productive early risers' to embracing the opportunities to support the 17-28% of workers – as well as the gamers, polyphasic sleepers, night owls, teenagers, and afternoon nappers – who don't conform to the normative pattern of modern sleep to live fuller, more connected lives.

REFERENCES

[1] 2009. Sleep Cycle | Sleep Tracker, Monitor & Alarm Clock. https://www.sleepcycle.com/.

[2] 2022. PhoneCell. https://www.phonecell.me/.

[3] Saeed Abdullah, Mark Matthews, Elizabeth L. Murnane, Geri Gay, and Tanzeem Choudhury. 2014. Towards Circadian Computing: "Early to Bed and Early to Rise" Makes Some of Us Unhealthy and Sleep Deprived. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, Seattle Washington, 673–684. https://doi.org/10.1145/2632048.2632100

[4] Saeed Abdullah, Elizabeth L. Murnane, Mark Matthews, Matthew Kay, Julie A. Kientz, Geri Gay, and Tanzeem Choudhury. 2016. Cognitive Rhythms: Unobtrusive and Continuous Sensing of Alertness Using a Mobile Phone. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, Heidelberg Germany, 178–189. https://doi.org/10.1145/2971648.2971712

[5] Miquel Alfaras, William Primett, Muhammad Umair, Charles Windlin, Pavel Karpashevich, Niaz Chalabianloo, Dionne Bowie, Corina Sas, Pedro Sanches, Kristina Höök, Cem Ersoy, and Hugo Gamboa. 2020. Biosensing and Actuation—Platforms Coupling Body Input-Output Modalities for Affective Technologies. *Sensors* 20, 21 (Oct. 2020), 5968. https://doi.org/10.3390/s20215968

[6] Deemah Alqahtani, Caroline Jay, and Markel Vigo. 2020. The Role of Uncertainty as a Facilitator to Reflection in Self-Tracking. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 1807–1818. https://doi.org/10.1145/3357236.3395448

[7] Kristina Andersen and Ron Wakkary. 2019. The Magic Machine Workshops: Making Personal Design Knowledge. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300342

[8] Jared Bauer, Sunny Consolvo, Benjamin Greenstein, Jonathan Schooler, Eric Wu, Nathaniel F. Watson, and Julie Kientz. 2012. ShutEye: Encouraging Awareness of Healthy Sleep Recommendations with a Mobile, Peripheral Display. In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems - CHI '12*. ACM Press, Austin, Texas, USA, 1401. https://doi.org/10.1145/2207676.2208600

[9] Nico Brand, William Odom, and Samuel Barnett. 2021. A Design Inquiry into Introspective AI: Surfacing Opportunities, Issues, and Paradoxes. In *Designing Interactive Systems Conference 2021*. ACM, Virtual Event USA, 1603–1618. https://doi.org/10.1145/3461778.3462000

[10] Tega Brian and Lavigne Sam. 2021. Perfect Sleep. https://perfectsleep.labr.io/.

[11] Michelle Carr, Adam Haar, Judith Amores, Pedro Lopes, Guillermo Bernal, Tomás Vega, Oscar Rosello, Abhinandan Jain, and Pattie Maes. 2020. Dream Engineering: Simulating Worlds through Sensory Stimulation. *Consciousness and Cognition* 83 (Aug. 2020), 102955. https://doi.org/10.1016/j.concog.2020.102955

[12] Zhenyu Chen, Mu Lin, Fanglin Chen, Nicholas D. Lane, Giuseppe Cardone, Rui Wang, Tianxing Li, Yiqiang Chen, Tanzeem Choudhury, and Andrew T. Campbell. 2013. Unobtrusive Sleep Monitoring Using Smartphones. In *2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops*. 145–152.

[13] Eun Kyoung Choe, Bongshin Lee, Matthew Kay, Wanda Pratt, and Julie A. Kientz. 2015. SleepTight: Low-Burden, Self-Monitoring Technology for Capturing and Reflecting on Sleep Behaviors. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 121–132. https://doi.org/10.1145/2750858.2804266

[14] Arunima Datta. 2020. Knocker Ups: A Social History of Waking Up in Victorian Britain's Industrial Towns. *Journal of Victorian Culture* 25, 3 (2020), 331–348.

[15] John Partomo Djajadiningrat, William W Gaver, and JW Fres. 2000. Interaction Relabelling and Extreme Characters: Methods for Exploring Aesthetic Interactions. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*. 66–71.

[16] Sara Eriksson, Filip Gustafsson, Gustav Larsson, and Preben Hansen. 2017. Takt: The Wearable Timepiece That Enables Sensory Perception of Time. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems (DIS '17 Companion)*. Association for Computing Machinery, New York, NY, USA, 223–227. https://doi.org/10.1145/3064857.3079150

[17] Jennifer Fereday and Eimear Muir-Cochrane. 2006. Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods* 5, 1 (March 2006), 80–92. https://doi.org/10.1177/160940690600500107

[18] Fitbit. 2007. Fitbit Technology | Sleep. https://www.fitbit.com/global/us/technology/sleep.

[19] Bill Gaver and Heather Martin. 2000. Alternatives: Exploring Information Appliances through Conceptual Design Proposals. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '00)*. Association for Computing Machinery, New York, NY, USA, 209–216. https://doi.org/10.1145/332040.332433

[20] Shelagh K. Genuis and Jenny Bronstein. 2017. Looking for "Normal": Sense Making in the Context of Health Disruption. *Journal of the Association for Information Science and Technology* 68, 3 (March 2017), 750–761. https://doi.org/10.1002/asi.23715

[21] Renaud Gervais, Jérémy Frey, Alexis Gay, Fabien Lotte, and Martin Hachet. 2016. TOBE: Tangible Out-of-Body Experience. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Eindhoven Netherlands, 227–235. https://doi.org/10.1145/2839462.2839486

[22] Colin M. Gray, Shruthi Sai Chivukula, and Ahreum Lee. 2020. What Kind of Work Do "Asshole Designers" Create? Describing Properties of Ethical Concern on Reddit. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 61–73. https://doi.org/10.1145/3357236.3395486

[23] Adam Haar Horowitz, Ishaan Grover, Pedro Reynolds-Cuéllar, Cynthia Breazeal, and Pattie Maes. 2018. Dormio: Interfacing with Dreams. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. ACM Press, Montreal QC, Canada, 1–10. https://doi.org/10.1145/3170427.3188403

[24] Dietmar Hank, Helen Ball, Ved P. Varma, Lee Scrivner, Hazel O'Dowd, Nigel Hudson, Louise Paterson, Robert Meadows, Brigitte Steger, and Katharina Wulff. 2012. *Sleep: Multi-professional Perspectives*. Jessica Kingsley Publishers.

[25] Lars Erik Holmquist. 2004. User-Driven Innovation in the Future Applications Lab. In *Extended Abstracts of the 2004 Conference on Human Factors and Computing Systems - CHI '04*. ACM Press, Vienna, Austria, 1091. https://doi.org/10.1145/985921.985995

[26] Ming-Chun Huang, Xiaoyi Zhang, Wenyao Xu, Jason Liu, and Majid Sarrafzadeh. 2014. EZwakeup: A Sleep Environment Design for Sleep Quality Improvement. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems (CHI EA '14)*. Association for Computing Machinery, New York, NY, USA, 2389–2394. https://doi.org/10.1145/2559206.2581250

[27] Matthew Kay, Eun Kyoung Choe, Jesse Shepherd, Benjamin Greenstein, Nathaniel Watson, Sunny Consolvo, and Julie A. Kientz. 2012. Lullaby: A Capture & Access System for Understanding the Sleep Environment. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing (UbiComp '12)*. Association for Computing Machinery, New York, NY, USA, 226–234. https://doi.org/10.1145/2370216.2370253

[28] Seema Khosla, Maryann C. Deak, Dominic Gault, Cathy A. Goldstein, Dennis Hwang, Younghoon Kwon, Daniel O'Hearn, Sharon Schutte-Rodin, Michael Yurcheshen, Ilene M. Rosen, Douglas B. Kirsch, Ronald D. Chervin, Kelly A. Carden, Kannan Ramar, R. Nisha Aurora, David A. Kristo, Raman K. Malhotra, Jennifer L. Martin, Eric J. Olson, Carol L. Rosen, and James A. Rowley. 2018. Consumer Sleep Technology: An American Academy of Sleep Medicine Position Statement. *Journal of Clinical Sleep Medicine : JCSM : Official Publication of the American Academy of Sleep Medicine* 14, 5 (May 2018), 877–880. https://doi.org/10.5664/jcsm.7128

[29] Ping-Ru T. Ko, Julie A. Kientz, Eun Kyoung Choe, Matthew Kay, Carol A. Landis, and Nathaniel F. Watson. 2015. Consumer Sleep Technologies: A Review of the Landscape. *Journal of Clinical Sleep Medicine* 11, 12 (2015), 1455–1461. https://doi.org/10.5664/jcsm.5288

[30] Bhanu Prakash Kolla, Subir Mansukhani, and Meghna P. Mansukhani. 2016. Consumer Sleep Tracking Devices: A Review of Mechanisms, Validity and Utility. *Expert Review of Medical Devices* 13, 5 (May 2016), 497–506. https://doi.org/10.1586/17434440.2016.1171708

[31] Kyung-Ryong Lee, Somi Ju, Temirlan Dzhoroev, Geonil Goh, Moon-Hwan Lee, and Young-Woo Park. 2020. DayClo: An Everyday Table Clock Providing Interaction with Personal Schedule Data for Self-reflection. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. Association for Computing Machinery, New York, NY, USA, 1793–1806.

[32] Ya-Fang Lin, Yi-Ju Chung, Chuang-Wen You, Yaliang Chuang, Bo-Fu Liu, Huming Chang, and Ming-Chyi Huang. 2018. Neither One Is Enough: Exploring the Use of Wrist-worn Activity Trackers to Assist Acute Psychiatric Healthcare. In

Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems. ACM, Hong Kong China, 27–31. https://doi.org/10.1145/3197391.3205407

[33] Wanyu Liu, Bernd Ploderer, and Thuong Hoang. 2015. In Bed with Technology: Challenges and Opportunities for Sleep Tracking. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction (OzCHI '15)*. Association for Computing Machinery, New York, NY, USA, 142–151. https://doi.org/10.1145/2838739.2838742

[34] Yizhou Liu, Da-jung Kim, Ting Miao, and Yaliang Chuang. 2020. SlumberBot: An Interactive Agent for Helping Users Investigate Disturbance Factors of Sleep Quality. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. ACM, Tallinn Estonia, 1–4. https://doi.org/10.1145/3419249.3420091

[35] Sara Ljungblad and Lars Erik Holmquist. 2007. Transfer Scenarios: Grounding Innovation with Marginal Practices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, San Jose California USA, 737–746. https://doi.org/10.1145/1240624.1240738

[36] Dan Lockton, Tammar Zea-Wolfson, Jackie Chou, Yuhan (Antonio) Song, Erin Ryan, and Cj Walsh. 2020. Sleep Ecologies: Tools for Snoozy Autoethnography. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 1579–1591. https://doi.org/10.1145/3357236.3395482

[37] Faith S. Luyster, Patrick J. Strollo, Phyllis C. Zee, and James K. Walsh. 2012. Sleep: A Health Imperative. *Sleep* 35, 6 (June 2012), 727–734. https://doi.org/10.5665/sleep.1846

[38] Terence M. McMenamin. 2007. A Time to Work: Recent Trends in Shift Work and Flexible Schedules Shift Work and Flexible Schedules. *Monthly Labor Review* 130, 12 (2007), 3–15.

[39] Robert Meadows, Sara Arber, Susan Venn, and Jenny Hislop. 2008. Engaging with Sleep: Male Definitions, Understandings and Attitudes. *Sociology of Health & Illness* 30, 5 (2008), 696–710. https://doi.org/10.1111/j.1467-9566.2008.01088.x

[40] Androniki Naska. 2007. Siesta in Healthy Adults and Coronary Mortality in the General Population. *Archives of Internal Medicine* 167, 3 (Feb. 2007), 296. https://doi.org/10.1001/archinte.167.3.296

[41] San San Nguyen, Da-jung Kim, Ting Miao, and Yaliang Chuang. 2020. Designing for Triggering Self-Investigations and Reflections on Factors Related to Sleep Health. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. ACM, Tallinn Estonia, 1–4. https://doi.org/10.1145/3419249.3421248

[42] Ōura Health Oy. [n.d.]. Oura Ring. https://ouraring.com.

[43] Kursat F. Ozenc, James P. Brommer, Bong-keum Jeong, Nina Shih, Karen Au, and John Zimmerman. 2007. Reverse Alarm Clock: A Research through Design Example of *Designing for the Self*. In *Proceedings of the 2007 Conference on Designing Pleasurable Products and Interfaces - DPPI '07*. ACM Press, Helsinki, Finland, 392. https://doi.org/10.1145/1314161.1314196

[44] Laura Pina, Sang-Wha Sien, Clarissa Song, Teresa M. Ward, James Fogarty, Sean A. Munson, and Julie A. Kientz. 2020. DreamCatcher: Exploring How Parents and School-Age Children Can Track and Review Sleep Information Together. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW1 (May 2020), 070:1–070:25. https://doi.org/10.1145/3392882

[45] Larissa Pschetz and Michelle Bastian. 2018. Temporal Design: Rethinking Time in Design. *Design Studies* 56 (May 2018), 169–184. https://doi.org/10.1016/j.destud.2017.10.007

[46] Stephen Purpura, Victoria Schwanda, Kaiton Williams, William Stubler, and Phoebe Sengers. 2011. Fit4life: The Design of a Persuasive Technology Promoting Healthy Behavior and Ideal Weight. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1978942.1979003

[47] Juliet Pusateri, Judith Leng, Qian Wang, Xiangzhu Chen, and Jessica Hammer. 2020. Designing Games for Healthy Sleep. (2020), 13.

[48] Tauhidur Rahman, Alexander T. Adams, Ruth Vinisha Ravichandran, Mi Zhang, Shwetak N. Patel, Julie A. Kientz, and Tanzeem Choudhury. 2015. DoppleSleep: A Contactless Unobtrusive Sleep Sensing System Using Short-Range Doppler Radar. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 39–50. https://doi.org/10.1145/2750858.2804280

[49] Ruth Ravichandran, Sang-Wha Sien, Shwetak N. Patel, Julie A. Kientz, and Laura R. Pina. 2017. Making Sense of Sleep Sensors: How Sleep Sensing Technologies Support and Undermine Sleep Health. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 6864–6875. https://doi.org/10.1145/3025453.3025557

[50] Joseph M Reagle Jr. 2019. *Hacking Life: Systematized Living and Its Discontents*. MIT Press.

[51] Revital Cohen. 2008. MoMA | Talk to Me | Artificial Biological Clock. https://www.moma.org/interactives/exhibitions/2011/talktome/objects/143181/.

[52] Tomaso Scherini, Paulo Melo, Toon van Craenendonck, Wenzhu Zou, and Maurits Kaptein. 2010. Enhancing the Sleeping Quality of Partners Living Apart. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS '10*. ACM Press, Aarhus, Denmark, 171. https://doi.org/10.1145/1858171.1858201

[53] Soomi Park and Sebastian Thielke. 2012. Vixen™_Circadian Stopwatch System (2012). https://soomipark.com/?portfolio=circadian-work-clock.

[54] B. Steger. 2003. Getting Away with Sleep–Social and Cultural Aspects of Dozing in Parliament. *Social Science Japan Journal* 6, 2 (Oct. 2003), 181–197. https://doi.org/10.1093/ssjj/6.2.181

[55] Neil P Walsh, Shona L Halson, Charli Sargent, Gregory D Roach, Mathieu Nédélec, Luke Gupta, Jonathan Leeder, Hugh H Fullagar, Aaron J Coutts, Ben J Edwards, Samuel A Pullinger, Colin M Robertson, Jatin G Burniston, Michele Lastella, Yann Le Meur, Christophe Hausswirth, Amy M Bender, Michael A Grandner, and Charles H Samuels. 2021. Sleep and the Athlete: Narrative Review and 2021 Expert Consensus Recommendations. *British Journal of Sports Medicine* 55, 7 (April 2021), 356–368. https://doi.org/10.1136/bjsports-2020-102025

[56] Jinyi Wang, Mudassar Ahmad Mughal, and Oskar Juhlin. 2015. Experiencing Liveness of a Cherished Place in the Home. In *Proceedings of the ACM International Conference on Interactive Experiences for TV and Online Video*. ACM, Brussels Belgium, 3–12. https://doi.org/10.1145/2745197.2745198

[57] Thomas A. Wehr. 1992. In Short Photoperiods, Human Sleep Is Biphasic. *Journal of Sleep Research* 1, 2 (June 1992), 103–107. https://doi.org/10.1111/j.1365-2869.1992.tb00019.x

[58] Stephan Wensveen, Kees Overbeeke, and Tom Djajadiningrat. 2002. Push Me, Shove Me and I Show You How You Feel: Recognising Mood from Emotionally Rich Interaction. In *Proceedings of the 4th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques (DIS '02)*. Association for Computing Machinery, New York, NY, USA, 335–340. https://doi.org/10.1145/778712.778759

[59] Kimberley Whitehead and Matthew Beaumont. 2018. Insomnia: A Cultural History. *The Lancet* 391, 10138 (2018), 2408–2409. https://doi.org/10.1016/S0140-6736(18)31275-3

[60] Maria A. G. Witek, Eric F. Clarke, Mikkel Wallentin, Morten L. Kringelbach, and Peter Vuust. 2014. Syncopation, Body-Movement and Pleasure in Groove Music. *PLoS ONE* 9, 4 (April 2014), e94446. https://doi.org/10.1371/journal.pone.0094446

[61] Paweł W. Woźniak, Przemysław Piotr Kucharski, Maartje M.A. de Graaf, and Jasmin Niess. 2020. Exploring Understandable Algorithms to Suggest Fitness Tracker Goals That Foster Commitment. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. ACM, Tallinn Estonia, 1–12. https://doi.org/10.1145/3419249.3420131

[62] Rayoung Yang, Eunice Shin, Mark W. Newman, and Mark S. Ackerman. 2015. When Fitness Trackers Don't 'Fit': End-User Difficulties in the Assessment of Personal Tracking Device Accuracy. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 623–634. https://doi.org/10.1145/2750858.2804269

[63] Jan Zekveld, Mathias Funk, and Saskia Bakker. 2016. The Tumble Clock: Bringing Users in Touch with Their Snooze Time. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems (DIS '16)*. Association for Computing Machinery, New York, NY, USA, 900–904. https://doi.org/10.1145/2901790.2901857

[64] Shikun Zhang, Florian Schaub, Yuanyuan Feng, and Norman Sadeh. 2019. "It Only Tells Me How I Slept, Not How to Fix It": Exploring Sleep Behaviors and Opportunities for Sleep Technology. In *Information in Contemporary Society (Lecture Notes in Computer Science)*, Natalie Greene Taylor, Caitlin Christian-Lamb, Michelle H. Martin, and Bonnie Nardi (Eds.). Springer International Publishing, Cham, 754–766. https://doi.org/10.1007/978-3-030-15742-5_71

A APPENDIX A: FULL SIZE IMAGES

Figure 6: Full-Size Map of sleep technology

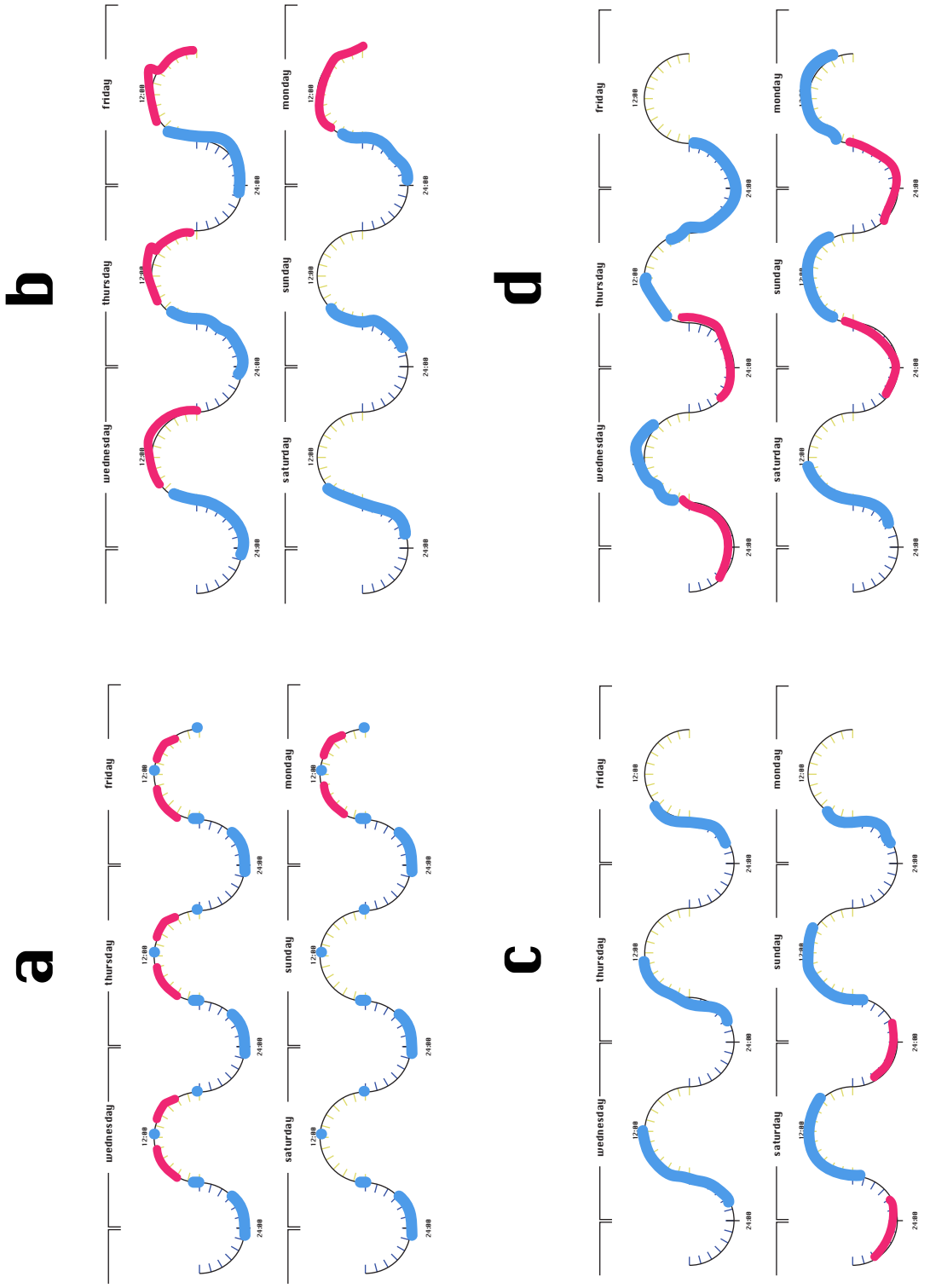

Figure 7: Full-Size Sleep Schedules

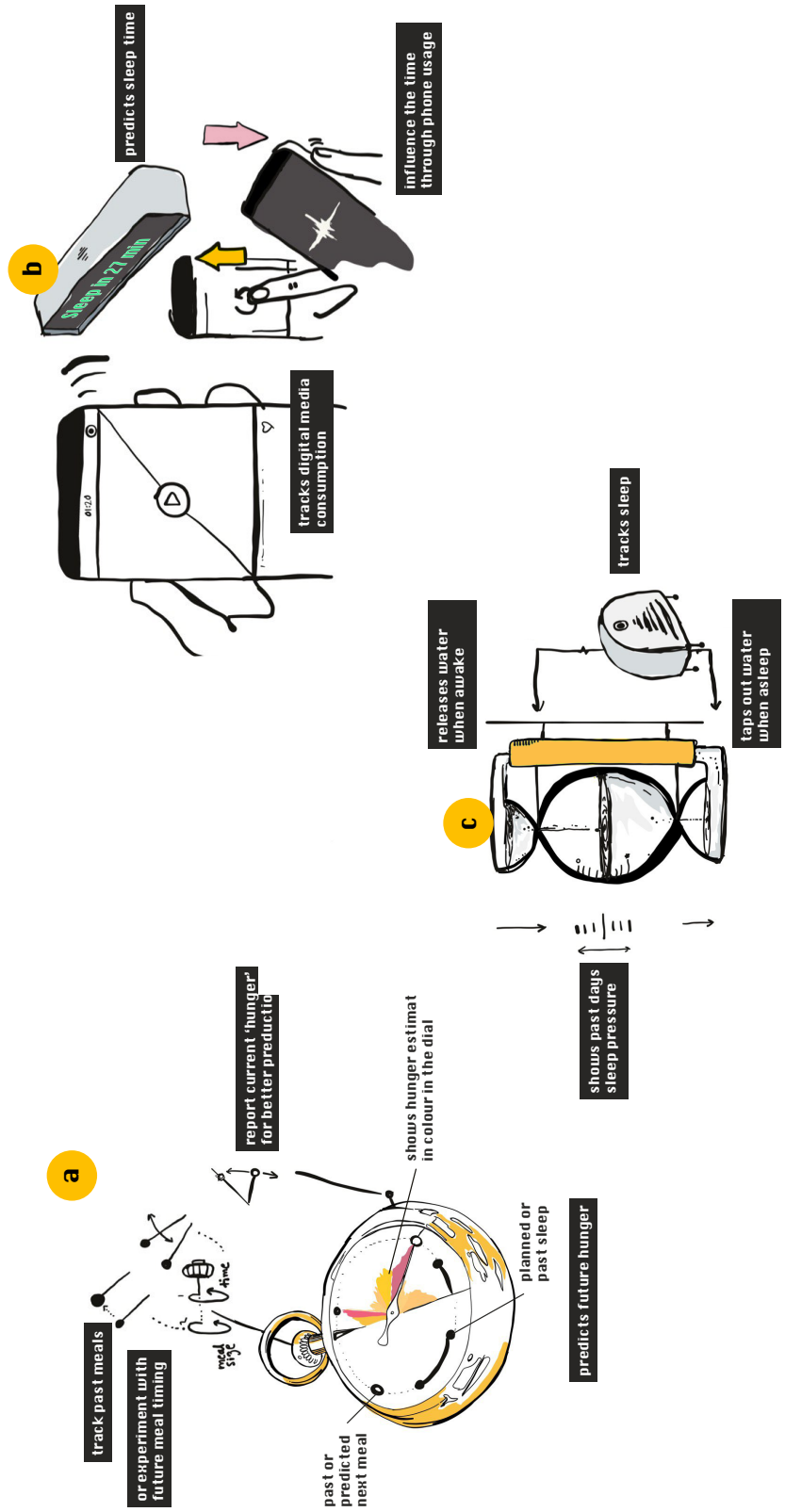

Figure 8: Full-Size Unravelling Designs

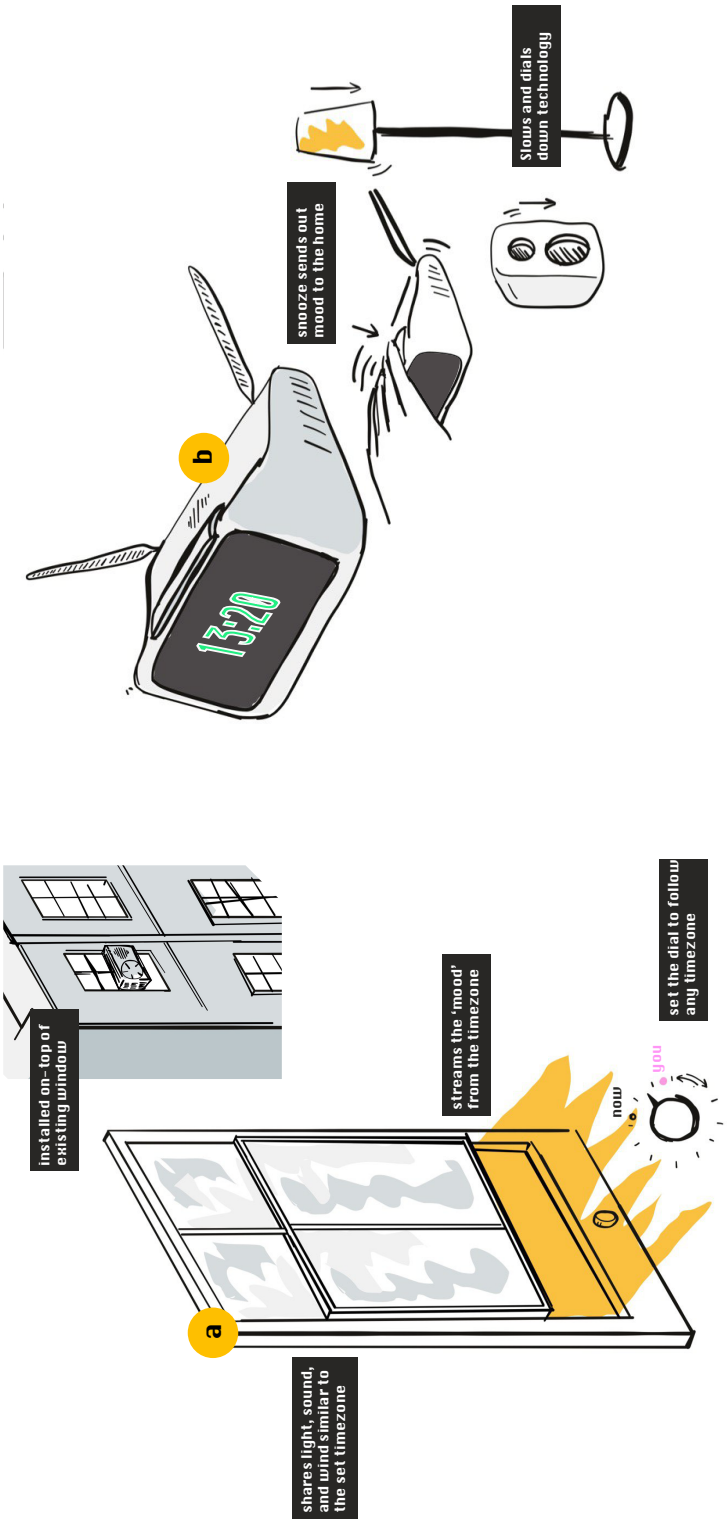

Figure 9: Full-Size Re-coupling Designs

Figure 10: Full-Size Re-valuing Designs