"*I Want to Keep My Phone Away From the Bed*": Designing a Smart Pillow for Sleep Onset

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Figure 1: Co-design Workshop Exploring a Smart Pillow Prototype for Non-distracting Sleep Onset Audio-based Digital Consumption

Abstract

Pre-sleep digital consumption is widespread. While it is a common concern for bedtime procrastination, recent research also highlights its importance in fulfilling various pre-sleep needs, such as claiming "me time". However, these benefits and underlying needs have largely been overlooked in the design of digital sleep interventions. In this paper, we present a co-design workshop with 16 participants, exploring a smart pillow that allows audio-based digital consumption through non-distracting interactions. We illustrate the smart pillow's potential in resolving the tension between digital consumption and sleep transition to support sleep onset — the transition from wakefulness to sleep. Our work highlights how the pillow's physical form affords audio consumption control with minimal effort, and positions sleep onset as a distinct design context that demands careful attention when designing for sleep. We offer design implications that leverage tangible and bodily interactions to accommodate the sensitive transitioning state during sleep onset.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; **Empirical studies in interaction design**.

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Keywords

Sleep Health, Embodied Interaction, Tangible User Interface, Materiality

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1 Introduction

Digital consumption, such as video watching and social media browsing, has become prevalent, including the time before sleep [18, 19]. It is commonly reported that people frequently engaging in pre-sleep digital consumption have a greater chance of experiencing bedtime procrastination [6, 40], consequently sleeping less, feeling more fatigue during the day, and having a higher association with depression and anxiety [21, 35]. Digital consumption typically occurs through screen-based interfaces that require sustained visual and cognitive attention. This conflicts with the physiological process of falling asleep, which involves closed eyes and a gradual decline in cognitive activity. The light exposure from screens compounds this issue by affecting melatonin secretion [64]. At the same time it has been shown that pre-sleep digital consumption often serves as a response to emotional and social needs, such as addressing stress [13], fear of missing out [8], or the need to reclaim personal time after a demanding day [58]. As such, the process of falling asleep is complex, entangled with many factors, including behavioral [36], physiological [34], emotional [27], and social aspects [58].

In HCI, extensive work has been done on designing digital interventions to improve sleep; however, little attention has been paid to why people engage in digital consumption and how it can be done in a sleep-compatible manner. Some studies have leveraged sleep-tracking data and persuasive strategies, aiming to improve users' sleep behaviour, such as avoiding using screens before sleep, or aligning with a targeted bedtime by helping reflect on their sleep patterns [39, 41, 54]. Other research has focused on different sensory modalities, such as visual, olfactory, tactile, or audio, to deliver relaxing stimuli to support sleep transition [2, 47, 68]. Some research has explored social ways to improve sleep, such as providing companionship and emotional comfort for distant couples [22, 56], but overall, pre-sleep digital consumption is often seen as something to avoid, whereas the underlying needs are generally overlooked.

In this paper, we present a co-design study of a *smart pillow* that explores how to enable digital consumption without disrupting the sleep process. While pre-sleep digital consumption is broad with various underlying needs, our study primarily focuses on the specific transition period of sleep onset, defined as the transition from full wakefulness to sleep [5]. Sleep onset serves as a bridge between these earlier active consumption activities and sleep, representing a critical nuanced period for design interventions. The smart pillow is designed for visual-free, embodied interactions during pre-sleep digital consumption, allowing users to control audio content on a mobile application via the pillow without requiring visual attention. We chose audio because it has already emerged as a popular medium for sleep. As part of the bed environment, the pillow is also widely used across cultures to support sleep, making it easily integrated into existing sleep routines without requiring additional devices or behavioural changes. With a smart pillow prototype, we conducted a co-design workshop composed of 4 sessions with 16 participants in total. Our work illustrates the potential of a smart pillow for audio control to resolve the tension between sleep and digital consumption, highlighting the importance of audio's non-visual modality and emotional comforting qualities, rich content choices, as well as the pillow's physical properties in supporting intuitive and sleep-compatible bodily control (e.g. with hugging). Drawing on our findings, design implications for sleep onset are discussed.

This paper makes four contributions: (1) We present a smart pillow prototype which allows pre-sleep digital consumption with embodied interactions for sleep onset; (2) Through a co-design study with 16 participants, we demonstrate how the smart pillow has potential in resolving this tension of fulfilling pre-sleep needs and transitioning to sleep by removing screen-based interactions in bed; (3) We offer design implications for the sensitive period of sleep onset by leveraging audio experiences, physical sleep objects and coarse bodily gestures; (4) We position sleep onset as a distinct design context, requiring careful design to address pre-sleep needs in a way that aligns with the physiological process of falling asleep.

2 Related work

Here, we will review the related work on digital consumption and sleep, as well as digital interventions for improving sleep.

2.1 Digital Consumption and Sleep

Prior research has consistently shown the negative impact of pre-sleep digital consumption on sleep. The practice of digital consumption itself can displace sleep time, leading to insufficient sleep [6]. Research has also highlighted how the instant availability of digital content and its activation of the brain's reward mechanisms drive compulsive usage patterns [17], often leading to prolonged screen time and excessive use, which are strongly associated with bedtime procrastination [25]. Studies also indicate that the inherent properties of technology devices, including screen light exposure, could disrupt sleep cycles by affecting melatonin secretion, decrease sleep quality and delay bedtime [24, 64].

While digital consumption is widely recognised as a sleep disruptor, it remains prevalent. Early Research revealed that most adolescents actively use digital technologies before sleep, including music (60%), television (37%), and computer games (22%) [18]. This trend has intensified significantly in recent years, as demonstrated by a 2024 study of 245 adolescents, which reported that 90.6% used smartphones in bed, with an average duration of 2.3 hours per day [6]. Beyond adolescents, studies show that substantial proportions of adults use television (31.2%), music (26.0%), the Internet (23.2%), and video games (10.3%) before their sleep too [19].

Studies reveal that people often turn to digital consumption, despite the risk of sleep disruption, to fulfil needs unmet in their sleep environment and routine. Research has found that some individuals view nighttime as their exclusive personal time, using digital technologies to pursue interests that daytime work commitments preclude [29, 58]. The pre-sleep digital consumption has also been identified as a coping strategy, as the pre-sleep period often involves heightened vulnerability to intrusive thoughts, worry, and rumination, which can interfere with the transition to sleep [48]. Research shows how different digital media are drawn on for other emotional needs during this period, including nighttime social media use to address fear of missing out among adolescents [8], music platforms like Spotify, iTunes, and Apple Music to soothe anxiety, video games for immersive alternative worlds to distract from negative thoughts and rumination effectively, and YouTube to shift away from self-consciousness [16].

2.2 Digital Sleep Intervention

Digital sleep interventions have been explored through three prevalent approaches: persuasive techniques, sensory interventions, and social approaches.

One main body of work is based on sleep-tracking [1], often combined with persuasive techniques to motivate behavioural change, e.g. goal-setting, feedback, and rewards [4, 39, 54]. For instance, *SleepFit* integrates sleep analysis, smart alarms, and sleep diaries to encourage healthier sleep routines [50]. *SlumberBot* employs sleep data and user-reported experiences to facilitate decision-making towards better sleep hygiene through conversation with a chatbot [41]. Hartl et al. developed smartphone app prototypes that use punitive sounds, virtual companions, and nighttime reminders —

triggered by self-reported sleep-tracking data — to encourage users to adhere to their intended bedtimes [26]. However, Ravichandran finds that users resist system advice when it conflicts with their established routines, such as avoiding pre-sleep screen use [54].

More research focuses on facilitating relaxation through multisensory interventions that encompass visual, olfactory, tactile and auditory stimuli. Visual experiences are often designed to shape the sleep environment; for example, *Smartsleep* simulates a sunset to create a relaxed atmosphere that prepares individuals for sleep. *Napwell* uses virtual reality to reduce sleep onset time by providing immersive experiences of a comforting environment [51]. The visual interventions sometimes use specific visual elements, such as slow movements or repetitive actions, to induce a relaxing sensation, as seen in animated videos [66]. Olfactory intervention, such as *Dream On* embed scent tokens into physical books to evoke calm for travellers sleeping in unfamiliar environments [52]. *Ezzence* releases scent during specific sleep stages to improve sleep quality [2] based on real-time sleep staging. More recent work has begun to make the interventions more intelligent based on biosensing. For example, *Dozer* utilises a wearable EEG to detect drowsiness, then triggers auditory and brain electrical stimulation via a beanie-based device, aiming to help users fall asleep more quickly [57]. *Earable* use a headband to sense multiple physiological signals and simultaneously control auditory stimulation to evoke appropriate brain responses for sleep promotion [46].

Tactile-based sleep interventions have received increasing attention for their ability to enhance bodily comfort and promote relaxation through haptic vibrations and tactile textures [28, 33]. For instance, Hui et al.'s mattress system converts music into vibrations delivered across the user's back, aiming to reduce stress before sleep through an immersive experience [68]. Also leveraging the mattress, Wu et al. proposed a layered design that optimises pressure distribution to maintain bodily comfort as sleep postures unconsciously shift throughout the night [67]. *The Rice Walker* provides a tactile intervention designed to smooth the user's pre-sleep states. It employs a pneumatic pad filled with rice that produces subtle textural and rhythmic feedback through users' footsteps, thereby facilitating a sense of calm and relaxation [43].

Among various sensory interventions, audio-based approaches are the most widely adopted and commercially developed for sleep support. This prevalence stems from multiple mechanisms through which audio facilitates sleep transitions. Research identified auditory tones as a means to induce physiological relaxation responses through binaural beats that entrain brain activity to theta frequencies associated with early sleep stages [38]. A mixed-methods online survey using audio content shows that audio can provide a distraction from intrusive or ruminative thoughts [61]. Additionally, white and pink noise mask environmental disturbances to create a more sleep-conducive acoustic environment [10]. Beyond these sleep-specific mechanisms, audio interventions benefit from high accessibility through existing consumer devices, with many smartphone-based applications offering a variety of soothing audio content to help users unwind before sleep [47, 53]. In HCI, *Wander* uses breath-control audio to facilitate sleep by avoiding pre-sleep digital usage [9]. *Sonic Blankets* explores a sound-augmented blanket as a relaxation tool and potential sleep enhancement aid [14].

Beyond individual sleep interventions, researchers have begun to explore social approaches that leverage interpersonal connections to enhance sleep experiences. This line of work has been particularly studied in the context of long-distance couples who sleep in separate locations. For instance, *Somnia*, a pillow designed for long-distance couples, demonstrates its functions to motivate individuals to go to bed through heating activation when their partner goes to bed, and foster intimacy by simulating physical presence [56]. Similarly, *SleepyWhispers* integrates audio messages into a pillow, allowing distant partners to share goodnight messages before sleep [22]. *Sensing Bed* bridges physical separation by detecting body positions and transmitting corresponding heat patterns to the partner's bed [23]. Explicitly focusing on bedtime media browsing, *Weight of Scrolling* is an interactive installation that reimagines social media scrolling through a tangible media interface, transforming the act of bedtime solo scrolling into a shared experience [49]. These social sleep interventions recognise that sleep decision is not merely a rational one but also more of a social and emotional one [56].

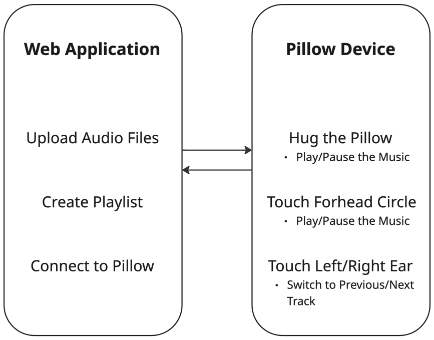
3 Design

In this work, a smart pillow is developed to explore audio-based digital consumption for sleep onset. We built a system comprising a web application and an interactive pillow. Users configure audio content in advance through the web application. Then they can engage with audio experiences using screen-free, low-effort control via the pillow after going to bed for sleep (Figure 2).

3.1 Design Rational

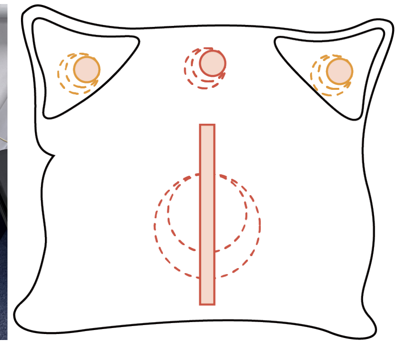
Audio Modality and Choice Audio has been leveraged as a promising modality for facilitating sleep [32]. Audio supports relaxation [38], and contributes to the creation of more conducive sleep environments [10]. Prior research has shown that participants exposed to audio-only stimuli experienced longer sleep time compared to those exposed to both audio and visual stimuli before sleep [32]. For this reason, we utilise audio as a non-intrusive modality for enhancing the sleep onset experience. In the workshop, we pre-configure the application with various types of audio, including slow-paced songs with and without lyrics, audiobooks, and podcasts, as examples.

Pillow as an Interface Supporting pre-sleep digital consumption requires not just appropriate content but also proper control mechanisms. Traditional digital consumption via screen-based devices requires visual engagement for deliberate manipulation, which could disrupt the sleep process [36]. To facilitate more embodied interactions with minimal interruptions, we selected the form of a pillow as the interface for interaction. A pillow is a familiar sleep aid used across cultures, allowing it to be naturally integrated into people's sleep routines without the need for adaptation. Through iterative design process, starting with a simple pillow only with hugging on and off functions, and with a couple of focus group discussions within our own team, we arrived at a smart pillow which is a square in shape, has a soft and furry surface, and an embroidered sleeping cat motif (Figure 2b): soft, fluffy materials invite users' actions like hugging and squeezing, which could be used as interactions; the tactile qualities of the material, such as the texture and contours shaped by raised stitching, also contribute



(a) The Architecture

(b) The Pillow Interface



(c) The Sensor Distribution

Figure 2: The Smart Pillow System

to interaction by guiding users' touch-based engagement without requiring visual attention; a cat motif was chosen so that we could use the ears as precise functional controls. The raised boundaries of the ears and a circle in the forehead create tactile markers that users can locate through touch in a visual-free context. This approach provides users with control over their sleep onset experience while bypassing the drawbacks of using conventional screens during bedtime, such as cognitive arousal or distraction. This way, various interactive needs are accommodated with a smart pillow as the tangible interface.

In summary, we have three interactions designed into the pillow (Figure 2c): hugging, forehead touching and ear touching. *Hugging* the pillow's centre, the most natural pillow interaction, for the most fundamental control function - playing or pausing audio playback. Certain pressure thresholds are tested and determined to distinguish intentional hugs from incidental contact during sleep, preventing accidental activation. This function is also allowed with *forehead touching*, enabled with a circle embroidered on the cat's forehead, as some users consider this to be more natural. For *ear touching*, we use the cat's ears to enable track navigation: the left ear for "previous", and the right for "next".

3.2 Hardware and Software

As mentioned, the prototype consists of a web application and a smart pillow as its tangible interface (Figure 2a).

3.2.1 Web Application. A web application was developed to allow users to set up the Bluetooth connection and configure the playlist. The web interface was implemented using Ionic [1], a mobile development platform. The web interface allows users to create personalised playlists and facilitates communication between the audio player and the smart pillow via Bluetooth. This allows users to remotely control the audio player by interacting with the pillow. For our study, the audio player was a laptop computer. Once connected, users can control the computer's playlist through the pillow.

The web interface consists of three tabs: "Upload Audio Files", "Create Your Playlists", and "Connect to the Pillow" (Figure 3). The first tab (Figure 3a) allows users to upload audio files. In the second tab (Figure 3b), users can create personalised playlists by selecting from the uploaded files and adjusting the playback order. The third tab (Figure 3c) enables users to connect to the smart pillow via Bluetooth, allowing them to control audio playback through the pillow.

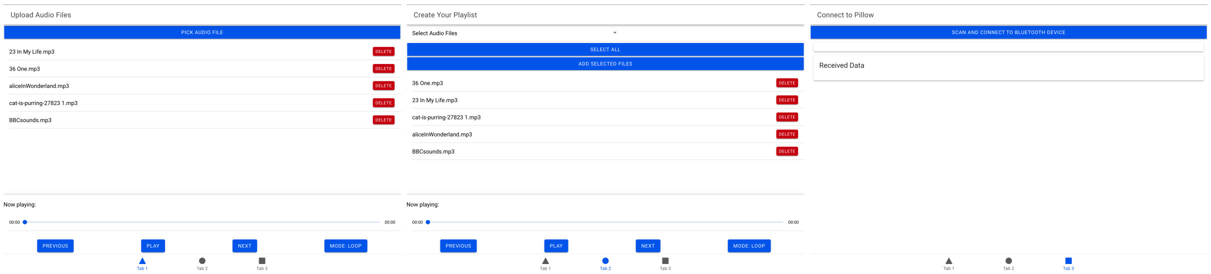
3.2.2 Pillow Hardware. The hardware of the pillow is comprised of a microcontroller (ESP32 development board), a touch sensor (Keyes TTP223), a film pressure sensor (RP-L70), and a power supply battery (2000 mAh, 5 V). The pressure sensor was placed beneath the main body surface of the pillow to detect hugging interactions, while the touch sensors were placed under the pillowcase's cat ears and forehead. To make the device washable and the components easily removable, we put all sensors in internal fabric pockets sewn into the pillow. The microcontroller and battery are placed inside the pillow core. For the workshop, the pillow is not designed to be waterproof, which would be important in a full-scale device.

4 Method

We used a prototype-based co-design workshop to explore how to enable digital consumption without disrupting sleep. The use of a prototype, a smart pillow in our study, aims to bridge the gap between abstract ideas and concrete experiential understanding. In this approach, the prototype acts as a probe that elicits responses, reactions, and insights that participants might not be able to access or verbalise through discussion alone. By providing something concrete to interact with, critique, and build upon, the prototype transforms participants into active co-designers who can demonstrate, rather than just describe, their needs and preferences.

Four sessions of a co-design workshop were conducted with different participant groups in a meeting room (Figure 4). Each workshop session followed a structured process: collecting consent and demographic information, introducing the workshop and demonstrating the smart pillow prototype, engaging in hands-on prototype interaction, facilitating individual ideation through structured worksheets, encouraging group discussion to generate ideas, and allowing participants to prototype through drawing. Following completion of an online consent form and a demographic questionnaire, we began each workshop session by introducing ourselves and the workshop's aims. We then demonstrated the current

[1] Iconic SDK Mobile Development https://ionicframework.com/



(a) Tab1: Upload Audio Files **(b) Tab2: Create Playlist** **(c) Tab3: Connect to the Pillow via Bluetooth**

Figure 3: Web Application

smart pillow prototype and explained its key features. Afterwards, participants engaged in hands-on interaction with the system to gain direct experience by controlling audio content on the web application via the pillow prototype. Once they gained sufficient experience with the system, we asked them to complete a worksheet to capture their experience, feedback, and ideas for further improving the pillow. Following this task, we facilitated a group discussion in which participants shared, critiqued, and refined their ideas about using the smart pillow noted in their worksheets. Each participant was then invited to consider how these ideas could be incorporated into the prototype, using sketches to illustrate their concepts. The group then discusses the individual's idea in turn. Throughout the workshop, we provided coloured pencils, pens, sticky notes, and sketch paper. We audio-recorded the workshop with the participants' consent. For each session, one of the authors acted as a facilitator, and the other author served as an observer, further documenting emergent ideas throughout the session in written notes and photographs.

To recruit participants, we used physical posters displayed across campus and digital advertisements posted on the university's recruitment platforms. We also used snowball sampling as a supplementary recruitment method. Participants were compensated with a £5 Amazon voucher for taking part. The number of participants changes slightly in each session due to the availability of participants' time: three in Session 3, four in Sessions 1 and 4, and five in Session 2. The study received ethical approval from the university's ethics committee (ethics number *<300240006>*) for research involving humans. In total, 16 individuals participated in our workshop sessions, as shown in Table 1.

Session	No.	Age	Gen.	Nationality
Session1	P1	20-40	F	China
Session1	P2	20-40	F	China
Session1	P3	40-60	F	Poland
Session1	P4	40-60	F	China
Session2	P5	20-40	F	China
Session2	P6	20-40	M	India
Session2	P7	40-60	F	United Kingdom
Session2	P8	20-40	M	Brazil
Session2	P9	20-40	M	Paraguay
Session3	P10	20-40	M	China
Session3	P11	20-40	F	China
Session3	P12	60-80	F	United Kingdom
Session4	P13	20-40	F	China
Session4	P14	20-40	M	Thailand
Session4	P15	20-40	M	Oman
Session4	P16	20-40	M	Czech Republic

Table 1: Participants Information

4.1 Data Analysis

Our dataset comprises 16 open-ended worksheet responses, 15 prototyping drawings (with P1 and P2 submitting a joint drawing), approximately four hours of audio-recorded workshop discussions, sticky notes from participants, and facilitators' written notes. For the analysis of prototyping drawings, we combined visual data from the drawings with participants' verbal explanations captured in the audio recordings.

Thematic analysis was used in our analysis [7]. Following audio transcription and immersion in the data, two primary authors conducted systematic coding across all materials, generating initial codes inductively from the raw data. Codes included "lower the workload of selecting music," "no distracting effect," "catering to emotional needs," and "not requiring conscious action." These codes were then iteratively organised into potential themes through multiple rounds of grouping and regrouping, generating initial themes like "leveraging sleep habits & sensory preferences," "leveraging sleep objects for easier interaction," and "leveraging sleep gestures." Through an iterative process with review sessions involving the entire research team, we refined these themes by merging overlapping themes, splitting or discarding weak or incoherent ones, and clarifying distinctions between them. Lastly, we identified two overarching themes, which will be presented in the findings section.

5 Findings

In this section, we will report findings from the co-design workshop. We present the potential of audio and pillows to support sleep onset,

(a) Workshop Setting **(b) Participant Interacting with the Prototype** **(c) Participant Completing the Worksheet**

Figure 4: Workshop Process

as well as how the tangible and physical properties of the smart pillow afford interactions during this transitional period. [2]

5.1 The Affordance of Audio and Pillow for Sleep Onset

5.1.1 Audio Consumption as More Sleep-compatible. In our study, participants confirmed that audio is well-positioned for sleep onset digital consumption, grounded in its non-visual modality [32] and its capacity to offer emotional comfort [38]. Actually, some participants had already engaged in online audio content, not visual, to facilitate sleep (e.g.P1 and P10). Others realised from the workshop that audio would be preferred over visual for sleep onset digital consumption. P12 put it this way: "*At the moment, I tend to watch programs before I fall asleep, but actually, it would be better to listen because I close my eyes, so listening is a better option.*" Participants (e.g. P3, P13) also liked the audio's ability to facilitate emotional comforting, a quality particularly valuable during the emotionally sensitive moments of sleep onset.

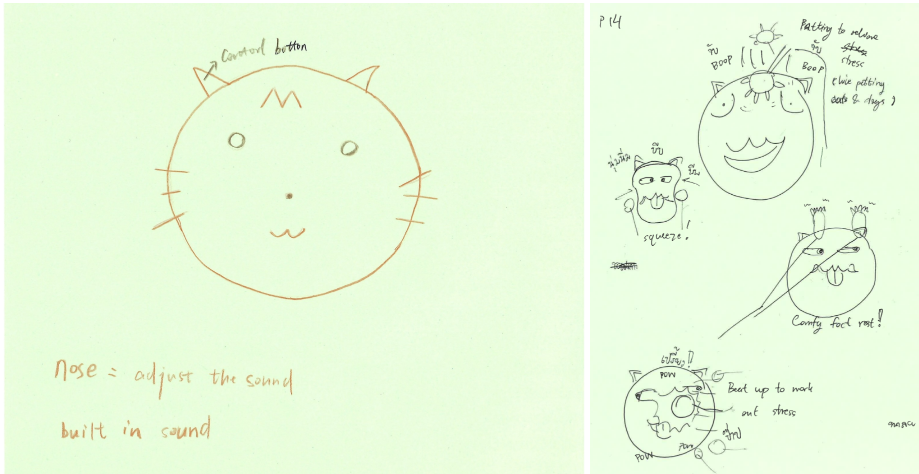
To enable audio-based digital consumption, participants emphasised the importance of incorporating rich audio content options to avoid getting bored before falling asleep. P12 suggested streaming functionality to achieve this content richness: "*A facility to stream something like podcasts or anything like that.*" To access the rich content more easily, some participants suggested connecting the pillow to external media platforms. Audio-based platforms such as Spotify were frequently mentioned, as participants had already curated extensive audio collections on these platforms. Similarly, P11 would like the pillow to be able to connect to NetEase Cloud Music: "*I like to listen to something before sleep, but I usually listen to them on other apps. It would be harder for me to use it if it couldn't connect to external apps.*" As shown here, not only the soothing effect, but also the capability for them to choose from a range of audio contents will be key for them to pass the sleep onset time.

To better support sleep transition, several participants suggested that the audio volume should be lowered and turned off gradually. This will align with the physiological process of diminishing sensory input as one falls asleep. Both P5 and P12 recommended a gradual shutdown because they think that a sudden stop of music could raise their alertness. For instance, P12 said: *Have an option for a gradual fade set by the user, e.g., a half-hour fade, so the sound doesn't wake you if you fall asleep early.*" P6 proposed a gradual transition to other sounds, such as white noise, to further aid sleep: "*A gradual shutdown of volume but no absolute silence, rather, some brown or white noise could be played.*"

5.1.2 Emotionally Supportive Pillow Design. New design ideas were generated around the physical form and rich meaning of the pillow, such as associations with participants' childhood memories or personal attachments, to enhance sleep onset further. P1 was temporarily separated from her cat, so she designed a cat-shaped pillow to get a sense of connection through interaction with it (Figure 5a). P12 recalled childhood memories: "*I think a lot of us got teddy bears when we were kids, it just gets back to childhood.*" Based on this, she proposed a teddy bear design that allows her to interact with audio content while hugging the bear (Figure 6b). P11 also wanted the pillow to have a stronger emotional connection with themselves, suggested a customisation option, "*I think it would be good if I can buy a product that has such sensor components, and I can just easily assemble it in my lovely bears or my personal belongings*". Several participants suggested that animal sounds be incorporated into animal-themed pillows to enhance their experience. P1, P3, and P12 all proposed using animal sounds, P12 mentioned: "*Possibly have 'purr' as an alternative to music...particularly if you've got an animal feature, if you made this a cat face, so that it purrs, or a dog face later (with dog barks), those are the sort of sounds that might help people as well.*"

The fluffy form of the pillow further inspired stress-relieving actions. During the early stages of sleep onset, participants stated that they often experienced emotional needs before sleep, and the animal-shaped pillow invited corresponding actions to help relieve stress. For instance, P14 designed a pillow with a funny face image, and suggested interactions such as patting the distinct "head" region or squeezing it to release stress: "*You can pat it on the head like a dog...You can beat it up to work out stress, or like, squeeze it.* (Figure 5b)" P1 also stated:"*When I feel sad, I want to hug it very hard.*"

[2]Throughout this section, we use the pronouns "they" and "their" when referring to participants. This choice is made to respect gender inclusivity and to avoid assumptions about participants' gender identities.



(a) (b)

Figure 5: (a): A cat-shaped pillow design to maintain connection with her separated pet; (b): A pillow design with facial features for stress-relieving interactions through patting and squeezing

These accounts highlight how the soft and squeezable physical properties of the pillow invited emotionally expressive interactions that participants could use to deal with stress and fulfil emotional needs before falling asleep.

5.2 Interaction Design During Sleep Onset

5.2.1 Supporting Non-distracting Experience. Participants appreciated the idea of using the pillow, as it helped them stay away from their digital devices while still allowing for controlled digital consumption to facilitate sleep onset experiences. For example, P11 shared: "*The first reason, if I choose the pillow instead of my phone to play something in bed, is that I want to keep my phone away from the bed.*" Both P2 and P8 expressed their frustrations about how they just wanted to set an alarm for tomorrow, but ended up browsing social media on their phones for a long time. Participants further commented that allowing a digital device to handle initial setup for more complex configurations is fine. Still, the pillow should be able to handle the interactions after that, not only to avoid distraction but also for ease of use. As put by P12: "*You can preset the playlist or whatever, but when you need to use it, just grab the pillow.*" Similarly, P4 said: "*I just want to use the pillow to control everything after things are set up with the mobile phone.*" P10 further emphasised interactions with the pillow should be extremely easy: "(Whether I will use it) depends on how easy it can be used. If you add too many extra steps, maybe I will not use it. But if you make it easier, maybe I'll make it a habit, e.g., by hugging it and turning it on by itself." As shown here, the smart pillow enables users to engage in digital consumption to fulfil their needs without the usual distractions associated with the use of multi-purpose digital devices.

Regarding audio selection processes, which could introduce distractions during sleep onset periods, our participants highlighted the need for more careful design. P6 put it: "*Yeah, because selecting itself is a huge task.*" To address this issue, some proposed personalised recommendations to reduce the effort needed. P5 envisioned: "*Based on play history, [provide a function of] guess what you like (like daily recommendation)*". P12 suggested preset sounds: "*So have some built-in preset sounds... and provide random playlist feature (by category too, e.g., chill, ambient).*" As such, features like a built-in library or daily recommendations could help with selections and reduce the risk of introducing disruptions.

The issue of feedback also became a point of active discussion, and many suggested using audio or haptic feedback rather than visual feedback to better align with sleep requirements. P11 mentioned "*It should be simple to use, avoid opening eyes to interact with it, which could stop the process of sleeping.*" P11, P12 and P13 all firmly rejected any light feedback, as put by P11: "*Absolutely no light.*" P12 confirmed: "*No lights – likely to wake me up!*" P10 suggested using tactile or haptic feedback "*It might be better to include haptic feedback like vibration for each interaction instead of just light.*" Participants also asked for proactive safeguards during the sleep context to prevent unintended activations. P6 highlighted the risk of unintentional triggers due to hand movements: "*If you, like, by mistake, move your hands, it could start playing and wake you up.*" P9 also expressed similar concerns: "*If you are hugging the pillow while you are sleeping, it wouldn't, like, play or stop suddenly?*"

Participants also highlighted the impact of delayed feedback in sleep contexts, as waiting for a response can disrupt their sleep process. In our current prototype, even a one-second delay was perceived as alarming. P12 explained: "*I think the delays are catching me out. I think it hasn't stopped, and I hug it again, and it starts again.*" P11 also pointed out that "*Users might be anxious when it can't be turned off immediately.*" P7 suggested incorporating buttons that provide a more evident and typical way of input: "*We feel like, if the button could be more like, you know, a tactile kind of button where you click on it and there's kind of a click sound that you know it's been clicked.*" Similarly, P8 advocated: "*A more tactile button, where you can notice if you pressed it or not.*" P14 and P15 further proposed auditory feedback that leverages the physical design of the animal-themed pillow, such as a cat meow, animal heartbeat or purring, to create a more calming and soothing feedback experience.

5.2.2 Leveraging the Pillow Form for Refined Interaction. Participants frequently mentioned that the pillow supports a natural way for them to interact during sleep onset. P15 proposed: "*Hugging and touching seem natural.*" P12 noted that they already hugged something during sleep, so it can be easily incorporated into their sleep experience: "*I do have a little pillow that I hold as well, so for me, this sort of design would work fine...I like the size. I quite like square, just because that would fit the way I sleep anyway.*" Participants also proposed other familiar pillow interactions as control methods. P4 noted: "*Not using a button, something like grabbing a corner might work.*" P12 suggested using established, familiar actions of the pillow to achieve different functions: "*Hugging for one feature, stop by squeezing or touching*". These simple actions, such as hugging, grabbing, and squeezing a pillow, were all considered easy and intuitive for this setting, afforded by the pillow's shape and material properties.

Participants further suggested leveraging the form, size, and orientation of the pillow for more refined control and accurate interaction. For instance, P12 raised concerns about distinguishing between different control zones, asking: "*How do I know which corner does which function?*" This would require the pillow to be rightly oriented - the pillow would need to be hugged with the cat's head facing upwards to ensure the control areas function as intended. P4 also suggested that having to identify the correct orientation before hugging requires too much effort. Instead, they proposed a long-shaped pillow, which naturally suggested a specific direction to hug: "*The shape of the pillow indicates how to hug. e.g. if it's a long-shaped pillow, you will naturally hug it this way (Figure 6a).*"e further suggested placing audio selection control on the side of the long cushion to ensure interaction is accessible regardless of which side faces the body.

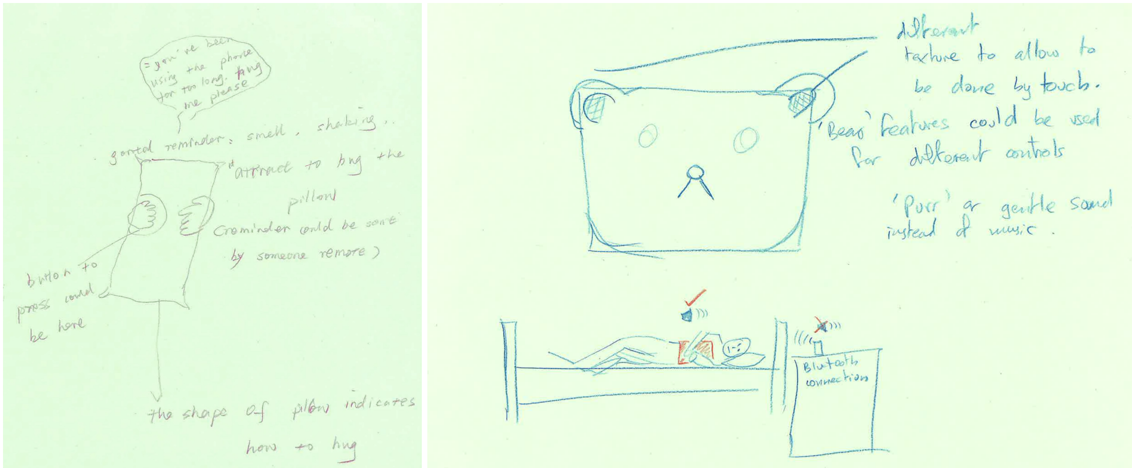
Beyond a standard geometric pillow form, some participants proposed animal-shaped pillows, where distinctive regions, such as limbs, ears, and different textured surfaces, can be utilised to afford different functions in a visually free manner. P12 proposed a teddy bear design with distinct textured regions, allowing interaction through tactile affordance: "*Because you've got something for you to grab on — nose, different textured fabrics, you can feel the areas. The nose could be for stop, the ear for something else. Different textures for interaction areas would help with control when the room is dark.*" Similarly, P1 described a cat-shaped pillow where the ear could serve as a control button and the nose might adjust the sound (Figure 5a).

5.2.3 Leveraging Bodily Posture for Minimal Effort. Some participants expressed frustration that the prototype required active movement and suggested a design that leverages different body parts to allow for minimal interaction. P5 said: "*I will put another arm like this (lay flat on bed) so I can only use one hand to interact, and I would like a large pillow that I could put my legs on. So if I use the buttons on the pillow and the pillow is large, the button will be all over the pillow...hard for me to reach.*" (Figure 7b). They then proposed a Bluetooth controller in their hand that she could control with minimal body movement. Similarly, P11 said they don't want to move around to control the button and suggested using tapping to reduce the effort for interactions: "*I hope I can use one hand to control it...tap once for next song, tap twice for the previous song instead of touching buttons at different places. e.g., I can tap it once when my mind is not so clear at night to turn it off. Tap it different times to give me different actions.*"

Participants also suggested enlarging certain interactive areas to reduce interaction effort, aligning with the decreased cognitive and physical capacity typical during sleep onset. For instance, P11 specifically recommended placing the stop function - the most important feature to use when she is almost falling asleep - in the largest area to make it the most accessible thus least effort: "*I designed a lovely teddy, I think there are different areas that could put in the sensor, the hand, the legs and the ears. I would put the stop function in the main body, the largest area.*" Similarly, P6 envisioned a long pillow with a large interaction area to enable higher accessibility, stating: "*A long pillow, half human size, with a sensor activation area in the middle.*"

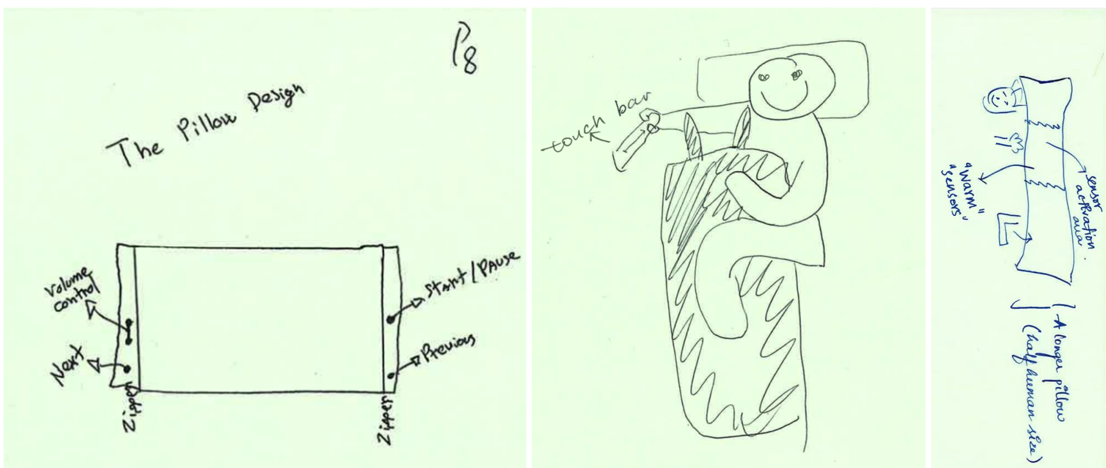
The fact that pillows are often used to support people's sleep posture is also considered a way to minimise interaction effort by positioning the interaction area where their limbs rest on the pillow. P10 has an Ikea shark at home to sleep with, and drew a sketch inspired by his shark to illustrate how to embed interaction zones within the natural reach of hands or legs to minimise effort: "*If the pillow is mostly designed to be used in a 'hugging' style, it might benefit from more ergonomic designs, like the IKEA shark. I usually put my arm around the fin and my feet on the tail when I sleep. If you put a button here (shark tail), I can just kick it. This way, it not only feels more comfortable to hold but also easier to locate the control buttons.*" P6 proposed a partitioned pillows with consideration of how his body is rested on the pillow to minimise effort and avoid mis-triggering: "*Because if you have your face over here, you don't really want to touch it, okay, so you want your arms to be accessible in this area... this part you don't really want your foot to be touching..*" (Figure 7c). As shown here, the pillow interface can create interaction zones that align with the user's sleeping posture, enabling motion-free interactions, avoiding mis-triggering, and creating a more comfortable sleep experience.

Participants emphasised the importance of accounting for users' varying sleep postures to ensure the pillow works effectively. While the interaction, like hugging, was favoured by side sleepers, some who sleep on their backs or stomachs required different interaction approaches and pillow shapes tailored to their sleeping postures. For instance, P11, who sleeps on their back, asked: "*How can you hug something when you lie down?*" P9 suggested a better usage form for those who sleep on their back: "*It would be difficult to use it while lying down. I might place it under my head instead of hugging it.*" P7 (sleeps on stomach) and P8 (sleeps on back) said: "*Because we're not much of a hugger for sleep, it would be good if you could integrate it into the pillow that you're actually sleeping on.* (Figure 7a)." P7, who sleeps on her stomach with her face down and arms beside the pillow, preferred a "more rectangular" design with controls on the side. This design allows easy hand access while preventing accidental activation from head movements: "*Control at the side is better, so if it's used as a pillow, your head won't accidentally press a button.*"



(a) (b)

Figure 6: (a): Long-shaped Pillow Suggest the Dirction of Hug; (b): Physical Form and Texture to Guide Visual-free Interaction



(a) (b) (c)

Figure 7: (a): Design for People Who Sleep on Their Back; (b): Enable Control without Hand Movement; (c): Large Interaction Area for Higher Accessibility

6 Discussion and Design Implications

The preceding sections examined the use of a smart pillow for audio consumption during sleep onset. We highlight that a smart pillow is promising for facilitating both sleep onset and digital consumption, as well as the transition into sleep, which involves gradually losing consciousness. These two co-existing activities often compete when digital consumption occurs through a screen-based interface. Through a smart pillow that controls digital audio content, users can engage with rich audio content — crucial for supporting sleep onset experience — while avoiding the use of digital devices in bed, thereby eliminating a primary disruption that leads to bedtime procrastination. We revealed how to leverage the smart pillow's form and material affordances to enable participants to use their natural sleep behaviours (e.g. pillow hugging) and postures as interaction methods. We will now reflect on how to design for the sleep onset experience.

6.1 Designing for Sleep Onset Experience

This study suggests that rather than inherently conflicting with sleep transition, digital consumption can be designed to align with the process of falling asleep. While previous work tends to blame digital consumption for sleep disruption, our work suggests a design space where digital consumption can simultaneously fulfil users' pre-sleep needs and facilitate sleep transition, based on the understanding that digital consumption could also serve for various benefits and needs before sleep[8, 13, 29, 58]. In a sense, this is similar to Williams' [59] critique of the common view about television

50 years ago, where television was blamed for social changes, such as the decline of community life. Williams argued, instead, that TV consumption is not an independent force but rather a product of cultural needs, industrial decisions, and political contexts. The same concept applies to the relationship between digital consumption and sleep. Instead of placing the blame for bedtime procrastination on digital technologies [15, 21], researchers should focus on designing systems to accommodate the needs associated with their use and foster a more desired sleep onset experience. Our research suggests that allowing people to consume digital content through sleep-compatible modalities and interactions — such as audio consumption via the interface of a smart pillow — may actually support sleep goals better than requiring complete elimination of digital consumption.

Audio consumption beyond relaxation. Previous research on audio for sleep onset, while acknowledging audio is a more suitable modality than visual content [42], mainly focused on the relaxing, sleep-promoting effects of specific audio types or features [10, 61]. However, as shown in our data, simply presenting audio as soft, ambient, and non-intrusive content is insufficient; instead, users require rich audio options, often integrated into their currently used platforms, as a way to address their underlying needs during sleep onset, such as claiming "me time".

The smart pillow's physical properties are as crucial as its digital capabilities. In our workshop, the smart pillow functions not only as an interface, but also provides comfort experiences that align with sleep onset emotional needs. Participants envisioned pairing matching ambient sounds with animal-shaped pillows and animal features (e.g., a cat-shaped pillow with purring sounds). Many participants attributed the pillow to personal symbolic objects such as childhood toys and pet representations, demonstrating how the pillow's physical form becomes integral to the comfort experience, and how the pillow's soft materiality and special form are inviting for stress-relieving actions such as hugging, patting, and squeezing, as meaningful interactions that extend beyond the pillow's role as an interface for audio control. While there are existing technologies such as smart speaker that might fulfil similar functions in a seamless manner, our findings suggest that the pillow's material qualities, form factors, and familiarity for sleep also play important roles in shaping the holistic experience of sleep. Taken together, by leveraging the pillow's rich physical affordances, such as its form, the symbolic associations embodied in its physical design, and its materiality, the smart pillow enables users to access both functional control and emotional support.

6.2 Designing for Effortless Interaction

The need to interact with rich audio content necessitates a new interaction design that supports user control in the context of sleep onset. This aspect has been largely overlooked in research primarily focused on using audio for soothing effects. As our findings revealed, a key challenge in supporting the need for sleep onset audio consumption lies in enabling users to control the audio content without disrupting their sleep process. Traditional screen-based interfaces are not appropriate here, as they demand visual engagement and focus attention on monitoring, interpreting, and manipulating. We present design implications around this transitioning bodily states, which can be adopted to inform design for other sensitive states where users experience limited visual [12], cognitive [3], and manipulative [30] capacities.

Sleep object as an interface to enable visual-free, non-distracting interaction Although sleep objects, such as mattresses and blankets, have been widely explored as tangible interfaces in the sleep context [14, 67, 68], their potential to enable visual-free, effortless control has not yet been fully explored. Regarding leveraging sleep objects as a tangible user interface (TUI), our study extends their usage during a sensitive sleep onset context by leveraging their unique interactive affordances. For instance, soft and deformable materials invite embodied interactions, such as hugging, which are not feasible with screen-based interfaces[11, 45]. Furthermore, embedding the interface into familiar everyday objects enables us to align interaction with users' existing practices, extending beyond standard TUI affordances [65], such as patting and squeezing in our case.

The physical properties of the smart pillow interface can deliver feedback through multiple sensory channels, which are compatible with the sleep process. Our study suggests that feedback in sleep onset should be perceivable without requiring visual attention and should remain non-intrusive to the sleep process. Participants expressed discomfort with conventional visual indicators, such as LED lights; instead, they preferred visual-free feedback, including haptic and subtle auditory cues. These modalities allowed users to stay informed about system status without requiring full alertness or risking disruption to their transition into sleep. Here, TUI not only enables visual-free interaction but also facilitates system feedback through alternative modalities, such as audio or haptic, offering less distracting communication.

Error handling should also be carefully designed, as sleep onset involves a transitional state in which users are cognitively and physically disengaging from their environment, lacking the capacity to detect, interpret, or correct errors. During this period, errors such as unintended activation or sudden volume increases are particularly disruptive, not only causing an unsmooth interaction experience but also directly undermining the fragile transition into sleep. Therefore, rather than relying on users to confirm actions or recover from mistakes, systems should proactively anticipate and constrain high-impact errors. For instance, this can be achieved by setting hard limits on maximum volume or capping the rate at which volume can increase.

However, effortless interaction during sleep onset does not exclude the use of screen-based interaction for configurations or other purposes before sleep. Participants emphasised the importance of non-disruptive and effortless interaction *during the specific sleep onset period*, but also felt it was acceptable, and even necessary, to configure audio content on a digital device in advance. The combination of screen-based and pillow interfaces allows the planning of digital consumption, and tangible interfaces for intuitive control. In other words, the tangible interface does not replace the digital platform but complements it, enabling users to offload cognitive tasks and avoid distraction at sensitive moments.

Coarse bodily postures for minimal interaction effort. One challenge in sleep onset interaction lies in the user's reduced motor precision. Interactions vary in the scale and coordination of movement they require: coarse, full-body gestures engage larger muscle groups and do not rely on visual guidance or fine motor control, whereas fine-grained manipulations depend on refined finger movement and hand–eye coordination. When sleeping, people's diminished visual ability results in a diminished capacity for precise motor actions [55], making fine interactions, such as pressing specific buttons, feel effortful. At the same time, coarse gestures, like "hug" or "grab," are perceived as more comfortable and effortless. More specifically, when designing for coarse interaction during sleep onset, interfaces should leverage the most spatially accessible areas of the object, such as the belly of a toy-shaped pillow, to minimise interaction effort.

While the coarse, embodied gestures are also adopted in other contexts, such as for visually impaired users and older adults, where visual or fine motor abilities are limited, they are primarily screen-based. For instance, [12] enables visually impaired users to access positioning functions by simply shaking the phone, instead of operating on the screen. Similarly, design guidelines for older adults recommend using coarse gestures, such as swiping rather than pinch-to-zoom, to alleviate the burden of precision control [44]. By adopting coarse embodied gestures within a tangible, familiar everyday object, such as a pillow, designers can reduce the effort required for coarse interaction even further.

By leveraging bodily postures, the design also brings the interface to the user rather than requiring users to reach out to control, further reducing the interaction effort. This aligns well with body-centric interaction, which explores interactions with bodily awareness, sensations, and movements [20, 31, 62]. This approach of using bodily sensations as interaction affordances is particularly suited to sleep onset contexts because bodily sensations operate at the most basic level of human-environment interaction, requiring minimal cognitive resources. We revealed that the physical contact area between the body and the pillow creates opportunities for interaction without requiring spatial orientation, making interaction with TUIs even more straightforward. Cognitively, this approach enables an egocentric perspective, which is immediate and intuitive, whereas adopting spatial perspectives different from one's own requires additional mental effort [63]. Physiologically, proprioception offers continuous, unconscious sensory feedback from muscles, tendons, and joints. Together, this approach brings interaction to the user, rather than requiring the user to reach out for control, therefore allowing the body to perform interaction with minimal conscious effort [37, 60], and facilitates faster and more seamless interaction [55].

7 Limitation

As a workshop-based study, our research captures initial user reactions and conceptual preferences rather than actual sleep behaviours, which constrains our ability to conclude real-world effectiveness. We acknowledge the benefits and underlying needs that drive pre-sleep digital consumption, which motivates our research on how a smart pillow can be designed to allow pre-sleep digital consumption in a sleep-compatible way. Future research would benefit from recruiting a larger sample size and conducting in-the-wild studies to observe how users interact with the pillow in their natural sleep environments, and empirically validating how such consumption addresses users' underlying needs without disrupting their sleep. This study, however, paves the way for such work, highlighting the need for design to support people's sleep onset experience.

8 Conclusion

A co-design workshop with 16 participants suggests the potential of designing a smart pillow to allow audio-based digital consumption without screen-based interactions for sleep onset. Our findings revealed both the inherent affordances of audio as a preferred medium for sleep onset consumption and the additional requirements necessary to support its effective interaction. We highlighted that the pillow's physical and material affordances, as well as its role as a familiar sleep object, could enable vision-free, intuitive, and low-effort control, essential for the sensitive period of transitioning to sleep. This work contributes new design insights to support sleep, and highlights an interaction design space characterised by sensitive bodily states and limited interaction capacity.

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