

The Subjectivities of Wearable Sleep-Trackers - A Discourse Analysis

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ABSTRACT

Self-reported quality and duration of sleep in Western populations is declining. The interest in wearable sleep-trackers that are promising better sleep is growing. By wearing a device day and night the sleeper is continuously connected to a more-than-human network. The mass-adoption of sleep-tracking devices has an impact on the personal, social and cultural meaning of sleep. This study looks at the discourse forming around wearable sleep-trackers. This extended abstract presents how non-human subjectivities are accounted for in this discourse. Through a posthuman discourse analysis of textual and visual artefacts from interviews, academic research and popular media, six distinct roles for these non-human social agents were identified: 'Teacher', 'Informant', 'Companion', 'Therapist', 'Coach' and 'Mediator'. This characterisation is a first step to understanding sleep-trackers as social agents, reorganising personal and contextual relationships with the sleeping self.

CCS CONCEPTS

- Hardware → Emerging tools and methodologies; • Human-centered computing → Empirical studies in HCI; User models; Ubiquitous and mobile computing design and evaluation methods; • Social and professional topics → Corporate surveillance; Personal health records; • Computing methodologies → Cognitive science.

KEYWORDS

posthumanism, subjectivity, agency, wearable technology, personal informatics, sleep-tracking, discourse analysis

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1 A CRISIS OF SLEEP

The human body requires sleep. About one third of a lifetime is spent sleeping and the quality of sleep affects how the time awake

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is perceived. Just a few years back sleeping little, just like the motto "work hard, play hard", was a badge of honour [28], but in recent years sleep research and the public sleep-discourse increasingly focused on the effects of sleep on health, memory, cognitive functions and alertness. Too little, too much and poor sleep are all associated with poor health.

Studies show that in the past half-century the self-reported sleep quality and duration among adults in the Western world have decreased [22, 39]. Sub-optimal sleep duration is linked to socioeconomic status, lifestyle, stress and age [9]. Lower socioeconomic status, lower education and lower income are strong predictors of shorter sleep duration, potentially intertwined with the effects of individual health- and work-related characteristics as the same demographic has less access to health-care and works more irregular schedules [63]. Smoking, heavy drinking, physical inactivity and obesity are associated with both shorter and longer sleep duration [60, 67]. While these factors are perceived as individual behaviors, they are linked to chronic emotional stress, which is an underlying reason for bad or short sleep, or insomnia [15]. Age is the other major contributing factor to sleep quality and quantity as the sleep architecture changes across the lifespan [49]. Reduced sleep time and quality among the elderly is linked to cellular changes, depression, pain, cardiovascular diseases, dementia and other medical conditions [30].

The market offers solutions to this sleep crisis which are mostly technical, medical and individual without addressing any social or contextual factors that contribute to bad sleep [38]. Sleep-related products promise the optimisation of the self by putting the positive, self-restorative effects of sleep to work [54], a notion widely advertised through the sleep industry in the 2000s. Individuals are promised that changing their sleep habits will lead to being healthier and more productive [11].

Eun Choe et al. [12] published a conference paper at CHI'11, outlining the opportunities for technology to support healthy sleep, based on the premise that tracking of personal data increases awareness and motivates desired behaviour changes. Since sleep-trackers have become widespread and accepted in the past 10 years, several studies look at their effectiveness to improve sleep. Sleep tracking does increase awareness about sleep patterns and can improve sleep quality, particularly for people suffering from insomnia and in clinical settings [3, 17]. Nevertheless, Liang and Ploderer [42] found that improving sleep quality by merely measuring sleep as a lifestyle choice is difficult because users do not know how to act upon the data. Sleep depends on many internal (mental and physical health) and external (social, economical, stress, environment etc.) factors which are often beyond the control of the individual. Making connections for improvement is difficult as sleep is not

a conscious activity. Similar results were found by Liu et al. [43] and Ravichandran et al. [53]. People with existing sleep-related problems are more interested in sleep technology, but sleep technology itself could be adding to the canon of technology which is disrupting sleep. Baron et al. [6] provide case studies demonstrating that sleep trackers can reinforce sleep-related anxiety. This leads to people seeking medical help for exacerbated insomnia due to their device, a phenomenon called orthosomnia.

2 SLEEP IS RELATIONAL

Sleep can only be known about from someone else, an observer who a sleeper depends on for knowledge [50]. Sleep-tracking is one way of accessing this knowledge. It makes the sleeping self observable. Sleep-tracking technologies influence the environment-body-mind dichotomy in different ways. Personal wearable technology can directly interact with a user's body and affect it without requiring conscious thought [5]. These systems establish a channel for unconscious communication between the body and the device, entering into a symbiotic relationship [21] which can be maintained during the unconscious state of sleeping.

This hybridity of human - non-human assemblages creates new realities that shift people's practices, subjectivity and change somatic limits and functionalities. It transforms the understanding of what it means to be human and how the world can be experienced. As more and more bodies and minds are being extended with technological sensors the boundaries between natural and artificial, human and non-human are being exposed to merely being socially constructed [10, 35, 36, 48, 66]. This notion reorients the human user as a node within a larger system of different materialities and rhythms of human and non-human interactions [29]. Digital devices actively transform meaning and regulate their external environment. They must be considered as social actors. They are produced in relation to human users and through interactions with them. Human and non-human are mutually influencing each other's subjective and individual becoming [27, 41]. This system of nested networks, which all life is part of, limits or enables different subjectivities and ways of life. This implies the related vulnerability of all actors involved [36, 65]. A critical posthumanist stance opens up new perspectives on how technology is involved in the re-composition of the human and non-human [10]. An understanding of agencies and relations and their role in shaping the world is necessary to address societal and environmental challenges through design. It is a suitable frame of thinking when analysing sleep technology since contemporary sleep patterns match societal inequalities. A posthuman perspective enables us to see the relationships between users and personal devices, and how structures of inequality play out in the use of sleep-trackers.

As smart wearables are becoming evermore ubiquitous, many of which offer a sleep-tracking functionality, sleep transforms from an unconscious, un-reflexive experience into an active, measurable performance. This paper presents the initial findings of a study set out to understand how sleep-tracking technologies as social agents are creating and forming a new discourse around the practice of sleeping. It describes the subjectivities of wearable sleep-tracking devices which produce new knowledge and meaning. The following description of non-human subjectivities of sleep-trackers serve as

a starting point to investigate the affective relationships within the more-than-human network of wearable sleep-tracking.

3 METHODOLOGY

Discourse analysis as a methodology developed in the writings of Michel Foucault [23–25] is a suitable methodology to research how technologies define what it is to be human and how they produce subjectivities. This study followed the guidance of Fairclough [20] and Gillian [26]. In order to make the affects and effects of digital objects more visible, devices were "interviewed" alongside human interview participants as described by Adams and Thompson [1]. In posthumanist research methodology, digital subjects are fully considered as social actors next to human users, with their own agency and truth. They have the capacity to make sense, create meaning through reflection and memory, translating between humans and data and changing people's individual and social behaviour [19]. Subjects of any kind are generated through their relationships and inseparable from their context [27]. Through this methodology non-human subjects are given a voice, making them available for critical analysis so that their subjectivities can be described.

3.1 Data Collection

Three types of textual and visual materials were collected for analysis: academic research papers, expert and user interviews, and online documents. All documents were stored, coded and analysed in the qualitative data analysis software MAXQDA¹.

3.1.1 Academic Research. After an initial search of key academic papers in the field of wearable sleep-tracking technology, a snowball method was used to collect additional documents of relevance that were referenced in the initial papers. Only papers after 2010 were included in the analysis, as this marks the time where sleep-trackers became increasingly available for end-users and Choe et al. [12] published an extended abstract leading to the paper "Opportunities for computing technologies to support healthy sleep behaviors" in 2011. This led to an increased interest in sleep-technology within the HCI community. A total of 30 papers were identified and underwent analysis for this study. The research communities talking about wearable sleep-trackers are multiple. The main perspectives are provided from three areas of research: human-computer interaction [12, 31, 42–44, 53, 56, 61] including interaction design [2, 16] and ubiquitous computing [13, 69]. Second is social sleep research [34, 45, 57] including the sociology of health and illness [14, 68] and qualitative research [59]. And the third area is medical sleep research [7, 8, 47, 64] including the study of chronobiology [18, 33], clinical sleep medicine [6, 55, 62] and medical computing [4, 32, 51].

3.1.2 Interviews. Interviews were conducted both with users as well as designers and developers of wearable devices (experts). Each interview followed the same interview guide, slightly adjusted for users and experts respectively. The questions covered general attitudes towards sleep as well as behaviours and rituals around the transitional moments between being awake and sleeping. They covered questions about sleep's impact on the time being awake and the impact of a wearable sleep-tracking device on sleep. Several questions investigated the particular sleep-tracker in use, for what

¹<https://www.maxqda.com/>

Table 1: User Interview Participants

ID	Device	Duration	Age	Gender	Place
SDRF	Oura	3m - 2y	26-40	F	USA
PLCN	Oura	3m - 2y	26-40	M	UK
AVSA	Oura	3m - 2y	41-55	M	NZ
AHPD	Oura	3m - 2y	41-55	F	USA
PPAW	Oura	3m - 2y	56-76	F	USA
VDVL	Oura, SleepOn	2-5y	56-76	M	USA
ASOG	Oura, Fitbit	3m - 2y	26-40	F	UK
ICSE	Fitbit	0-3m	26-40	F	IRE
MCGI	Dreem	0-3m	26-40	M	UK
LTYL	WHOOP	3m - 2y	41-55	M	SGP
FUDE	Garmin	5+ y	56-76	F	USA

purposes they are employed and how the user-device relationship and interactions evolve over time. This is followed by questions about the interpretation of sleep data. Several questions were informed by the methodology for interviewing digital objects to evoke the telling of stories about the affective relationships between users and their device(s) [1]. This study was approved by the Queen Mary Ethics of Research Committee (QMREC2413).

A screener questionnaire to gather users of sleep-trackers for the interview was shared in several active special interest groups online². Users had to confirm their regular use of a wearable device and its functionality for sleep-tracking in order to be interviewed. The recruitment of interview participants followed a quota aligned to marketing statistics representing the demographics for users of fitness-trackers [40, 52]. To the best knowledge of the researchers, no publicly available demographics of sleep-tracker users existed at the time. Details of the user interview participants can be found in Table 1, including their participant ID, sleep-tracking device brand, duration of consistently using a sleep-tracker, age-range, gender and country of residence.

The experts were contacted individually via LinkedIn by the first author, as their profile identified each expert working for any of the sleep-tracking devices used by the user participants in a role in design or development of the sleep-tracking functionalities. Two experts worked for the Paris (France) based company Dreem, one for the Oulu (Finland) based company Oura, one for the Boston (USA) based company WHOOP, one for the Hangzhou (China) based company SleepOn and one for the San Francisco (USA) based company Fitbit. Their job titles (in no specific order) at these companies are Director of Product, Group Product Manager, Marketing and Communications Manager, Chief Science Officer, Scientific Consultant, Head of Biosignals and New Business Lead.

All interviews were conducted between 22 July 2020 and 16 April 2021 via video calls on the platform Jitsi³ and each interview lasted for one hour on average. The interviews were screen-recorded and transcribed manually. The transcription follows a light-weight

protocol for inline annotation of transcripts for disfluency and laughter after Hough et al. [37].

3.1.3 Online Documents. In addition to academic research and interviews a total of 95 digital artefacts dating back to 2010 were collected to further inform the discourse analysis. These materials include the websites (8) and social media accounts (4) of wearables' companies, blog posts (19), product reviews (11), news headlines and articles (49) and ads (4).

3.2 Data Coding and Analysis

This paper presents an overview of the non-human subjectivities the sleep-tracking discourse produces. The data was looked at through a lens of identifying those subjectivities and their relationships to human users. All materials were coded by the lead author according to themes emerging from the language in use [20]. The same codes were applied across all types of materials. Using MAXQDA, codes were summarised first on a document level and then in a summary table across documents. Materials for this analysis refer to various different brands and models of wearable sleep-tracking devices, but patterns of subjectivity occur across the brands. In order to analyse the non-human subjectivities and the relationship between human and non-human agents, object personas are created [46]. The six personas emerged from a category with the label "Role", including sub-codes for references to the role a sleep-tracker plays in a user's life. Examples and evidence of those occurrences is provided in Figures 1-6.

4 PRESENTATION OF THE RESULTS: NON-HUMAN SUBJECTIVITIES

Wearable devices influence the way their users behave, move, talk or feel. These devices feel alive as they demand to be engaged with. The embodied self of the sleep-tracker exists both as an object in the world but also as a subject of experience. It is subjectively aware of the world through its sensors, algorithms and encoded standards and norms. And it is participating and present in social life [10, 36, 41]. In the following, six types of sleep-tracker subjectivities are presented.

4.0.1 Teacher. The Teacher provides information, insight and knowledge about one's sleep and sleep in general, both to the user on a personal level and also the general public by presenting aggregated sleep data and feeding their knowledge into the wider discourse. The description of the sleep-tracker as a teacher comes mostly from expert interviews (E1, E2, E6) and academic research ([43, 59, 69]). The Teacher encourages interest and curiosity about the personal sleep pattern and quality (Gibbs 2014a). They teach their user new habits and give suggestions on how to improve sleep (Fisher 2014, [59]). Through educational content they help their user by making correlations and changes in the collected data visible and explaining those trends (E1, E2, E6). The Teacher's objective, however, is more to inform their user than actively trying to change their habits. Educating the user about their personal data is the most meaningful, as sleep-data is individualistic. A comparison with others, goals or averages are less actionable for sleep than for other measures ([43]). Through a blog and other communication channels the Teacher educates a wider audience beyond the immediate user on sleep, sleep

²Quantified Self 'Sleep' Forum, Oura Ring Facebook Group, Fitness Trackers for Human Performance Tuning & Analysis Facebook Group, Health Unlocked - Sleep Matters Forum, Fitbit 'Sleep Better' Forum;

³<https://jitsi.org>

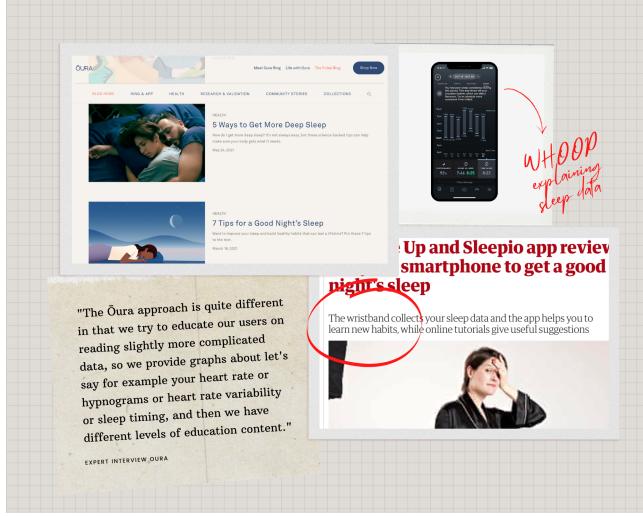


Figure 1: Collage of materials describing the ‘Teacher’.

data and sleep improvement (E2). Their data is used in collaboration with scientists to generate new insights. Device-specific education and conceptual definitions are important as well. The data across devices varies due to the types and sensitivity of embedded sensors and the brand-proprietary algorithms interpreting sleep (E6, [69]).

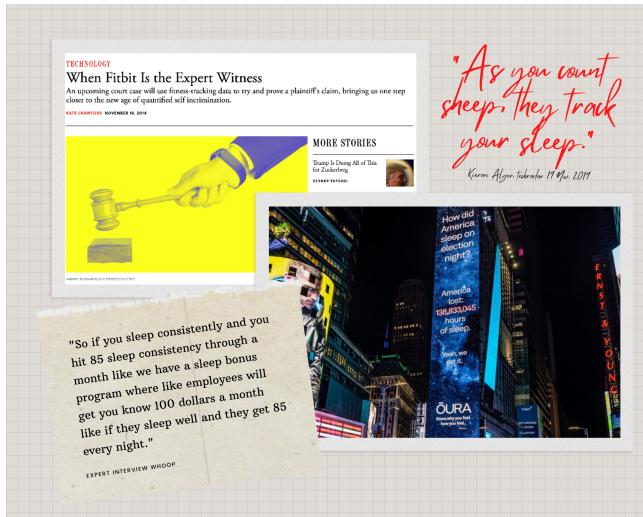


Figure 2: Collage of materials describing the ‘Informant’.

4.0.2 Informant. The sleep-tracker observes and monitors the sleeping human body, creates knowledge and distributes this data among other interested parties external to the user. Experts (E1, E3), the media (Crawford 2014, Federman 2020, Filloux 2013) and academics ([51, 68]) describe the sleep-tracker as an Informant. As sleep can only ever be understood through an other, information from sleep-tracking devices influences a personal understanding of the sleeping body (E1, E3, Allison 2020, Corbyn 2014, Hopkins Medicine 2020, SleepOn 2021, Williams 2020, WHOOP 2021, [68]).

The Informant propagates a shift towards a data-driven regime of truth. Studies show that humans consider data to be more true and objective than personal experiences (E3), but there is no direct measurement for consciousness or sleep. Sleep-trackers are not very accurate detecting different sleep stages (Turk 2019), they over-estimate sleep duration compared to polysomnography but they underestimate it compared to the self-reported sleep duration (E5). This makes a difference when data is considered an objective truth (Crawford 2014). The Informant delivers a continuous stream of data to their developing company and helps inform the development of the product as well as marketing campaigns (E2). Media and researchers express a concern about how the data is used to monitor and influence people (Crawford 2014, [51]). The Informant’s data could be used to discriminate in multiple ways such as deny health benefits, employment or similar (E3).

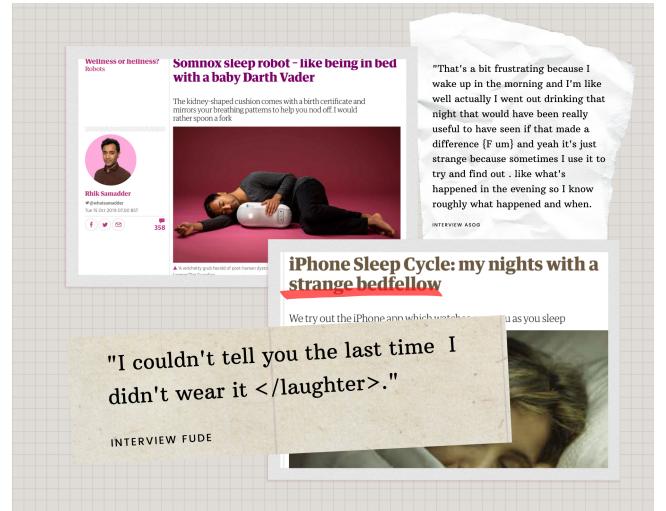


Figure 3: Collage of materials describing the ‘Companion’.

4.0.3 Companion. Mainly users (ASOG, FUDE, LTYL, SDRF) and the media (Alger 2019, Bellabeat 2020, Bramley 2018, Green 2020, Samadder 2019, Skidelsky 2010) use language associated with companionship or friendship to talk about the sleep-tracker. The Companion is continuously present in their user’s life, since sleep-trackers are usually worn around the clock (ASOG, FUDE, LTYL, SDRF). They are participating in the intimate practice of sleeping and thus develop a strong bond with their user (Alger 2019, Bramley 2018, FUDE, SDRF). The Companion is referred to when users are in conversation with friends. They are part of their social circle (SDRF). The connection between Companion and user is so strong, that a user feels regret when the Companion’s battery runs out during sleep (SDRF) or they forgot to put it on. Even if their form does not resemble any known living being, the presence of a Companion can be calming, give a sense of security and control, which facilitates restfulness (Bramley 2018, Samadder 2019, Skidelsky 2010, [51, 61]). The Companion can be a neutral, non-judgemental partner when life is difficult for the user and good sleep is not possible (E1). They are supporting their wearer in reaching personal sleep-goals (Bellabeat 2020, LTYL, SDRF). Companions are participants and

co-producers of knowledge in people's lives. They can give useful information about sleep quality and help reflect on decisions made in the past day (E1). It can bring awareness to things that cannot directly be experienced by a person (Green 2020).

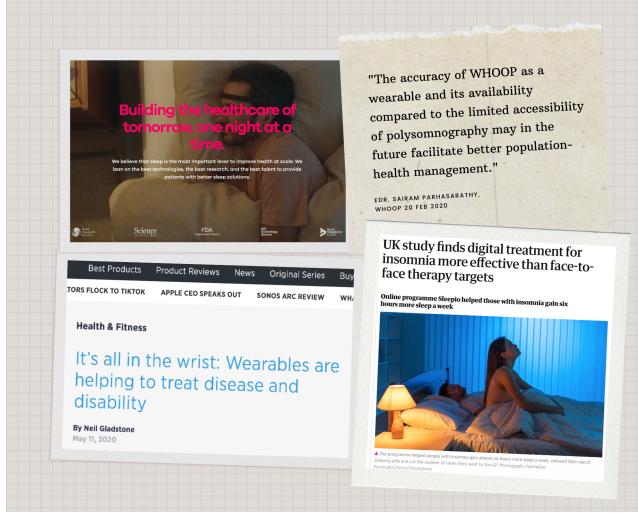


Figure 4: Collage of materials describing the 'Therapist'.

4.0.4 Therapist. Academic and medical research, experts, users and the media all refer to the therapeutic potential of consumer sleep-tracking devices. A medicalised approach to sleep has led to the development of consumer devices for the diagnosis, treatment and even cure of sleep disorders. They are involved in clinical studies (Dreem7 2021, [7, 55]) and used by patients and medical professionals to monitor health and symptoms (ASOG, AHPD, FUDE, SDRF, VDVL). It is the persona of the Therapist which allows the sleep lab to enter the home (VDVL, [68]). Therapist wearables are inspired by medical technology and aspire towards being as accurate in detecting sleep stages as polysomnography (Turk 2019). The accuracy of measurement is important when users are patients who want to monitor their condition and decide whether or not to seek medical advice ([51, 69]). The Therapist performs multiple tasks a medical professional would do, while being more cost effective (E6, ASOG, FUDE, VDVL). Insomnia or sleep disorders are medically speaking symptoms of other pathologies, nevertheless Therapists promise treatment for insomnia, cure sleep disorders or other therapeutic effects (Gabbatt 2017, E4, E6, Campbell 2020, [13]). The Therapist produces data which can be taken to and discussed with a medical professional to support diagnosis (Devlin 2019, [12, 43]), or they can help a human doctor to monitor health and symptoms of illness outside the doctor's office (Gladstone 2020, [62]). Due to its accessibility the Therapist could support governments with population health-management (Dreem1 2021, WHOOP). Often users trust their Therapist so much, that they use the insights for computer-aided self-diagnosis of sleep disorders as the devices track for various symptoms (ASOG, AHPD, FUDE, SDRF, VDVL, Campbell 2020, Chen 2019, Oura2 2020, SleepOn10 2021, [8, 64, 68]). Therapists focus on physiological signs of health and wellbeing and provide their user with a feeling of control over their holistic

health (AHPD, FUDE, SDRF, VDVL). Professional athletes wear sleep trackers to improve their recovery time and in order to reduce their proneness to injury (WHOOP).

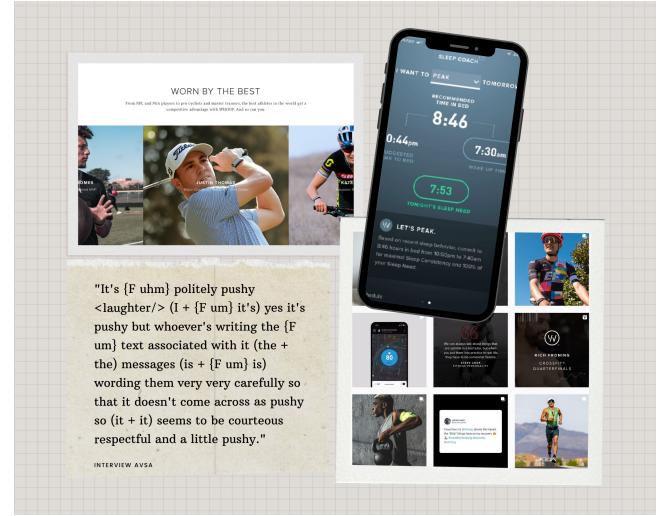


Figure 5: Collage of materials describing the 'Coach'.

4.0.5 Coach. Experts, users, academics and the media put a strong emphasis on presenting the sleep-tracker as a Coach. Sleep-tracking alone does not change behaviour but together with coaching or guidance it improves the outcome (E5, [6]). The Coach empowers people to make better lifestyle decisions in relation to their sleep. They consider personal circumstances and devise a personalised plan, sleep schedule and sleep targets for a user to follow to meet their personal sleep needs and improve sleep quality (E1, ASOG, AHPD, AVSA, LTYL, MCGI, PPAW, PLCN, SDRF, Fitbit12 2020, Green 2020, Oura12 2018, WHOOP 2021, [58]). The Coach is at times considered more reliable than human, personal feelings (AHPD). Sleep-trackers are not necessarily accurate but they help to understand sleep. A Coach can successfully act as a guide to improving it. The Coach executes guidance through different features such as reminders, warnings, goals, scores and verbal assessments (Green 2020, [12]). The Coach uses biometrics to measure habits and introduces biometric and sleep goals into their user's life and establishes new terms like wellness or readiness (E5, ASOG, AVSA, PPAW, PLCN). The sleep scores or readiness scores provided by their Coach helps the user understand how prepared they are for the day ahead and to take informed decisions (Fowler 2020, Turk 2019, WHOOP 2021). The Coach is modeled on a personal trainer, which not everyone has access to due to cost constraints. They push their wearer to their limits and optimise the recovery to increase physical performance (E2, WHOOP, [68]). The Coach also sets boundaries during the day for how much activity is enough in order to not strain the body too much (E2, AVSA, LTYL, SDRF). They inherently link improved sleep quality to improved daytime performance. The Coach tells their user what to do and gives realistic expectations on which goals can be met (AHPD, WHOOP 2021). The Coach is informed by data as a baseline view of what is normal for an individual and how it deviates from the norm (Fowler

2014). The Coach also describes and ranks their user in comparison with users of a similar demographic so the user can improve and compete both with them-self but also with the data peer group (LTYL). Creating data driven games or competitions perpetuate the notion that data stands for scientific values, objectivity, reliability and trustworthiness (Crawford 2014, [45]).

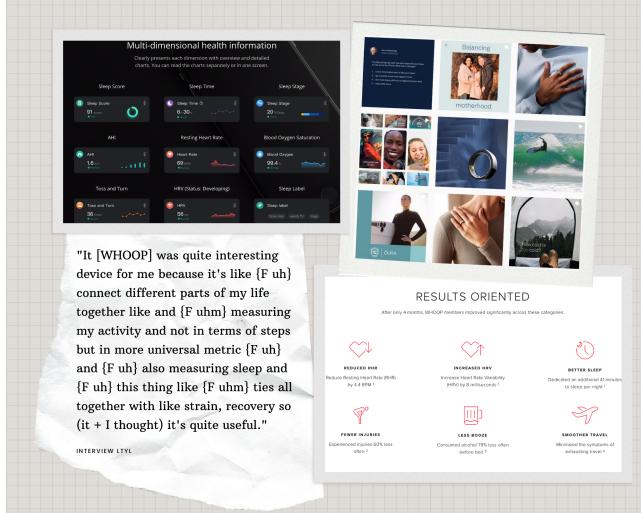


Figure 6: Collage of materials describing the ‘Mediator’.

4.0.6 Mediator. Sleep-trackers operate at a point where internal and external factors of a user’s life collide, aiming to balance behaviours and feelings with the natural circadian rhythm (E5, Oura9 2020). The sleep-tracker as Mediator combines and correlates various aspects of life and their user’s body data and mediates their behaviour through the data. It is a concept that emerges from user interviews (ASOG, AVSA, LTYL, MCGI) and academic research ([51, 57, 68]). Mediators look at user behaviours and feelings and collate them into universal metrics (AVSA, LTYL). The Mediator negotiates between activities and feelings. They want to help their user reflect on their lives but do not present themselves as the objective truth (ASOG, AVSA, MCGI). They acknowledge that sleep data is an abstracted form of the experience itself, influenced by particular standards of what it means to be healthy (Crawford 2014). Accuracy towards a gold-standard or comparison to average users is not necessary or desirable when the Mediator presents data for self-reflection. Mediators play a role in shaping the understanding of the human self. The Mediator helps a user to take informed decisions and sometimes to communicate to medical or training professionals - therefore the Mediator needs to be taken serious by their user ([51]). Mediators act as translators, opening invisible aspects of everyday life to scrutiny, making them visible, identifiable, knowable and linking them to the theme of self-optimisation by inviting scrutiny and intervention (ASOG, AVSA, [57, 68]). Mediators create data-doubles of their users, constructs of information without a body, that invite self-reflection and behaviour change (ASOG, AVSA, LTYL, [57]).

5 DISCUSSION

Subjectivities of sleep-tracking devices are produced through various discourses influencing each other: clinical sleep research, sleep-related consumer products, their users and an increasing public awareness around the importance of sleep. This study presents findings towards an understanding the ways that consumer sleep-tracking technology influences the personal, social and cultural meaning of sleep. The presentation of these findings is aimed at starting a conversation around norms of the sleeping human body and how it is affected through the relationship with a wearable, connected, sleep-tracking device.

After reviewing and analysing the discourse around wearable sleep-trackers, it appears that the motto “work hard, play hard” [28] sounds more like “work hard, sleep hard” today. For a consistent sleep schedule and to meet the demands and stress of working life there is not much time for play but only for continuous quests of self improvement. Sleep-trackers play important and varied roles to facilitate the market’s need to create a productive workforce and at the same time sell to a perceived need of perpetual self improvement. Lyall and Robards [45] describe the roles of digital self tracking-devices with the categories of Tool, Toy and Tutor. The Tutor is similar to the roles of the Teacher or the Coach as discussed in this extended abstract. However, the role of a Toy has not been found to be applicable for sleep-trackers. Despite the gamification of the sleep-experience through sleep-tracking devices there is a clear demand for employing sleep to improve productivity, health or well-being. The measuring of sleep as a lifestyle choice can create sleep disorders such as orthosomnia [7]. An understanding and discussion of a wearable sleep-tracker merely as a Tool, not acknowledging it as an agent, is not useful. As Verbeek [66] describes, “technological development has reached a stage in which technology has started to interfere explicitly with the nature of human beings. Intentionality used to be one of these concepts which belonged to the realm of the exclusively human, but by now it has become clear that it needs to be extended to the realm of technology – and to the realm of human–technology amalgams.” If one decides to wear a sleep tracker one also has to acknowledge that it will influence their behaviour, self-knowledge and change decision-making.

Existing consumer-grade wearable devices are helping certain individuals with their sleep problems, to meet sleep-related goals and raise awareness about sleep as suggested by Choe et al. [12]. They are, however, not directly addressing any of the key contributors to sleep quality and duration, namely the socioeconomic background, chronic emotional stress or ageing [9, 15]. For now, sleep-trackers potentially increase social inequalities due to the required personal and financial freedom for sleep improvement as well as financial accessibility to novel technologies. They also require a certain technological affinity which might exclude the elderly. Improvements in accuracy of the devices could contribute to facilitating and reducing the cost of clinical sleep research and improve global access to healthcare [18].

The findings of this study demonstrate how a sleep-tracker is never a neutral device. They are inseparable from their own and their user’s subjective becoming. A data-driven regime of truth around sleep compromises the human experience and can have

far-reaching impacts which are beginning to be understood. Posthumanist research offers ways to re-contextualise human existence and to move forward through more-than human collaboration, empowerment and creativity [10]. This reading of sleep-trackers as subjectivities can open up new ways for designing with and around sleep, a physiological need that all organisms share. It is an attempt to open up a new direction for the design of sleep-technology to improve planetary health through a better mediation between economic and natural rhythms which in turn could lead to a better balance between the interests of human and planetary needs for a sustainable future.

The six roles sleep-trackers can play in user's lives as presented in this study can be considered by designers when developing digital health and well-being tools and programmes. In a next step the researchers will map the affective relationships between human, non-human and technology, and how this is mediating the experience of sleeping.

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