



Article

Autoethnography of Living with a Sleep Robot

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Abstract: Soft robotics is used in real-world clinical situations, including surgery, rehabilitation, and diagnosis. However, several challenges remain to make soft robots more viable, especially for clinical interventions such as improving sleep quality, which impacts physiological and mental health. This paper presents an autoethnographic account of the experience of sleeping with a companion robot (Somnox), which mimics breathing to promote better sleep. The study is motivated by the key author's experience with insomnia and a desire to better understand how Somnox is used in different social contexts. Data were collected through diary entries for 16 weeks (8 weeks without, 8 weeks with) and analysed thematically. The findings indicate improved sleep and observations about the relationship developed with the companion robot, including emotional connection and empathy for the technology. Furthermore, Somnox is a multidimensional family companion robot that can ease stomach discomfort and stress, reduce anxiety, and provide holistic care.

Keywords: sensing technology; medical robotics; sleep robot; autoethnography; insomnia; sleep; arousal; hyperarousal; sleep intervention



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1. Introduction

Insomnia is a sleep disorder characterised by difficulty falling or staying asleep, requiring symptoms to persist for at least four weeks for diagnosis according to the International Classification of Diseases (ICSD-10) [1]. Globally, the prevalence of insomnia and insufficient sleep pose significant public health concerns, with work–life boundaries blurring in our 24 h society [2]. The Mayo Clinic identifies standard sleep disorders like sleep apnoea and insomnia, often triggered by stress, medication, or mental health issues, particularly affecting females and those over 60 [3]. This issue spans all age groups, often undetected and contributing to economic costs through decreased productivity [4]. In developed nations, around 30% report chronic insomnia symptoms [5], exacerbated by the COVID-19 crisis, leading to heightened mental health challenges [6].

Those affected with these conditions often experience constant fatigue, low mood, reduced energy, and impaired attention [5]. Adequate sleep is essential for both physical and mental health. The absence of quality sleep can lead to daytime tiredness, irritability, and reduced cognitive function. This leads to a negative impact on work and overall quality of life [3]. Moreover, insomnia commonly co-occurs with various conditions such as diabetes, hypertension, depression, and neurodegenerative disorders, contributing to decreased lifespan and cognitive impairment [7]. Recognising and treating sleep abnormalities early may help delay functional decline and mitigate associated risks [8].

Clinicians commonly recommend several treatments for insomnia, including lifestyle changes, medications, and cognitive-behavioural therapy (CBT). Medication is often the preferred choice due to accessibility. However, it can lead to significant improvement,

albeit with potential side effects like daytime drowsiness and dependence, necessitating dosage adjustments and causing dizziness. Alternatively, CBT usually takes about six months to show effects and has proven more effective than medication, with a lower withdrawal rate and no pharmacological risks. Additionally, non-pharmacological approaches such as muscle relaxation, mindfulness, and stimulus control therapy can enhance sleep quality, but at a higher cost [9]. Medical experts prescribe medication in clinical settings and use polysomnography as a gold standard for objective sleep measurement. Outside clinical settings, sleep tracking devices, such as wearables or smartphones, offer continuous monitoring options [10].

Increasingly, digital health technologies such as telemedicine, wearables, and app-based sleep trackers are gaining importance in managing sleep problems and well-being. Commercial developers have recently developed robots to promote improved sleep [11]. It also empowers people to live more independently by reducing the financial burden on the NHS and minimising risks [10]. Due to the increase in population ageing and a shift in the culture of working from home, which increases sleep disturbance, people require more assistive technology for a better quality of life [10].

Somnox is a clinically tested sleep soft robot that is available on the market, for sleep and well-being. Designers have created this weighted pillow-type robot with mechanical and pneumatic elements that mimic breathing to improve sleep quality. Somnox can assist users in falling asleep faster, achieving deeper sleep, and waking up refreshed. It is operated by artificial intelligence (AI) technology providing physical and auditory guidance to slow breathing [12]. A randomised waitlist-controlled trial involving 44 adults with insomnia and sleep-disturbing arousal investigated Somnox. The research included 79 assessments consisting of pre- and post-arousal scales, a sleep diary, and actigraphy. Other co-morbidities including anxiety and depression were also measured in the individuals. Somnox demonstrated significant improvements in sleep quality compared to controls, particularly in reducing symptoms of insomnia and hyperarousal [12]. Additionally, that study found that different breathing guidance could reduce hyperarousal and enhance sleep [12]. When other interventions like CBT and pharmaceuticals are inaccessible, Somnox can be used as an alternative [13].

Although these initial studies have paved the way for using soft robots for sleep and well-being, they still provide some limitations. Therefore, we propose leveraging those in this paper. Previous studies primarily relied on a short self-reported questionnaire during the clinical trial to assess sleep improvement, neglecting other measurable factors like anxiety, well-being, and broader human–computer interaction (HCI) aspects such as usability and user experience [12]. Our study employs an in-depth qualitative and quantitative approach through self-study autoethnography to uncover user experiences and contextual insights. Contrasting everyday sleep environments with clinical settings highlights the potential of our method to capture observations not typically observed in patients [14].

Considering the practical implications of soft over hard robotics, especially in sleep contexts, requires a distinct approach. Most research emphasises how materials shape practices and user experiences, posing challenges in understanding interaction designs due to the varied materials used [15]. We bring value by using the soft robot Somnox as a home treatment to improve sleep and well-being, extending beyond conventional clinical study settings to explore its efficacy in diverse real-world scenarios. Most of the clinical studies performed on Somnox have focused on traditional sleep settings (e.g., sleeping in a bed at night), and there are further 112 non-traditional contexts in which we identified the Somnox system could be deployed and tested. These include whilst travelling, working, resting during the day, staying in hotels and sleep settings.

This study provides empirical insights into the experience of sleeping and living with a robotic sleep companion, potentially contributing a novel perspective to the HCI field. While existing HCI research often concentrates on sleep tracking [16,17], this paper stands out by focusing on interventions aimed at enhancing sleep quality. Moreover, it offers

an opportunity to reflect on interactions with robotic companions, contrasting with other companion robots like Paro [18], the Seal [19], and Purrble discussed in the HCI and HRI literature [20]. Both Somnox and Purrble emphasise the self-regulation of emotions through breathing and sensory stimulation. Our findings may encourage the development of more personalised, multidimensional soft robotic solutions for sleep and mental well-being, offering alternatives to conventional treatments without compromising patient outcomes.

2. Related Work

In our modern society, disrupted sleep results from various factors, including poor sleep hygiene, excessive screen time, and electronic device use, such as smartphones, tablets, and smart speakers emitting blue light that disrupts melatonin production. This study highlights stress and screen usage as significant factors affecting sleep quality. According to research, breathing through our mouths at night and external disturbances like noise and traffic further contribute to interrupted sleep patterns. Therefore, most research suggests the importance of quiet sleep environments and the potential benefits of scents like lavender in promoting sleep. Additionally, physical sensations such as weighted blankets may reduce anxiety and aid in falling and staying asleep [21]. Insomnia is increasingly prevalent not only in adults but also in adolescents [22]. Predictions indicate a growing epidemic of sleep problems linked to increased risk of depression, anxiety, and academic performance decline [23].

2.1. Currently Available Digital Solutions

Various intelligent solutions exist for sleep and well-being, including digital therapeutics accessible through the Internet and smartphones. Class 1 medical devices like the Lumie Bodyclock Luxe 750DAB, which gradually fades lights to regulate sleep patterns and aid relaxation [24]. Intelligent pillows capable of playing sounds and detecting sleep apnoea offer personalised real-time treatment [25], while smart embedded heating blankets regulate temperature to enhance sleep [26]. Commercially available personal robotic products such as Paro, Nao, and iRobot Roomba promote physical activity and well-being, alleviate caregiver burden, and improve quality of life [10].

These robots mimic biological systems, possessing capabilities like detecting breathing and sensory input, which influence human–robot interactions and experiences. With a shift towards at-home care and an ageing population, there is a growing demand for assistive robotic technologies to enhance the quality of life, especially amidst increasing sleep disturbances due to cultural and lifestyle changes [10].

2.2. The Context of Human–Robot Interaction

Researchers and developers categorise robots for human interaction into “hard” and “soft” robotics. Hard and complex robotics typically focuses on functional tasks, replicating or replacing repetitive, dangerous, or menial tasks. On the other hand, soft robotics uses softer and more malleable materials and is designed specifically for intimate human interaction contexts, such as robotic companions. However, qualitative research into soft robotics is challenging due to its infancy, making it difficult to test interactions rigorously across different contexts [27], while previous studies have explored interactions with traditional hard robots in various contexts. Soft robotics is characterised by a body made from soft materials and capable of autonomous behaviour. Some studies suggest that soft companion robots effectively prevent loneliness in the ageing population and improve respiratory function in children [28,29]. Soft robotic technology holds promise in modern science, society, and medicine. It can potentially reduce clinician strain and promote better mental well-being. However, challenges remain in terms of durability and reliability compared to traditional devices. This necessitates further investigation, especially regarding its application in medical technology and clinical care [30].

With the increasing burden on healthcare systems for sleep medicine care, devices like soft robots offer potential stress management benefits and improve society’s overall

well-being [31]. For instance, the novel robot Omnie has significantly improved anxiety and focus through haptic interactions and audio cues [32]. Researchers have widely studied one companion robot, Paro, which resembles a baby harp seal and is used for therapeutic purposes. However, studies have found no significant difference in sleep outcomes between control and robot groups [33]. While some studies suggest that robotic pets or companion robots may have positive physiological and emotional effects on humans, contradicting results highlight the need for further research in this area [10].

A recent paper shows how robots can significantly impact family dynamics by fostering emotional connections and enhancing interactions within family units. The study highlights the roles of various family members, such as parents, children, and siblings, in engaging with robots in diverse contexts, including education, healthcare, and home settings. It underscores the potential of social robots to act as companions, assistants, and mediators, contributing to family well-being and cohesion. It guides and implements social robots to effectively support and enrich family interactions [34]. Furthermore, an interesting paper investigated living with a light touch and suggested the effectiveness of haptic feedback on interpersonal connections. It fostered emotional closeness and helped maintain meaningful long-distance relationships [35]. Another study, which looked at designing multispecies worlds for robots, cats, and humans, found that integrating robots into environments for animal care required careful design of both the robots and their surroundings. Therefore, creating adaptive, intelligent environments that cater to all users is essential to ensure safety, well-being, and successful interactions [36].

A joint autoethnographic study highlighted the difficulties faced by two UK-based academics suffering from Ankylosing Spondylitis in balancing their professional duties with chronic pain. Their findings indicated that enhanced support and understanding within academic institutions were required to better accommodate and support individuals dealing with chronic illnesses [37]. A collaborative autoethnographic study emphasised the need for institutional support systems to manage researchers' emotional strain when studying long-term COVID in healthcare workers during the pandemic. The socio-political climate and remote work exacerbated it. It suggested strategies like emotional reflexivity to cope with these challenges [38].

2.3. Autoethnography

Autoethnographic diary studies are increasingly accepted in HCI and Computer-Supported Cooperative Work (CSCW) [39]. They are used to monitor and record experiences longitudinally providing an alternative to interviews and retrospective recall. It can also introduce biases and overlook critical details. Immediate reflection and recording of experiences mitigate recall biases, enabling a deeper understanding of user perspectives and emotional responses to technology use. This is crucial in HCI's design aspects and technology evaluation. Unlike traditional methods, autoethnography combines observation and personal experience, offering researchers and users' perspectives simultaneously [40]. A method similar to autoethnography is ethnography, which is a well-established method that focuses on describing and observing culture. At the same time, autoethnography allows researchers to incorporate personal experiences, challenging assumptions in technology design and providing alternative interpretations [41]. Despite potential biases, this method provides valuable insights into technology use while addressing ethical considerations related to privacy and protecting individuals' rights. Researchers have applied this method in various contexts, including smart-home cybersecurity, mobile phone usage, and wearable technology for babies [42]. Chang et al. provided detailed narratives of cultural experiences, emphasising empathy and interpretation [18]. Autoethnography's adaptability allows researchers to question and reimagine technology use, as seen in the exploration of mobile blood pressure monitor devices during non-routine usage [41]. Researchers have used quantitative and qualitative methods to investigate healthy student sleep in sleep autoethnography, creating artifacts to aid self-inquiry [43].

3. Methodology

This section provides an overview of our autoethnographic method and details our research procedure. Our focus is on three main areas: (1) Understanding the needs and concerns of using the soft sleep robot technology, (2) comparing subjective and objective data with or without Somnox, and (3) identifying design principles for long-term engagement in individuals with sleep issues.

3.1. Autoethnography Selection: Rationale

We used autoethnography because it has been an established qualitative research method in multiple fields. It involves the exploration of personal experiences to gain insights into cultural phenomena. Initially introduced by Carolyn Ellis, a prominent qualitative researcher and professor of Communication Studies, autoethnography has since been widely utilised in various research [44]. Autoethnography offers a rich data source, capturing intricate details that traditional research methods may overlook [45]. This method is particularly valued when delving into unknown territories. This prompts researchers to conduct pilot studies to gain in-depth knowledge, especially in emerging technologies such as our soft robot “Somnox”. It also fosters methodological innovation, allowing researchers to creatively gather data from personal narratives, ethnographic observations, and cultural contexts [46]. In our case, we identified a gap in research regarding utilising the robot “Somnox” beyond its intended purpose, e.g., improving sleep. Our study aimed to explore its potential in various settings, both within and outside the home environment, e.g., while travelling, using it at work, when feeling anxious or sick, or visiting family and friends. This transparency in our research approach enables readers to contextualise our findings.

While acknowledging the subjectivity inherent in autoethnographic research, we recognise its ability to capture diverse perspectives. This enriches our understanding of the phenomenon. We particularly note that researchers have used such methods to gain a better understanding of interaction and experience with digital devices. Prior research, such as the examination of mobile device use during non-routine tasks [42], has demonstrated the effectiveness of autoethnography in providing valuable insights, particularly in the field of human–computer interaction. Our study drew inspiration from similar research endeavours, such as exploring children’s interactions with robots in domestic settings [47]. This aligns with our objective of investigating everyday interactions with soft robots. It emphasises authenticity and reflexivity, prompting researchers to critically reflect on their biases, assumptions, and cultural contexts [48]. This self-awareness enables a comprehensive examination of the researchers’ role in shaping the findings and uncovers connections between personal narratives and broader social structures.

3.2. Participant Information and Positionality (*P = the Participant*)

Note that we use the letter P to denote the participant for ease of reading. P was a 26-year-old Asian British Bangladeshi who suffered from insomnia and migraines with aura since childhood, regularly managing these conditions with medication. With a background in clinical and digital health research, P was particularly interested in the relationship between sleep-related neurodegenerative diseases, given her family history of memory problems, and explored the potential of soft robotic tools to aid patients. Despite maintaining a healthy lifestyle through hydration, exercise, and balanced nutrition, P still struggled with sleep onset and experienced migraine episodes. While familiar with various technologies like apps and wearables for sleep, P had not previously used the specific robot “Somnox”. Other authors in this research shared interests in sleep and cognitive decline, with one being a consultant neurologist with clinical expertise in sleep and neurodegenerative diseases. The remaining authors focused on soft robotic technology and possessed expertise in understanding user experiences.

3.3. Apparatus

We utilised the “Somnox” sleep robot (Figure 1), currently the sole soft robot available for sleep aid. Resembling an intelligent pillow, Somnox employs soft robot technology, automatically adjusting its breathing pattern to mimic human respiration, thus meeting the criteria of a robot. Emitting sound and vibration interacts with users to induce a calming effect and guide them towards relaxation [49].



Figure 1. Exploring sleep quality enhancement: image of Somnox soft robot companion in use.

This bean-shaped cushion detects and adapts to breathing patterns using a microphone and motion sensor, synchronising with the user’s respiration rate. Additionally, it offers a selection of music, including white noise and integrates with a mobile application for breathing interventions and music uploads. Somnox weighs approximately 5 lbs and is equipped with AI functionality. It facilitates bedtime routines meditatively and aims to promote winding down at night [49]. The different components of Somnox are shown in Figure 2. In addition to Somnox, we employed the commercially available Apple Watch Series 3 for daily sleep monitoring [50]. Apple watches have been utilised by researchers as alternatives to actigraph watches, demonstrating high accuracy in detecting adequate sleep of 97.3%, a sensitivity of 99.1%, and a specificity of 75.8% [51].



Figure 2. Somnox sleep system: improved sleep quality and well-being through soft robotic technology.

3.4. Research Procedure

3.4.1. Timeline

The study spanned 4 months, with the first 8 weeks dedicated to excluding the use of the Somnox device, followed by 8 weeks of active usage. This duration was chosen for its suitability to pilot the study and facilitating the collection of qualitative and quantitative data, aligning with previous autoethnography studies [52]. Throughout the study period, P maintained their routine and adhered to their medication regimen for migraine management as needed.

3.4.2. Context

Figure 3 shows an example of a digital diary containing the gathered information.

I fell asleep fairly early yesterday as I was very tired. My sleep was better partially due to taking medicine and a long journey. I used the robot even on the bus and while listening to music. I slept with my sister by the end of the night I abandoned Somnox as it was taking up space, the bed was moving a bit, and the music was annoying to my sister and was disturbing her sleep.

Afternoon- I have not used it during the day at all

Evening- I have not used Somnox much as I wasn't working today. Plus, carrying it from upstairs to downstairs was a pain. Today, I am not having medicine as I am very tired from working from home and had to help out with our renovation. Looking forward to a good night's sleep. I think in terms of design, if we could have something that we can attach to our body, that would be great. There were no instructions on how to hug it, which could also be useful.

Figure 3. An example of an autoethnographic digital diary: reflecting daily experiences with Somnox sleep robot.

P conducted an autoethnography study documenting daily routines and non-routine activities (see Figure 4).

Routine activities included studying, clinic visits, remote or office work, public transportation, and gym sessions. Somnox usage extended to atypical scenarios such as holidays, travel, sleeping with a partner, and interactions with family, friends, and visitors. Others also experimented with Somnox during these activities. P utilised Somnox during flights and public transit journeys (Figure 4). We tracked sleep quantity and quality using an Apple smartwatch. Workdays were interspersed with holiday breaks, alternating between home, clinic, and office settings, involving frequent face-to-face interactions. Family interactions, including a visit to a friend with engineering knowledge, provided additional insights.

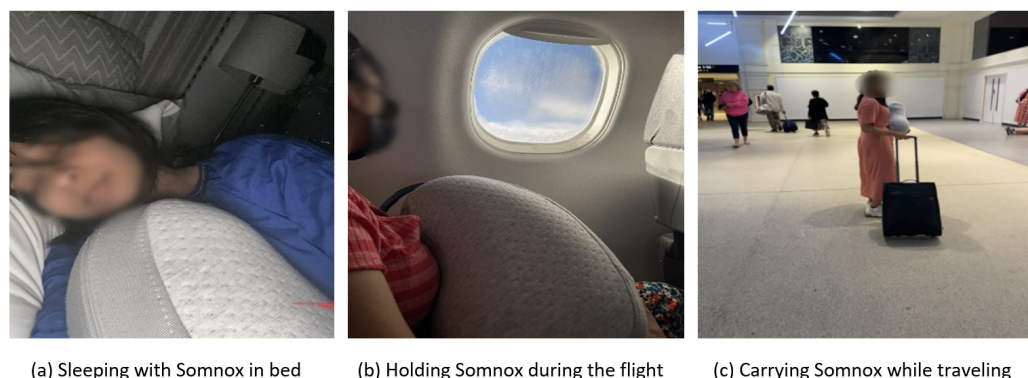


Figure 4. Images of using Somnox in diverse contexts: exploring soft robotic sleep assistance in various settings.

3.4.3. Procedure

We employed pre-planned guiding questions to ensure robust data collection through reflective journaling to investigate the efficacy of tools like “Somnox” in improving sleep habits. We structured our data collection, inspired by Cochrane et al.’s inside-out approach. We gathered qualitative data through a daily digital diary, completed twice daily—once in the morning upon waking and again in the evening for day-end reflection. Entries comprised bullet points or paragraphs capturing experiences, emotions, and thoughts, with no word limit. We preferred the digital diary method for its accessibility, spontaneity, and efficiency in automatically logging detailed information, accommodating images, as well as organising responses. P supplemented entries with contextual photos and descriptions. Reflections encompassed design evaluations, task performance, ease of use, and impacts on sleep and well-being. Additionally, objective sleep data were obtained from the Apple Watch to compare intervention outcomes before and after using Somnox. This method facilitated comparing subjective and objective measures of the companion robot experience.

The diagram below illustrates the activities and the process of data collection (Figure 5).

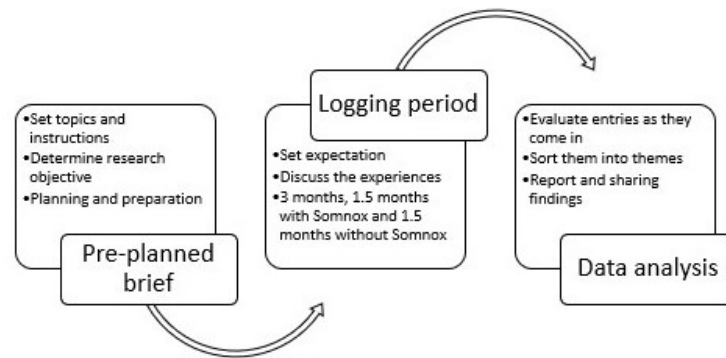


Figure 5. Process of data collection: utilising reflective journaling and autoethnography to capture experiences with the Somnox sleep robot.

P pre-planned guiding questions (Table 1) to help obtain more valid data through reflective journals, which focus on the first-person experience associated with sleep and well-being. A first-person inquiry in HCI helps define personal experiences with technology, fostering long-term design insights and self-awareness [53].

Table 1. Pre-Planned guiding questions for reflective journaling: structuring data collection for investigating the impact of Somnox on sleep and well-being.

Questions
How do you feel interacting with Somnox?
What is your favourite thing about using it?
What is the biggest challenge you faced using it?
What would you change about it in terms of the design and to improve interaction?
How is it helping you?
What do you like about using it?
Are you becoming dependent if so, how?
When do you use it the most?
How has it impacted or influenced your lifestyle in any way?
What do you think about Somnox compared to other aids for sleep and well-being?
Do you think your sleep improved or got worse after using it?

4. Results

4.1. Data Analysis

The pilot diary study yielded 100 diary entries and 183 days of sleep data from an Apple Watch (illustrated in Figure 3). Entries ranged from 100 to 400 words, occasionally accompanied by images. The Apple Watch data were analysed using Python 3.8.5, while the diary entries underwent iterative thematic analysis in NVivo software by the first author [54]. The thematic analysis aimed to identify common patterns, highlight issues related to the technology use, and understand its role in promoting sleep and well-being. A thematic analysis, as introduced by Braun and Clarke in 2012 [55], is a systematic method used to identify and analyse patterns (themes) within qualitative data. This approach involves several key steps. For the analysis, the first author of this paper transferred the digital diary entries to NVivo qualitative analysis software. Then, two researchers looked at the data separately, familiarised themselves with the data, made some annotations at first, and then created memo notes. Then, they coded the data by systematically labelling meaningful segments that captured key concepts or ideas. Afterwards, they compared

their analysis and created themes together. All the other authors then reviewed, refined, and defined these themes with clear names that encapsulated the essence of the data. Co-authors, including clinicians and HCI practitioners, contributed to data interpretation and study design. The analysis focused on capturing the experiences and reactions of both P and others, considering various factors influencing the use of the Somnox device in different contexts. The generated themes are summarised in Figure 6, and each is theme discussed in detail below.

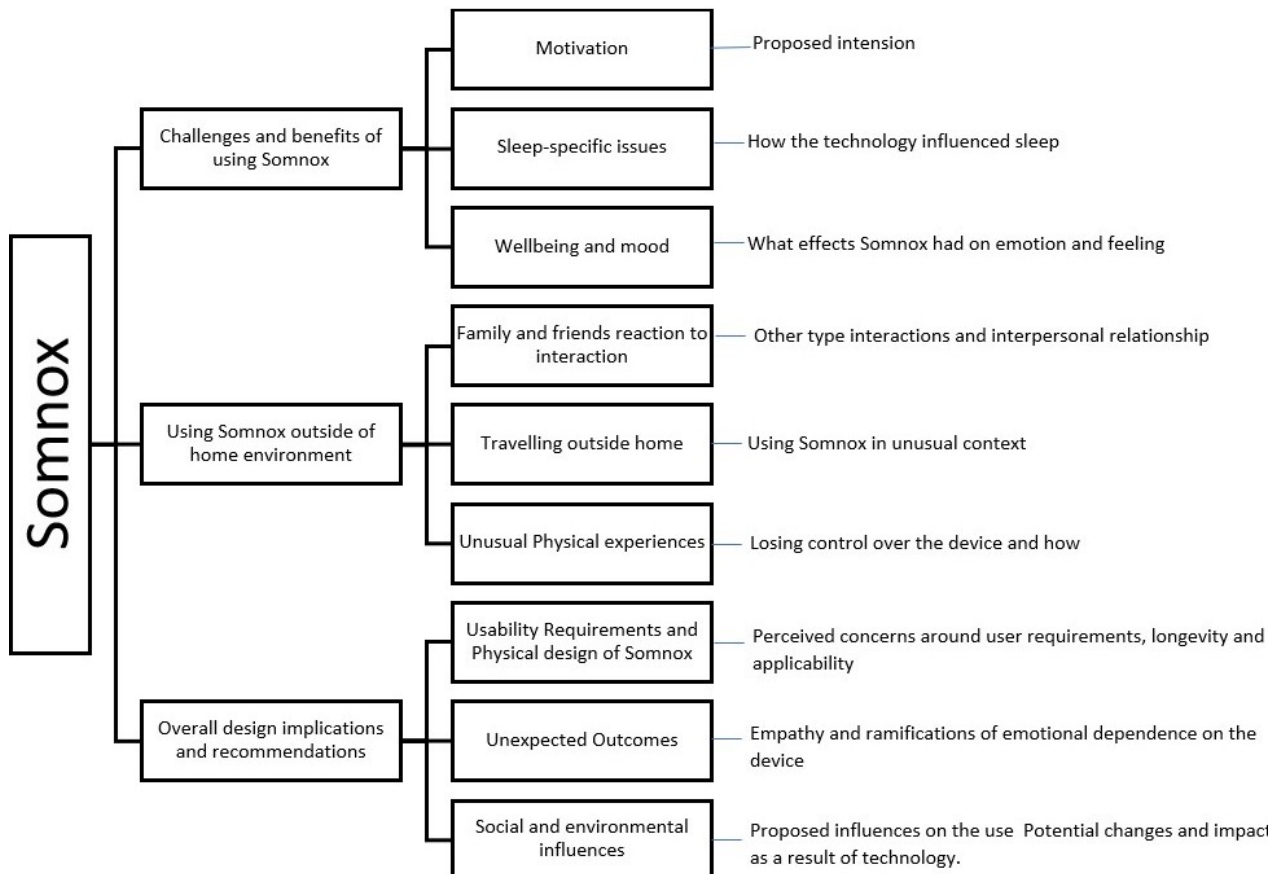


Figure 6. Generated themes of diary entries: exploring experiences and insights in living with the Somnox sleep robot.

Central themes were identified, each containing three sub-themes detailed in Figure 6. Those are discussed in detail in chronological order.

4.2. Theme 1: Challenges and Benefits of Using Somnox

The study included a controlled comparison of P's experience before and after using the Somnox system to evaluate its impact.

4.2.1. Motivation: Transition from Medication to Technology for Sleep Improvement

The participant (P) expressed a strong inclination towards reducing dependency on medication for managing sleep and mental health. P articulated, "I do not want to be dependent on drugs for my health" reflecting a desire for alternative solutions. The other reason P thought this was worth researching is that P encountered patients with memory issues. P highlighted the challenges faced by patients with memory issues who are responsible for medication adherence. P stated that it "puts a burden on them", and commented in the early weeks, "for many people, sleep problems are not serious health issues". Despite societal perceptions, P emphasised the significant impact of poor sleep:

“without having a good night’s sleep, it is very difficult to work; it even affects my personal and professional life”.

P’s interest in leveraging technology to improve sleep stemmed from a desire to help individuals like herself achieve restful sleep without relying on medication or constantly trying new methods. P expressed, “I want to help people like me have a good night’s sleep without having to think about taking multiple pills, changing lifestyle habits, or trying out new methods every day”. The disruption of sleep routines, particularly during travel, motivated P’s exploration of technology-based solutions. P described the challenges faced during holidays when the focus on sleep overshadowed relaxation: “it kind of takes joy away from being all relaxing during the holiday, solely the focus is always on sleep”. P expressed, “usually during the holiday, I have to think so much like the focus on what I eat, whether or not to have a cup of coffee or an alcoholic drink”. P also said, “I had to constantly think about having Somnox with me, which was quite annoying”.

P’s experience with Somnox revealed its effectiveness in promoting physical and mental well-being. Somnox helped alleviate stress and anxiety during the day, contributing to improved daytime functioning. P noted, “Somnox helped me to function better during the day and reduced worry and palpitation”. The initial hesitation to use Somnox in public was overcome by its practical benefits, including mitigating disturbances related to light, noise, and temperature changes. P found it a helpful distraction and a means to address lifestyle needs during holiday travels.

Somnox’s impact extended beyond sleep, as P observed changes in daily routines and activities. P noted a cessation of bedtime reading habits during the period of Somnox usage, highlighting its effectiveness in promoting uninterrupted sleep. P remarked, “My habit of reading a book stopped, and I did not require any routines or interventions to sleep”. Despite initial apprehension, P recognised Somnox’s role in facilitating relaxation and comfort, ultimately contributing to improved sleep quality and overall well-being.

4.2.2. Sleep-Specific Issues

P’s first encounter with Somnox was when P “Opened the packaging, I felt like I was almost holding a baby; it was quite heavy”, P noted, describing their initial encounter with Somnox. Despite finding the material texture “very rough”, P remarked that it felt “more suitable as a leg pillow”. P expressed uncertainty about how to hold it initially, pondering whether it should be against the chest or stomach. Regarding usability, P commented, “it may be more suitable for young adults due to the complex setup and use of the app and settings”.

P found comfort in Somnox’s lighting and white noise, which made them feel reassured about their surroundings. Reflecting on sleep quality, P shared, “My sleep quality declined after I stopped using the device”, as shown in Figure 7 from the Apple Watch data. Somnox was viewed as a sleep aid and a potential lifelong companion. P recalled, “Initially, sleep seemed okay without it, but then my awake time increased over time”. This led P to resume medication to ensure adequate sleep, highlighting the device’s significance in their sleep routine. Reflecting on the experience, P expressed missing the sensation of hugging and breathing against something in bed, suggesting the device’s adaptive breathing feature was effective despite an initial annoyance.

4.2.3. Wellbeing and Mood

P noted the impact of Somnox on their well-being and mood, sharing, “Somnox helped me fall asleep and provided comfort during stressful and anxious moments”. It reduced palpitations and served as a source of solace when tense, reinforcing affective needs. P suggested it could be beneficial for individuals living alone or grieving, likening the sensation of respiration to holding a loved one’s belly.

In the absence of Somnox, P experienced feelings of loneliness and dependency, realising they had become reliant on the device for relaxation and improved breathing. P’s experience during a severe migraine underscored the device’s importance, prompting reflec-

tion on its potential as a medical intervention. Detox from Somnox revealed its significant impact on sleep quality and autonomy, prompting considerations about its classification as a medical device. Despite perceiving Somnox as a friend, P questioned the role of robotic companions in improving well-being and fostering confidence in interpersonal interactions.

4.3. Theme 2: What Was It Like Using Somnox Outside of the Home Environment?

This section of the study gained insight into the feasibility of using Somnox in several unusual contexts.

4.3.1. Family and Friends' Reaction to Interacting with Somnox: Somnox Meeting Friends and Family

The participant's interactions with friends and family unveiled a spectrum of reactions to Somnox, from curiosity to scepticism. P's friend's comparison of Somnox to a "cashew" exemplifies the diverse perceptions surrounding the device's appearance and function. Despite initial excitement, concerns about societal judgments prompted P to downplay Somnox's health-related purpose, framing it as a versatile "sleep robot" rather than a medical device. To avoid disclosing health issues, P said, "This is a sleep robot, but I think it can be used for much more than just sleep because I am unsure whether you can see it as a buddy". This tension between perceived utility and social stigma underscores the importance of nuanced design considerations to enhance acceptability. P's reluctance to use Somnox in communal settings, citing disruptions in conversation and perceived hassle in adjustment, suggests practical limitations in shared usage scenarios.

P's apprehensions about others' opinions regarding Somnox's appearance and purpose are evident in the statement, "I was worried about what people's opinions would be!". Therefore, P's strategic framing of Somnox as a multifunctional "sleep robot" to avoid disclosing health issues highlights the complexities of navigating social perceptions. The divergence between societal norms and personal experiences is further emphasised by P's friends' comparisons between Somnox and conventional comfort items. This includes teddy bears, and their subsequent discomfort with its unconventional appearance in public settings. They said, "You can have a buddy, but this just looks a bit strange. Isn't it a bit odd to carry this outside home?". They followed with, "Is it a bit usual for an adult to carry a stuffy toy? It is a great source of embarrassment".

P realised it was worth investigating acceptability beyond that audience and set to think about designs. P was "sceptical and hesitant to sleep with "Somnox" during my visit to my friend's". Although to "learn more about the device, it was essential to try it while sleeping in a new environment". It took P a long time to fall asleep, and while P was conversing with P's friend, "it disrupted the conversation because of breathing sound; I did want to adjust it with the app, it was too much hassle". Interactions with family members revealed evolving perceptions of Somnox, from initial scepticism to integration into familiar routines. P's mother's critique of Somnox's appearance prompted reflections on design considerations, highlighting the potential for anthropomorphic features to enhance user appeal. Family members' enjoyment of personalised music playlists and synchronised breathing experiences underscored Somnox's role as a communal sleep aid. However, P's reluctance to use Somnox due to its weight and inconsistent usage patterns during the holiday suggests that individual preferences and situational factors influence the acceptance and adoption of the soft robot Somnox.

It was awkward to conduct this self-study in public settings, especially when visiting family and friends. Although the negative experiences taught P to "think about different design considerations". When P first took Somnox to a different city to visit family, they first thought that because it was a robot, "it could walk and move", but then P showed them how it worked. Soon enough, "they began treating it as part of the family" and they used it themselves to experience it. P's mother thought it was "pretty weird looking, and I would have preferred it if it was more colourful and cuter looking". That made P think, "A face would have been nice to have like a teddy bear which can be used for children

to fall asleep as well as for postpartum mothers". This suggests that when designing technology, we should think about user needs and our duty to get a perception of nonusers. Families mainly enjoyed putting on their "own music and listening to it while hugging and napping". Sometimes, "when any of the family members felt restless after a long day roaming around, they would ask to use the robot to avoid outside influence". One day, "my mother and my sister both hugged from two sides to fall asleep on the sofa", which suggests a companion that does not need to be only used in bed. They both also said, "it was easier to synchronise their breathing when they focused on listening to the podcast". At other times, "P was reluctant to use it when P was tired because of how heavy it is even though P felt the need of it, but it was irritating to hold it". During the holiday, P wanted to use "Somnox right away, and sometimes every few hours". It was noticed that due to the disruption in their sleep cycle, "P was not always in the mood to use it, did not want anything to sleep". This suggests that the sleep robot is only sometimes the choice. People need their own space and do not necessarily want Somnox to be their mediator.

4.3.2. Travelling Outside Home

Participants' experiences using Somnox during travel unveiled novel insights into its efficacy and social dynamics. Despite initial reservations, Somnox provided a sense of comfort reminiscent of childhood companionship. Additionally, P's observations of physiological feedback, such as "reduced impatience and travel anxiety", suggest potential benefits of Somnox beyond sleep induction. P's proactive engagement with Somnox in public settings facilitated serendipitous interactions with fellow passengers, fostering curiosity and dialogue surrounding its function and utility. The device's integration into family dynamics during travel highlighted its role as a cherished possession and conversation starter, challenging preconceived notions of robotic companionship. However, perceptions of Somnox as an "alien" or unconventional travel accessory underscored the need for public awareness and education initiatives to foster acceptance and understanding of emerging technologies.

P's strategic use of Somnox as a "neck pillow" during travel underscores the importance of positioning the device as a familiar comfort item rather than a novel or stigmatised technology. Interactions with fellow passengers and security personnel further illustrated the device's potential as a conversation starter and catalyst for public discourse on emerging technologies. Typically, P's sleep is adversely affected during travel due to changes in environment and weather. However, P noticed a significant improvement in sleep quality with Somnox, expressing that "my sleep was more calming and deeper". This suggests that such interventions can positively impact individuals without causing any side effects. However, the perception of Somnox as an electronic device during airport security checks highlighted the need for clearer communication and public education about its function and purpose.

4.3.3. Unusual Physical Experiences

Participants' physical experiences with Somnox revealed both benefits and challenges associated with its usage. P's initial discomfort with Somnox's breathing patterns and perceived invasion of personal space reflect the device's potential to elicit mixed physical responses. P initially found the breathing distressing, saying that "the breathing is not soothing, rather unnerving". The sensation of bed vibrations and intrusive breathing movements posed challenges to sleep quality and interpersonal dynamics, exacerbating anxiety and disrupting partner sleep. "It is almost like having a third person between us", suggesting Somnox could create distance in relationships. P also noted that it was "creepy to have Somnox, and sometimes it felt like it can sense everything about you". "It's like having a camera with a microphone that can see, listen and react". "Sometimes the breathing becomes slow and may think I am dead, or something is wrong with my breathing [...] this would worry my partner and wake [...] up in the middle of the night".

At times when P “would go to bed and halfway through, it randomly breathes faster”. This “increased my breathing and disrupted my sleep”, “leading to abandoning it”. The following day, I would “not use it and would get rid of it for long hours until I would use it for relaxation purposes”. This denotes that to optimise the sleep robot’s usage, it must work accurately.

4.4. Theme 3: Overall Design Implications and Recommendations

This theme encompasses the information gathered pertaining to future design ideas and applications.

4.4.1. Usability Requirements and Physical Design of Somnox

Travelling with Somnox revealed a significant usability challenge: its weight; “it is very heavy”. The participant found it cumbersome, with P noting that it was like carrying a “big bag”. This inconvenience led to deliberate decisions to forego engaging with the technology during travel. Over time, the participant increasingly perceived Somnox as burdensome, “it was a headache”, particularly when transporting it between different locations. P “avoided using Somnox as it was a pain to carry it from upstairs to downstairs”. That made P think that in terms of the design, “if we could create a technology that is more lightweight, wearable, and portable, it would be useful”. The rigidity of Somnox’s shape further compounded usability issues, prompting suggestions for a more malleable design to enhance portability.

Additionally, the participant identified several design enhancements to improve Somnox’s functionality and user experience. Suggestions included integrating a temperature sensor for relaxation purposes and incorporating features to monitor breathing rates and oxygen levels. P said “if Somnox had a temperature sensor, it could be beneficial for relaxation. It will act more like a temperature-changing pillow” and “if Somnox could detect breathing rates and oxygen levels, it would be useful to monitor when breathing is insufficient or irregular”. Such advancements could serve as alternatives to bulky medical devices like CPAP machines, aligning with the growing demand for digital health interventions for sleep management.

Early usability issues, such as uncertainty about automatic shutdown features, underscored the importance of intuitive design. P said, “I was enthusiastic about exploring the app, but with time, due to malfunctioning at times, I lost interest”. Despite these challenges, P consistently reported feelings of comfort and relaxation while using Somnox. However, a lack of understanding of breathing techniques hindered confidence in adjusting settings, highlighting the need for user-friendly interfaces and educational resources within the accompanying app. P “felt unsure and did not feel confident to change the breathing settings”. Due to the uncertainty, P “stuck to default settings” and stated, “it would have been helpful through the app to figure out how to improve breathing, where there are areas for improvement”. They also suggested, “If the app could have adapted the breathing setting according to the collected data, it would have been ideal”. This suggests that P had a low engagement with the mobile app in the long term due to unfamiliarity and lack of reliability.

The participant expressed a desire for “integrated wearables to track sleep metrics conveniently and without the need for additional devices”. This would facilitate self-reflection and streamline data collection, eliminating the need for separate gadgets like smartwatches to “avoid the hassle of using a smartwatch”. Suggestions for improvements also extended to the device’s physical features, with recommendations for lighter vibrations “to make it more comfortable while sharing a bed with someone”. P also thought of anthropomorphic elements to enhance emotional connection, like giving Somnox a “cute-looking face”, which would improve human–robot interaction.

4.4.2. Unexpected Outcomes

The participant experienced unexpected outcomes during the study, revealing Somnox's potential beyond sleep aids. Notably, on day 20, P found relief from stomach ache by simply holding Somnox: "[some of my] pain was relieved simply by holding Somnox", highlighting its therapeutic potential for pain management. Similarly, while using Somnox at work, P described "feeling comfort and warmth akin to a hot water bottle", suggesting versatile applications beyond traditional sleep aids.

An unexpected emotional connection emerged as the participant grew reliant on Somnox for sleep and mood improvement. Early in the study, P noticed feelings of emptiness and unease when Somnox was absent, indicating emotional dependence. This emotional bond extended to empathetic responses towards the device's perceived emotions, with P expressing concern for unintentionally mistreating Somnox.

Curiosity and speculation arose regarding Somnox's behaviour and emotional capabilities. The participant pondered whether Somnox could experience loneliness or react emotionally to neglect, suggesting human-like attributions to technology. P stated, "If Somnox was imitating heavy breathing or playing music temperamentally, I got angry and threw it away unintentionally". This made P wonder if the device "felt hurt by my actions". This observation suggests that we build expectations from our technology over time and project emotions onto them. Additionally, concerns about accidental contact or displacement of Somnox underscored the evolving dynamics and interactions within shared spaces.

The absence of Somnox disrupted the participant's routines and heightened awareness of their dependence on the device. Despite initial reservations and perceived creepiness, the participant found themselves missing Somnox's presence and its soothing effects, even resorting to medication when without it. P "wondered how it felt, whether it feels emotion towards me or does it feel lonely when I casts it aside". This leads to the idea of robots having emotions and feelings as they learn to behave in a certain way. Giving computers emotions could be useful as it will be easier and more enjoyable to interact with them [56]. When P shared a bed with P's sister during the holiday, P's sister said she was worried that "I might accidentally kick or touch Somnox", and P also expressed concerns, "I was worried that I might annoy my sister due to the music".

P experienced a situational change when they no longer engaged with the technology. P noted that "for 6 weeks, on the first day when I did not use it during the day, I 'felt a bit empty' as I would usually sit down with Somnox to work from home. I was habituated to having it on my lap, so it did disrupt my routine". During the evening, when P sat to watch TV, P described their state as feeling "uneasy". Initially, when P started using Somnox, P thought "it was a pain to use this all the time". However, after stopping use for the day, "I did not hate it as much I thought I did". P was not sure whether P was missing holding a "hot-water bag" in P's lap or the Somnox when it was absent. Similar feelings continued for a few days. On day 10, P noted that without the Somnox intervention, P's sleep deprivation became prominent, forcing them to take medication again. When P slept with medication, it made P "feel tired the next day". However, with Somnox, they felt relatively more relaxed even when using it in conjunction with medication.

The manual instruction needed more information for first-time users. P "did not self-experiment with the breathing setting" due to a lack of guidance. During the last weeks, P started experimenting with YouTube videos' guidance and changing breathing settings on different nights in Somnox to see whether any changes could be seen.

On day 16, "whilst holding it, I realised it may trigger some people's experiences of holding a child, and it might be beneficial to improve sleep but also cognition". Experimentation with breathing settings and observations of Somnox's resemblance to holding a child hinted at its potential benefits for individuals with memory loss or emotional needs. On day 2, P was upset and the "first instinct was to hug Somnox and it somehow cheered me up and I wished it could hug me back". On day 15, P fell asleep with the Somnox while watching movies at night, and a cousin saw this. When P woke up, their cousin had many

questions, including when P used the device, to which P replied with working, travelling, and performing other non-routine tasks such as watching TV; “This made me realise how much time I spent with it”.

4.4.3. Social and Environmental Influences

During the last week of the control period (days 15 to 21), P stayed at their friend’s house and noted that sleep was deteriorating “as I was used to using it in the same setting for a long time”. P also mentioned, “I was scared when I slept alone because of the breathing as if someone is sleeping next to me when Somnox got detached from me”. P practised sleeping with Somnox, which comforted P, but after stopping using it, P was missing it and shifted to hugging a pillow in the absence of Somnox. P described their feelings as an “addiction to technology use”. P noted that “sleeping without it in the bed made it feel empty, and P would search for it at times”. Also, “I sometimes thought, is this alive? I left it. Did it feel alone?”. This shows that empathy for technology can lead to dependence on technology. Also, there were withdrawal symptoms even with the technological invention; therefore, preventative strategies need to be introduced to reduce this effect. On some days, P forgot to use the device throughout the day, and on other days, “I felt uncomfortable using it due to social inappropriateness”. Therefore, it is important to consider different social and environmental factors when using social companion robots.

4.5. Quantitative Data—Apple Watch

Figure 7 presents Apple Watch sleep data, providing insights into the relationship between Somnox usage and sleep quality for participant P. Sleep quality metrics derived from the Apple Watch data demonstrated a noticeable improvement after P began using Somnox. This suggested a potential positive correlation between Somnox and sleep. We observed a gradual decline in sleep quality indicators as P used Somnox less frequently. This pattern reinforced the possible association between Somnox use and sleep benefits. The integration of qualitative diary data complemented the Apple Watch findings. Diary entries supported a decline in subjective sleep quality after P stopped using Somnox, aligning with the trend seen in the objective data. While numerous factors influence sleep, the data in Figure 7 point to a likely positive impact of Somnox on P’s sleep quality. It is important to note that these data are indicative, and further research is needed to establish a definitive causal link.

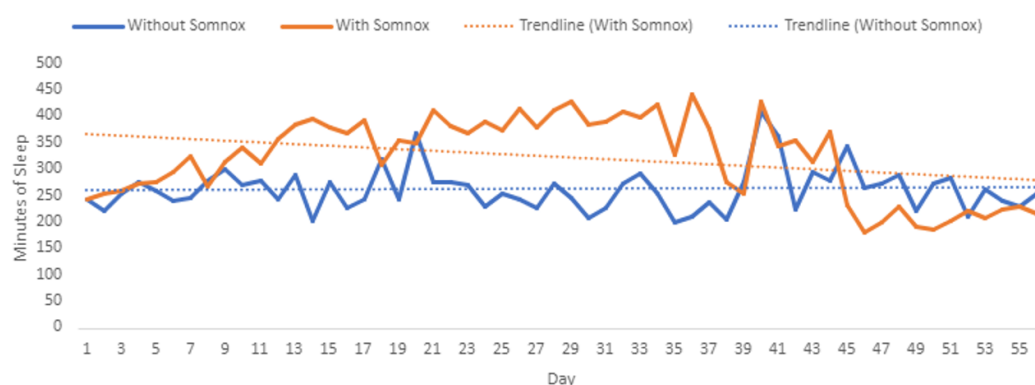


Figure 7. Sleep data trends over 16 weeks: visual analysis with trendline.

We also conducted a Wilcoxon signed-rank test; we found a significant difference ($V = 314.5$, $p < 0.05$) between the two conditions and before using Somnox (mean = 264.73) and after using Somnox (mean = 323.35). This difference, accompanied by a moderate effect size (0.372), indicated a meaningful improvement in sleep quality following the use of Somnox.

The observed correlation between Somnox usage and participant P’s sleep aligns with other studies exploring the use of haptic feedback and rhythmic stimulation for sleep [57].

This study highlights the interplay between objective sleep data and user experience, suggesting that adherence and perceived benefits are crucial factors in determining technology effectiveness. This underscores the need for HCI approaches that prioritise user-centred design and long-term engagement when developing such technologies [58].

5. Discussion

The objective Apple Watch data and subjective insights from P's diary offered a richer interpretation of P's sleep patterns. These findings, though inconclusive, contributed to the understanding of Somnox as a potential sleep aid. The observed correlation, combined with the participant's self-reported experiences, suggested that further investigation into the effects of Somnox on sleep quality was warranted.

This study delved into maximising the optimal utilisation of the sleep robot system Somnox. We initially conducted a literature review on personal informatics and sleep solutions. Following this, we conducted an autoethnographic study using digital diary recording and visualised Apple Watch data to gain profound insights.

Findings suggest that Somnox can be utilised across various settings and serve multiple purposes. It provides insights into the lived experience of utilising a pillow-like soft robot, offering breathing and vibrotactile interaction to induce relaxation and potentially enhance sleep quality. The research utilised subjective sleep diaries and objective technology data, aligning subjective experiences with objective measurements to ensure accuracy in understanding behavioural changes. However, determining whether improvements are psychological or attributable to medication remains challenging and warrants further investigation, particularly regarding Somnox usage with or without medication. Somnox was perceived as a versatile tool for sleep, fostering a sense of companionship and promoting awareness of sleep-related issues, particularly among individuals with sleep disorders. This study underscored the importance of usability considerations and proposed enhancements to Somnox's functionality.

5.1. Benefits and Challenges of Sleep Robot

The breathing feature of Somnox, which is designed to provide a comforting sensation akin to being hugged to bed, may evoke complex responses that warrant further exploration. While intended to promote relaxation, this rhythmic breathing simulation could also trigger unexpected reactions such as fear or discomfort, possibly due to its resemblance to a living entity. Understanding the underlying science and phenomenology of breathing and breath-based technologies is crucial for optimising user experience and addressing potential concerns.

This study highlights the importance of investigating interaction modalities, particularly breathing and sonification, within the context of sleep technology. Research in this area can illuminate how such modalities facilitate non-verbal communication and rhythmic attunement between humans and devices like Somnox. By studying these interactions, we can understand how rhythmic stimuli, such as breathing patterns, influence emotional states and physiological responses during sleep induction and relaxation.

Exploring the intersection of technology, physiology, and human perception opens doors to innovative approaches in sleep therapy and wellness interventions. Future studies should delve deeper into the nuanced effects of breath-based technologies on user psychology and behaviour, considering individual preferences, cultural interpretations, and the potential for personalized sleep experiences. This research can pave the way for enhanced design principles and tailored functionalities that optimise the therapeutic potential of devices like Somnox, ultimately improving sleep quality and well-being for users.

5.2. Implication for Design

Our autoethnographic exploration of living with the Somnox sleep robot offers nuanced insights with broader implications for researchers in health technology and sleep studies. It provides a practical solution for improving sleep quality and overall well-being

for a wide range of individuals. Potential users include those struggling with insomnia, anxiety, or stress-related sleep disturbances, as well as shift workers, frequent travellers, seniors experiencing age-related sleep issues, and individuals diagnosed with sleep disorders like sleep apnoea. Students and professionals facing high-stress levels, caregivers looking after individuals with sleep-related challenges, athletes prioritising recovery, and people seeking holistic wellness approaches can also benefit from Somnox. By targeting these user groups, Somnox aims to provide a valuable sleep enhancement tool that promotes relaxation, reduces stress, regulates sleep cycles, and supports overall sleep health and quality of life.

The study underscores opportunities for designers and researchers to explore Somnox's applications beyond clinical settings. Personalisation emerges as a critical aspect, with suggestions for integrating features like multimedia capabilities, personalised interventions, and wearable technology. Enhancements such as a human-like face, temperature sensors, and personalised intervention within the mobile application could enhance user engagement and overall effectiveness.

In the future, researchers could integrate AI and machine learning technologies to monitor individuals' sleep patterns remotely, automatically analyse data, and share insights with clinicians. With widespread adoption, these data could contribute to developing predictive models for detecting sleep and mental health issues, facilitating personalised and immediate treatment interventions. Integration with popular platforms like Alexa could enhance performance, enabling improved music synchronisation and expanded functionality. For example, we collected data from Apple Watch separately in our study. However, integrating such technologies into unified devices or platforms capable of collecting and analysing multiple data streams could significantly enhance performance and user experience through streamlined data interpretation and presentation within the dedicated Somnox apps.

5.3. Social Aspect

While Somnox is primarily used for sleep and napping purposes, broader social acceptance poses challenges for its utilisation in other contexts [59]. Somnox offers innovative features for promoting relaxation and improving sleep quality, but its potential in diverse settings needs to be improved regarding concerns about societal acceptance and dependence on technology. Further investigation is warranted to examine the implications of developing dependence on robotic companions like Somnox and the evolving nature of human–robot interactions.

Understanding the dynamic relationship between robotic technology and human emotions is critical in the context of advancing artificial intelligence. Qualitative studies are essential for exploring how individuals perceive and interact with robotic devices like Somnox in various settings, especially as these technologies become more sophisticated and integrated into daily life. Research in this area can shed light on the psychological and social implications of relying on robotic companions for emotional support and relaxation.

Moreover, investigating the long-term effects of technologies like Somnox on human behaviour and social norms is crucial for shaping future developments in this field. By studying user experiences and societal attitudes towards robotic sleep aids, researchers can inform the design and implementation of such technologies to enhance user acceptance and foster positive human–robot relationships.

As AI continues to evolve, the need for interdisciplinary research that bridges robotics, psychology, and social sciences becomes increasingly apparent. This collaborative approach is essential for ensuring that robotic technologies like Somnox are technically advanced and ethically and socially responsible, ultimately contributing to improved well-being and quality of life for individuals and society.

5.4. Methodological Limitations and Future Research Directions

While this study offered valuable insights into using sleep robot systems like Somnox, future research must address several methodological limitations. As this was a single-participant study, one limitation lies in the sample size and demographic diversity of participants. Future studies could benefit from a larger and more diverse sample size to ensure the generalisability of findings across different populations and contexts. Additionally, we could extend the duration of the study to capture long-term effects and behaviours associated with soft sleep robot usage.

Another limitation concerns the reliance on self-reported data and subjective experiences. Therefore, incorporating objective measures, such as physiological data or sleep monitoring devices, including actigraph and portable electroencephalography (EEG), could provide a more comprehensive understanding of the impact of sleep robots on sleep quality and patterns. Furthermore, while autoethnography offers valuable insights into individual experiences, it may also introduce subjective biases. Future research could employ complementary methodologies, such as qualitative interviews or observational studies, to complement the autoethnography, or researchers could consider implementing mixed-methods approaches that combine qualitative and quantitative data as well as biological tests. This includes collecting blood samples, as well as cortisol and cortisone collection methods, to triangulate findings and enhance the robustness of results.

Furthermore, it is essential to provide a clearer comparison with other technological and non-technological sleep interventions. This could include methods like CBT, psychotherapy, pharmacology treatment, smart sleep mats/mattresses, aromatherapy, and more. Such a comparative analysis offers a broader context for understanding sleep robots' unique advantages and challenges and could shed light on the effectiveness of different sleep interventions. This could inform recommendations for improving sleep health outcomes, a crucial aspect for clinicians and sleep experts in providing person-centred care plans and for designers in creating technology personalised to the user's needs.

6. Conclusions

The landscape of companion sleep robotic technology is steadily advancing, with innovations like "Somnox", the first soft-sleep robotic technology offering promising solutions to the prevalent issue of sleep deterioration, particularly in ageing populations facing increased workloads. This paper delved into the potential utilisation of Somnox by elucidating an individual's day-to-day experiences with this pioneering technology. Despite its potential, soft robots such as Somnox have remained relatively obscure globally, primarily due to a need for more awareness and understanding within the human–robot interaction field. Commercially available soft robotic products are scarce, and evaluating their safety and usability in real-world scenarios presents challenges.

Looking ahead, integrating breathing therapy and elements of cognitive behavioural therapy into Somnox holds promise for improving sleep outcomes. Balancing the collection of users' subjective experiences with data collection methodologies is crucial for sustaining a meaningful feedback loop. Furthermore, leveraging data visualisation as a communication tool with medical experts can enhance the utility of Somnox in clinical settings.

Our findings suggest that Somnox serves as a viable companion and alternative treatment option for sleep-related issues, emphasising the importance of user engagement. Design strategies should focus on seamless integration, incorporating reminders and new features such as bed sensors to enhance usability and reduce lapses in usage. This research extends beyond clinical studies of Somnox, contributing to the broader field of HCI and underscoring how sleep robots can positively impact individual well-being by fostering human–robot interaction and support.

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