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DIGITAL HEALTH INTERVENTIONS FOR PROMOTING SLEEP WELLBEING: A DESIGN APPROACH USING SELF-DETERMINATION THEORY

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ABSTRACT

The "Sleep-Well" project explored the problem and solution spaces relevant to design of sleep-wellbeing products, services and systems. It was set as an 8-week concept design project within the scope of a 15-week graduate course. In the first half the course, students were given formal input on design for health and wellbeing and in the second half of the course the project ran in collaboration with an industrial partner specialized in the healthcare domain. Students worked in pairs to generate final concept design proposals, ranging from innovative solutions to problems/opportunities that they identified; new approaches to existing products/systems; or unforeseen problems to solve. The 'Sleep-Well' project also had the pedagogical goals of successfully directing students: i) to learn how digital technologies can be best integrated to track and respond to people's health data and environmental conditions; and ii) to intrinsically motivate users by relating three principal factors from self-determination theory (i.e., autonomy, competence, relatedness) to their design proposals. Student learning was demonstrated through the diversity in outcomes and successful integration of the abovementioned goals, as well as formal student feedback received at the end of the course.

Keywords: Product design, design for health, sleep wellbeing, digital health

1 INTRODUCTION

At least one in three adults complain about their sleep: insufficient sleep quantity and poor sleep quality are common among adults. In industrialized countries, the average sleep duration among adults has decreased substantially during the past few decades, and complaints about poor sleep quality are frequent. Sleep clinics, which were a rarity, are now a feature of most major hospitals [1]. It may not be so easy to solve sleep problems caused by e.g., stress, medical conditions, or a baby screaming in the house, however we are likely to have more control on external factors, such as the environment in which we sleep, as it greatly affects the quantity and quality of our sleep.

The work presented in this paper was carried out as part of the authors' ongoing research looking into how people's health and wellbeing can be promoted through digital health interventions. The research aims to generate inspirational exemplars for further R&D in product design and innovation. In addition to generating exemplars for product design, the 'Sleep-Well' project had the pedagogical goals of successfully directing students: i) to learn how digital technologies can be best integrated to track and respond to people's health data and environmental conditions; ii) to consider engineering and healthcare domain constraints for utilizing most convenient technological methods, positioning relevant hardware components and adapting healthcare market structures and stakeholder requirements and iii) to intrinsically motivate users by relating three principal factors from self-determination theory (i.e., autonomy, competence, relatedness) to their design proposals.

2 SELF-DETERMINATION THEORY

Self-Determination Theory (SDT) is a broad theory of human personality and motivation, which was founded in the mid-1980s [2]. The theory concerns itself with human motivation, personality, and supporting our natural or intrinsic tendencies to behave in effective and healthy ways. Rather than just the amount of motivation, it focuses on different types of motivation. SDT states that three principal factors represent the innate psychological needs that drive human behaviour: Autonomy (a sense of choice and endorsement in a task); Competence (the experience of mastery over a task or particular domain); Relatedness (feeling cared for and connected with others; sense of belonging) [3]. As mentioned by Peters [4], these factors have been validated across cultures and are measurable. Fulfilment of these needs is a predictor of positive domain-specific outcomes. As for designers, extrinsic motivation can be used to motivate users to do various things or behave in certain ways. Therefore, SDT can be useful within design processes because it tells designers how to provide the necessary factors that users look for in products/services. Yet, the SDT factors have only very recently got the attention of design researchers. This was a major motivation to include SDT in the concept design project reported in this paper.

3 SLEEP-WELL CONCEPT DESIGN PROJECT

The project reported in this paper, "Sleep-Well", explored the problem and solution spaces relevant to the design of sleep-wellbeing products, services and systems. It was set as an 8-week concept design project at Middle East Technical University, Turkey within the scope of a 15-week graduate course 'Design for Sports, Health and Wellbeing' attended by 12 industrial design MSc and PhD students. Later in the semester, one student dropped the course because of an unforeseen circumstance caused by the COVID-19 pandemic, thus 11 students completed the course. The project was set in the second half of the course. In the first half, through lectures, invited seminars are workshop activities, the students were given formal input on design for health and wellbeing including the theoretical background (e.g., positive psychology, self-determination theory, types of motivation) and strategies to leverage people's motivation by integrating e.g., positive technologies and gamification strategies.
The project ran in collaboration with an industrial partner specializing in the healthcare domain. Throughout the project, a sleep medicine doctor was consulted for specialist knowledge on sleep disorders. The representative of the industrial partner was a health-tech entrepreneur, who had over 10 years of experience with R&D, product development, piloting, serial production and marketing phases of IoT and ICT solutions for certain sleep disorders. Having an industry partner is not an uncommon practice in design education [5], [6] within the scope of this project, the industrial partner attended the classes to offer input on technologies applicable for measuring, processing and tracking sleep related data, relevant constraints of technology selections on design considerations, as well as to offer critiques for students' design development on potential impacts of design components based on end users' pain points, healthcare domain structures and stakeholders' expectations. Students generated their final concept design proposals ranging from innovative solutions to problems/opportunities that they identified; new approaches to existing products/systems; or unforeseen problems to solve.

3.1 Scope of the project

Students were expected to use the correct terminology from the literature covered in the first half of the course, to build a bridge between a constructed sleep persona and a final design proposal. The proposed solutions were required to be in line with positive design but also be functionality suited to the persona that students constructed. The students were organized to work in pairs (4 pairs and 1 triplet due to the departing student) to take a 'design for wellbeing' approach while responding to the common goal: "to design a physical product (and an accompanying app if relevant) that provides a solution for a specified sleep problem". As the concept design project brief was set within a relatively short graduate-level course, the level of technical resolution expected for the project was modest. Students were not required to deal with manufacturing processes or product assembly. On the other hand, careful selection and integration of digital technologies was essential. It was argued that the most exhausted solutions on the market are in the form of a smartwatch and mobile app combination. This combination was relevant to the project, but equally, innovative solutions outside the combination were encouraged.
The following infrastructure components were pointed out to students as commonly used in health tracking, and that proposals based on such infrastructure were also welcomed: i) health IoT platform; and iii) a gateway (a wearable or stationary device with activity tracking capabilities, e.g., smartwatch, router, etc.).
Subsequently, the following evaluation criteria were defined for the project.

- identifying and detailing a 'sleep targeted problem' and a 'sleep persona' and situating the two in a consistent usage scenario; making a clear argument for how the final design proposal fits to an intended persona, identified sleep problem, and the scenario.
- a design solution for tracking and/or improving sleep quality.

- offering feasible technologies for tracking relevant sleep data.
- leveraging (perceived) three essential elements (i.e., autonomy, competence, and relatedness) of basic human needs through the final design proposal.

3.2 Stages of the project

A Miro-Board workspace was created for each pair to document their design process. The project was managed across the following stages.

3.2.1 Specialist input by the healthcare experts

To set the right scene and to provide foundations, the project commenced with two introductory lectures. The first lecture was given by a medical doctor, specializing in pulmonary diseases and sleep disorders, introducing basic sleep terminology such as sleep quality, optimum sleep, and sleep hygiene. It also covered topics including factors affecting sleep, whether these factors can be controlled, and how personal sleep tracking differs from a professional (clinic) sleep study. The second lecture provided a case study on sleep apnoea tracking, offered by the specialist from the collaborating firm. The study required domain knowledge from different fields, which was possible only through a multidisciplinary team consisting of professionals from healthcare, industrial design, user research and engineering. Although medical solutions were outside the scope of the Sleep-Well project, the case study usefully exemplified how sleep apnoea, as a serious health condition, and the medical device set-up to diagnose and track it, can be improved through a carefully planned user-centred R&D project. Students learned about the research and design activities that were necessary to carry out, and which design iterations and technical development stages were completed.

Later in the semester, the specialist from the firm offered a technical seminar on various kinds of sensors and sensing technologies that are relevant for tracking sleep data. The lecture covered topics including the types of sleep trackers available; what they track and how they track; and common sleep tracking features (e.g., time spent asleep, the quality of sleep, time spent in each stage of sleep, and sleep-related health metrics such as respiration, movement patterns, pulse oximetry, body temperature and electrophysiology data) and their correlation with environmental parameters (e.g., humidity, room temperature, particle concentration, ambient sounds and illumination), personal lifestyle (e.g., physical activities, stress and fatigue levels, daily habits, diet and exercise), health and living conditions (e.g., chronic disease, pregnancy, assisted or independent living). Two tracking technologies that were introduced to students in detail were Electrocardiography (ECG), which measures heart rate, and Electroencephalography (EEG), which monitors brain activity. As well as becoming knowledgeable about the provided facilities, possible limitations and resulting restrictions of regarding technologies, students were expected to evaluate which of the technologies might be most suited to their usage scenario. They were additionally advised to familiarize themselves with common wireless communication technologies (e.g., Bluetooth, Wi-Fi, GPRS etc.), their key specifications, and indoor/outdoor coverage relevant to product design.

3.2.2 Example solutions for tracking and improving sleep disorders

To build awareness of existing design solutions for sleep related problems, each student reviewed products (i.e., product, system, service that can be in the form of mobile apps, physical products, or some combination) targeted at tracking and/or improving sleep quantity and quality. These included non-medical, commercial or conceptual solutions identified mostly from Internet search or products that students own themselves. The students were then asked to choose two of these products and give a brief presentation covering the following information: What is the product? Who is it for? What problem does it aim to solve? How does it work? What technologies does it utilise? Where is it used? (indoor, outdoor, home, work, etc.) How is it used? etc.

The students were encouraged to include available media, such as photos and videos, to help explain the product; the system map (or a system schematic to explain the interaction/information flow between user-product-technology, etc.); and an overview of customer reviews (in the case of commercial products). If observable from the available information, the presentations also included a brief commentary on the following: Does the product employ a positive design approach? Does it incorporate aspects of ‘motivation’? How would you develop the product to (better) motivate its users? They were asked to answer the questions by making direct references to the product’s features, functions, interaction, etc.

3.2.3 Persona characteristics / identified problem / key design considerations
Students were asked to develop a ‘sleep persona’, including the main and secondary (if relevant) characters that they will design their product concepts and/or offer their solutions for. To guide the students, a work-template was provided, with sections including the characteristics of the persona; specific sleep related problem/situation that the persona is experiencing; key design goals; motivation strategy/wellbeing approach; technologies that may help to achieve the design goals (see Figure 1). Students were asked to work with their partners to discuss and elaborate on each of the sections by writing down and sketching out their notes.

3.2.4 Idea generation
Students’ creative ideation commenced. They were required to sketch initial ideas for their ‘Sleep-Well Products’, attending to system, service (app), product, interaction and technology requirements. Ideation also included technical realization for the kinds of technologies that could help, as well as continual scenario iteration. Furthermore, students developed strategies for motivating users that would be relevant to their persona’s needs and specific scenarios.

3.2.5 Interim project submission and student presentations
At this stage, each student pair was asked to present two design ideas, which could be two diverse concepts or a variation on a single concept, within relevant scenarios. Storytelling was requested to bring the scenarios to life, covering answers to questions posed at stage 3.2.3. The presentations were made using the presentation mode of the online collaboration software Miro.

3.2.6 Concept development
After presenting their ideas, students received feedback about strengths, weaknesses and aspects to improve for their concepts, then as a pair, they decided which concept to take forward for finalization. Throughout the concept development, instructors gave regular critiques to students. Experts also joined in some of the sessions for specialist input. Additionally, students were supported through mini-lectures followed by in-class activities (e.g., on motivation, gamification), as well as take-home exercises and directed readings.

3.2.7 Final submission and presentation
The final submission and presentation comprised multiple components: a Bēhance webpage (i.e., platform for showcasing and discovering creative work), 2-minute video presentation, and project report. The webpage presented the concept development stages in chronological order. The video included CAD renderings of the final design proposal with key aspects of the usage and interaction scenario, supported with high-quality renderings and animations supplemented with text labels/captions to identify parts, features, technologies used etc. and the context of use. Finally, the report included a detailed description of the project stages and the final design proposal; and reflections on how the three principal factors from self-determination theory were employed and the extent to which they were useful for driving their ideation.

4 DISCUSSIONS ON FINAL DESIGN PROPOSALS
The Sleep-Well project resulted in five diverse product proposals. The proposals varied based on the sleep-related problems that they tackled, as well as the personas and specific needs they responded to. All proposals took a product-service system approach, designed as a combination of multiple physical product components delivering complementary functionalities. Within the scope of smart connected products, information and communication technologies were implemented for tracking health and/or environmental conditions and giving relevant feedback to users. Although it was not a requirement, all student pairs decided to develop their final proposal with an accompanying mobile app. Summary information about the design proposal and aim, persona, product-service-system components, and digital technologies utilized in each project can be found in Figure 1.
One of the objectives in the course was to introduce students to the three essential elements of the basic human needs from the SDT during lectures, in-class discussions and activities. The outcome shows that students were able to successfully transfer the SDT elements of autonomy, competence and relatedness into their final design proposals (Figure 2). Indeed, the SDT elements were a driver for creative thinking and a motivating strategy for students to take a user-centred approach to their ideation. The nature of

this approach may inevitably lead students to consider aspects of autonomy, competence, and relatedness while generating their ideas. Introducing the topic in a more formal way helped students to make more direct connections to strengthen their final proposals. Student feedback gathered at the end of the course also supported this. For example, *"Since I have not worked on such a topic before, I think it has added a lot to me in terms of definitions and practices in different fields."*
At the end of the semester, various aspects of the course were evaluated by the students over a 5-point Likert scale survey. As a headline result, half of the students "strongly agreed" and the remaining half "agreed" that the SDT direction adopted for the project was useful. The survey showed SDT was useful for students as a way to increase empathy with their developed persona. As a new direction for most students, there were also comments about offering more concrete outlines to follow between SDT and quick in-class activities. This will be taken into account in subsequent delivery of the course and its projects.

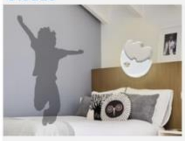
Design Proposal/Persona	Aim	Product/Service/System Components	Digital Technologies
Fall-E  Adults having difficulties in falling asleep due to anxiety	Supports users to create sleep and meditation routine by utilising guided EFT tapping technique	MAIN STATION: guides the meditation with ambient light and speakers SLEEP MASK: provides EFT tapping and collects data during sleep DATA TRACKER: detachable from the mask; portable to monitor daily stress level during the day APP: enables users to create a personalised routine	Sleeping mask and tracker: Photoplethysmography (PPG) sensor; Electroencephalography (EEG) sensor (to track sleep quality and collect data during daytime); Technology to enable EFT tapping By Açelya Küçükkurt, Yağmur M. Arık
Obversa  People with irregular sleep patterns	Helps users with irregular sleep cycles to have healthy sleep pattern by introducing an artificial circadian cycle	CEILING LIGHT: simulates natural flow of the day SHADE: a motorised device with wheels that automatically pulls curtains to block the natural light intake BAND: a wearable tracking device that collects vitals during daytime and asleep APP: enables users to create day-cycles and to review feedback about their sleep and wakeful wellbeing	ALL: Machine learning to create personalised sleep cycle; IoT (to provide proper sleep environment) BAND: Accelerometer; Heart rate sensor; Bioimpedance (to collect data during sleep and daytime) By Sarper Seydioğlu, Cem Özcan, Toprak İpek
Sleep Buddy  First-time parents wanting their babies to develop healthy sleep habits	Supports users to create sleep and meditation routine by utilising guided EFT tapping technique	MAIN BODY: an interactive device with a camera, LED lights and a speaker that creates personalised sleep environment for the baby and collects sleep-related data PARENT'S MODULE: detachable/portable part that remotely controls the main body, monitors the baby during sleep and displays baby's sleep-related data	MAIN BODY: Temperature and humidity sensor (via thermal camera); Motion sensor (to track movements during sleep); Sound processing (to gather sound data when baby asleep); Bluetooth By Öykü Elif Şare, Zeynep Özcan
Journey  Pregnant women experiencing sleep problems due to physiological discomfort or psychological state	Improves sleep quality of pregnant women by providing reassurance, comfort, and security	J-PILLOW: a personalised sleep pillow that ensures the best sleeping position for each trimester J-BUTTON: an interactive companion that provides psychological support and optimises environmental noise J-APP: displays sleep-related data, provides information regarding pregnancy and sleep	J-PILLOW: Pressure sensor (to track sleep quality); Bluetooth J-BUTTON: Touch control By Serhat Ünlü, Büşra Kabaoğlu
Cloudo  Children resisting to sleep at night or having sleep difficulties	Encourages children to go to bed on time provides them with comfortable, safe environment before/during sleep	PILLOW: a hug pillow provides vibration and light feedback, collects sleep-related data MAIN HUB: a hub attached to bed's headboard provides sound (music and stories) and light illusions APP (children): enables children to create bedtime stories, collect sleep points, grow avatars, and connect with friends APP (parent): displays children's sleep-related data and their progress overtime, enables parents to create bedtime routine for their children	ALL: IoT (to create a proper sleep environment); Bluetooth MAIN HUB: Motion sensor (to detect the child's position in bed); Heat and humidity sensor (to collect data and share it with the app); Voice control (voice recognition) (to interact with minimum distraction) PILLOW: Pressure sensor; Motion sensor (to track sleep movements) By Sümeyye Şimşekler, Eren Dönertaş

Figure 1. Key points of five Sleep-Well proposals

5 CONCLUSIONS

Sleep disorders are common and may adversely affect health and wellbeing. While some sleep disorders are quite challenging to treat, it is suggested that most can be easily managed with adequate interventions [5]. This paper demonstrated how digital interventions coupled with a design approach can lead to creative solutions. The Sleep-Well project was completed within a timeframe of eight weeks. The project requirements were found to be effective for graduate level design students, confirmed through formal

student feedback received at the end of the course, allowing them to demonstrate their advanced design skills as well as reporting their reflections on academic literature in a written format.
Students working on the Sleep-Well project were guided through a systematic approach, to provide them with specialist input on sleep, sleep problems, tracking and possible ways to alleviate sleep disorders, as well as relevant digital technologies. The expert lectures and the project development critiques given by the firm representative were invaluable in making sure that identification of the sleep disorders was realistic, and the solutions were technologically realizable. Final design proposals were evaluated by the course instructors, invited academic members, the firm representative and the medical doctor who gave a seminar at the start of the project. As envisaged, students created diverse solutions: some add-ons to familiar products to expand them with new features; some entirely new solutions; and some dealing with relatively less attended areas.

	AUTONOMY	COMPETENCE	RELATEDNESS
Fall-E	Allows users to create a personalised routine (App) Offers options for user preferences before/during meditation (All)	Provides daily feedback about the sleep quality and progress of the user (Tracker & App)	Offers personalised sleep and meditation programs according to the user personal data (Tracker & App)
Obversa	Allows users to take control over their sleep cycle and create artificial circadian cycle	Provides daily feedback about the users sleep and wakeful wellbeing	Provides user with an artificial environment which mimics the flow of the day, creates relatedness with the natural sleep-wake cycle
Sleep Buddy	Offers settings (e.g., song, ambient light, sleep duration etc.) to arrange before/during sleep (All) Enable parents to take control over their babys sleep routine	Provides simultaneous and daily feedback about babys sleep quality (Tracker & App) Enables parents to keep track of their babys sleep progress	Creates an environment promoting the sense of safety and comfort (as if they are companied by a family member) Enables connection between mother and the baby during sleep
Journey	Helps pregnant women to take control over their sleep routine (All) Increases empowerment by providing pregnancy-related information (J-App)	Provides information about stages of pregnancy and sleep during each stage (J-App) Presents sleep-related data (J-App)	Shares pregnancy experiences of other women (App) Provides psychological support by giving light feedbacks (J-Button) Offers personalisation and different usage options for each trimester (J-Pillow)
Cloudo	Enables children to create personalised stories and environment for themselves Enables parents to create personalised sleep routines for their children	Provides daily feedback about the sleep quality and progress of children (for parents) Enables children to keep track of their progress through the points	Provides children with a platform to communicate with their friends and exchange sleep-related experiences Introduces an avatar that grows as children gain points Promotes the sense of safety, comfort and attachment/companionship (J-Pillow)

Figure 2. Features supporting Autonomy, Competence and Relatedness in Sleep-Well proposals

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