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‘M-mapping’ Sleep? Trends and Transformations in the Digital Age.

Abstract:

This paper critically explores recent trends and transformations in the monitoring and management of sleep in the digital age, taking as its focus the advent of new digital technologies to trace and track the sleep of ‘ourselves’ far away from the institutional confines of the conventional sleep laboratory or clinic. Our argument, to further contextualise these matters, is dually situated within the history of sleep science and medicine on the one hand, and the rise of new digital forms of so-called ‘self-tracking’ or ‘self-quantification’ and m-Health on the other hand. Whilst the recent history of sleep science and medicine may rightly we suggest, in keeping with Kroker (2007), be characterised as a concern with the ‘sleep of others’, a new chapter in this story may well be dawning through the advent of these smart new mobile tools and technologies for mapping, or ‘m-mapping’ as we term them, ‘the sleep of ourselves’ in the digital age as we become in effect, for better or worse, our very own sleep laboratories or clinic. The problems and prospects this holds are further critically considered and some preliminary conclusions ventured, including remaining questions and future agendas in this rapidly evolving and exciting new digital domain.

Key words: Sleep, laboratory, clinic, digital, m-health, quantified-self (QS).

Introduction

The past two decades have witnessed a growing turn to sleep matters within the social sciences and humanities (Williams and Wolf-Meyer 2013), including a recent special issue of social science and medicine on sleep, culture and health (Henry, et al 2013).

In this paper we add a further important digital dimension and dynamic to these debates in the guise of new technologies to monitor and manage sleep *ourselves* in everyday/night life, far away from the conventional sleep laboratory or clinic. Our key argument in this regard, is that current efforts to monitor or map what Kroker (2007) terms the sleep of ‘others’ within the sleep laboratory or clinic, are now being joined by the advent of smart new digital technologies, available on our mobiles, laptops and tablets, to monitor or ‘m-app’ (as in mobile – app) sleep ‘ourselves’ in everyday/night life: a case of ibodies in the bedroom in other words, as the sleep lab enters the home and we become, in effect, something akin to our very own sleep labs or clinics ¹.

Sleep, and the ways in which we measure it, is a particularly interesting sociological case to study here on several counts. First, because biological sleep need is universal, crossing class, culture, gender, ethnicity and even species boundaries, it is something we all do; a normal, natural part of our everyday/night lives. However, at the same time, the ‘doing of sleeping’ (Taylor 1993) or our sleeping practices are inextricably tied to social context and hence affected by all the aforementioned factors and more. The spaces, places, times and values given to sleep differ amongst and between social groups (Coveney, 2014; Meadows et al. 2008; Nettleton et al, 2011). Sleep moreover has become increasingly problematized and politicized (Williams 2011), as the quality and quantity of our sleep are ever more linked to health outcomes, including cognitive performance and emotional wellbeing, as well as wider public safety issues.

Secondly, sleep is an unconscious part of our lives which we can only ever come to know and understand indirectly. The ways in which we come to see and know our sleep therefore, through the eyes of others or through technologies that monitor and measure our sleep, influences the ways in which we come to know and understand our dormant or sleeping bodies and selves. The visualizing, monitoring and mapping of sleep using new digital technologies and platforms in turn ties into Foucauldian notions of technologies of self, governmentality and surveillance; another ‘vital’ part of ‘the politics of life itself’ (Rose 2007), that is to say, where quantifying, customizing or optimizing our sleep in the name of health or performance is linked to prevailing neoliberal, if not ‘bioliberal’ (Fuller 2006) mandates associated with identity and selfhood, individualization and responsabilization.

In making our claims regarding these transformations in the technoscientific gaze from the sleep of ‘others’ (cf. Kroker 2007) to the sleep of ‘ourselves’, the analytical approach we adopt in this paper is located at the nexus of Science and Technology Studies (STS) and the Sociology of Health and Illness (SHI). In doing so, we aim to bring the technologies around mapping and monitoring sleep to the fore; to acknowledge the social significance of these developments beyond their technical meanings or applications; and to discuss the new forms of ‘*digital biosociality*’ (Hagen 2013) that they enable or encourage. Some preliminary theoretical remarks are therefore in order at the outset as to how we are approaching these technosocial matters.

Tracing Sleep Through Science and Technology: A Theoretical and Methodological Sketch

Bringing together ideas originating in STS and SHI, in this paper we conceptualise the technologies we discuss as sociotechnical objects that have been co-produced in a particular historical and cultural context (Jasanoff, 2004; Winner, 1980). We recognise that the technologies that exist and are being developed to monitor, quantify, assess, track and visualise sleep - from the polysomnograph (PSG) or watch actigraphy through to the sleep m-apps available in the domestic sphere - exist within complex socio-technical networks or ‘assemblages’ (Deleuze and Guattari 1988), in a particular place and space in time that gives meaning to their use and non-use, both within and outside the sleep clinic or laboratory. They have been created and designed for a specific purpose, within a particular sociocultural context and with a user group in mind (Mackenzie and Wacjman, 1999; Woolgar, 1991). To borrow from Law et al (2011), these ‘methods’ have a *social life*. Values and politics are incorporated into the design of these technologies, they are coded with ideologies about the social lives, relationships, self-image and characteristics of their users (Akrich, 1993; Lakoff, 2005; Rose, 2007), which reflect and refract contemporary knowledge claims about sleep, health and the body. However, technologies have both *makers* and *users*; the expectations of innovators, the experience of users and the adaptation of technology to meet their needs, wants and desires in everyday life all influence the cultural spaces which the technology eventually comes to occupy (Borup et al 2006; Oudshoorn and Pinch, 2005). Their meaning is therefore *shaped by*, and simultaneously *shapes* or *reshapes*, our understandings, knowledge of our bodies and its processes in specific ways.

Additionally, the contemporary medical and more broadly health-related information scapes are important to consider in this vein. Nettleton (2004) for example, drawing on De Mul's (1999) writings on the 'informationalisation of the world view', usefully refers here to the emergence of a new era of what she terms 'e-scaped medicine'. In this era, medical knowledge is transformed into medical or health-related information which, through a process of e-scaping, flows in compressed time-space through the nodes and networks that together comprise our contemporary information scapes to escape its traditional institutional confines. To the extent, moreover, as Halford et al. (2012) have recently argued, that the web evolves from a 'web of documents' to a 'web of data', then this clearly raises a host of further critical questions and issues concerning the politics of data and expertise, within and beyond the medical and health domain. Caution nevertheless is clearly needed here, as Mort and Smith (2009) valuably remind us, given the often more 'artful' or 'creative', if not 'modest' or 'messy' realities and resistances at work here in practice, thereby complicating or challenging claims, if not 'fantasies' or 'myths', regarding the 'transformational' power of these information technologies.

Within the remainder of the paper, we trace and track the emergence of sleep m-apps and begin to map out where they are situated within the history of sleep science and medicine on the one hand, and the emergence of wider m-Health/quantified self (QS) movements on the other hand. In our analysis, we pay attention to the roles of these non-human actors in the changing nature of how we come to 'see' and understand our sleeping bodies and selves in the digital age, while acknowledging their mutual shaping by developers and users in a wider context of these shifting information scapes. We focus on how sleep becomes a problem and priority in these different domains, the user-technology configurations that are coproduced in each domain, how new technologies are negotiated alongside competing knowledge claims surrounding sleep and health, and how this creates new spaces or scapes of representation and intervention where new potential identities (Nettleton, 2004) and forms of digital biosociality might emerge. We end with some further comments and reflections on how these digital m-apps and matters may not simply change our understanding of our bodies, our sleep and our identities in an era of digital health but escape themselves (Nettleton 2004), so to speak, through their discussion, dissemination and diffusion within the wider web and social media.

In order to begin to develop a picture of the emergence of sleep m-apps we searched Amazon.co.uk to identify the range and scope of sleep tracking devices (Table 1). We then searched the NHS apps library to identify health apps which purported to aid sleep (Table 2). Finally, we used Google searches to find out more about the apps themselves and to identify relevant blogs, websites and online forums. The claims we make regarding the tracing and tracking of sleep in digital age, and the questions we pose for future research are therefore based on a broad preliminary scoping exercise rather than a systematic empirical investigation. The paper in this regard is best read as an early theoretical exploration or mapping of these problems, prospects and possibilities, pending subsequent investigation at various levels and scales of complexity -- from user perspectives and practices in everyday/night life to the analysis of the big data trends and patterns these digital developments generate.

Mapping Sleep: The ‘Sleep of Others’?

(i) *Wired Bodies: Inside the Sleep Lab*

For centuries, Kroker (2007) reminds us, the origins of knowledge about sleep came from personal experience and testimony. ‘Knowing sleep’, in other words, was primarily a matter of “I” and “thou” and was refracted through the prism of individual experience’ (p. 5).

The practices and technologies of the sleep lab fundamentally ‘changed all this’, however, Kroker claims. “Relying on the testimony of instruments rather than individuals”, he states, “investigators interested in sleep began to create a new series of sleep phenomena that refashioned sleep as a scientific object” (2007: 5). The users of these measuring and monitoring technologies were predominately scientists seeking to understand sleep as ‘object’, its biological foundations, mechanisms and functional roles. The sleeping person too becomes an object in this relationship, one of study and knowledge generation. The information gathered about one’s subjective sleep is translated through these measuring devices and instruments to contribute to the body of scientific knowledge about sleep as an object of study. Hence the concern, in Kroker’s terms, with

the ‘sleep of others’ which, as the above quotation suggests, is heavily invested in and indebted to tools and technologies to monitor and measure sleep in the sleep laboratory and subsequently the sleep clinic.

A full history of these developments is clearly beyond the scope of the present paper. Key issues nevertheless include the early development and uptake of electroencephalography (EEG) as a way of recording brain activity during sleep; the subsequent bifurcation or cleaving of sleep, courtesy of the EEG and other recording devices, into distinct rapid eye movement (REM) and non-rapid eye movement (NREM) stages; and the retooling of the sleep lab in the service of the sleep clinic. Tracing and tracking the sleep of others, in this way, involves a complex assemblage of tools, technologies and techniques – with a ‘sleep study’ (polysomnography or PSG) often including EEG (brain activity), EOG (eye movements), EMG (muscle activity), ECG (heart rhythm), as well as respiratory measures and peripheral pulse oximetry (saturation of haemoglobin), plus other monitors and measures to watch and listen throughout the night -- that together transform the sleeper’s sleep in the sleep lab or clinic into relevant scientific or clinical data which is then amendable to expert interpretation if not intervention, including diagnosis and treatment. In the context of the sleep clinic, with clinicians as primary users of these measuring and monitoring devices, relationships between the technology and the sleeping body are thoroughly mediated via the clinical gaze. Those who come into contact with the sleep clinic then, come to know and understand their own sleep through a medical or medicalised lens of abnormalities, disorder and diagnoses, whereby their identity becomes one, in part at least, of ‘patient’ (Moreira, 2006).

ii) Watched Bodies: Beyond the Lab/Clinic

It is not simply a case of technologies to monitor and measure sleep in the sleep lab or clinic, however. Clinicians and researchers have also attempted to measure the ‘sleep of others’ in the home, using a range of technologies. These medical surveillance technologies include portable EEG/PSG ambulatory monitoring devices to record such things as pulse oximetry, bio motion sensors, sleep switch devices, remote viewing and ‘wrist actigraphy’ (van de Water et al 2011). The latter, a watch-like device which utilises

accelerometers to measure movement, is built on the proxy idea that sleep can be inferred from lack of activity (Levitt 1966). Over the space of twenty years, wrist actigraphy has shifted from being defined as a useful research tool with little clinical value (Sadeh et al 1995), to being viewed as a tool capable of diagnosing circadian rhythm disorder (Martin and Hakim 2011). Although wrist actigraphy technology is worn by the person whose sleep is being monitored and used in the domestic sphere, the data it gives rise to remains the ‘property’ of those with clinical expertise and hence the knowledge about one’s sleep that is generated is hitherto only made accessible and meaningful to the sleeper once it has been transformed through this expertise.

The rapid growth of home technologies for observing and measuring sleep is attributed to a range of ‘drivers’. Almost as soon as Kleitman and Dement had begun defining ‘how to see’ an EEG, researchers started questioning the validity of the first night of laboratory recordings as individuals acclimatised to the new surroundings. Thus the ‘first night effect’ became both a phenomenon worthy of further study (i.e. Le Bon et al 2001) and a catalyst to more ‘naturalistic’ study methods, which would improve ‘the chances of measuring something approaching the usual sleep pattern’ (Westcombe and O’Dowd 2012:235). As paper and pencil sleep diaries could only get you so far (Reyner and Horne 1995), both agendas required new technologies. ‘Cost’ also became a dominant rhetoric; particularly with respect to ambulatory monitoring of sleep-apnoea. Insurance companies became directly implicated in the movement of sleep-apnoea tests away from the laboratory and into the home as they pushed for more ‘cost effective’ and ‘convenient’ measures (PulmCCM 2013).

Whilst the development of home sleep recordings then, had the potential to conflict with the practices of the sleep lab, the focus remained on ‘the sleep of others’. It also reinforced the idea that polysomnography and the clinic are the ‘gold standard’ to which all developments aspire. When discussing the merits of watch actigraphy, for example, researchers invariably add the caveat that it is “not a replacement for EEG or PSG” (Ancoli-Israel 2000: 1300).

‘M-Apping’ Sleep: The ‘Sleep of Ourselves’?

It is precisely at this juncture however that a range of other possibilities open up for us today in the digital age; possibilities that are no longer simply about monitoring or mapping the sleep of ‘others’ in the foregoing ways, important as that is, but about monitoring or m-apping, in our terms, the sleep of ‘ourselves’. We may, in this regard, identify two closely related yet analytically distinguishable strands of recent activity here to do with the ‘self-tracking sleeper’ and the ‘better slept’ or ‘successful sleeper’ respectively.

(i) *Monitor Your Sleep: The Self-Tracking Sleeper*

A range of new digital consumer products are now available for monitoring and measuring our own sleep today, far beyond the conventional sleep lab or clinic, as Table 1 clearly indicates.

INSERT TABLE 1 - ABOUT HERE

Anyone “willing to take their phone to bed” (Newman 2013), in fact, can now monitor their own sleep. The *Zeo* sleep manager (also known as the ‘personal sleep coach’), for instance, was first introduced in June 2009. Consumer sites, such as Amazon.co.uk, describe the *Zeo* product as a tool to help you analyse sleep and improve it; to be the best you can every day, linking improved sleep quality to improved performance. The device consists of a headband which contains sensors able to record a range of EEG, EOG and EMG signals. The headband broadcasts wirelessly to a receiver station and, since 2011, can broadcast to an iPhone. A neural network model classifies data into wake, light NREM, deep NREM and REM sleep (Kelly et al 2012). The user can upload data to a website to view trends over time and receive personalised sleep advice.

The number of accelerometer based devices has also increased over recent years, including the *Fitbit*, *Lark Pro*, *SleepTracker*, *SleepBot* and most recently *Jawbone UP*. ‘SleepBot’ for iOS, is recognized by the United States National Institutes of Health and the National Academy of Engineering and offers an ‘intuitive smart alarm’ which uses movement data to determine sleep stage and wake you in the morning when in the ‘lightest’ sleep phase. Winner of *Time* Magazine ‘invention of the year’, *SleepTracker* is one of several commercially available devices which utilise wrist-worn accelerometers.

According to the manufacturer, *SleepTracker* uses ‘SmartStart’ technology to monitor sleep stages throughout the night and uses this data to wake you at the optimum time. Data is also uploaded to ‘SleepTracker Analytics’ which shows how well you slept and offers an overall sleep score. *SleepTracker* claims to be within 95% accuracy of professional sleep monitors used within sleep clinics. These commercial devices appear to share some similarities with previous measures developed in the clinic for home use. Early versions of the SleepTracker required you to manually input sleep time (Pogue 2009) – just as early versions of clinical watch-actigraphy required you to press a marker to indicate bedtime and get-up-time. The Lark Pro (which is endorsed by the US National Sleep Foundation) also states that it is built on technology widely used by sleep clinics and appears to echoe clinical practice parameters when it suggests that users should wear the watch on their non-dominant wrist.

The main difference here then to summarise, compared to previous portable devices, is that the user–technology relationships configured through the use of these newer digital sleep-monitoring technologies are primarily between the sleeper and the artefact. The information about sleep feeds directly back to the user, providing the sleeper with new knowledge about their dormant (or not-so-dormant) body/self, knowledge which itself is imbued with a sense of responsibility for them to act to improve their sleep. Hence, sleep, or the sleeping body/self, becomes yet another site for ‘improvement’ or ‘optimisation’ in terms of performance and health, a form of optimisation or enhancement that is enacted well beyond the clinical sphere. Take *Jawbone UP 3.1*, for instance, which is an apt example here. Users can pair Jawbone Up with ‘UpCoffee’ to track relationships between caffeine intake, sleep timing, sleep duration and nocturnal awakenings (<https://jawbone.com/up/coffee>). Jawbone product manager, Jason Donahue, suggests that there is a “*perfect storm of strong need for sleep information* because we’re not getting enough of it, and technological capability to deliver it” (Donahue, quoted in Lynley 2014; para.8 *emphasis added*).

Of course, to say that these devices and apps exist (or that they have been downloaded and won awards) tells us nothing about whether or not they are actually being used and if so by whom. One instance of uptake has been very visual and visible however. In 2007, *Wired* writers Gary Wolf and Kevin Kelly became interested in what they described as a

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“new culture of personal data” (Wolf 2009; para 4) and the ways it linked to new forms of self-knowledge. Developments in data collection methods had started to make self-tracking and the sharing of data on Web 2.0 platforms easier. Wolf and Kelly decided to monitor this further, under the rubric of ‘The Quantified Self’ (QS). This grew into a QS *community*. Whilst the idea of the Quantified Self appears, at first glance, rather individualistic if not narcissistic or self-focused (Nafus and Sherman 2013), the QS community hold regular meetings at international venues, and have constructed mechanisms for sharing data, experiences and case studies (see Boesel 2013 for example). One discussion thread in the Quantified Self forum (<https://forum.quantifiedself.com/>) for example, begins with an ‘established user’ posting a graph of their sleep data and a link to the R (a software programme language) code they developed to graph the data. The resulting discussion focuses both on the sleep data itself and the merits of using R to analyse these digitized sleep records. A separate thread begins with a user posting links to code for analysing *Zeo* data. The user then responds to comments by suggesting that others could analyse her ‘public’ data. The Quantified Self twitter feed contains similar examples. On September 29th 2014, for example, Quantified Self (@quantifiedself) tweeted “Christel de Maeyer found that alcohol blocks her REM sleep, among other insights from 3 years of sleep tracking”.

What we maybe witnessing here then, is the dawn or evolution of new digital ways in which we are coming to know, understand and present aspects of ourselves online and relate to others in the form of collectives identifying and mobilising around such *self-tracked* sleep matters.

(ii) *Manage Your Sleep: Self-Care and the ‘Successful’ Sleeper*

New digital technologies and techniques for mapping sleep are not only linked to wider interests in body tracking and self-quantification *per se*. They are also being developed in the name of so-called m-Health; mobile digital developments within the health arena, that is to say, whereby patients, proto-patients and wider publics may now track their bodies, share their data, participate in online discussion and support groups, and use the information they gather to improve or optimise their health. Complex user-technology relationships again arise here therefore, in which the sleep of ourselves and the sleep of

others becomes more blurry. On the one hand, one's own sleep is mapped and monitored in the home or bedroom, with the knowledge delivered straight into the hands of the user; the responsibility to act on this data being theirs and theirs alone. On the other hand, like older sleep monitoring tools, the user is often designated as 'patient', with the information fed back or mediated through a clinical or medical lens.

The NHS health apps library (<http://apps.nhs.uk/>), for example, first launched in March 2013, includes various NHS approved health and lifestyle apps that can now be downloaded straight to your smart phone or tablet (see Table 2).

INSERT TABLE 2 – ABOUT HERE

The website reassures its visitors that “these apps have been reviewed by clinicians to ensure that they are safe and trusted”. In relation to sleep, the apps available (at the time of writing) focus predominantly on insomnia management via the delivery of Cognitive Behavioural Therapy for Insomnia (CBTi). There are two ‘e-therapy’ apps available to purchase, *Sleepio* – “a clinically-proven sleep improvement programme” and *Sleepstation* – “an online version of the therapy which [NHS] sleep doctors use in clinic to treat patients with insomnia”. In addition, there is *Sleep Diary*, a free to download app to help people with insomnia log their sleeping and activity levels to help them identify patterns that may be affecting their sleep.

Sleepio is a six-week course of personalised CBTi developed by a leading British sleep expert. The programme aims to help its users get their “sleep schedule, thoughts, lifestyle and bedroom into shape” with the goal of helping them to “sleep well without pills or potions.” (<http://www.sleepio.com/>). It involves users filling in an online questionnaire about their sleep and keeping a sleep diary, which is reviewed by a clinician during a weekly meeting where they are taught new CBTi techniques to take home and put into practice. The app also includes other tools such as the ‘Thought Checker’ and ‘Daily schedule’. The *Sleepio* app can be used in conjunction with the previously mentioned Jawbone UP and Fitbit; as well as Bodymedia; the data from which can be stored online in an individual's Sleepio account (<http://www.sleepio.com/>)

By downloading the app the user becomes a member of an online community and support group and can also get around-the-clock advice and assistance from “The Prof”; a virtual sleep expert who is on hand to guide them through the sleep programme, day or night. By downloading the app the user becomes a member of an online community and support group and can also get around-the-clock advice and assistance from “The Prof”; a virtual sleep expert who is on hand to guide them through the sleep programme, day or night. Whilst only fully signed up members can view the online community, Fisher (2014) for example, based on her own experience of using Sleepio, writes that... “I’d say the active members [of the forums] were enthusiastic, supportive and knowledgeable.”

Sleepstation too is a six-week sleep course which claims to “deliver the same therapy used to treat patients with insomnia in the NHS clinic” (<https://sleepstation.org.uk>). The app has been built in conjunction with another UK sleep doctor, who, we are informed, “has many years experience of treating several thousand patients with sleep disorders” (<https://sleepstation.org.uk>). Furthermore, we are told, this e-therapy app is being *prescribed* by GPs in selected areas of the UK. It too involves assessment and diagnosis of the sleep problem and if the patient is deemed suitable for the programme, they will be asked to complete a daily sleep diary and given a personalised sleep therapy programme to improve their sleep based upon the information they provide. As its developer recently noted, “the key thing about the Sleepstation is that it’s *personalised* for each user. If you put a particular pattern into your diary it will change the programme to make it fit your sleep pattern” (Anderson, quoted in Hattersley 2014; para. 20 our emphasis).

Alongside these clinician-endorsed apps for insomnia, monitoring and self-tracking sleep also features in several other NHS approved m-Health apps. For instance, the ‘Lifepsychol’ app aimed at people living with chronic health conditions, is designed to track a number of key issues, from mood to sleep to mobility. Its goal is to enable its users to monitor and manage any changes that they feel are impacting on their quality of life and provide a structure and focus for medical consultations. Another example is Total Baby which combines 14 separate timing, tracking, and logging functions to record various aspects of childcare such as vaccination schedules, weaning and sleep patterns. The app claims to “help parents and caregivers easily and conveniently track up to 6 children” (<http://apps.nhs.uk/app/total-baby/>). The goals of these apps then, although

clearly still within the health arena, go beyond treating sleep problems to tracking sleep patterns in our daily lives in order to understand the impact our sleep has on how we feel and function, and to use this information to make changes to our behaviours in order to become a 'better' or 'successful sleeper' and improve quality of life outside the clinic.

Built on the technologies and ambitions of the sleep clinic therefore, to summarise, these technologies have enabled, if not encouraged, the m-mapping of our *own* sleep or, to adapt Kroker, the 'sleep of ourselves'. Sociotechnical networks have formed and the interests of various parties have aligned over recent years to create a space for such m-apps to emerge as another face or facet perhaps of more 'personalised' medicine and health care in the twenty-first century. These technologies, furthermore, continue to evolve: 'the next wave of sleep gadgets expected to hit the market within six months', as Gibbs (2014: para. 17) notes, "is likely to include more sophisticated sleep-trackers that can monitor brain wave activity" and eventually incorporate other biometric indicators currently routinely collected in the clinic as part of a 'sleep study'/PSG.

Discussion

Where then does this leave us in terms of the foregoing digital trends and transformations, and what further theoretical issues does it raise? Perhaps most crucially and critically of all, Kroker's (2007) thesis on the 'sleep of others' may well, to repeat, need supplementing or updating in this light, in favour of something akin to the 'sleep of ourselves' in the digital age. A case of the 'm-mapping' of sleep far away from the institutional confines of the conventional sleep laboratory or clinic, that is to say, or *ibodies* in the bedroom, to repeat, as we become in effect something akin to our very own sleep clinics or labs (2.0) in the digital age.

This in turn raises three further interrelated sociological and political issues concerning selfhood, (bio)sociality and governance respectively in these digital times of ours.

Returning to the notion of our absent or dormant bodies/selves whilst asleep, it may be considered that digital apps of this kind do, to some extent at least, enable us to gaze deeper into the inner workings of our bodies, to visualize and make known aspects of

our bodies/selves – such as sleep – that were hitherto inaccessible to us, or otherwise obscured or hidden from view. Thus, their use may then indeed transform our understandings, not simply of our sleep, but of ourselves more generally, particularly, if new standards and ideals are set in train to become a ‘better’ or more ‘successful sleeper’.

On the one hand of course, recalling Leder (1990), sleep is a *recessive* mode of embodiment, which devices of this kind can help us to capture or recover whilst the ‘sleeper sleeps’ so to speak: a sort of ‘digital archive’ of our dormant selves whilst we sleep. On the other hand, the very notion that we are ‘quantified selves’, asleep or awake, cannot be pushed too far given knowledge of the self is no mere by-product of these sorts of digital devices and data systems, however important they may become. Even recourse to the more *qualitative* or *narrative* dimensions of all this talk of the ‘*quantified* self’, indeed, still glosses or misses the fact that try as we might, we are never fully knowable or transparent to ourselves. There is always something in other words, as Cohen puts it, “in excess of what can be known and communicated” about ourselves; an obscurity if not obstinacy or residue of ‘darkness’ amidst the ‘light’ in a “scientific and media culture where nothing unknown can remain thus” (2014: xv-xvi).

A similarly complex picture arises with regard to claims of the ‘digital cyborg’ kind (Lupton 2013). Whilst there is, to be sure, considerable mileage and merit in such claims and analyses, what tends to get lost or underplayed here is the degree to which, as Rose (2007: 21) remarks in another context with Haraway (1990) in mind, technological developments of the biomedical kind today render us ‘all the more biological’. ‘All the more biological’, that is to say, for our purposes in this paper, in the sense that some if not many of these digital devices and developments are concerned with monitoring and m-mapping, if not transforming or optimising, ‘life itself’, including the ‘vital normativities’ (Rose 2007) of the body, from our blood glucose levels to our sleep patterns and practices, thereby extending far beyond the mere tracking of activity levels or other behavioural or lifestyle factors. To the extent indeed that this is so, or becomes so in future, and to the extent that this provides the basis for new digital modes of sociality and subjectivity if not new ‘epistemological communities’ or ‘communities of practice’ (Akrich 2010), via web 2.0 platforms, then we may also perhaps profitably refer here to the beginnings of new *digital* or *online* forms of ‘biosociality’ in the twenty-first century (Hagen, 2013). Forms of sociality and selfhood, in other words, based on vital digitally mediated and monitored *biometric* data, which on the one hand lend further support to

Rabinow's (1996[1992], 2008; Gibbon and Novas 2008) previous biosocial musings and predictions, and on the other hand, borrowing from the likes of Castells (2000, 2009), may equally be regarded as the latest instance not so much of 'virtual reality' but of '*real virtuality*'².

Here we arrive at third closely related set of issues within which each of these foregoing matters are embodied and embedded, namely the relationship or intersections between what, in Foucauldian terms, we might refer to as these new *digital* 'technologies of self' (Foucault 1988), including the aforementioned digital 'biosocialities', and the wider issues of governmentality, submission and surveillance they raise both now and in future.

To the extent, for example, that these digital technologies mesh or chime with existing processes of individualization and responsabilization, and neoliberal values of enterprise and enhancement, then they constitute perhaps the latest chapter or instance of a by now familiar story line concerning the problems and prospects of self-governance, self-optimisation and the politics of life itself in the twenty-first century; this time albeit in a digital biosocial (Hagen 2013), if not bioliberal (Fuller 2006), guise. There is, to be sure, a certain seductive power to tracking, monitoring and managing ourselves in the interests not simply of self-knowledge or even self-governance, but self-improvement or optimisation. Yet this in turn, of course, fits into wider patterns of voluntary and involuntary submission to creeping forms of monitoring and surveillance that seems to characterise our lives today within and beyond the medical and health domains. Forms of more or less continuous control (Deleuze 1992; Massumi 1995), submission and (post-panoptical) surveillance (Foucault 1977, Bauman 2000), that is to say, that we willingly or unwillingly, wittingly or unwittingly, submit or succumb to in our everyday/night lives, particularly in the digital era of so-called 'big data'.

Further critical questions of resistance also arise here, however. Whilst the self, for example, as Nafus and Sherman (2013: para 6) suggest, "...is the site of internalization of dominant big data visions that do control people in Foucauldian, biopolitical ways... it is also, at the same time, a means of [soft] resistance". Members of the Quantified Self (QS) movement, for instance, are said to be re-asserting ownership of their bodies by taking control of data (already) produced. Ambivalence, apathy or just plain boredom too may constitute alternative potential sites or sources of rejection or resistance. Early

reports, for example, are already suggesting that some users of such tracking devices get bored with them after a while (Gibbs 2014). Why anyway, if you are already a 'good' or 'successful' sleeper would you bother to track your sleep, particularly if doing so, as Gibbs (2014) suggests, made you more, rather than less, prone to worry about your sleep in a self-defeating fashion? It is indeed somewhat ironic perhaps that the very information and communication technologies which elsewhere are criticised or demonised by experts as the 'enemy' of sleep -- no computers or texting in the bedroom for instance -- are in this case transformed or touted as their 'aid' or 'ally'. Hence it is only perhaps in situations where sleep quantity or quality is perceived to be an enduring problem that such apps might appeal to those *without* an interest in self-tracking *per se*, as in those outside of the QS movement.

It is precisely at this juncture however that we encounter the other side of these digital developments and debates in the guise of the potential exclusions as well as inclusions they entail: issues regarding the accessibility, affordability and legibility of these new digital technologies, that is to say, health related or otherwise. Undoubtedly some groups will be more digitally literate and technologically 'savvy' than others, have access to tablets, smartphones and laptops, afford to be able to run them, and live in a geographical area with reliable access to the Internet.

A return to questions of so-called 'e-scaped' medicine (Nettleton 2004) is also instructive at this point. Whilst not all these foregoing digital developments are health or medically related of course, they do nevertheless lend further support to the notion of e-scaped medicine as sleep expertise both escapes and e-scapes the institutional confines of the conventional sleep laboratory or clinic in favour of something perhaps, as already noted, approaching or approximating sleep lab or clinic 2.0 in the digital age, as we become, in effect, our very own sleep labs or clinics. The potential, moreover, for users to further appropriate and reconfigure the meanings and uses of technologies in unanticipated ways should also of course not be underestimated here: a case perhaps of these technologies further 'escaping' *themselves*, so to speak, through their wider diffusion, e-scaping or 'flow' within web 2.0 and associated social media platforms.

The sleep lab or clinic may very well, in this respect, recalling Kroll-Smith's (2003) previous musings on these matters, resemble something of a (living dead) 'zombie

institution' (cf. Bauman 2000, Beck and Beck-Gernsheim 2002), if not now then in future. To date however it is still very much alive, with digital sleep apps at most *supplementing* rather than replacing the sleep clinic any time soon. For now indeed it could reasonably be suggested that it is only really 'insomnia' which is currently 'e-scaping' its traditional institutional/clinical confines – if indeed it was ever institutionalised in this fashion in the first place (c.f. Kroker 2007). To the extent moreover that future data from these digital apps and devices increasingly find their way *back to* the sleep clinic, through uploading and sharing practices, then this may constitute a further blurring of the slope between the 'sleep of others' and the 'sleep of ourselves'; thereby extending the *real virtualities* of the clinical gaze still further in the process too.

Tracing and tracking the roles of sleep measuring devices and monitoring technologies then, to summarise, demonstrates the changing roles of these non-human actors in how we come to see and know our sleeping selves. The advent of new digital apps, in this regard, adds potentially significant new dimensions and dynamics to sleep matters today in the digital age; a case of the 'm-apping' if not 'optimisation' of the sleep of 'ourselves', in short, and the associated questions of selfhood, sociality and governance this raises, both now and in the near future. At the very least, we suggest, digital developments of this kind constitute another important site and source of the problematisation and politicisation, if not 'deprivatisation', of sleep matters today (Williams 2011).

Conclusions

Firm conclusions at this particular juncture may well be unwise, given the embryonic nature of these developments so far. A number of conclusions may nevertheless be drawn here in closing.

First, and perhaps most conclusively of all now given a recent upsurge in interest, this paper demonstrates once again that sleep is quite literally a vital sociological matter, in health and beyond. Our argument in this respect, as a further contribution to this growing corpus of writings on sleep in the social sciences and humanities today (Williams

and Wolf-Meyer 2013), is that recent developments in the digital domain open up significant new problems and prospects for the monitoring or ‘m-apping’ of the sleep of ourselves, far beyond the conventional sleep laboratory or clinic. A case in other words, of the ‘sleep of ourselves’ as much as the ‘sleep of others’ (Kroker, 2007), albeit with due acknowledgement that any such boundaries are now becoming increasingly blurred in the digital age through the sharing of such data with experts as well as family and friends and the advent of big data.

At stake here too we have suggested, are a further series of critical sociological and political issues concerning the recovery or incorporation of our absent, dormant or sleeping bodies/selves, the potential for new digital forms of biosociality and communities of practice to emerge, and the wider questions of control, surveillance and resistance this raises in the age of big data: part and parcel of the growing problematisation and politicisation of sleep matters today, in short.

As for future research agendas in this newly emerging domain, the sociology of health, medicine and the body clearly has much to contribute, particularly as we have demonstrated, through its intersections with science and technology studies. Key questions here, for example, returning to our previous theoretical themes of selfhood, sociality and governance/surveillance, arise in relation to what the digitization of sleep means to people in the contexts of their daily lives. Future research in this regard could profitably take a more empirical focus, examining the ways in which new digital sleep apps are produced and promoted, taken up, valued, trusted and evaluated by their users in everyday/night life and the gains and losses entailed therein -- paying particular attention to the how user-technology relationships are configured and reconfigured in the process and exploring how this links to wider patterns and practices of e-health care, self-governance and optimisation in the digital age. Also of interest is how mapping our own sleep might impact not only on the ways in which sleep comes to be positioned, problematized or prioritised in our daily lives, but also how it in turn may change the ways in which we come to know and understand our sleeping selves, and the forms of digital biosociality that are created and recreated as we manage and share this data with others online.

Sociologists of health and illness then, to conclude, have much to contribute here, both to sleep matters in general as another vital dimension of health and illness, and to these digital developments and debates regarding sleep matters in particular. Our preliminary ‘m-mapping’ of sleep in this regard, may profitably be read as both a critical case study or test case of these wider digital trends and transformations to date in its own right, and a wider digital rallying or wake-up call, in keeping with the likes of Lupton (2012; 2013) and Pope (2013), for more sociological research of this kind in future, sleep related or otherwise, in health and beyond.

Notes

1. Although beyond the scope of the present paper, there are also of course important global North/South dimensions to these issues too – not least of all because the ‘doing’ of sleep is culturally variable. Of particular note for future research, m-Health technologies are becoming situated as solutions to global health problems, such as Non Communicable Diseases and Universal Health Coverage (Mehl and Labrique 2014). Whether, and how, sleep apps become framed within this agenda are important questions for future consideration.
2. For more detailed recent expositions of the relevance of Castells for the sociology of health, see Williams (2012, 2013) and Pope (2013).

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Table 1: Summary results from Amazon.uk search (using ‘Sleep Track’)*

Device	url
Fitbit Flex wireless Activity Tracker & Sleep Wristband	http://www.fitbit.com/uk
Withings – Activity, Sleep, Heart Rate and SPO2 Tracker for iOS and Android	http://www.withings.com/uk/
Zeo Sleep Manager (personal sleep coach)	No longer in business
UP by Jawbone	https://jawbone.com/up
Polar Loop Activity and Sleep Tracker	http://www.polarloop.com/uk-en/
Smart Wristband fitness and sleep tracker	Not found – possibly a seller of all types
Douself Vidonn X5 Bluetooth 4.0 IP67 Smart Wristband Sports& Sleep Tracking Health Fitness for iPhone	www.viddon.com/en
Soleus Go Fitness Band activity and sleep tracker	http://www.soleusgo.com/
iHealth AM3 Wireless Activity and Sleep Tracker	http://www.ihealthlabs.com/fitness-devices/wireless-activity-and-sleep-tracker/
Fitbug Orb Bluetooth Movement and Sleep	https://www.fitbug.com/uk/orb?lng=en_UK
Misfit Shine Personal Physical Activity Monitor	http://www.misfitwearables.com/
XNFit the Clip Activity Trainer	http://www.xnfit.co.uk/
Kool™ Pedometer and Smart Wristband	Unknown (possible Amazon seller)
Fiturbo US Activity Tracker	http://fiturbo.com/
LUMO Back Improve your posture for iPhone (records sleep position)	https://www.lumobodytech.com/

*the search also returned self-help tapes, music (‘the lion sleeps tonight’) etc. We have not included multiple items from a single company – but these can be viewed by following the url. We recognise that there may be other devices in existence which have been developed since this search or which did not fall within the search terms.

Table 2: Results from search of NHS Health apps library (using sleep as a term)

App	Description (direct quote)
Sleepstation	Sleepstation is an online version of the therapy which our sleep doctors use in clinic to treat patients with insomnia
Sleep Diary	Use this app to log sleeping & activity to help identify patterns that may be affecting your sleep
Sleepio	Sleepio is a clinically-proven sleep improvement programme – improve your sleep with CBT [cognitive behaviour therapy] not pills
FibroMapp	Giving you control. Helping you cope
Kvetch	Sharing is caring. Misery loves company
Happy Healthy	Reveal what impact your lifestyle, exercise, nutrition and sleep have on your mental wellbeing and be coached to make healthier choices
Total Baby	Total Baby is one of the most popular Baby logging and tracking application (sic) on the App Store. It will help you log and time all aspects of your child's care through a smart and sleep interface that makes tracking easy and fun.
Lifepsychol	Lifepsychol is a new app that helps people with long term conditions bring meaning to their quality of life and helps them to monitor and track how their quality of life is changing