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Sleep: Studies in Sociology and Machine Learning

By

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Doctor of Philosophy

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An abstract of a dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
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Abstract

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By

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Although sleep constitutes a third of daily life, sleep is understudied in sociology. One interpretation for this neglect is that sleep represents a withdrawal from the social world and must therefore be uninformative of it. However, by neglecting sleep, sociologists miss an opportunity to study a socially patterned determinant of health, and to use sleep as an index of cultural values. In short, by neglecting sleep, sociologists miss an opportunity to understand better things they want to understand well.

This dissertation gives four illustrations of the use of sleep to sociology. The following chapters show how sleep is patterned by social relationships, socio-demographics, social health, and culture. The first study examines 26,943 news articles from major news publications to show the evolution of sleep discourse in the US media. Specifically, it shows how sleep is increasingly construed as essential for health. Furthermore, it shows that attitudes towards sleep are put in tension with attitudes towards work and how sleep is a health outcome that has been resistant to medicalization. The next three chapters focus on embodiment by showing how sleep is patterned by social support, social strain, socio-demographics, social integration, and social well-being. These chapters use a subset of a nationally representative sample, the MacArthur Study of Successful Midlife Development (MIDUS).

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Introduction

Sleep is intensely private and individual, a retreat from the social, public sphere. The father of American sleep medicine William Dement defined sleep to be a state in which the individual mind is a closed system which does not interact with anything outside of it. His definition of sleep required that "sleep [erect] a perceptual wall between the conscious mind and the outside world." (Dement and Vaughan 2000) The outside world, and everything in it, is closed to the sleeping mind.

How, then, is sleep an object of sociological inquiry? That is, how can sleep – when sleep is defined to be the exclusion of the outside world – remain sensitive to its social arrangements?

Sleep is sociological in at least two senses: embodiment and embeddedness. (Meadows 2005; Williams 2007) The first is embodiment. While it is true that the sleeping individual is separated from the outside world, she brings with her to bed the set of embodied experiences from her social environment. The fight with the spouse, the word of encouragement from a colleague, the stress of living in a deprived neighborhood, encounters of racism – these experiences "get under the skin" and affect sleep – its quality, duration, regularity, efficiency, and capacity for restoration. Put simply, sleep is affected by the social contexts in which individuals are nested.

The way social contexts are patterned and ordered is reflected in the way health outcomes are patterned and ordered. This is a fundamental premise in a sociology of health and holds equally with sleep as it does stress (Pearlin 1989) or cardiovascular disease (Kaplan and Keil 1993). If neighborhood crime and psychological distress are patterned by neighborhood quality, then so too are sleep quality and duration. (DeSantis et al. 2013; Hale, Hill and Burdette 2010; Hill, Burdette and Hale 2009) If mental health is patterned by social participation, so too are

night time awakenings and sleep fragmentation. (Chen, Lauderdale and Waite 2016; Kawachi and Berkman 2001) If caregiving responsibilities are patterned by gender, then so too are expectations for who sacrifices their sleep to perform that caregiving. (Arber et al. 2007; Venn et al. 2008) As Matthew Wolf-Meyer puts it in The Slumbering Masses, "Sleep is always social, affecting others and affected by others. Society cannot exist without sleep, or sleeping without social expectations." (Wolf-Meyer 2012)

These social expectations are a significant feature of the second way in which sleep is sociological: embeddedness. Individuals are embedded in cultures that define and redefine normal or desirable sleep. For instance, cultural norms and ideals inform individuals of what desirable sleep looks like (8 hours in one shot), what desirable sleep for a certain type of person is, and to whom one goes for sleep problems. The medical resident and captain of industry alike are not only expected to, but perhaps even boast of operating on little sleep. The sleepless flock to doctors and pharmaceuticals en masse if they consistently fail to attain the cultural ideal of uninterrupted slumber.

How did these norms and expectations arise? Many of our modern social arrangements and expectations derive from the rapid reorganization of societies in response to the Industrial Revolution. From urban living to extended work days and countless other aspects, the Industrial Revolution shaped modern living.

Modern expectations surrounding sleep are no exception. Modern day (Western) sleep expectations and norms were a natural response to rapid social change. Whereas pre-industrial societies slept and woke more closely in harmony with nature's rhythms – shorter in the summer, longer in the winter, waking with sunrises and sleeping after sunsets - industrialized societies learned to "rise consistently to the sound of a factory bell and organize their downtime

accordingly." (Reiss 2017) Whereas in nights past, normal sleep was bi-phasic – split into two segments with a brief late-night interregnum of relaxation, reading, or love-making – modern sleep is monophasic (i.e. in one 8 hour block). (Ekirch 2006)

In another sense, however, modern sleep norms are the exception. For if modern societies are historically atypical, so too are modern expectations of sleep. As Ben Reiss observes,

> What's strangest is that although all of these features [e.g. 8 hours of private sleep in one go] are taken as natural or normal ways to sleep, not one of them seems to have been in force at any time anywhere before around 1800 in Europe and North America… virtually nothing about our standard model of sleep existed as we know it two centuries ago. (Reiss 2017)

Modern ways and norms of sleeping have been, in other words, socially constructed. Assessment of modern sleep norms, therefore, may yield insights into changes in American culture. As Simon Williams (2005) puts it, "the sleepicisation of society… aided and abetted by the media, has the power or potential to permeate all spheres and spaces of society, and to translate all manner of social and medical 'problems' into sleep-related matters." That is, sleep is an aspect of daily life increasingly suffused with social and medical significance. The study of embeddedness is the study of that interplay between medicine, society, and sleep.

In the final analysis, I argue that sleep is a prism through which social concerns can be refracted, to great intellectual profit. Furthermore, I argue that the terms embodiment and embeddedness to describe social sleep – which have been used infrequently and seemingly interchangeably in the literature – are, as demonstrated earlier, analytically distinct aspects of a sociology of sleep.

The following chapters give examples of sleep as embodied and embedded. They show how healthy sleep is socially patterned and subject to social forces, and how sleep can be viewed

as an index of cultural values, and thus cultural change over time. The chapters follow the citation and writing styles within their respective subfields.

We begin with embeddedness. Chapter 2 begins with an examination of the historical and cultural forces that have shaped modern American sleep. Because the literature has used historical texts to track historical sleep norms, I use modern texts to track modern sleep norms. I present analyses of news articles over the past 35 years in order to give a sense of how media discourses around our sleep norms have changed. Entitled *The Social Construction of Sleep in the U.S. Print Media: 1983-2017*, this chapter presents analyses of 26,943 news articles from major U.S. print publications from 1983-2017. A machine learning algorithm – structural topic modeling – is used to determine dominant topics in the data; these data are then analyzed over time. Themes around health, daily living, science, and medicine are explored. This computational analysis is complemented by a close reading of representative articles within each topic.

Having understood the cultural and recent historical context of U.S. sleep, we turn to chapters 3-5, which focus on the other aspect of sociological sleep: embodiment. Chapter 3 is a solo-authored paper published in 2017 in the National Sleep Foundation's journal, *Sleep Health*. Entitled *Social support, social strain, sleep quality, and actigraphic sleep characteristics: evidence from a national survey of US adults*, it investigates the effect of social relationships – social support and social strain – on various sleep characteristics. Data are drawn from a subsample of the MacArthur study of successful Midlife Development in the United States (MIDUS), a national probability sample of U.S. adults. I find that the negative aspects of social relationships (social strain) exert more powerful effects on objectively measured sleep

characteristics than do the positive aspects (social support). Perceptions of social support and strain variously associate with sleep parameters such as sleep efficiency, quality, and variability.

The next chapter considers various sleep parameters in concert, for each sleep parameter is, in theory, a different facet of the same sleep experience. How can we incorporate a more holistic understanding of sleep into our analyses? Chapter 4 operationalizes sleep health, a recently defined concept, using data from MIDUS Wave II, the MIDUS Milwaukee sub-sample, and the MIDUS biomarker supplement. (Buysse 2014) Sleep health is operationalized by k-means clustering. These clusters are associated with metabolic syndrome, a constellation of symptoms of cardio-metabolic health including high blood pressure, blood sugar, central obesity, triglycerides, and unhealthy levels of cholesterol. (Grundy et al. 2004) The social distribution of these sleep clusters is described. Analyses suggest 1) that there are three types of sleepers: good, poor, and intermediate; 2) that these types are socially patterned; and 3) that the clusters have clinical utility in association with metabolic syndrome. Specifically, having good sleep – the characteristics of which are high total sleep time, efficiency, reported quality, and reported alertness the following morning – shows large and statistically significant reduction in odds of having metabolic syndrome. Entitled, *Three classes of sleepers, their social distributions, and associations with metabolic syndrome in an actigraphy and daily diary study of healthy, non-institutionalized US adults*, the final manuscript will include co-authors Meredith Wallace and Daniel Buysse whose suggestions will shape the ultimate publication.

Chapter 5 builds on the sleep health operationalized in chapter 4 to address social health and its effect on sleep. This chapter is titled *Social health and sleep health: Analyses of social integration, social well-being, and actigraphic and diary-reported sleep in a national survey of U.S. adults*. Social health is argued to be a combination of social integration and social well-

being. I find that this social health index is positively associated with odds of belonging to the good sleep cluster (operationalized in chapter 4). I conclude that social health is important for sleep health. Yet social integration and social well-being are distinct, if related, aspects of social health. What is the relationship between these indices of social health and sleep? I thus present a theoretical model of these relationships. It is hypothesized that social integration is a cause of social well-being. Social well-being, in turn, is hypothesized to affect odds of attaining good sleep. That is, social well-being is a plausible mediator between social integration and sleep. Counterfactual mediation analyses suggest that social well-being does mediate the relationship between social integration and sleep. The significance of this study is that the theoretical model may apply to other health outcomes such as depression and mortality and help explain one mechanism by which a classic sociological concept – social integration – can confer protective benefits to those who embody them.

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Chapter 2.

Sleep as embedded

Title: The Social Construction of Sleep in the U.S. Print Media: 1983-2017

Introduction

Despite the apparent significance of sleep to health, productivity, and daily living, sociology has mostly neglected this topic. (Meadows 2005) To paraphrase one sociologist, sleep is the unexplored third of the sociological landscape. (Williams 2005) This inattention is puzzling because recent scholarship in history, literature, and anthropology has profitably used sleep to investigate social, political, and literary concerns. This interdisciplinary literature has examined several facets of the social significance of sleep, from the regularization of sleep schedules after the Industrial Revolution, the move to monophasic sleep, and its medicalization and commercialization (by pharmaceutical companies). (Ekirch 2006, Reiss 2017, Wolf-Meyer 2012) This chapter contributes to the literature by examining how sleep discourse has evolved over 35 years in the U.S. print media in order to track the evolution of sleep norms over time.

The evolution of sleep norms over time is essential to the study of sleep as socially constructed. For if it is true that societies undergo change over time, so too should sleep norms. Drawing from historical books on manners, Norbert Elias in *The Civilizing Process* noted that as societies "civilized", the practice of sleep began to shift from the social, communal sphere to a private one. Drawing from ethnographic research and historical archives, Matthew J. Wolf-Meyer investigated the Protestant origins of American sleep and the rise of both sleep medicine and pharmaceutical interventions for sleep problems. Drawing from historical and literary texts, Ben Reiss and A. Roger Ekirch have observed that the norm of an uninterrupted 8-hour block of sleep a night (monophasic sleep) is a rather recent invention, prompted both by the invention of electric lighting and a negotiation between factory workers and management in the wake of the Industrial Revolution and its punishing work schedules. Thus arose the idealized "Eight hours labour. Eight hours recreation. Eight hours rest" formulation by the industrialist Robert Owen.

If historical texts have been the dominant source of information about historical sleep norms, modern texts should form the basis of analysis for modern sleep norms. One source of such data are the print media. Thus, this chapter focuses on news articles in the U.S. print media from 1983 to 2017 to better understand sleep discourse and norms as expressed in text.

The chapter begins with a brief history of the social study of sleep. It then summarizes the distinctively Protestant character of America's attitude towards sleep. Modern scholarship in the cultural study of sleep is reviewed. A description of the current investigation is offered, and results are shown and interpreted. The data evince several trends, notably regarding a recently declining relationship between sleep and medication, and increasing relationships between sleep and health, daily living, strategies for better sleep, and sleep disorders. Other significant themes were discovered but are left for a later scholarly treatment; such themes include the evolving relationship between sleep and technology and discussions around safe infant sleep conditions. Although these are essential topics, in this chapter I focus on aspects touching on daily living, health, and medicine.

In all, these data suggest that sleep is more than a neuro-biological sequence of events; it is a subject of public debate and discussion: are naps "un-American" as one article prompts? Another poses the conundrum that while a majority of polled readers said they don't get enough sleep, nearly half also claimed that work-related matters keep them up at night. Is eight hours really the optimal sleep duration? What health outcomes are associated with poor sleep? The rising prevalence of these topics are investigated. To put these discussions into context, let us first turn back the calendar and examine the history of the social study of sleep.

A Brief History of the Social Study of Sleep

Pre-Industrial Revolution

The history of sleep may be divided into two time periods: pre- and post-Industrial Revolution. Pre-industrial societies tended to experience nightly sleep in two distinct segments. Sleep featured one major awakening as opposed to our customary one segment with (ideally) no night-time awakenings. The first segment was approximately four hours and was called "first sleep" – in French, "*premier sommeil* or *premier somme*, in Italian, *primo sonno* or *primo sono*, and in Latin, *primo somno* or *concubia nocte*." (Ekirch 2006)

First sleep was followed by a brief awakening lasting an hour or more. Sometimes called "watch" or "watching," this intermission allowed people to read, write, meditate, nurse infants, or make love. This night awakening was the norm: "So routine was this nightly interruption that it provoked little comment at the time… as a vital commonplace of an earlier age, country-folk yet knew about it in the early twentieth century." (Ekirch 2006:300-01) Following this brief intermission, "second sleep" would follow until morning awakening. This pre-industrial pattern of sleep appears to follow natural bodily rhythms. In the 1990's Thomas Wehr at the National Institutes of Mental Health took seven individuals and restricted their photoperiod (light exposure) such that they were immersed in darkness for 14 hours per night for four weeks. When light was experimentally restricted in this way for a set of test subjects, this biphasic pattern – sleep, wake, sleep – has been replicated in modern settings. (Wehr 1992)

Pre-industrial sleep tended to follow nature's rhythms in another sense: it changed in duration with the seasons. (Reiss 2017) One English physician observed that "In winter, longer sleepe is requisite than in Sommer." (Reiss 2017:41) Cold winters with its shorter days and often shorter food supply prompted rest instead of action. A British report of Russian peasants observed that in the lean winter months, "everyone would wake up once a day to drink some

water and eat a piece of hard bread… Afterward, everyone went to sleep again." (Reiss 2017:43) Similar circumstances prompted Canadian Inuits to lay mostly dormant through the frigid winter months: "Changing sleep patterns were part of a cyclically occurring ebb and flow of supply and demand: sleep occurred in inverse proportion to supplies of food and heat." (Reiss 2017:44)

A third feature of pre-industrial sleep is that it was primarily social. Even in the beginnings of the Industrial Revolution, the bedroom as we now know it – a private sanctuary for sleep, relaxation, intimate conversations and/or sex – is a modern invention. (Reiss 2017) Bedrooms were for entertaining guests and for shared sleeping quarters. Elias's *The Civilizing Process* devotes several pages to bed manners, for example, allowing the partner of higher social status to pick on which side he/she would prefer to sleep. It was not uncommon for grown men to sleep by children or grown men to sleep in the same bed as other men. This was equally true of parent-child co-sleeping, or at least parent and child sleeping in the same room. Sleep was a social event, not a private one. Thus, in summary, pre-industrial sleep was characterized by biphasic patterns, expansion during winter, contraction during summer, and was predominantly social[1].

Post-Industrial Revolution

The Industrial Revolution marked a "taming" of sleep. Sleep no longer followed nature – it followed work schedules.

Work schedules were reorganized when work was reorganized – during the Industrial Revolution. In the process, the concept of time began to be understood differently. (Reiss 2017) Instead of the sun and stars, it was the hands on a clock or the clang of a factory bell that prompted human action and repose. When work schedules became untenable, it was the workers

[1] There are, of course, other ways in which pre-industrial sleep differed: the bedding, chamber pots, a lack of indoor climate control, and many others. These are not social or structural and do not concern us here.

who demanded standardization of work and sleep schedules: “What they pictured was a time that was reserved exclusively for sleep… The eight-hour ideal as we know it is largely a result of this push and pull between management and labor.” (Reiss 2017:9)

If pre-industrial sleep was social, post-industrial sleep marked a difference by privatizing sleep. Norbert Elias observed that “sleeping has been increasingly shifted behind the scenes of social life.” (Elias 1939:138) In contrast to social Medieval sleepers, “for bourgeois European families, sleeping in private, out of view of others, became a hallmark of ‘civilization’ across the eighteenth and nineteenth centuries.” (Reiss 2017:11)

A further development of history with significant effects on the structure of sleep is the rise of technology. According to the sleep physician Charles Czeisler, “Technology has effectively decoupled us from the natural 24-hour day to which our bodies evolved, driving us to go to bed later.” (Czeisler 2013) Beginning with gaslight and later electric light, computers, and smartphones, sleep schedules were pushed back until biphasic sleep merged to become consolidated monophasic sleep. (Reiss 2017:10) “Civilized” societies began to privatize sleep at a time of technological development and work-schedule regularization that resulted in monophasic sleep. This is the world of sleep in which we now live.

The Protestant Ethic and the Spirit of Sacrificed Sleep

We have better understood the social structural consequences of the Industrial Revolution to sleep: biphasic to monophasic, social to private. This section briefly reviews a *culture* of sleep – attitudes toward sleep and its function in life.

This story begins in the mid-16th century with the arrival of Protestantism. “Sleep’s purpose, emphasized the devotional work *The Whole Duty of Man* (1691), is to restore “our frail bodies” to “make us more profitable” spiritually and materially, “not more idle.” (Ekirch

2006:264) Idleness was considered wasting time, which was "counted by God and paid for by men". As Max Weber noted of Protestant beliefs in *The Protestant Ethic and the Spirit of Capitalism*, "Waste of time is thus the first and in principle the deadliest of sins... Loss of time through sociability, idle talk, luxury, even more sleep than is necessary for health, six to at most eight hours, is worthy of absolute moral condemnation." (Weber 2002:104) The Protestant ethic "embodied in a new form of 'possessive individualism' which created a culture dedicated to hard work, bodily asceticism and the transformation of the human environment."(Williams 2011:28) Hard work and asceticism required the control or "disciplining" of sleep. (Williams 2011) As we have seen, the Industrial Revolution demanded this "disciplining" and found in the incipient Protestant ethos willing participants.

A Modern Cultural Sociology of Sleep

We have just seen how both the structure of sleep and cultural attitudes towards it have changed over time. Both appear to have been influenced by the demands of regimented work and a Protestant ethos of work and asceticism. In the process, sleep had to become scientifically controlled, an object of rational study. These themes appear to continue to today. Here, I review the modern literature on the cultural sociology of sleep. There are two perspectives from which to view this literature: 1) sleep and its relation to the other domains of daily life, predominantly work; and 2) the rational control of sleep through medicalization. I examine these briefly in turn.

1. Sleep, Work, and Leisure

Implicit in Robert Owen's tripartite classification of daily living is that expansion of one area – work, play, sleep – involves a reduction of another. Cultural sociologists in the U.K. have studied the social construction of sleep and work in the British print news media and found that the 1980's saw a glorification of the tireless captain of industry: "the power-elite such as

Margaret Thatcher, Donald Trump and Bill Gates viewed sleep as sacrificial to their work and leisure time." (Boden et al. 2008:546) This ethos was not restricted to the elite. According to Juliet Schor in *The Overworked American, the Unexpected Decline of Leisure*, "sleep has become another casualty of modern life often sacrificed in favor of long work hours, demanding work schedules and a twenty four-hour business culture." (Schor 1991:11)

Furthermore, these expectations appear to have a masculine edge to them. Indeed, the term "sleep machismo" was coined to characterize the idea that sacrificing sleep was a sign of vitality, toughness, and ambition - an embrace of "a macho political culture where sleep is seen for 'wimps'." (Williams 2011:9) Although the sacrifice of sleep for *paid* work appears to be a masculine ethos, women engage in unpaid housework and care-giving duties, sometimes called the second shift. These women appear to also be subject to imperatives to sacrifice sleep. Women working second shifts "could not tear away from the topic of sleep… These women talked about sleep the way a hungry person talks about food." (Hochschild and Machung 2012:10) Although women, on average, tend to sleep longer than men, much of this difference is explained away by a concomitant reduction in leisure time, of which men appear to have in greater amounts. (Burgard and Ailshire 2013) The demands of caregiving appear to fall on the shoulders of women, displacing their sleep and their leisure time. (Venn et al. 2008)

Recent evidence shows, however, that the trend of sacrificing sleep in favor of work may have reversed and that "sleep is now being more positively construed as the ultimate performance and productivity enhancer." (Boden et al. 2008:551-52) In a qualitative study of 40 British men (2008), a primary purpose of sleep was to "[regain] the reserves and energy to do whatever you want to do the next day" because sleep is "critical for functioning in my job." (Meadows et al. 2008:703) Sleep is less a threat and more an enhancement of productivity.

In this sense, U.K. researchers have argued that sleep is being "customised", meaning that the apparently incompatible demands of daily living (such as work) and individual need for sleep are increasingly reconciled. (Williams, Coveney and Gabe 2013) Hard-nosed notions of over-work and under-sleep to avoid seeming lazy are reframed into a "work smarter" ethic in which sleep is not a barrier for productivity but rather an essential ingredient for it. Consequently, napping (even at work) has gained positive spin in the press, as has reorganization of shift-work. The shifting significance of sleep – initially as a resource to be exploited in favor of work and later as a resource to be protected for the sake of productive work – suggests an opportunity to investigate a social current that may signal a change in America's relationship with sleep, work, and leisure.

2. The Medicalization of Sleep

The medicalization of sleep is not an entirely separate topic from sleep and work. The medicalization of sleep, according to Dr. Benjamin Reiss, was a direct consequence of our newfound working conditions: "Sleep science emerged as a profound response to the industrial age, in which the rhythms of daily life came unstuck from the internal rhythms of workers, and experts were needed to understand what was happening in order to repair the damage." (Reiss 2017:9)

Sleep has become medicalized in at least three senses: through the use of medical vocabulary (i.e. insomnia, restless leg syndrome) to describe "abnormal" sleep, the use of medical institutions to address sleep problems, and in the interaction of patient and doctor in discussing sleep problems. (Williams, Coveney and Gabe 2013) One way to understand the medicalization of sleep is to track sleep diagnoses and prescriptions. From 1993/1994 to 2007 in a nationally representative US sample of physician visits, investigators found a two-fold increase

of sleeplessness complaints, a seven-fold increase in diagnoses of insomnia, and a thirty-fold increase in nonbenzodiazepine sedative hypnotic prescriptions (e.g. Ambien). (Moloney, Konrad and Zimmer 2011)

The media may play a central role in the increasing awareness of people who have sleep "problems." Using an interpretive reading of U.S. print media up to 2000, one researcher came to the conclusion that

> "… the conspicuous influence of newspapers, magazines and the Internet in shaping a persuasive cultural directive to become conscious of soporific states and their possible deleterious consequences. Attending to this cultural directive, a growing number of people are self-diagnosing with a novel sleep disorder, excessive daytime sleepiness. The increasing significance of popular culture in the creation of medical troubles summons an alternative version of medical sociology."
> (Kroll-Smith 2003:625)

According to this analysis, sleepiness has become a condition for which there is a medical response. Doctors are now the professionals to seek out when one is having problems with sleep.

The medical establishment is only one avenue through which sleep is expressed as a health concern. In the U.K., researchers find provisional evidence for "healthicization" as a strategy the media have offered to manage sleep. (Seale et al. 2007:419) Healthicization refers to the increasing understanding of proper and healthy sleep patterns as "an obligation of responsible citizenship." (Seale et al. 2007:419) In a world increasingly out of sync with natural bodily rhythms, the responsibility on the individual to maintain healthy sleep for the sake of personal and public health has grown. (Seale et al. 2007:419) To be a responsible citizen, it is implied, one must sleep adequately to maximize performance at work, avoid work-place accidents, and maintain one's health and the public health. In short, sleep and sleep problems have become medicalized, customized, and healthicized.

The Social Construction of Sleep in the U.S. Media: 1983-2017

Modern research into the social construction of sleep in a Western context has primarily focused on media and newspapers in the U.K. In a US context, I found two studies: a 2003 interpretive study using data from the year 2000 and earlier, and a study focusing on patient records. Thus, the literature so far has predominantly focused on a non-US context and/or leaves post-2000 America unexplored. As has been suggested, sleep is being "redescribed" which is "sociologically interesting when it changes the way people routinely see, think, and behave towards themselves, others, and the world." (Kroll-Smith 2003:630) To investigate this "redescription" of sleep in the United States, I have gathered 35 years of print media data, from 1983 to 2017.

Another motivation to focus on the US media is that the possible difference in number of articles on sleep may suggest a difference in interest in sleep between the US and UK. For instance, from 5 UK daily newspapers, investigators found 1,054 articles in which "sleep" was found in the headline or first few paragraphs; using the same criteria, I found over four times that number (~4,500) in the New York Times alone in the same time period. Indeed, the final sample size is 26,943 news articles drawn from large newspapers with national readerships such as the New York Times, USA Today, and the Washington Post. To help analyze the extraordinary amount of data available, I turned to an increasingly common approach in cultural sociology for the measurement of "culture": computational text analysis or, more broadly, machine learning.

Computational social science, machine learning, and culture

The strength of certain machine learning algorithms is that they allow for the automated classification and parsing of texts to investigate the mapping of cultural environments and their evolution. (Bail 2014, DiMaggio 2015) Computers help researchers get around the problem of an

insurmountable amount of data. However, DiMaggio et al. warn against a naïve application of computers that sums up instances of a word (word frequency), and researchers then assume that it means something. They note that this approach "violates a fundamental principle of cultural sociology, i.e., that meaning emerges from relations among terms rather than inhering within them." (DiMaggio, Nag and Blei 2013)

Therefore, a computer-based approach is necessary, but it must accommodate this last fact of "relationality," along with three others: the approach "must be explicit," "automated," and "inductive." (DiMaggio, Nag and Blei 2013) The method I used is a machine learning algorithm called structural topic modeling. (Roberts et al. 2013, Roberts, Stewart and Airoldi 2014, Roberts et al. 2014) This approach assumes little prior to analysis, is reproducible, automated, and respects the fact that meaning arises not from a single word but from words in relation to one another. Let us take a closer look at topic modeling.

Topic modeling

One definition of a "topic" is that it is the group of words that "tend to come up in a discussion… whenever that (unobserved and latent) topic is being discussed." (Mohr and Bogdanov 2013:547) That is, out of the universe of available words in any given language, a "topic" is the collection of words clustered in a particular galaxy. This fulfills the natural language processing dictum, "You shall know a word by the company it keeps." (Firth 1957)

While topic modeling imposes few assumptions on content, the method itself assumes that each text may be treated as a "bag of words." In this metaphor, the document is the "bag." An author picks words associated with the intended topics and puts them in the bag until the "bag" is "full" (i.e. the document is complete). One implication is that the order of the words does not necessarily account, just as the tiles in a Scrabble bag are not necessarily "ordered."

Each “bag” is surmised to contain a mix of topics. Thus, each news article is generated by an author who intended to write about two topics, say, “sleep and work” and “napping and caffeine” at a ratio of 30% “sleep and work” and 70% “napping and caffeine”. The author picks words associated with those topics (perhaps “caffeine,” “productive,” “fatigue,” etc.) and uses them repeatedly until he/she finishes the article. The words the author chose to use reside in a mental space associated with those topics; other words associated with other topics are less likely to have been chosen because they are further away than the mental space the author is currently occupying. This provides some insight into the vocabulary set from which the author believes is relevant to write about a topic.

The researcher can only know the finished article. But he/she hypothesizes that some words (“health,” drug,” “nap”, etc.) are more likely associated with some topics (sleep-problems) than others (“burritos”). He uses computational methods to analyze not just one but tens of thousands of articles to see if there are some common words (“health,” “drug”) that tend to co-occur. Furthermore, he determines whether this particular topic has increased in proportion over time, that is, whether the share of attention paid to a particular topic has increased. He infers that health writers are now associating the words “health,” “doctor,” and “productive” to the inferred topic of “sleep.” This is akin to “… reverse-engineering the intents of the author(s) in producing the corpus [body of text].” (Mohr and Bogdanov 2013:547)

Methods

News articles from major U.S. newspapers written in 1983-2017 were acquired from ProQuest. Publications were included if they were in the top 15 newspapers by circulation (Alliance for Audited Media) or digital traffic (Pew Research Center) and available on ProQuest. (2013, 2015) Articles from the New York Times, Washington Post, Chicago Tribune, USA

Today, the Wall Street Journal, the Orange County Register, and Los Angeles Times were collected. Articles were included if 1) "sleep" appeared in the title or abstract; 2) were written between January 1st, 1983 to January 1st, 2018; and 3) were written and published in the U.S. For instance, Wall Street Journal articles written in Belgium on the European economy were excluded. Articles with full texts from 1983 to 2017 were retained for analysis (excluding January 1st, 2018) (n=26,943).

The data were pre-processed in R (a statistical computing language). Each document was considered the unit of analysis. Stop words – words that contain little semantic meaning such as "a", "the", and "and" – were removed. The text was lower-cased, and punctuation and URLs were removed. If a term did not occur in at least 500 out of the 26,943 documents, the term was dropped. Examples of dropped terms include names of books or people quoted in the media. The remaining terms were stemmed (e.g. when "sleep," "sleeps,", and "sleeping" are all equivalently treated as "sleep").

To analyze the data, a variant of topic modeling was used: structural topic models (STMs). (Roberts et al. 2013, Roberts, Stewart and Airoldi 2014, Roberts et al. 2014) Structural topic models extend traditional topic models through several innovations. First, STMs build metadata into the topic model. Metadata are document level covariates, information about the text such as author, title, publication, and year of publication. This allows for a dynamic (i.e. longitudinal) analysis when year of publication is used as a covariate. Secondly, STMs allow for inter-topic correlation. Traditional topic models assumed independence between topics. See Roberts, Stewart, Tingley, and Airoldi (2013) for more details.

STMs are not wholly automated. Because the number of topics (k) is supplied to the algorithm by the user, a key question is: "how many topics are there?" Several approaches were

used to determine k. First, the approximate number of topics was estimated by running an open STM model (i.e. k = 0) using spectral initialization. Doing so gives the algorithm free reign to select its own number of topics. It is to be emphasized that this does not represent the "true" or best number of topics but is rather a starting point. When run, depending on the covariates included, these models suggest 71-73 topics.

Consequently, several more models were run, with a wide range of k. Topics were examined for coherence. While those on the lower range of k (e.g. 10-20) were coherent, many subthemes in the texts were treated as a single topic. One run with k = 100 failed to converge; another converged successfully. This suggested that values for k much lower than 71-73 produced coherent but combined topics, whereas values much greater than 71-73 produced unstable models that may or may not converge. With the principle that a lower number for k is safer, a 70-topic structural topic model was run on the corpus containing 26,943 documents, 5,920,850 tokens (words), and 2,779 unique terms.

Analytic strategy

Structural topic models were used in three ways. First, STMs were used to discover the highest probability words within each topic and to track a particular topic's prevalence over time. A topic's prevalence over time was measured by proportion: a Bayesian linear regression was run in which the outcome is the proportion of each document about a topic and the covariate was the year of publication for that document. Year of publication was b-spline transformed for smoothing in plots. A separate linear regression was run to test the significance of the year covariate (without b-spline transformation). The p-values of these regressions are reported.

Second, STMs were used to identify documents with particularly high probability of containing a topic of interest so as to reserve them for closer reading. That is, one use of STMs is

that the trained model can serve as an intelligent document search engine which uses "topics" instead of "key words" to identify documents to read. The top 25 documents considered to be most representative of each topic were read and analyzed.

Third, because STMs are extensions of correlated topic models, the marginal correlation between topics is obtainable. I plotted the correlations among the topics, setting the threshold at 0.1 – any correlation under 0.1 will not show an edge on the network graph.

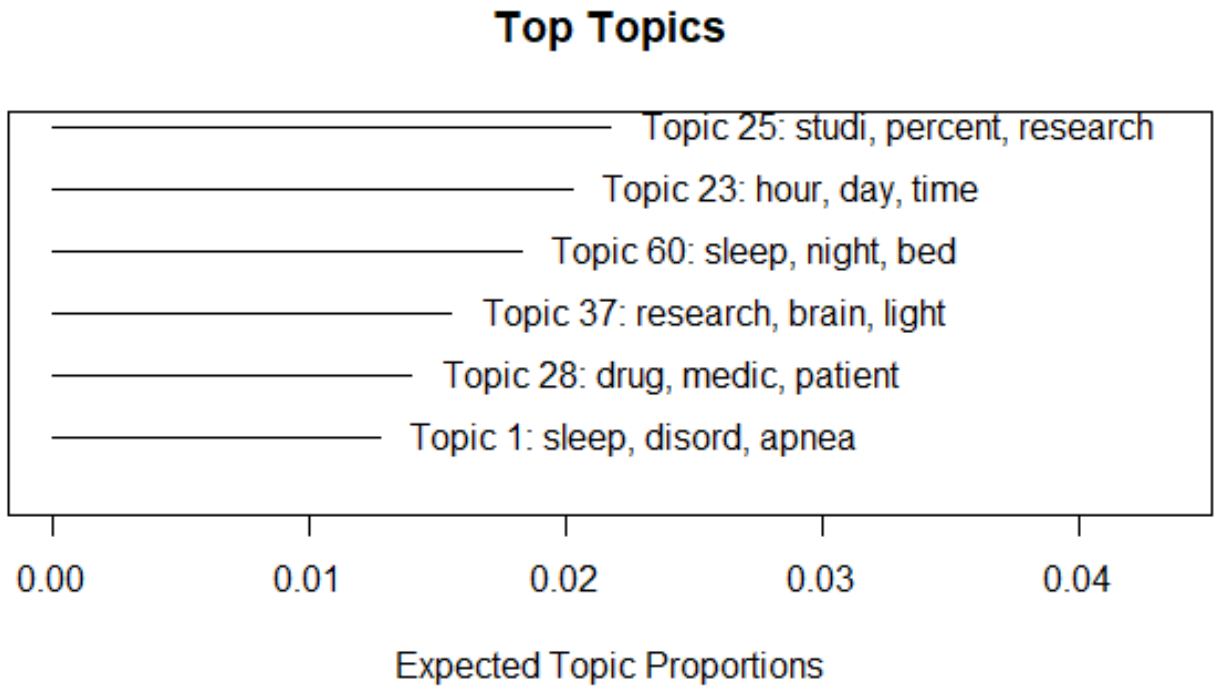
Results

The 70-topic STM identified coherent and intelligible topics. Topics show various definitions of sleep, and include the relationship between sleep and technology, the sports media, college students, and affairs (e.g. "Dear Abby, my husband is sleeping with…"). These are not the focus here. Six topics were picked for their literal use of "sleep" and their association with health, medicine, and daily living:

1) scientific research linking poor sleep to serious health outcomes (topic 25)
2) daily living, including the relationship between sleep and work and the status of napping (topic 23)
3) recommendations to get a good night's sleep (topic 60)
4) scientific research in biology and neurobiology (topic 37)
5) medications (topic 28)
6) disordered sleep such as sleep apnea (topic 1)

The topic numbers are arbitrary (e.g. topic 1 has no ordinal relationship to topic 25). Figure 1 shows the relative ranking of these topics in terms of their expected topic proportion. These topic proportions denote each topic's "share" of the attention paid to that topic in the data. The expected topic proportions (x-axis) should be understood within the context of a 70-topic STM: if all topics had the same proportion, they would each have proportions of 1/70 or 0.014 because the proportions of all topics should sum to 1.

Figure 1. Six topics from a 70-topic STM related to health, medicine, and daily living.



Topic 25 is the leading topic among the six topics and focuses on health outcomes associated with poor sleep, such as diabetes, cardiovascular disease, and obesity. Topic 23 frames sleep in relation to work, naps, productivity, and personal safety (i.e. workplace accidents). Topic 60 focuses on recommendations for obtaining a good night's sleep such as attention to sleep hygiene, the proper temperature to keep one's bedroom, and the virtues of sleeping alone. Topic 37 introduces the biology of sleep, focusing on circadian rhythms in animals and humans. This topic is hinted at throughout previous topics but is the central focus in topic 37. Topic 28 focuses on medications to treat insomnia such as Ambien and Lunesta, as well as over the counter sleep aids. Finally, topic 1 deals with sleep disorders generally and sleep apnea specifically.

The following sections delve more deeply into these topics. I begin with representative quotes of a topic, drawn from the first sentences of high probability articles (i.e. in the top 25). I show the trend over time in prevalence of that type of article and comment briefly on each topic.

I show two validation topics and the correlations among all topics presented. I end with a discussion of the findings as a whole.

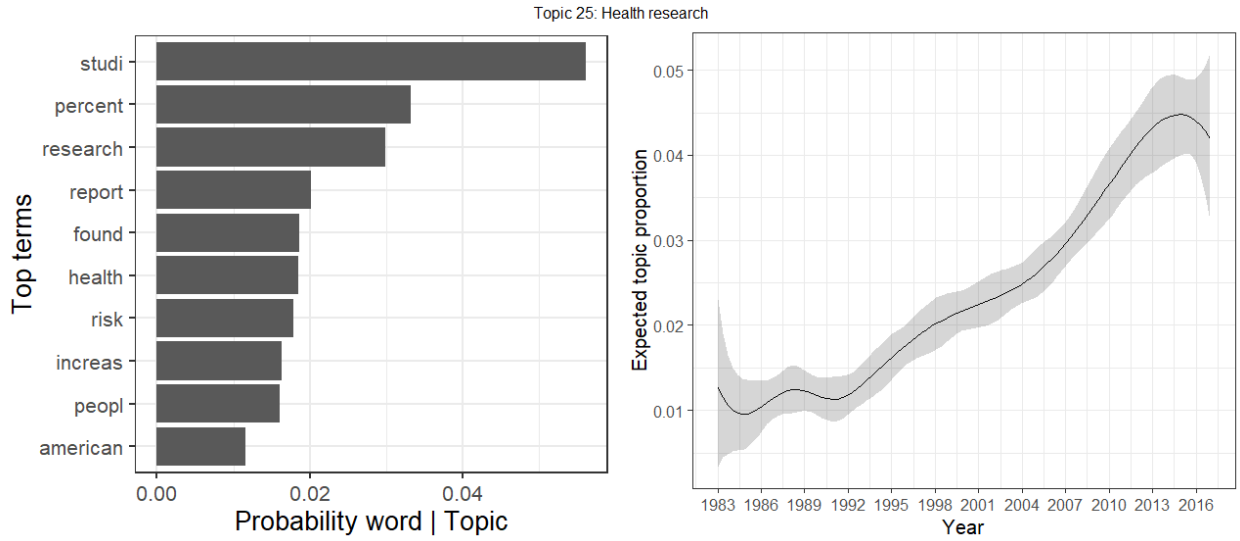
Topic 25: Scientific research on poor sleep

> People who slept, on average, six or fewer hours a night had a 48 percent greater chance of developing or dying from heart disease than did those who averaged seven to eight hours of sleep a night. – *Washington Post* (2011)

> With less sleep, normal aging-related structural changes in the brain progress slightly faster in middle-aged and older people, according to a new brain imaging study. – *Chicago Tribune* (2014)

The largest topic by proportion (25) relates to the recognition that poor sleep is an antecedent to other health outcomes. Figure 2 shows the growth in expected topic proportion and its top terms.

Figure 2. Topic 25 prevalence trend and top 10 terms.



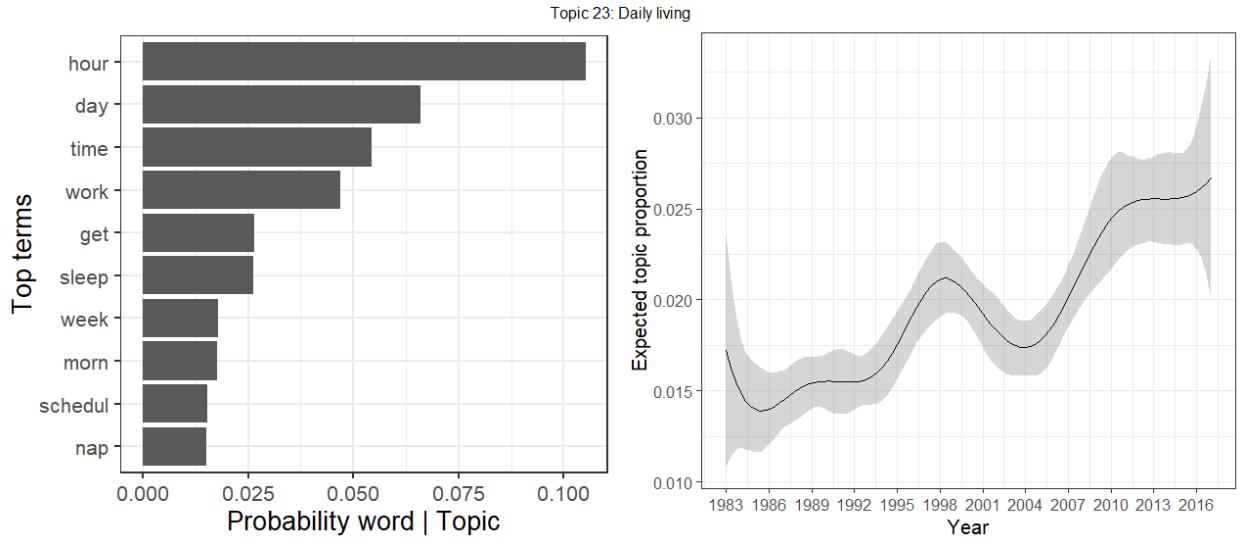
High probability terms in this topic ("studi", "percent", "research", "report", "health") suggest that sleep research is a rich source of knowledge for science and health journalism. Furthermore, the high probability term "risk" indicates a negative orientation. The data suggest a quadrupling in attention from 1983 to 2017 to the serious health consequences of inadequate and poor-quality sleep. Year of publication as a covariate was significant ($p < 0.001$).

Topic 23: Sleep, work, and daily living

> Fifty-eight percent of workers feel they do not get enough sleep, and 61% say lack of sleep has a negative impact on their work. However, as much as insufficient sleep affects workers' jobs, the reverse also is true: 44% of workers indicate that thinking about work keeps them up at night… – *USA Today (2016)*
>
> Many busy people argue that with demanding jobs, commuting and family obligations there simply isn't time to sleep eight hours a night. Are they doomed? It depends on whom you ask. – *USA Today (1998)*
>
> An afternoon snooze refreshes, revitalizes, recharges body and soul. Yet in our caffeine-buzzed society, naps are downright un-American. – *Chicago Tribune (2007)*

Topic 23 acknowledges the interplay between ideal work and ideal sleep. It also expresses some uncertainty about those ideals. Figure 3. shows expected topic proportions by year and top terms for the relationship between sleep and daily living.

Figure 3. Topic 23 prevalence trend and top 10 terms.



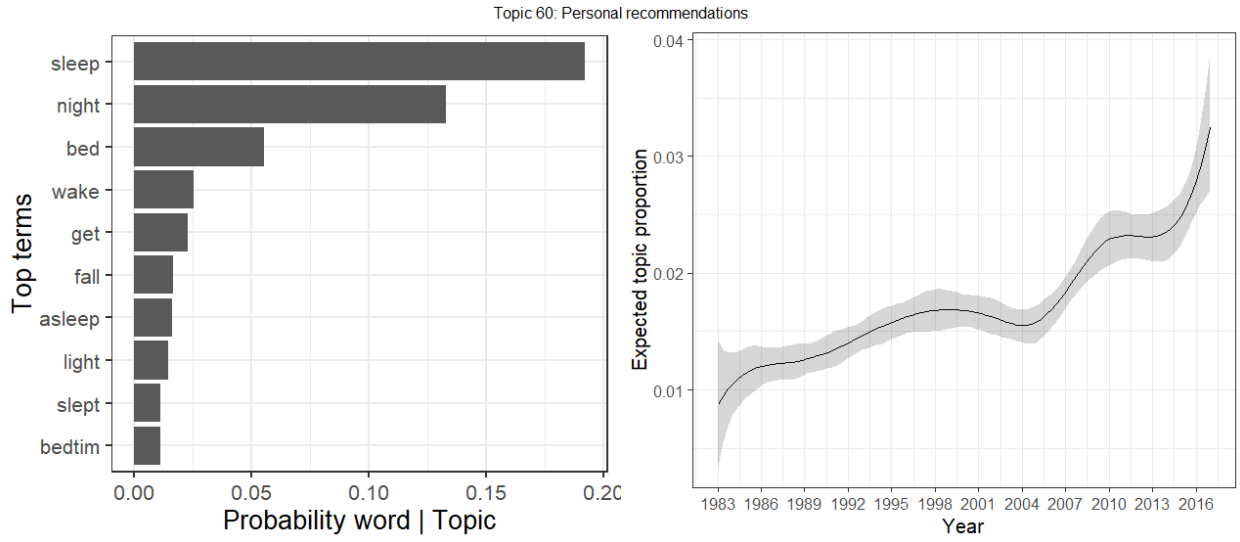
The top terms (“hour”, “day”, “time”, “work”) suggest that a common concern is when and how much to sleep, particularly to be productive at work. The top terms “nap” and “schedule” suggest that napping is an important subject in relation to work and night-time sleep. The data suggest an overall positive trend in prevalence of this topic. Year of publication as a covariate was significant ($p < 0.001$).

Topic 60: Personalized recommendations

> Having trouble falling asleep at night? Here are some techniques to improve "sleep hygiene" from Dr. Elliott Phillips, medical director of the Sleep Disorders Center at Holy Cross Hospital. – *LA Times (1985)*
>
> Here are some tips for a good night's sleep from Martin Cohn of the Sleep Disorders Center of Southwest Florida: - Use your bed for sleeping only. – *Chicago Tribune (1993)*
>
> To get a good night's rest, you're better off sleeping alone than with a bed partner, even if you think otherwise. That's the conclusion of Francesca Pankhurst, a sleep researcher at Loughborough University in England. – *Chicago Tribune (1994)*

Topic 60 focuses on strategies for people wishing to improve their sleep. Figure 4 shows the overall growth in topic proportion and the top terms.

Figure 4. Topic 60 prevalence trend and top 10 terms.



The top terms (“sleep”, “night”, “bed”, “wake”) are frequently used in recommendations for a proper night’s rest. The data suggest a more than double increase in topic prevalence for this topic. Year of publication as a covariate was significant ($p < 0.001$).

Topic 37: Biology (of sleep)

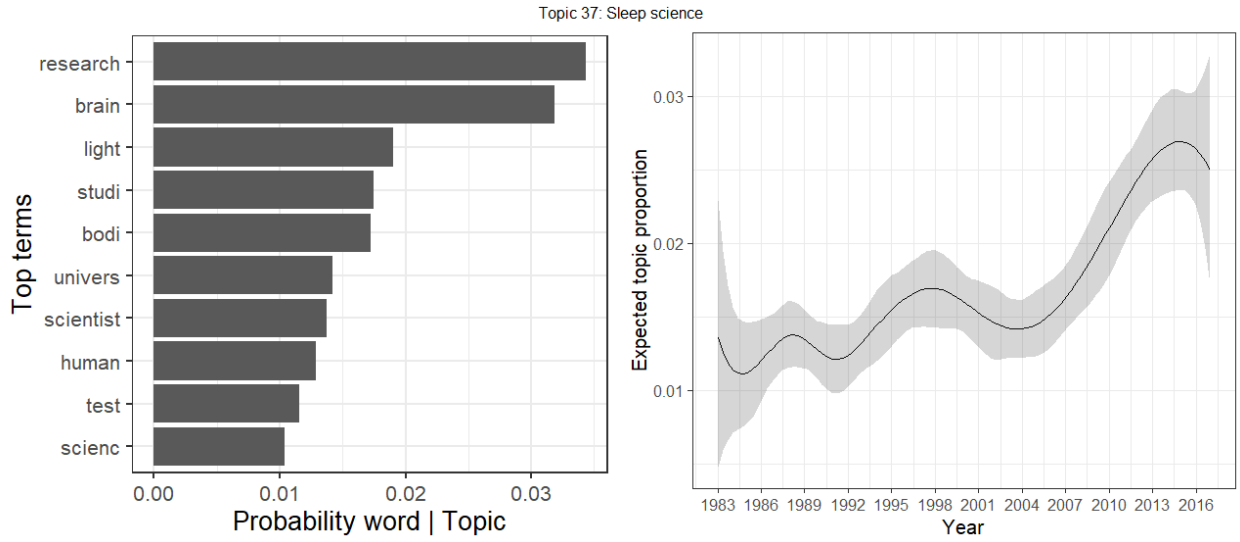
> Fluctuations in internal body temperature regulate the body's circadian rhythm, the 24-hour cycle that controls metabolism, sleep, and other bodily functions, according to a study published in Science. – *USA Today (2012)*

> Scientists may have figured out how the fruit fly keeps its internal clock in sync with the 24-hour day, a finding that could eventually shed light on jet lag and other human problems. – *Chicago Tribune (1996)*

> What purpose does sleep serve? Two separate research teams have suggested a remarkable answer to this elusive question-that it may be an essential ingredient to memory and learning. – *Chicago Tribune (1994)*

Topic 37 focuses on the biology and neurobiology of sleep. Figure 5 shows the overall growth in topic proportion and top terms.

Figure 5. Topic 37 prevalence trend and top 10 terms.



The top terms for topic 37 ("research", "brain", "light", "studies", "university", "science") suggest that university research on circadian rhythms and neurobiology are distinct from medical research on the effects of poor sleep (topic 25). For instance, the top 25 articles for topic 37 do not contain the word "doctor". The data suggest an overall increase in expected topic proportion. Year of publication as a covariate was significant ($p < 0.001$).

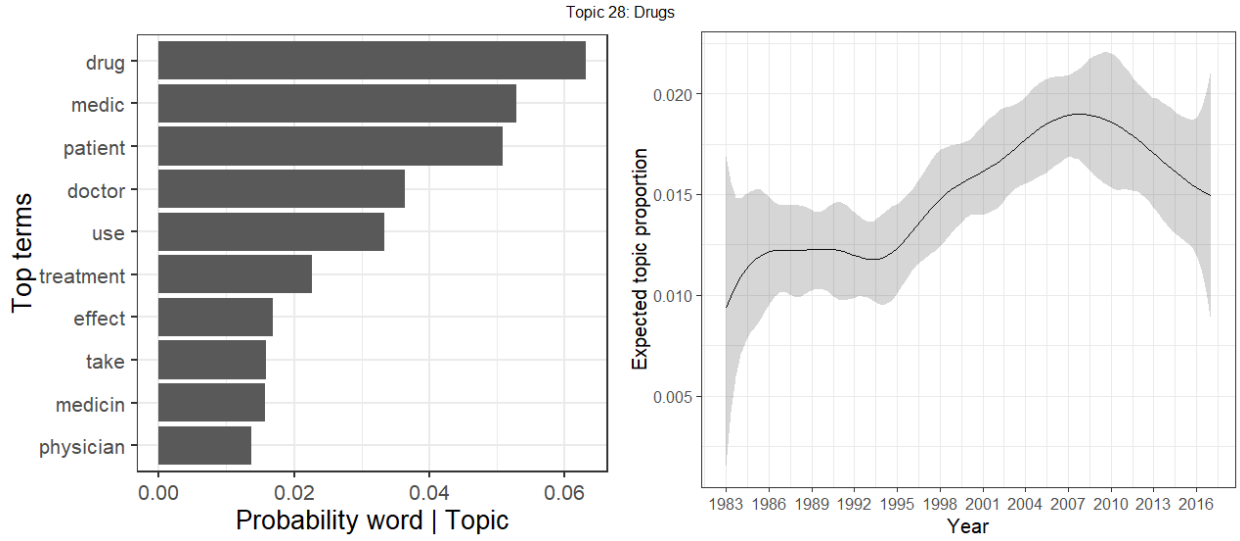
Topic 28: Drugs

> A federal advisory panel on Wednesday partly endorsed a proposed sleep drug from Merck & Co., saying the product was effective and acceptably safe at lower starting doses. Merck is seeking Food and Drug Administration approval of a drug called suvorexant to treat insomnia… – *Wall Street Journal (2013)*

> Sleep researchers have reported an unusual number of incidents of sleepwalking in people taking Ambien, the top-selling sleep aid in the U.S. The Food and Drug Administration has received similar reports. *The Washington Post (2013)*
>
> Sanofi-Aventis SA said it has reviewed its database of patient reactions to the sleeping pill Ambien and finds no reason to recommend a change in the drug's safety profile or prescribing information. *Wall Street Journal (2006)*

Topic 28 is focused on drugs generally and sleep drugs predominantly. As the above quotes demonstrate, a primary theme in these data is the safety of such medications. Figure 6 shows the overall trend in topic proportion and the top terms.

Figure 6. Topic 28 prevalence trend and top 10 terms.



The top terms (“drug”, “medicine/medical”, “patient”, “doctor”) suggest that drugs/medication are a significant topic in relation to sleep. The data suggest a peak in prevalence around 2007 and a decline in this topic afterwards. Year of publication as a covariate was significant ($p < 0.001$).

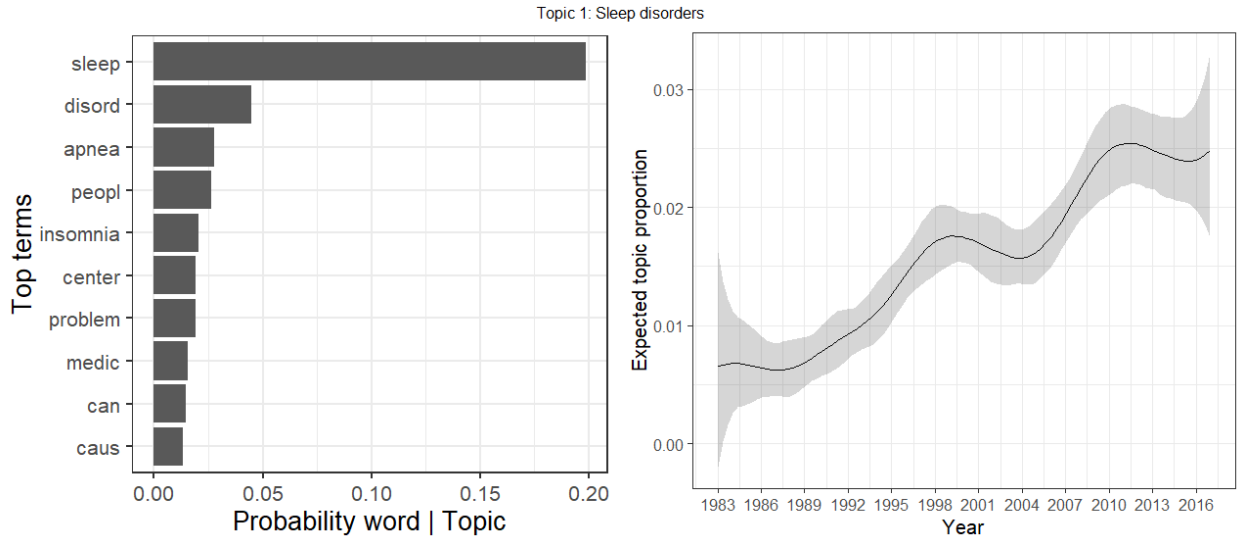
Topic 1: Disorder

> Here are some signs and symptoms of the sleep disorder called apnea, the subject of the main health story on this page: - Loud snoring, interrupted by pauses in breathing - Daytime sleepiness - Gasping or choking during sleep - Restless sleep - Memory loss and poor concentration - Hypertension – Obesity. – *Chicago Tribune (1999)*
>
> Carrying too much weight appears to be associated with a common sleep problem. A study in this week's Neurology reports that being obese may increase the risk of restless

> legs syndrome, says author Xiang Gao, an instructor in medicine at Harvard Medical School. – *USA Today (2009)*
>
> Do you have problems falling asleep at night or staying asleep? Is it a struggle to get your child to go to bed at night? Do you stop breathing or gasp for breath during your sleep? Experts with the National Sleep Foundation will participate in a live chat today from noon until 4 p.m. ET/ 9 a.m. until 1 p.m. PT as part of National Sleep Awareness Week. – *USA Today (2002)*

Topic 1 focuses on sleep disorders generally and sleep apnea specifically. Insomnia is mentioned in the top 25 articles (8 times), as are restless legs (11 times) and apnea (58 times). Figure 7 shows the prevalence trend and top terms associated with the sleep disorder topic.

Figure 7. Topic 1 prevalence trend and top 10 terms.



The top terms (“sleep”, “disorder”, “apnea”, “insomnia”, “problem”) suggest that this topic is less associated with ordinary sleep deprivation and more associated with clinical sleep disorders. The data suggest that the increase in prevalence of this topic has increased 3- or 4- fold. Year of publication as a covariate was significant ($p < 0.001$).

Validation

With the exception of topic 28 on sleep medications, the rest of the topics suspiciously show an overall upward trend until 2017. It may pardonably be wondered whether these trends

were driven by some quirk of the data. One way to assess topic validity is to look at other topics with a priori common-sense interpretations. Here I take two topics and illustrate that their topic proportions are expected based on what we know. The first relates to Presidents George H.W. and George W. Bush and the Iraq wars. For this topic, we should expect to see - within the timeframe 1983 to 2017 - two peaks associated with the two Bush presidents and the two Iraq wars. The peaks in topic proportion should occur roughly around 1991 and 2004. The second topic relates to the debate over school start times in Fairfax, Virginia, culminating in an actual delay to 8 a.m. for high schoolers in 2015. This debate occurred primarily in 2013-2014, and we would expect a peak in topic proportion for those years.

Topic 55: Bush and Iraq war(s)

> When in battle, the center's report said, "commanders who fail to get enough sleep court disaster." It said that "sleep deprivation causes leaders at all levels to make mistakes and decisions which directly or indirectly cause the 'death' of not only themselves but their units." – *New York Times (1998)*
>
> …The Post reported, captives have been handed over to foreign intelligence services known for using questionable interrogation tactics -- including Jordan, Egypt and Morocco. Prisoners released from the military camps at Guantanamo Bay in Cuba and Bagram air base in Afghanistan have said in interviews with Amnesty International that they were subjected to human rights abuses, including sleep deprivation and forced injections of drugs. – *The Washington Post (2003)*

Figure 8. Topic 55 prevalence trend and top 10 terms.

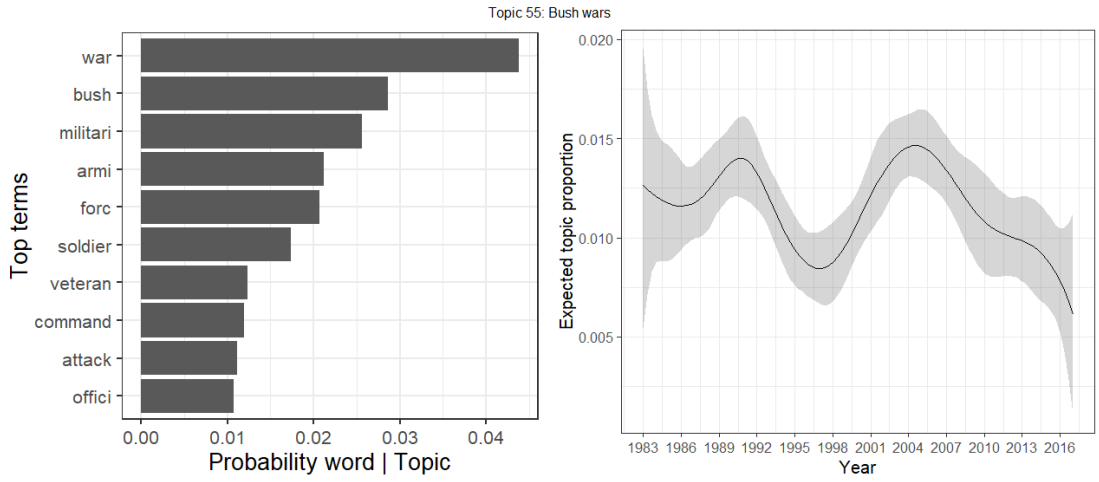


Figure 8 shows that that not all topics are strictly increasing. Rather, it shows good agreement with common-sense. During the 1st and 2nd Iraq wars, there was high mention of "Bush" and "war"; during the Clinton and Obama years, there were fewer mentions of this topic. Indeed, the top terms ("war", "bush") indicate that this topic is specific to the two Iraq wars.

Topic 10: School start times

> Schools Superintendent Karen Garza plans to push for later start times at Fairfax County high schools next year [2015], aiming to begin their day no earlier than 8 a.m. in an effort to give teenagers more time to sleep. – *The Washington Post (2014)*
>
> Fairfax County teens will get extra sleep next fall under a new initiative approved late Thursday that will push back the first class of the day in high schools to 8 a.m. or after. – *The Washington Post (2014)*
>
> High school students in Arlington will gain 45 minutes of shut-eye each morning beginning in September after the School Board voted to move the starting time of classes from 7:30 to 8:15 a.m. – *The Washington Post (2000)*

Figure 9. Topic 10 prevalence trend and top 10 terms.

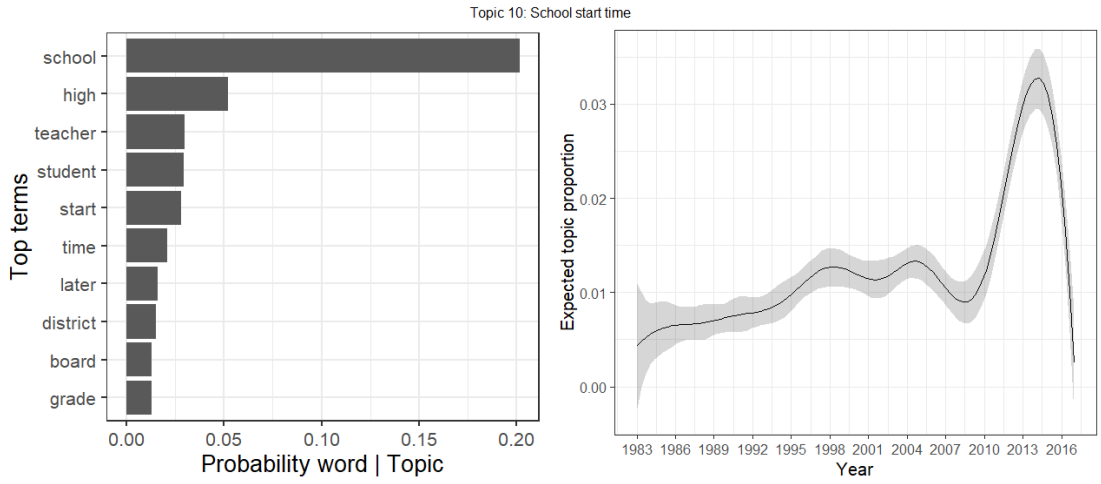


Figure 8 shows a peak in topic proportion as expected in 2014. As one article notes, the push for later school start times in Fairfax began in the early 1990s, but it appears that media coverage spiked in 2013-2014 when proposals were closer to becoming reality.

Figure 10. Topic correlation graph

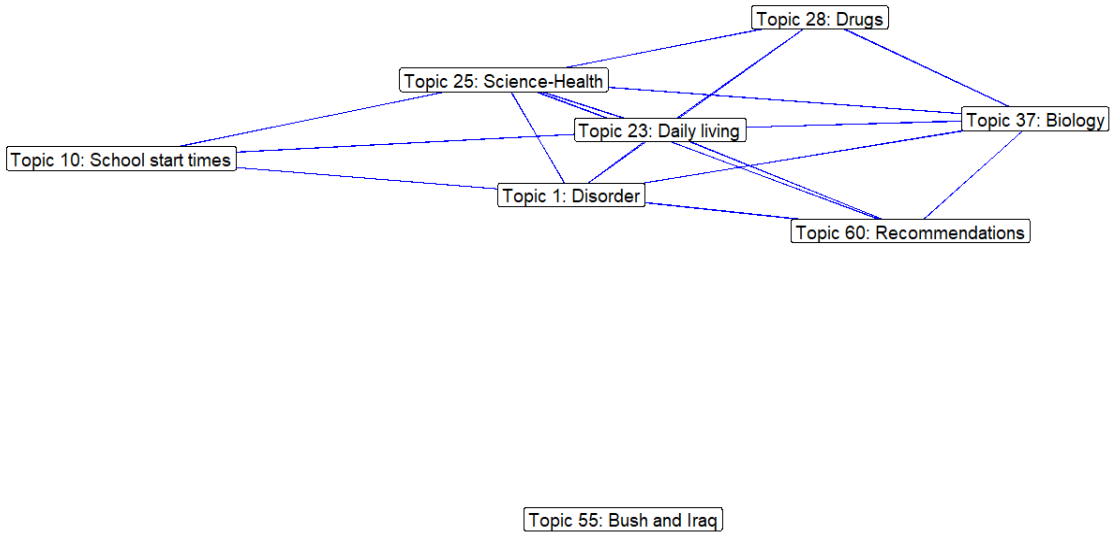


Figure 10 shows correlations among topics. It appears that "Topic 23: Daily living" and "Topic 25: Science-Health" are central and correlated with every other topic (except "Topic 55: Bush and Iraq" which intuitively should stand on its own). The topic of drugs is not correlated with "Topic 10: school start times," and indeed the articles on school start times have no recommendations for teens to dose themselves with Ambien in order to get to sleep on time. "Topic 10: school start times" is weakly correlated with all other topics; when the threshold for correlation is set to 0.12 (instead of 0.10), the edge between topic 10 and all others disappears. Interestingly, "Topic 60: Recommendations" bears no direct relationship with drugs; this topic is predominantly focused on personal strategies, not medication. In all, however, most topics are correlated with several other topics in this space.

Discussion

The chosen topics focused on three major themes: health, medicine, and daily living. The study of their interplay within society is the study of embeddedness. This interplay tends to give rise to issues of the *why* of healthy sleep (for health and work), the *how* of sleep (circadian

rhythms, drugs, and how to obtain good sleep), and the *what* of sleep (what is normal, disordered, or unacceptable). The *why* of sleep shows a few straightforward narratives of medicalization, but the story is not so simple. There are also appeals for sleep for its own sake, for personalized health ("healthicization"), and for work. To work hard, one has to sleep smart. Consequently, the *how* of sleep introduces itself in order to achieve ideal sleep. However, in the process of discussing the *why* of sleep, there is some uncertainty over the *what* of sleep, that is, what is normal or abnormal.

Why sleep? Work and health

Why should we protect our sleep? According to the health topic (topic 25), the answer lies in sleep's status as a determinant of other health outcomes. The increasing prevalence in the health topic (topic 25 – Figure 2) suggests that this view occupies more and more of the share of sleep focused news articles. Thus, there are signs of medical "creep" in which individuals free of sleep disorders are nonetheless target audiences for research findings and recommendations by professionals housed in medical institutions. It appears that poor sleep is like obesity in that it is becoming medicalized because it is a "pre-disease." Like obesity, which was classified as a disease by the American Medical Association in 2013 despite a lack of dysfunction (since obesity is a result of normal biological function), insufficient sleep is of increasing interest because it is a hypothesized determinant of poor health outcomes downstream.

The typical article on the medicalization of sleep begins with a statement of the consequences of poor sleep. Then, credibility is established by reference to researchers/experts, their institution, and the academic journal in which the article was published. Methods and findings are summarized. The article typically ends in one of two ways: 1) with a recommendation from

an expert on what should be done; or 2) an emphasis that the findings need further validation. Consider, for instance, the following short article from the Chicago Tribune in 2008:

> People who sleep less than six hours a night -- or more than nine -- are more likely to be obese, according to a new study that is one of the largest to show a link between irregular sleep and big bellies… The research supports studies that found health problems in those who don't get proper shuteye, said Dr. Ron Kramer, a spokesman for the American Academy of Sleep Medicine. "The data is all coming together that short sleepers and long sleepers don't do so well," Kramer said. The study released on Wednesday is based on door-to-door surveys of 87,000 U.S. adults from 2004 through 2006 conducted by the National Center for Health Statistics... About 33 percent of those who slept less than six hours were obese, and 26 percent for those who got nine or more. Normal sleepers were the thinnest group, with obesity at 22 percent… Other studies have linked inadequate sleep to appetite-influencing hormone imbalances and a higher incidence of diabetes and high blood pressure, said James Gangwisch of Columbia University. "We're getting to the point that they may start recommending getting enough sleep as a standard approach to weight loss." – *Chicago Tribune (2008)*

In this respect, sleep falls under the definition of medicalization offered by Zola (1983): a "process whereby more and more of everyday life has come under medical dominion, influence, and supervision." In this view, obesity and insufficient sleep have come under the purview of the medical establishment not because they are disorders or illnesses, but because they augur or even cause future illness. (Zola 1983) As a consequence, medicalization partially functions to promote medicine as a frame of reference, the preferred well from which to draw understanding of sub-optimal aspects of daily life such as insufficient sleep.

If sleep is critical for health, it also has been framed as critical for work productivity. The three broad components of daily life – work, sleep, and leisure – have not always been conceived of as complementary. Indeed, as has been noted, sleep has in recent memory been framed as oppositional to other aspects of daily living. Some evidence in the U.S. suggests this tension. As one article (an invited response commentary) says,

> "OK, what I see here are choices... No one is forcing someone to stay up and watch David Letterman… It all really boils down to priorities and time management. ... If you're not happy with how much sleep you get, make changes so you can get more. It really is that simple!" – *USA Today (2010)*

This zero-sum relationship between sleep, work, and leisure is also noted in the Wall Street Journal, which wrote that "Americans spent more time working and less time sleeping in 2016 than the year before, echoes of an improving labor market." Less sleep, in this view, is the outcome of a reorganization of priorities in daily life: work over sleep.

On the other hand, there is evidence of what Williams et al. (2013) have described as 'customisation', the attempted molding of sleep and work into a less oppositional relationship. Attempts at 'customisation' (hereafter customization) in the U.S. data tends to take one of two forms: 1) emphasis on the business costs and safety of sleep-deprived workers; and 2) appeal to increased productivity.

Consider the following excerpt from a New York Times article (2000) in which safety and likely business costs of sleep-deprived workers are emphasized, with the health consequences of poor sleep as an appended afterthought:

> Studies have shown that sleepy workers make more mistakes and cause more accidents, and are more susceptible to heart attacks and gastrointestinal disorders. – *New York Times (2000)*

Another article emphasizes the harm to productivity that sleep deprivation can bring:

> Fifty-eight percent of workers feel they do not get enough sleep, and 61% say lack of sleep has a negative impact on their work… "We see more and more workers check into the office at all hours of the day, give up vacation time, and work even when they're sick. Yet, it's not necessarily making us more productive, and companies are starting to recognize that. – *USA Today (2016)*

In these settings, the relationship between work and sleep appears to be an uneasy one. Thus, customization offers an oblique recommendation: change work to allow better sleep which will make work more efficient.

One article actually suggests an overhaul of the entire work week (later Monday start times, longer Wednesdays) for the sake of productivity. Another reports the salutary effects of reorganizing long night shifts. For instance, Charles Czeisler, a sleep expert from Harvard

Medical School, was employed by police departments in Philadelphia to optimize their work schedules. Officers worked night shifts 18 days in a row rather than 8 days, giving them time to acclimate to the new schedule, and reduced the number of consecutive work nights to 4. The effect was that:

> After 11 months on the new schedule, officers reported significant declines in sleep problems, sleepiness on the job and fatigue and an increase in alertness. On-the-job automobile accidents fell by 40%, sleeping pill and alcohol usage dropped 50% and sick time declined 23%. Family satisfaction with the new schedule increased fivefold. Although the quantity of time spent with families remained about the same, the quality improved. Officers said they felt more rested, more energetic and less irritable. – *LA Times (1989)*

However, this social experiment on work schedules to accommodate sleep does not appear to be the norm. The inherent malleability of night-shifts may not generalize to ordinary notions of a standard work week.

While a wholesale redesign of work weeks does not seem likely, customization has given another potential solution: a reexamination of naps. The high probability term "nap" in topic 23 suggests that the status of napping in America is likely more a subject of discussion here than in other cultures in which a mid-day siesta is assumed rather than open to debate. To even broach the subject of napping in the U.S. requires considerable justification through appeal to high prestige institutions, science, and quotations from experts. One article, for instance, from USA Today (2009) leverages the authority of the Mayo Clinic:

> Here is permission from a Mayo Clinic sleep specialist: it is okay to take a nap. A short nap - 10 to 20 minutes is just right for most people - can be restorative, reveals Michael Silber, codirector of the Center for Sleep Medicine, Rochester, Minn.

Another, a Chicago Tribune article (2007), draws authority from Stanford's School of Medicine:

> … if you snooze, you lose, right? Not according to scientific research. The rejuvenating effects of naps has resurfaced in a recent Stanford University School of Medicine study. Emergency room doctors and nurses who worked overnight shifts and were allowed 40-minute naps showed a boost in alertness and performance over those who worked straight through. Which group of doctors would you prefer probing your abdomen for a 38-

> caliber slug? "Napping is a very powerful, very inexpensive way of improving our work," said Dr. Steven Howard, one of the study's authors.

Even personal anecdotes are dotted with reference to physicians:

> My college roommate, Dr. Linda Himot, a psychiatrist in Pittsburgh, who has a talent for 10-minute catnaps between patients, says these respites help her focus better on each patient's problems, which are not always scintillating. – *The New York Times (2000)*

Finally, another article cites Winston Churchill and other significant historical figures as the grounds by which the author justifies her own tendency to nap:

> "You must sleep sometime between lunch and dinner, and no halfway measures. Take off your clothes and get into bed. That's what I always do. Don't think you will be doing less work because you sleep during the day. That's a foolish notion held by people who have no imaginations. You will be able to accomplish more. You get two days in one, well, at least one and a half." -- Winston Churchill. As a short sleeper who is rarely in bed for more than six hours a night, I'm a strong believer in naps for recharging my batteries. Sir Winston and I are in good company. Napping enthusiasts have included Albert Einstein, Napoleon Bonaparte, Thomas Edison and at least three presidents: John F. Kennedy, Ronald Reagan and Bill Clinton. – *The New York Times (2000)*

Yet it might be noticed that Churchill's recommendation seems not to have gained full cultural legitimacy in the U.S. Despite official sanction from the medical community (and exemplars from history), napping in the U.S. appears to still retain association with laziness and unproductivity. As the above-mentioned 2007 Chicago Tribune article continues,

> Convincing bosses that productivity improves with a nap hasn't met with success. Despite being supported by medical studies, the benefit of naps has been ignored for the illusion of an indefatigable workforce. In the 1990s, the 20-minute power nap stirred corporate America, but it was just a ripple. Sleeping on the job with the boss' blessing remains a rare perk. "Slackers or an old person," said lifelong napper Karen Calhoun, 39, of Elk Grove, Calif., offering her take on America's opinion of nappers… Trouble is, there's plenty to get in the way of a good nap--guilt, jobs, commute time, appointments. "Our society has evolved to where napping is not part of our culture," [Linda] Wytrzes said. – *Chicago Tribune (2007)*

There are implicit associations of napping with a lack of vigor ("an old person"). We also see moralistic valuations of sleep by reference to feelings of "guilt" and evaluations of nappers as "Slackers", echoes of the Protestant stance against the sin of wasting time.

Pronouncing nappers to be slackers may signal an outward conformity to cultural norms. In reality, it appears that unsanctioned workplace naps are common. One USA Today article (2016) cites a poll which claimed that "43% [of respondents] have caught someone sleeping at work." These instances may be individuals succumbing to bodily needs or, perhaps, a sign of inexperience in disguising one's workplace sleep:

> Of those who take workplace naps, 70 percent say they do so secretly. "We've heard interesting stories on how people secretly nap," said William Anthony, 61, a Boston University psychologist. "A number of people--from 5 to 10 percent in our survey--do it in a bathroom stall. One lady told us she rests her head on the toilet paper roll." – *Chicago Tribune (2003)*

Thus, to nap at work is to invite social judgment, unless one has mastered the art of sleeping when no one is watching.

It appears that our natural biological rhythms in fact encourage us to nap, sometime between 2:00 pm and 4:00 pm. This mismatch between a culture of incessant work and biological rhythms implies that customization has been limited in its effect on changing work culture. Some of the news media have paid closer attention to these biological rhythms, how to control erratic sleep, and how to achieve good sleep.

How – Circadian rhythms, drugs, and how to achieve good sleep

How does sleep work? How do we achieve good sleep? Deriving from the Latin "circa" (around) and "dies" or "diem" (day), circadian rhythms refer to biological rhythms that occur within roughly a 24-hour period. Articles focused on circadian rhythms (topic 37) are primarily devoted to scientific studies on flies, animals, and humans and the mechanisms by which these rhythms are regulated. One article presents research on the TIM protein (so called because it is the expression of the "timeless" gene) in fruit flies that decomposes in response to light exposure; another explains that lower body temperature is a signal for sleep.

However, features of daily living can disrupt these natural rhythms, as some articles claim (topic 60). The issue is not, in their view, whether there is anything wrong with people biologically. Rather, the issue is that people may unintentionally knock their internal clocks off kilter by poor sleep hygiene: “Left to their own devices, humans' internal circadian clocks keep our sleep patterns in sync. At least until our personal habits get in the way.” – *The New York Times (2017)*

One way to combat problematic sleep is to use medication. Indeed, study of the medicalization of sleep has often included pharmaceuticals as a primary theme. However, the data in this project suggest a different story. While the prevalence of topic 28 (drugs) shows an early upward trend, after 2007 this topic began to decline. The true cause of this decline is unknown, but several explanations are possible.

First, 2007 marked the year that the popular sleep medication Ambien went generic. It may be that “Ambien” and “sleep drug” were considered synonymous and that when Ambien went generic, the topic of sleep medications went into decline – what was there to talk about? It may also be that as Ambien went generic, less money went into its promotion.

A second possibility is that the safety and side-effects of sleep medications had come under scrutiny. Consider, for instance, some of the following first sentences of articles within topic 28 (drugs):

> Makers of sleeping pills such as top-selling Ambien and Lunesta should stiffen warnings on allergic reactions and behaviors such as sleep-driving, the Food and Drug Administration said yesterday. – *The Washington Post (2007)*

> The Food and Drug Administration is requiring the makers of certain sleep-inducing drugs, including Ambien, to lower doses of the medicines because they have been shown to impair activities -- such as driving -- the morning after the drugs have been taken. – *Wall Street Journal (2013)*

If these articles sufficiently communicated the hazards of sleep medications by 2007, then presumably there was less motivation to emphasize an established fact in subsequent years, unless they revealed novel dangers.

A third possibility is that there has been an assertion in moral attitudes towards resorting to medications for a problem that individuals believe they should manage themselves. (Williams, Meadows and Arber 2010) Even if the dangers of sleep medications were already established (and thus not so newsworthy), the problem of poor sleep would persist. This might create a demand for non-pharmaceutical ways to achieve better sleep, and indeed the data demonstrate increasing prevalence of articles focused on personal recommendations to manage sleep (topic 60).

In contrast to articles focused on the sleep-health or sleep-work link, these articles (topic 60) tend to stand on their own: a good night's sleep is an end unto itself. For example, the terms "job", "work", and "health" were infrequently used. These articles are highly personal, written as though the writer were a knowledgeable and trusted coach giving advice. The style and grammar of these articles tend to be prescriptive, phrased as imperatives ("Listen to your body clock. Go to bed when you're tired."), and consequently tend to use an explicit or implied "you" pronoun:

> KEEP TO A SCHEDULE: Go to bed and wake up at about the same time every day, including weekends. Taking medications, exercising and even watching television should occur about the same time every day, too. AVOID NAPS: If you must take one, set the alarm so you don't sleep for more than an hour. Don't take a nap after 3 p.m. AND SCREENS: Turn off the tablet, the television and the phone. The blue light in your screen has the same effect on your brain as sunlight, which means it wakes you up just when you want to be drifting off. – *The New York Times (2017)*

> Whether you suffer from insomnia or are just having an off night, the solution is mostly mind over matter. No gadgets, no pills, no hypnotism, just some sound advice from Northwestern Memorial Hospital's Dr. Lisa Woofe, a physician who specializes in sleep medicine. Set your internal clock. "Have stringent times for getting into and out of bed," Woofe said. "Your body has a clock that helps regulate your brain when you're awake and asleep, and your body will auto-start the sleep process accordingly." – *Chicago Tribune (2009)*

The advice is fairly general but also individualized; there are no recommendations for a specific wake or bed time. Exercise and watching television may be a given in most peoples' lives, but these articles do not recommend a specific regimen. Most conspicuously, there are only a few mentions of sleep duration recommendations. If readers followed the recommendations, what would this ideal sleep look like?

What – What is normal, abnormal, and what do we do about it?

While drugs and personal strategies may give us methods to achieve sound sleep (the *how*), it is unclear from the media what ideal sleep consists of. What is normal, abnormal, and disordered? In short, what is deviant? Deviance here is used in its sociological sense to denote a behavior judged by society as condemned or is otherwise "negatively defined." (Conrad and Schneider, 1980). Two general perspectives in the medicalization of deviance are relevant: the positivist and interactionist traditions. (Conrad and Schneider, 1980)

The positivist tradition corresponds most closely to medicalization of sleep disorders (topic 1). Topic 25, while displaying some evidence of medicalization, primarily focuses on sleep as etiology, not the etiology of sleep. Medicine and etiology, the study of the set of causes for a disorder, primarily operate within this positivist tradition. (Conrad and Schneider, 1980) This tradition asks, "what are the objective or physiological determinants of this disorder?" Sleep apnea, for instance, is diagnosed by an in-lab or in-home sleep test complete with electrodes, a pulse oximeter, microphones to record snoring, and other objective measurement devices. Restless leg syndrome is a cause of poor sleep because it "causes leg sensations such as burning, a creepy-crawly feeling, throbbing and an uncontrollable urge to move your lower limbs. That can make it hard to fall asleep, and it can wake you up." Disorders such as sleep apnea and restless legs syndrome fall decisively within the positivist tradition.

Other sleep "disorders" are more difficult to pin down. Consider, for example, "adjustment sleep disorder" – a type of temporary insomnia – which one news article acknowledges "is a normal response to temporary stress or illness; it affects an estimated 35 percent of Americans at some time in their lives…" As Allan Horwitz has argued in another context, expected reactions to life events and stress do not conform to strict medical notions of dysfunction and disorder. (Horwitz 2002) In this view, trouble sleeping in the face of stress is a sign that the human body is, in fact, functioning *normally*. That a normal and expected consequence of stress has become pathologized suggests that the boundary between normality and abnormality – what is deviant and not – has shifted.

For these "disorders," the interactionist tradition provides the better tools for analysis. The interactionist tradition considers "deviance" to be socially constructed. (Conrad and Schneider 2010) Sleep is not necessarily deviant when it is placed into a category of medical diagnosis (although this is possible), but rather when it strays beyond the bounds of what is considered normal or desirable. The interactionist tradition says that "adjustment sleep disorder" and sleepiness became deviant when they were defined as such, regardless of whether they are indicative of underlying dysfunction. (Conrad and Schneider 2010, Kroll-Smith 2003) Even normal or expected sleep behaviors and patterns can be considered deviant when they clash with social notions of appropriateness, whether in the form of work-place naps or the choice to forgo sleep in favor of work or leisure or vice versa.

However, the interactionist tradition assumes that these social notions of appropriateness have been clearly defined. For non-clinical sleep, this has yet to occur. The data show significant confusion over what should be considered normal or optimal sleep for those without sleep disorders:

> Not quite the achiever you'd like to be? Perhaps you need more sleep, or less, or get up too early, or too late. Consider: 1. Thomas Edison-slept five hours a night 2. Albert Einstein-10 hours a night 3. Winston Churchill-four hours a night in World War II 4. Calvin Coolidge-10 hours a night 5. Harry Truman-awoke at 5:30 a.m. 6. Napoleon-slept few hours, awoke at midnight 7. Wild Bill Hickok awoke at noon. – *Chicago Tribune* (1993)

The common notion of 8-hours of sleep as sleep par excellence is further thrown into doubt in the media:

> To get the health benefits of a good night's sleep, is it just the number of hours that counts?... Optimal sleep duration varies widely, depending on a person's genetic makeup, underlying health conditions and daytime activities, among other factors, Dr. Krieger said. – *The New York Times (2013)*

> There are some experts who argue that eight hours of sleep a night may not really be necessary. Jim Horne, with the sleep research laboratory at Loughborough University in England, says many people do very well on seven … hours a night. "I don't think the evidence is strong enough (to support sleeping eight hours). – *USA Today (1998)*

So how much sleep do we really need? The medical answer conveyed through the news is: “it depends.”

This may, in fact, have driven topic 60 which focused on personal recommendations. Because normative sleep is poorly defined, sleep appears to be a subject for advice in a way that other health outcomes such as cardiovascular disease, stroke, and broken bones are not. The latter seem to carry more standardized recommendations for medical treatment, whereas sleep is somewhat medical, somewhat personal, and somewhat placed in the context of other aspects of daily living.

Summary

Media discourse around sleep is at once consistent and complex. The *why*, *how*, and *what* of sleep consistently and increasingly occupy the nation’s broadsheets (or websites). The lone exception is that the U.S. media seems to be paying less attention to sleep medication in recent years. This drop in medication topical prevalence is juxtaposed with the 3- to 4-fold increase in

topical prevalence of the health consequences of poor sleep and the consistent attention paid to interplay of work and sleep. Consequently, news articles offer many strategies for the personal management of sleep.

But to what end? What is this sleep ideal we need to achieve? The media show some uncertainty over what should be considered normal or ideal sleep. The evidence does not suggest that ordinary, non-clinical sleep has become wholly medicalized, for the outcome of medicalization should not be mass confusion over what constitutes ideal sleep. Furthermore, naps are a source of contention in American culture. On the one hand, naps are endorsed by the medical community and should have gained legitimacy. On the other hand, there seems to be a pervasive cultural reluctance to engage in napping. If sleep had become fully medicalized, would it not be viewed predominantly through the lens of medicine than through the Protestant culture that informs our work ethic?

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Chapter 3.

Sleep as embodied

Title: Social support, social strain, sleep quality, and actigraphic sleep characteristics: evidence from a national survey of US adults.

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Objectives: To determine the associations between average family and friend social support and strain over 10 years and multiple sleep measures: sleep quality, sleep efficiency, total sleep time, and night-to-night total sleep time variability.

Participants: Non-institutionalized English speaking US adults aged 34-81 who participated in the MacArthur Study on Aging: Midlife in the United States (MIDUS).

Measurements: Sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI) and by a 7-day daily diary. Sleep efficiency, total sleep time, and night-to-night total sleep time variability were assessed by actigraphy (MiniMitter 64).

Results: Social support, but not social strain, was significantly associated with both self-reported measures of sleep quality (social support $\beta = -1.239$, $p = 0.019$ for global PSQI scores; social support $\beta = -0.248$, $p = 0.016$ for diary assessed quality). Lower scores on both quality measures indicate better sleep. In contrast, social strain, but not social support, was significantly associated with sleep efficiency (social strain $\beta = -3.780$, $p = 0.007$) and night-to-night sleep variability (social strain $\beta = 0.421$, $p = 0.034$); however, the overall model was not significant ($F = 1.54$, $p = 0.088$, $n = 236$). Neither social support nor social strain was significantly associated with total sleep time.

Conclusion: Future research on social relationships and sleep should analyze both positive and negative aspects of relationships in tandem because effects appear to differ based on outcome.

Keywords: Social support, social strain, sleep quality, sleep efficiency

Introduction

The consequences of poor sleep are increasingly understood to affect health, from mortality risk to cardiovascular disease, obesity, diabetes, and many others (see Czeisler 2015 for a summary).1-5 The significance of sleep to health begs the question: what contributes to poor sleep? The determinants of sleep can be found at different levels of analysis, from the genetic to the social. This paper operates at the social psychological level to understand how social support and social strain from family and friends may impact both subjective and objective sleep characteristics. The sleep literature at the social psychological level tends to consider three aspects of social relationships: social support, loneliness, and social strain, which are operationally defined as *perceptions* of the supportive, lacking (in connection), or strained aspects of the individual's social network.

The first aspect is social support. Seminal work by Cassel and Cobb in the 1970's established social support as a significant protective factor for a variety of health outcomes.6-8 These protective effects appear to hold for many aspects of sleep; conversely, a lack of social support is predictive of poor sleep. Low social support is associated with increased odds of shorter self-reported sleep duration, whether duration is operationalized as ≤6 hours, ≤7 hours, or perceived days of insufficient sleep per week.9-11 When sleep was assessed by actigraphy, however, different results were obtained: emotional support was not predictive of total sleep time (or sleep quality) but was predictive of lesser wake after sleep onset.12 Despite some differences between subjective and objective sleep outcomes for total sleep time, it appears that supportive social relationships generally have a positive effect on sleep.

Supportive social relationships are thus highly desirable. When people want social connectedness and yet have their wishes frustrated, the result is conceptualized as loneliness.

Loneliness, the second aspect of social relationships, is defined as a *perception* of a lack of social connection. Loneliness contributes to poor sleep efficiency, poor daytime function, and sleep fragmentation, but not sleep duration.13-15 The mechanism by which loneliness affects sleep may include "feelings of vulnerability and unconscious vigilance for social threat, implicit cognitions that are antithetical to relaxation and sound sleep."16 (p 4)

However, as desirable as relationships may be, relationships can themselves be a source of strain. Thus, a third approach builds on the social support literature to include the negative aspects of social relationships. It is important to note that the presence of strain does not necessarily imply the absence of support, for there is evidence to suggest that social support and strain are independent.17, 18 Since a lack of social support is not the same as the presence of strain, analysis of support alone would yield a partial understanding of the effect of social relationships on sleep. To date, however, few articles on sleep have included social strain.19, 20 This appears to be an oversight because the literature indicates that the effects of the negative aspects of social relationships on well-being generally tend to be either as powerful or even more-so than the positive aspects of social relationships.[21] If this proposition holds for sleep, then negative aspects of social relationships may have a greater effect on sleep parameters.

This third line of research typically analyzes support and strain together. It consistently finds that negative aspects of relationships influence sleep. High levels of family strain and low levels of family support produce the highest odds of reporting weekly/daily sleep problems.19 Interpersonal distress is correlated with sleep and arousal.22 Aversive social ties correlate with poorer self-reported sleep quality, and supportive ties correlate with better sleep quality, with depression as a significant mediator.20

Strides have thus been made toward a fuller understanding of how social relationships affect self-reported sleep. However, it is well-known that self-reported and objectively measured sleep outcomes often yield different results, which suggests that they may be distinct phenomena deserving separate analysis.23-25 Additionally, some aspects of self-reported sleep such as global sleep quality and sleep problems do not have straightforward objective analogues. Thus, the literature has left open to investigation whether social support and strain are associated with *objectively* measured sleep parameters such as total sleep time (TST), sleep efficiency (SE), and night-to-night variability in total sleep time, a parameter of increasing interest due to its association with depressive symptoms and subjective well-being.26, 27 Further, it is unknown whether social support or strain will have the larger effect on objective sleep parameters and if results differ with self-reported sleep. A study employing both objective and subjective sleep outcomes may provide a clearer picture of the effects of social relationships on sleep.

Thus, the questions that motivate this study are: What are the contributions of social support and social strain to sleep quality, efficiency, total sleep time, and night-to-night total sleep time variability? Which has the greater effect on sleep, social support or social strain? It is hypothesized that support should be predictive of higher sleep quality, sleep efficiency, total sleep time, and lower night-to-night total sleep time variability. Social strain, on the other hand, should be predictive of lower sleep quality, sleep efficiency, total sleep time, and higher night-to-night total sleep time variability. However, if a comparative claim can be made, strain may have the larger effect, consistent with the literature on well-being.21 This paper thus considers the associations between positive and negative aspects of social relationships and sleep using multiple objective sleep parameters. Further, this paper analyzes sleep in a subset of a national probability sample, which is demographically diverse in age, gender, and marital status.

Participants and Methods

Data are drawn from the MacArthur study on Midlife Development in the United States (MIDUS), a national probability sample of non-institutionalized English speaking adults in the contiguous United States obtained by random digit dialing, aged 34-84 at Wave II. Of the several waves, the first and second waves of MIDUS (1994-1995; 2004-2006) and the Biomarker supplement (2004-2009) are utilized. Of the 7,108 respondents at Wave I, 4,963 also responded at Wave II. A subsample of this population, 1,255 respondents, was assessed for the Biomarker supplement; data were collected 5 to 64 months after Wave II. A further subsample participated in the sleep study. After exclusion of missing values on covariates and outcome variables, the total number of observations is 236.

The MIDUS study included a subset of twins and siblings. These observations are retained, necessitating the use of cluster robust standard errors. Cluster robust standard errors allow for intraclass correlation and compensate for overly precise estimates in regressions with possibly dependent observations by inflating standard errors and thus widening confidence intervals. 28

Outcome variables

Sleep quality was assessed in two ways. The first is the Pittsburgh Sleep Quality Index (PSQI), a widely used and well-known survey instrument intended to measure sleep quality over the previous month. It consists of 19 items used to form 7 component scores: Subjective sleep quality, Sleep latency, Sleep duration, Habitual sleep efficiency, Sleep disturbance, Use of sleeping meds, and Daytime dysfunction. Scores are coded and summed into a global score with a possible range of 0 – 21. 29 Lower scores represent better sleep.

Participants who completed the biomarker assessment were invited to complete a subsequent 7-day daily diary and actigraphy study. In the daily diary, respondents rated the

overall quality of their sleep the previous night on a scale of 1 (very good) to 5 (very poor). The phenomenon of interest is patterns of sleep quality, and thus the average of these 7 scores was calculated. Lower scores represent better sleep.

Total sleep time (TST) and sleep efficiency (SE) were calculated by data collected from actigraphs, a sensor worn on the wrist of the non-dominant arm that allows tracking of movement. The actigraph used in MIDUS was the MiniMitter Actiwatch 64. Actigraphy is particularly informative of sleep patterns as wrist actigraphs are relatively inexpensive, non-invasive, and record data that allow for the calculation of total sleep time, wake time, wake bouts, sleep efficiency, and many other features of sleep that are useful to the researcher. The 7 TST and SE scores from each night were averaged to form an average of total sleep time (TST) and sleep efficiency (SE) over 7 nights. To capture variability across the 7 nights, night-to-night TST variability was calculated using mean squared successive differences (MSSD).26, 30 MSSD was calculated by the differences in successive TST squared, summed, and divided by n-1. This variable was log transformed for normality (log MSSD Shapiro-Wilk $p = 0.302$). All outcomes were tested for significance of association with each other by Pearson correlation (Table A.1).

Social support and strain

The primary independent variables of interest are social support and social strain. Social support and strain are constructed variables that are intended to measure, for support, "one's perceived notions of the caring and understanding exhibited by the network," and for strain, "individuals' general perception of the critical, irritating, and unreliable nature of their network."31 (p 7) There are three network domains: family, friend, and spouse. For friends and family, respondents were asked four support questions: how much friends or family "care about you," "understand the way you feel," "how much you can rely on them," and "how much you

can open up to them"; strain questions asked how often friends or family "make too many demands on you," "criticize you," "let you down when you are counting on them," and "get on your nerves". Spouse support and strain asked similar questions and two more in addition: support questions asked how much can the respondent "relax and be yourself around him or her" and how much does one's spouse "appreciate you"; strain questions asked how often does "he or she argue with you" and "make you feel tense." (See Walen and Lachman 2000 for a detailed treatment)

The domains of interest for this analysis are family and friends. Spousal characteristics were excluded for four reasons. First, the mechanisms by which a bed or cohabitating partner affects sleep (e.g. snoring, child caregiving, marital satisfaction) plausibly differ from how family and friends affect sleep, and much of the spouse literature appears to be specific to spouses, or spouses with children, and not social relationships in general. Second, the inclusion of spousal variables results in a loss of nearly a third of the sample since a precondition for reporting spouse support and strain is having a spouse; some others simply did not respond. Third, a spousal analysis may represent a selection bias of the sample.32 Finally, it is not clear that spousal variables are fully commensurable with friend and family variables (see above). For these reasons, a dedicated analysis on the important domain of spousal relationships seems warranted, and the current paper focuses on family and friends. Thus, social support and strain are constructed as the average between family and friend support and strain, and averaged again between Waves I and II (see Yang, Schorpp, and Harris 2014 and Yang et al. 2016 for a similar treatment).33, 34

Levels of average family and friend social support and strain remain relatively stable across a 10-year interval, the modal change is no change, and the vast majority of the

variance is captured within one unit on either direction of 0 if Wave I support and strain scores are subtracted from those from Wave II. The object is to capture long-term patterns in social relationships, and thus averages of both waves are utilized instead of using data from one wave only. The assumption is that average levels of support and strain across a decade would not change drastically in the short time between social relationship measurement and sleep measurement.

Control covariates

The following control covariates were included based on prior literature and preliminary bi-variate tests of association and regression analyses: Self-rated health35, dyspnea36, and number of chronic conditions36 as physical health controls; depression20 (in its dichotomous form as measured by the screening version of the Composite International Diagnostic Interview) as a psychological health control; and age[37], gender[38], and marital status as demographic controls.[b] Race was omitted because the race/ethnicity of study participants is relatively homogenous. Educational attainment, household income, and employment status were found to be not significant in bi-variate tests of association with the outcomes and/or independent variables of interest and/or not significant as effects in regression models, thus were not included in the final analysis. The actigraphy and daily diary analyses include several additional covariates collected in the daily sleep diary: minutes of moderate or vigorous exercise, number of caffeinated drinks, and number of alcoholic drinks were reported by respondents and averaged across the seven days of data collection and included as controls. However, these variables were not included in the PSQI analysis because the data were not collected at the same time. The data were cleaned in R and analyzed and visualized in R and STATA SE/IC 14.

[b] There was only one individual reporting Poor self-rated health; this was recoded to Average health.

Descriptive statistics and plots

[Table 1: Descriptive statistics about here]

Analytic strategy

Ordinary Least Squares (OLS) regression was used to regress social support and strain on all sleep variables, including the Pittsburgh Sleep Quality Index (PSQI). Although the PSQI is discrete-quantitative, it is under-dispersed (mean = 5.64, sd = 3.21) and thus violates the Poisson assumption that the mean and variance parameter are equal. Negative Binomial models are not used because while these models are generalizations of the Poisson, these models can account for over, but not under, dispersion. The assumption in the OLS analysis is that the discrete quantitative PSQI data arose as a result of an underlying normally distributed data generating process. Average sleep quality obtained from the daily diary is approximately normally distributed but does not pass a Shapiro-Wilk test ($p = 0.032$). Sleep efficiency is uni-modal, left-skewed, and right truncated since efficiency cannot surpass 100% (actual max = 93.6%). The statistic of interest is the conditional mean, the univariate mean does not differ substantially from the median (median = 79.51, mean = 82.76), and therefore Ordinary Least Squares regression is used. Total sleep time (Shapiro-Wilk $p = 0.078$) and log transformed MSSD (Shapiro-Wilk $p = 0.302$) are approximately normally distributed. Cluster robust standard errors are reported (clustered on family number). In all regressions, the largest category by frequency is set as the reference (e.g. married, female, not depressed, etc.). Models were checked for multicollinearity by variance inflation factors. Functional form specification was tested by the Ramsey RESET test for omitted variable bias by the powers of the fitted values and powers of the independent

variables. Residuals were checked visually by their distributions and by a Shapiro-Wilk test for normality.

Results

[Table 2 about here: Regression results]

For the PSQI, social support is significant ($\beta = -1.239$, $p = 0.019$). The 95% confidence interval indicates that with each unit increase in social support, a respondent's PSQI score is plausibly expected to decrease (better quality) anywhere from 0.206 to 2.271 units. Social strain is not significant ($\beta = 0.079$, $p = 0.876$). This model accounts for approximately 20.33% of the variance ($F = 4.01$, $p < 0.001$, $n = 236$).

For average daily diary reported sleep quality, social support is significant ($\beta = -0.248$, $p = 0.015$). The 95% confidence interval indicates that with each unit increase in social support, sleep quality scores are expected to decrease (better quality) anywhere from 0.049 to 0.447 units. Social strain is not significant ($\beta = 0.102$, $p = 0.406$). This model accounts for approximately 14.02% of the variance ($F = 2.78$, $p < 0.001$, $n = 236$).

For sleep efficiency, social strain is significant ($\beta = -3.780$, $p = 0.007$) whereas a similar claim cannot be made for social support as it is not significant at the 0.05 level ($\beta = -1.999$, $p = 0.111$. The 95% confidence interval for social strain indicates that sleep efficiency is expected to decrease anywhere from 1.066 to 6.494 percentage points with each unit increase in social strain. This model explains approximately 23.3% of the variance ($F = 3.74$, $p < 0.001$, $n = 236$).

For total sleep time, neither support nor strain was significant (social support $\beta = -0.119$, $p = 0.434$; social strain $\beta = 0.024$, $p = 0.903$). Very few covariates were significant. Sex was significant with males sleeping on average, 39.15 fewer minutes than females ($p < 0.001$). This model accounts for approximately 16.1% of the variance ($F = 2.70$, $p < 0.001$, $n = 236$). A logistic regression run on total sleep time split into dichotomy at <7 hours (not shown) produced

similarly insignificant results for support and strain (social support p = 0.288, social strain p = 0.539).

For log transformed night-to-night variability in total sleep time, social strain is significant (β = 0.421, p = 0.034) whereas social support is not significant (β = -0.011, p = 0.948). Aside from social strain, only one other covariate, number of chronic conditions, was significant (β = 0.088, p = 0.028). However, the full model was not significant (F = 1.54, p = 0.088, n = 236).

Discussion

Results from this analysis suggest that social support, but not social strain, is consequential for subjectively assessed sleep quality. This partially supports Ailshire and Burgard's (2013) and Kent et al.'s (2015) findings that both support and strain contribute to self-reported sleep problems or quality.[c] [19, 20] The mechanisms by which support may protect sleep quality specifically can only be speculated at this point, though social support as a protective factor for health generally is a well-studied concept. See Cohen, Underwood, and Gottleib (2000) or Thoits (2011) for a discussion of social support measures and mechanisms.39, 40

Different results were obtained with objective actigraphic assessed parameters. Objectively assessed sleep efficiency was not associated with social support while significantly associated with social strain. For objective sleep efficiency, since only social strain was significantly associated with sleep efficiency, it has the greater effect. Social strain might operate

[c] In a preliminary analysis of the PSQI in a larger sample (n = 947), both support and strain were significant in regressions with the PSQI used both as a continuous and dichotomous (>5) outcome. This larger sample (n = 947) is comparable to the reported sample (n = 236) in mean age (55.17 vs 53.61), proportion of females (0.53 vs 0.56), and marital status (proportions of 0.72 vs 0.75 married; 0.14 vs 0.10 divorced; 0.05 vs 0.05 widowed; 0.08 vs 0.10 never married, respectively). The failure to find significance for social strain in the current analysis for the PSQI may derive from reduced statistical power. Further research may test this hypothesis. Analyses available on request.

through a similar mechanism as loneliness: heightened vigilance. Further research may test this pathway.

Total sleep time appears to be insensitive to both social support and strain as measured and analyzed for this paper. This result is consistent with that of Troxel et al. (2010) who similarly did not find significant effects for support on actigraphy assessed total sleep time.[12] The literature on social relationships and total sleep time or insufficient sleep appears to be mixed (see introduction). How social relationships and sleep are measured (i.e. actigraphy, perceived insufficiency, self-reported duration) may matter. While social strain was significantly associated with night-to-night total sleep time variability, and indeed was one of only two covariates significant in the model, the overall model was not significant.

Support was significant for self-reported sleep quality and not for objective sleep efficiency; however, this does not diminish the importance of sleep quality because self-reported sleep quality and objective efficiency are not equivalent aspects of sleep. It was earlier suggested that subjective and objective assessments of sleep may represent distinct phenomena. For example, it has been suggested that the PSQI may, in fact, measure dissatisfaction or psychological symptoms rather than sleep characteristics.[24, 25] If this is true, then the results of this paper suggest that social support is associated with psychological characteristics operationalized as sleep quality, but not actual sleep. Therein may lie the striking difference in empirical results.

It is worth noting, however, that global PSQI scores were significantly associated with all actigraphic sleep parameters in bi-variate tests of association (Table A.1), consistent with a previous analysis using MIDUS data.[27] The interpretation here would be that the PSQI measures psychological symptoms, and that these psychological symptoms are significantly associated

with objective sleep measurement. Still, the fact that there are significant associations between the PSQI and sleep characteristics is noteworthy, because these results contrast with earlier reports that did not find any statistically significant associations between PSQI scores and total sleep time or sleep efficiency obtained by actigraphy or polysomnography.[24, 25] There are several possibilities for the lack of agreement. First, the current analysis includes data with possibly dependent observations; however, after further subsetting to remove dependence, PSQI scores were still significantly associated with actigraphy parameters. Second, the PSQI and actigraphy data were not collected at the same time in MIDUS, although this would seem to make correlation less likely, not more. A third more likely explanation is that different results were obtained because they were tested on different samples. Since it was not the intent of the current analysis to test the concordance of the PSQI and actigraphy parameters, further investigation may be warranted.

This paper has several limitations. First, this paper focused on chronic levels of support and strain and thus did not address acute events of support and strain. The shorter-term effects of social relationships were not captured in this analysis. Furthermore, this paper operated at the social psychological level. As such, perceptions of social support and strain were analyzed, not actual or received support and strain. The literature indicates that social support is variously measured. Thus, care should be taken to be explicit about how social support is operationalized and measured.[39]

Second, for theoretical and practical reasons, spouses were omitted from the analysis. A rich sociological literature indicates that there are many important aspects particular to spousal relationships and sleep such as marital satisfaction, night-time caregiving, snoring, and children coming home later at night.[41-43] Many of these articles highlight a distinct inequality for females.

Thus, the effects of spousal support and strain on sleep parameters deserve more attention in a dedicated analysis with a theoretical framework that emphasizes gender. Another omission was race. The data for this analysis, while diverse in age, gender, and marital status, were not diverse in race. Thus, the results may only generalize to white American adults. Whether the findings hold for other racial/ethnic groups remains an open question.

A final limitation lies in the uncertain direction of causation. While all sleep parameters were measured after support and strain were measured, causality cannot be inferred. For example, it is possible that the sleep data in MIDUS represent patterns of sleep that existed previous to measurement of support and strain; sleep could have simply been measured after support and strain instead of being influenced by them. The relationship between sleep and social relationships may be bi-directional; longitudinal research may test this hypothesis.

Despite these limitations, this paper advances knowledge of the associations between family and friend relationships and multiple sleep parameters, adding to the broader literature of the social determinants of sleep. In *The Civilizing Process* (1939), Norbert Elias observed that "sleeping has been increasingly shifted behind the scenes of social life."[44 (p 138)] While this may be historically true, sleep appears to remain sensitive to social influences, a fact that becomes clearer with each addition to the growing literature on the social determinants of sleep.

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Appendix A

[Table A.1 about here]

Tables

Table 1.

Descriptive statistics[a] for data drawn from Midlife in the United States: A National Longitudinal Study of Health & Well-Being (n = 236).

Statistic	**N**	**Mean**	**St. Dev.**	**Min**	**Max**
PSQI	236	5.644	3.213	1	17
Daily sleep quality	236	2.315	0.680	1	4.857
Sleep efficiency	236	82.759	8.132	44.271	93.609
Total sleep time	236	6.410	0.985	2.556	9.562
log MSSD[b]	236	8.454	1.009	5.511	10.611
Support	236	3.397	0.462	1.875	4
Strain	236	1.966	0.397	1	3
Age	236	53.610	11.668	34	81
Female	133	0.564			
Marital Status					
Married	178	0.754			
Divorced	23	0.097			
Widowed	11	0.047			
Never married	24	0.101			
Self-Rated Health					
Average	19	0.085			
Good	68	0.288			
Very Good	101	0.428			
Excellent	48	0.203			
Depressed	22	0.093			
No. chronic conditions	236	2.089	1.967	0	10
Dyspnea	236	0.424	0.695	0	3
Average alcoholic drinks	236	0.561	1.05	0	7.286
Average minutes of exercise	236	39.988	47.640	0	377.143
Average caffeinated drinks	236	2.432	2.031	0	12.143

a Note: proportions reported for categorical variables. Log MSSD is the log of the mean square of successive differences in total sleep time (night-to-night total sleep time variability).

Table 2.

Ordinary Least Squares regression results[a, b] of social support and social strain on Pittsburgh Sleep Quality Index (PSQI) global scores, daily sleep quality, sleep efficiency (SE), total sleep time (TST), and night-to-night variability in total sleep time (logmssd). N = 236.

	PSQI	Daily sleep quality	Sleep efficiency	Total sleep time	Night-to-night variability in total sleep time
	B	β	β	β	β
Support	-1.239*	-0.248*	-1.999	-0.119	-0.011
	(0.524)	(0.101)	(1.251)	(0.152)	(0.171)
Strain	0.079	0.102	-3.780**	0.024	0.421*
	(0.508)	(0.122)	(1.376)	(0.198)	(0.197)
Constant	9.158***	3.109***	106.624***	7.118***	7.705***
	(2.549)	(0.697)	(6.983)	(0.920)	(0.882)
Observations	236	236	236	236	236
R^2	0.2033	0.1402	0.2334	0.1610	0.0882
F Statistic	4.01***	2.78***	3.74***	2.70***	1.54

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

a Note: Models adjusted for age, sex, marital status, self-rated health, depression, number of chronic conditions, and dyspnea. Average daily sleep quality, sleep efficiency, total sleep time, and night-to-night variability in total sleep time models additionally adjusted for average minutes of exercise, average alcoholic drinks, and average caffeinated drinks. Lower values on the PSQI and the daily sleep diary represent higher quality sleep. Cluster robust standard errors reported in parentheses.

b Note: The fully adjusted model results (reported in the table) are substantively similar to parsimonious models in which only socio-demographics (age, sex, and marital status) are controlled for. In these reduced models, support and strain remain significant or non-significant consistent with the reported results. Analyses available on request.

Table A.1.

Pearson correlations of the Pittsburgh Sleep Quality Index (PSQI), daily sleep quality, sleep efficiency (SE), total sleep time (TST), and night-to-night variability in total sleep time (log MSSD)[a].

	PSQI	Daily sleep quality	SE	TST
Daily sleep quality	0.434 (<0.001)			
SE	-0.205 (0.002)	-0.086 (0.191)		
TST	-0.131 (0.044)	-0.001 (0.991)	0.572 (<0.001)	
log MSSD	0.226 (0.001)	0.040 (0.545)	-0.315 (<0.001)	-0.087 (0.182)

a Note: p-values reported in parentheses

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Chapter 4.

Sleep as embodied

Title: Three classes of sleepers, their social distributions, and associations with metabolic syndrome in an actigraphy and daily diary study of healthy, non-institutionalized US adults.

Abstract

Sleep health is multi-dimensional, comprised of adequate sleep, high efficiency, sufficient quality, alertness the following morning, and appropriate timing. (Buysse 2014) However, there is not a consensus method to operationalize the concept using objective and subjective sleep data. Using data from a 7-day actigraphy and daily diary study from the MacArthur study of Midlife Development, this paper offers: 1) an identification of clusters of adult US sleepers; 2) their socio-demographics; and 3) a demonstration of the clusters' utility by their associations with metabolic syndrome (operationalized according to the National Heart, Lung, and Blood Institute/American Heart Association's criteria). The cluster analysis revealed three populations of sleepers: those with good sleep health, poor sleep health, and intermediate sleep health. Sleep health clusters were patterned socio-demographically by sex, race, marital status, household income, and age. In multivariate analyses, the "good" sleep cluster showed 66% lower odds of having metabolic syndrome. In all, sleep health is well-operationalized by clustering, is patterned socio-demographically, and is associated with metabolic syndrome.

Introduction

Problematic sleep is a well-established risk factor for adverse health outcomes such as mortality (1), cardio-metabolic risk (2, 3), and mortality (4). Because sleep is a risk factor for serious health outcomes, and sleep is a modifiable behavior, poor sleep and sleep disorders are of exceptional population health interest. (5)

Paradigm shifts in conceptions of health, however, suggest that a negative focus on insufficiency, poor quality, or disorder is overly narrow. (6) The World Health Organization, for instance, defines health to encompass not only the absence of disease but the presence of well-being. (7) Similarly, sleep health is characterized by more than the absence of clinical disorders or insufficient sleep duration. A positive, more precise, definition of sleep health was advanced by Buysse (2014), (8) who has defined sleep health in terms of five aspects: "subjective satisfaction, appropriate timing, adequate duration, high efficiency, and sustained alertness during waking hours." (8) In Buysse's view, sleep health is a complete state, characterized by the presence of appropriately timed, sufficient, efficient, satisfying sleep that promotes high functioning the following day.

However, the literature has yet to settle on consensus approaches to how sleep health might be operationalized. This study has three aims: 1) to operationalize sleep health into clusters (SHC) using a variant of k-means clustering, sparse k-means; 2) to characterize SHCs by socio-demographics such as age, sex, race, marital status, and educational attainment; and 3) to assess the association of SHCs with metabolic syndrome.

Operationalizing sleep health

There are several possible approaches to operationalizing sleep health. One approach, for instance, might parallel that of allostatic load in which a summary index is created out of upper-quartile splits of individual sleep parameters. (9) Another might use predicted values of a factor analysis. Sleep data might be obtained via questionnaire (10), a validated survey instrument (11), daily diary, actigraphy, or polysomnography.

One operationalization of sleep health is the survey-based Sleep Health Index by the National Sleep Foundation. (11) The 28 item index measures three aspects of sleep: self-reported duration, quality, and disordered sleep in the past 7 days. Because it is survey-based and was validated on a national sample of US adults, it should prove valuable to large-scale population assessments of sleep health when objective sleep parameters are not feasible to obtain. The index has the additional attraction that the instrument is scored on a unidimensional scale out of 100 and is therefore easy for researchers and policy-makers to understand. (12)

While the benefits of a unidimensional scale are clear, one drawback is that such a scale may obscure distinctions among sleepers. This is because sleep health itself is not unidimensional. Rather, sleep health is multi-dimensional, situated, for instance, along the five dimensions of satisfaction, timing, duration, efficiency, and alertness. While some dimensions tend to correlate strongly (e.g. duration and efficiency), others correlate weakly or not at all (e.g. objective duration and subjective quality). (13, 14) Thus, individuals may show high sleep efficiency but report low alertness; sufficient sleep, and low quality. Multi-dimensionality does not preclude these seeming disagreements among aspects of sleep health. If the intent is to score respondents on a scale for ease of implementation, analysis, and interpretability, then a

unidimensional scale is justified and preferable. If, on the other hand, the intent is to distinguish types or classes of sleepers, an alternative approach is warranted.

Cluster analysis forgoes a unidimensional scale and instead partitions observations into distinguishable clusters. Observations belonging to the cluster have similar characteristics (intra-class similarity) while remaining distinguishable from those in other clusters (inter-class similarity). In sleep research, cluster analysis has been employed to detect novel sleep phenotypes (15), nighttime symptoms of PTSD (16), and associate various sleep health parameters with all-cause mortality (17). Thus, cluster analysis would greatly facilitate an understanding of the types of sleepers found in a healthy population. The first question that drives this paper is: what populations or clusters of sleepers are found in a healthy sample of U.S. adults and what is their social distribution?

Sleep health and metabolic syndrome

Sleep health derives its conceptual force not only from its positive orientation, but also the empirical associations of its components with health outcomes. One such outcome is metabolic syndrome[4]. Metabolic syndrome (metS) is defined as a "cluster of risk factors for cardiovascular disease and type 2 diabetes mellitus." (18) It is characterized by central obesity, raised blood pressure, dyslipidemia (raised triglycerides and lowered high-density lipoprotein cholesterol), and raised fasting glucose. Dysfunctional levels in any three of the five risk factors meet the diagnostic criteria for metS.

[4] A summary of sleep health parameters and their associations with other health outcomes can be found in Buysse 2014.

Several sleep parameters have been found to associate significantly with metS. Self-reported short sleep duration (<6 or 6-7 hours) was significantly associated with increased odds of having metS in a regional sample of 1,173 southwestern adult Pennsylvanians. (19) Other self-reported measures such as sleep quality have similarly been linked to metS: global Pittsburgh sleep quality scores were predictive of increased odds of metS in a similar Pennsylvanian sample. (20) Finally, reports of unrefreshing sleep, difficulty falling asleep, and loud snoring have been linked with significantly increased odds of having metS. (21) Various aspects of sleep appear to have various associations with metS. Thus, the second question that drives this study is: are sleep health clusters associated with metabolic syndrome? That is, does a positive orientation of sleep health operationalized into clusters show clinical utility?

In summary, the research questions that motivate this paper focus on how to operationalize sleep health into clusters, whether this operationalization has any clinical utility, and whether the social distribution of the clusters (e.g. by race, age, marital status, sex, education) mirrors that of other well-known inequalities in health generally.

Participants and methods

Data were drawn from the MacArthur study of Midlife Development in the United States (MIDUS), a longitudinal, national sample of non-institutionalized adults living in the contiguous United States, obtained by random digit dialing. Wave I (1995-1996) featured 7,108 respondents; Wave II (2004-2006) featured 4,963 respondents. Due to under-representation of minorities in the sample, additional data were collected in Milwaukee county, Wisconsin on a sample of 600 black respondents (2005-2006).

Both MIDUS II and Milwaukee project respondents were invited to participate in a biomarker study at one of three General Clinical Research Centers (GCRC). A total of 1,255

participants provided a detailed medical history, completed questionnaires, and had current medications inventoried by project staff. Fasting blood, 12-hour urine, and saliva samples were taken. One of the GCRCs, the University of Wisconsin-Madison, additionally recruited a subsample of individuals for sleep assessment through a 7-day actigraphy and daily diary study. A total of 385 respondents had complete sleep data. Participants wore actigraphs (MiniMitter Actiwatch sensor on the non-dominant wrist) and completed a daily sleep diary for one week beginning on a Tuesday. Details on data collection, participation rates, and cross-project participation have been published elsewhere (22); exemplar studies using MIDUS data to associate sleep and biomarker parameters can be found in references (3, 23-25).

Drawing from Buysse's 2014 definition of sleep health, the sleep variables of interest are 7 days of total sleep time (tst), sleep efficiency (se), quality, and alertness. Only respondents with complete information across all 7 days were retained. Tst and se were obtained from actigraphy: epochs of 30 seconds were coded as either "sleep" or "awake" based on respondent movement. Quality and alertness were obtained from the daily sleep diary. Respondents were asked on a scale of 1 (very good) to 5 (very poor) to rate the i) quality of their sleep the previous night and ii) feelings of alertness that morning. Responses were reverse coded such that higher scores reflected better sleep.

Clustering

Sleep health clusters were assigned by sparse k-means clustering. Sparse k-means is an unsupervised clustering technique used to assign observations to one of k clusters when the number of parameters presented to the clustering algorithm (e.g. 28) is large relative to the number of observations. (26) Sparse k-means achieves sparsity (and thus avoids overfitting) by applying an L1 (lasso) penalty. As in lasso regression, some weights (aka beta coefficients in

regression) can be shrunk towards zero, effectively down-weighting variables that do not contribute highly to explaining overall variance.

The data used to compute clusters were 7 days/nights of tst, se, quality, and alertness the following morning, for a total of 28 variables (7 measurements x 5 constructs)[5]. The data were centered and scaled such that each sleep parameter had a mean of 0 and standard deviation of 1[6]. Observations were then assigned to sleep clusters. The number of clusters was determined by several methods (details in Appendix A). First, a within sum-of-squares plot was produced (Figure A1.) There is an elbow at three clusters, after which there are diminishing returns in reduction of variance. Second, 30 separate indices were used to determine the best number of clusters. Among the 30 indices are common cluster validation statistics such as the Gap, KL (Krzanowski and Lai), Hartigan, and silhouette statistics, etc. (see Charrad, et al. 2014 for more details) (27) A majority of the indices indicated a 3-cluster solution[7]. (Table A1; Figure A2) Finally, cluster stability was assessed, with 3 clusters providing the least instability (Figure A3). (28, 29) Because the balance of evidence pointed to a 3-cluster solution, sparse k-means clustering was used to assign individuals to clusters with k = 3.

Metabolic syndrome

Metabolic syndrome (metS) was operationalized by the National Heart, Lung, and Blood Institute/American Heart Association criteria as the presence of elevated or clinical levels in any three of the following five biomarkers: waist circumference (> 102 cm for men and > 88 cm for women), triglycerides (>= 150 mg/dL), reduced HDL-C (<40 mg/dL in males; <50 mg/dL in

[5] While sleep timing (i.e. shift work) is an aspect of sleep health, this variable was not included - only 11 individuals reported shift work as defined by self-reports of 1) being employed and 2) beginning work in the P.M. Only one individual each was present in clusters 1 and 3, rendering inference untenable. Furthermore, k-means clustering is inappropriate for dichotomous or categorical variables.
[6] The distributions of correlations between the 28 sleep variables can be found in Figure B1
[7] Cluster validation results are similar if 7-day averages of tst, se, quality, and alertness are considered in a 4-variable model of k-means.

females), blood pressure (systolic >= 130 or diastolic >= 85 mm Hg), and fasting glucose (>= 100 mg/dL). (18) Each biomarker was dichotomized at the recommended cut-points and summed into a metS symptom score. For a categorical decision, the metS symptom score was dichotomized at $\geq$3 to represent metS. 37.9% of the final sample was categorized as having metS. This is similar to but slightly greater than prevalence estimates of 34% of metS in a larger sample of US adults around the same time period (2003-2006; n = 3,423). (30)

Covariates

To assess the social distributions of sleep health, the covariates of interest are age, sex, race (white, black), married (dichotomous), educational attainment (high school diploma or less vs more than high school), and total household income. Insufficient numbers of other races precluded their inclusion, and thus only blacks and whites were considered.

In multivariate analyses regressing on metS, several known correlates of sleep and/or metS were added: depressive symptoms, smoking status (ever smoked regularly - dichotomous), regular exercise (3 times/week, at least 20 minutes – dichotomous), use of blood pressure or cholesterol lowering medication (both dichotomous), and fast-food consumption (never, less than once a week, more than once a week). (31-38) Depressive symptoms were measured by the Center for Epidemiological Studies-Depression scale (CES-D). (34) Since the CES-D includes a question on restless sleep, scores from that question were subtracted from overall CES-D scores. Blood pressure and cholesterol lowering medications were brought by respondents and inventoried by project staff at the University of Wisconsin GCRC concomitant with biomarker collection. After exclusion for missingness, the final sample size is 330.

Analytic strategy

First, to inform multivariate analyses, bivariate associations between SHCs and covariates were assessed. Second, SHCs were compared against 7-day averages of tst, se, quality, and alertness in multivariate regressions on metS symptoms and metS. Each sleep characteristic was substituted into regressions to compare their effects. While the metS symptom score is discrete-quantitative, it is under-dispersed (mean = 2.08, variance = 1.83), violating the Poisson assumption that the mean and variance parameter are equal. Thus, for metS symptoms, Ordinary Least Squares (OLS) regression was used. For metS, logistic regression was used; odds ratios are reported. All regressions are adjusted for age (centered), sex, race (black vs white), married (married vs not married), educational attainment (high school or less vs more than high school diploma), household income, depressive symptoms, smoking status, regular exercise, fast food consumption (never, <1x a week, >1x a week), and the use of cholesterol or bp lowering medications. The poor sleep cluster was used as the reference; coefficients of the good and intermediate clusters are reported.

[Table 1 about here]

[Table 2 about here]

[Figure 1. Total sleep time, sleep efficiency, sleep quality, and alertness decomposed by cluster. N = 330.]

Results

What types or clusters of sleepers are there? Cluster validation suggested that 3 distinct groups of sleepers were present in the sample (see methods and Appendix A). Figure 1 shows the distribution of 7-day averages of tst, se, quality, and alertness by cluster[8]. There are good and

[8] Hereafter, 7-day averages of tst, se, quality, and alertness are reported for parsimony instead of each of the 28 sleep parameters.

poor sleepers whose sleep characteristics differ significantly across all four domains of tst, se, quality, and alertness (Table 2). There is also a third category of sleeper: those whose actigraphy measured tst and se are indistinguishable from those of good sleepers (post-hoc Tukey $p = 0.858$, $p = 0.334$, respectively), yet whose diary reported quality and alertness are worse than those of poor sleepers (Tukey $p < 0.001$, $p < 0.001$, respectively).

Are these sleep clusters socially patterned? Clusters were significantly associated with sex ($p = 0.006$), race ($p = 0.001$), marital status ($p = 0.007$), household income ($p = 0.042$), and age ($p = 0.001$). Educational attainment was not significantly associated ($p = 0.305$; see Table 2). The lowest marginal proportions of respondents in the poor sleep health category were white, female, and married; those in the poor category also tended to be younger and less wealthy.

[Figure 3: OLS regression results]

[Figure 4: Logistic regression results]

Do sleep health clusters have clinical utility? Figure 3 shows linear regression results comparing different sleep health attributes (cluster, tst, se, quality, alertness) and their associations with metS symptoms. Both the good and intermediate SHCs were associated with a reduction in metS symptom scores. Those in the good sleep cluster are expected to have, on average, anywhere from 0.31 to 1.25 fewer symptoms of metS compared to poor sleepers ($\beta = -0.78$, $p = 0.001$). Those in the intermediate cluster are expected, on average, to have anywhere from 0.02 to 0.92 lower symptom scores of metS ($\beta = -0.47$, $p = 0.042$) compared to poor sleepers.

Alertness had modest associations with metS symptoms. With each unit increase in alertness, metS symptom scores are expected to drop anywhere from 0.01 to 0.45 units (β = -0.23, p = 0.044). Tst (p = 0.340), se (p = 0.054), and quality (p = 0.056) were not significant.

Figure 4 shows logistic regression results comparing different sleep health attributes (cluster, tst, se, quality, alertness) and their associations with metS. For SHCs, only the good cluster (OR = 0.34, p = 0.006) was significant. Those in the good cluster are expected to have 66% lower odds of having metS. Quality (OR = 0.71, p = 0.048) and alertness (OR = 0.67, p = 0.032) also showed modest, but significant associations. With each unit increase in quality, odds of having metS are expected to drop anywhere from 1% to 50%. With each unit increase in alertness, odds of having metS are expected to drop anywhere from 4% to 54%. Tst and se were not significant at the 0.05 level in full models (p = 0.474, p = 0.193).

Discussion

Three broad conclusions may be drawn from these analyses. First, sleep health is well operationalized by clustering, consistent with previous approaches. (15, 17) Second, sleep health is socio-demographically patterned. Third, sleep health has clinical utility. Cluster analysis suggested three distinct types of sleepers: good, intermediate and poor. Intermediate sleepers had just as long and high total sleep time and efficiency as good sleepers, yet their self-evaluations of their sleep quality and alertness were far worse.

SHCs were patterned by age, sex, race, income, and marital status. The healthiest sleepers in the good category, tended to be older, wealthier, female, white, and married. Conversely, males, Blacks, and the unmarried tended to have lower probabilities of attaining “good” or even “intermediate” sleep. These results track well with existing knowledge of sleep differences. Women, for instance, tend to enjoy advantages in sleep duration, though this advantage is

counter-balanced by a reduction in leisure time, often through care-giving burdens. (39-42) Racial disparities in sleep are well characterized in the literature also, with whites having healthier sleep durations (i.e. neither too short or long), sleep quality, and other sleep parameters compared to blacks. (43-45) Income, education, and associated constructs such as socio-economic status are also known correlates of sleep disparities; those with the lowest income, those in poverty, or those having trouble making ends meet tend to have worse sleep quality and duration. (46, 47) Finally, the married tend to have longer sleep durations compared to the unmarried. (48) Spouses may act as "social zeitgebers" or "time keepers" while additionally functioning as a source of stress-buffering through social support. (49)

Good sleep health was significantly associated with reduced metS symptom scores in linear regressions. Although the intermediate cluster reached statistical significance in linear regressions on metS symptom scores, it did not reach practical significance since the 95% confidence interval did not suggest that an entire symptom of metS could be lowered by belonging to this category (i.e. the lower bound did not include -1). This is noteworthy because those in the intermediate category had high tst and se; it appears that having partially good sleep health may not be enough for a practically meaningful association with reduced metS symptom scores.

Good sleep health was associated with dichotomous metS (scores >= 3). In fact, the good cluster was the only significant covariate in the regression. When compared with logistic regressions substituting various sleep parameters for SHC, neither tst nor se was significant; quality, and alertness were significant but had modest effects with confidence intervals nearly reaching 1. That the good cluster showed markedly reduced odds of metS while its component

parts did not suggests it is the combination of such variables – through operationalization of sleep health as a whole – that achieves this significant association.

This study has several strengths. First, the method of operationalization is flexible: cluster analysis is able to accommodate additional sleep parameters. The present analysis operationalized sleep health closely in accordance with the original definition, but other research has effectively included other aspects of sleep such as rhythmicity and continuity. (17) Future research might consider adding such sleep parameters as well.

Second, the sample was socio-demographically diverse in age, sex, marital status, and educational attainment. Moreover, as a subset of a broader national study on successful midlife development, the sample had appropriately robust and varied measures for statistical control, such as depressive symptoms, health behaviors, and medication use.

Third, the accuracy of sleep health assessment was increased by using objective measures of sleep from actigraphy data. Retrospectively reported sleep duration is not only notoriously inaccurate at estimating objectively measured total sleep time, these inaccuracies appear to be systematically biased by race, obesity, depression, and apnea risk. (50) In one study with diary estimated duration, participants were poor judges of their own total sleep time, with over a third of participants (34%) reporting more than an hour's deviation of sleep duration than was measured by wrist actigraphy. (51) Operationalizing SHC with retrospective self-report or diary estimated sleep may thus provide different results.

Despite these strengths, several limitations warrant consideration. First, while the sample was socio-demographically diverse, minorities other than black were not included. For multiple racial/ethnic comparisons, a much larger sample size is likely required. Large population studies

of metS using National Health and Nutritional Examination Survey data, for instance, report significant differences in metS by age, race, and sex. (30, 52) That the current analysis failed to find significant socio-demographic associations with metS suggests insufficient statistical power.

Second, the data are considered cross-sectional in nature; several studies have treated the data as such, since both the biomarker and sleep data are part of the same MIDUS sub-project. (3, 23-25) Strictly speaking, however, sleep data were measured when respondents returned home from their GCRC visit, after biomarker collection. No causal claims can be made unless one begins with the assumption that the sleep data are representative of habitual sleep patterns that existed previous to biomarker data collection. Thus, the relationship between SHC and metS is associational, not causal. If causal, it may be that the relationship is bi-directional. Further studies may test this hypothesis.

Finally, while the use of objective sleep data may have increased accuracy, these measures are cost-prohibitive in many research settings. Indeed, a primary motivation for the National Sleep Foundation's Sleep Health Index instrument was for broader coverage in situations for which objective sleep assessment is not feasible. Until a large national sample of US adults is assessed by actigraphy, instruments like the survey-based Sleep Health Index will likely remain the most cost-effective option for future population research.

In summary, sleep health is a complex, multi-dimensional concept with a positive orientation. Its component parts have demonstrated links with various health outcomes; mounting evidence suggests the same for sleep health as a whole. This paper advances sleep health knowledge by demonstrating that sleep health can be operationalized by cluster analysis, that these sleep clusters are patterned by socio-demographics, and that sleep health clusters show significant association with metS.

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Appendix A. Cluster validation

The largest sample of complete sleep data was used for clustering and cluster validation (N = 385). Currently there is no consensus method of determining the optimal number of clusters. The most common method is the elbow method. K-means clustering is run with several values of k (e.g. k = 1, 2, …) up to a reasonable number (e.g. 15). The within-cluster sum of squares for each k is plotted against k. Analgous to a principal components scree plot, the "elbow" signifies a marked change in variance explained with each additional value of k. Our within-cluster sum of squares plot shows an elbow at 3 clusters:

[Figure A1. K-means clustering within group sum of squares plot]

Several other methods of cluster validation have been proposed. Charrad et al. (2014) have developed an R package, NbClust, which uses 30 different indices to determine the optimal number of clusters.(27) The optimal number of clusters is chosen by majority rule. For more details, see Charrad et al. 2014.

[Table A1. A comparison of optimal k by 30 different methods]

[Figure A2. NbClust dot plot of optimal k. N = 385.]

Finally, Ben-Hur, Elisseeff, & Guyon (2001) proposed a method to determine the optimal number of clusters based on clustering stability in the presence of perturbation by sub-sampling. (28) The normalized distribution of pairwise similarities in clustered sub-samples is considered a measure of stability.

[Figure A3. Normalized cluster instability: lowest instability at k = 3]

Tables

Table 1. Descriptive statistics[a] for data drawn from MIDUS: A National Longitudinal Study of Health & Well-Being. N = 330.

	Overall	
	Mean	Standard error
metS (%)	125	37.9
metS symptom score	2.11	1.38
Sleep health cluster (%)		
Good	138	41.8
Poor	52	15.8
Intermediate	140	42.4
TST	6.27	1.05
SE	80.77	9.46
Quality	3.61	0.76
Alertness	3.80	0.74
Age	54.75	11.94
Black (%)	87	26.4
Female (%)	206	62.4
Not married (%)	125	37.9
More than HS (%)	228	69.1
Household income	61994.57	50328.58
CES-D	7.63	7.40
Fast food consumption (%)		
Never	65	19.7
<1x a week	120	36.4
1-3x a week	145	43.9
Regular exercise (%)	239	72.4
Smoking status (%)	157	47.6
Cholesterol medication (%)	86	26.1
Blood pressure medication (%)	135	40.9

a Note: mean (sd) reported for continuous variables; n (%) reported for categorical variables.

Table 2. Bivariate associations between clusters and covariates. N = 330.

	Good	Poor	Intermediate	p	Effect size (eta-sq)
n	138	52	140		
metS symptom score	1.82 (1.29)	2.65 (1.34)	2.19 (1.40)	0.001	0.045
metS (%)	38 (27.5)	26 (50.0)	61 (43.6)	0.003	-
tst	6.53 (0.89)	5.06 (0.95)	6.47 (0.90)	<0.001	0.255
se	84.49 (4.98)	63.53 (8.48)	83.51 (5.36)	<0.001	0.625
Quality	4.14 (0.52)	3.51 (0.77)	3.12 (0.59)	<0.001	0.382
Alertness	4.40 (0.43)	3.78 (0.70)	3.22 (0.48)	<0.001	0.541
Age	57.70 (11.93)	53.42 (12.05)	52.34 (11.35)	0.001	0.045
Black (%)	29 (21.0)	26 (50.0)	32 (22.9)	<0.001	-
Female (%)	91 (65.9)	22 (42.3)	93 (66.4)	0.006	-
Not married (%)	48 (34.8)	31 (59.6)	46 (32.9)	0.002	-
More than HS (%)	88 (63.8)	37 (71.2)	103 (73.6)	0.199	-
Household income	65391.91 (56053.25)	45935.06 (42910.31)	64610.71 (45914.23)	0.042	0.019
CES-D	4.93 (4.78)	10.41 (8.96)	9.26 (8.05)	<0.001	0.099
Fast food consumption (%)				0.152	-
Never	35 (25.4)	8 (15.4)	22 (15.7)		
<1x a week	50 (36.2)	22 (42.3)	48 (34.3)		
1-3x a week	53 (38.4)	22 (42.3)	70 (50.0)		
Regular exercise (%)	110 (79.7)	31 (59.6)	98 (70.0)	0.016	-
Smoking status (%)	59 (42.8)	26 (50.0)	72 (51.4)	0.324	-
Cholesterol medication (%)	39 (28.3)	10 (19.2)	37 (26.4)	0.462	-
Blood pressure medication (%)	56 (40.6)	27 (51.9)	52 (37.1)	0.187	-

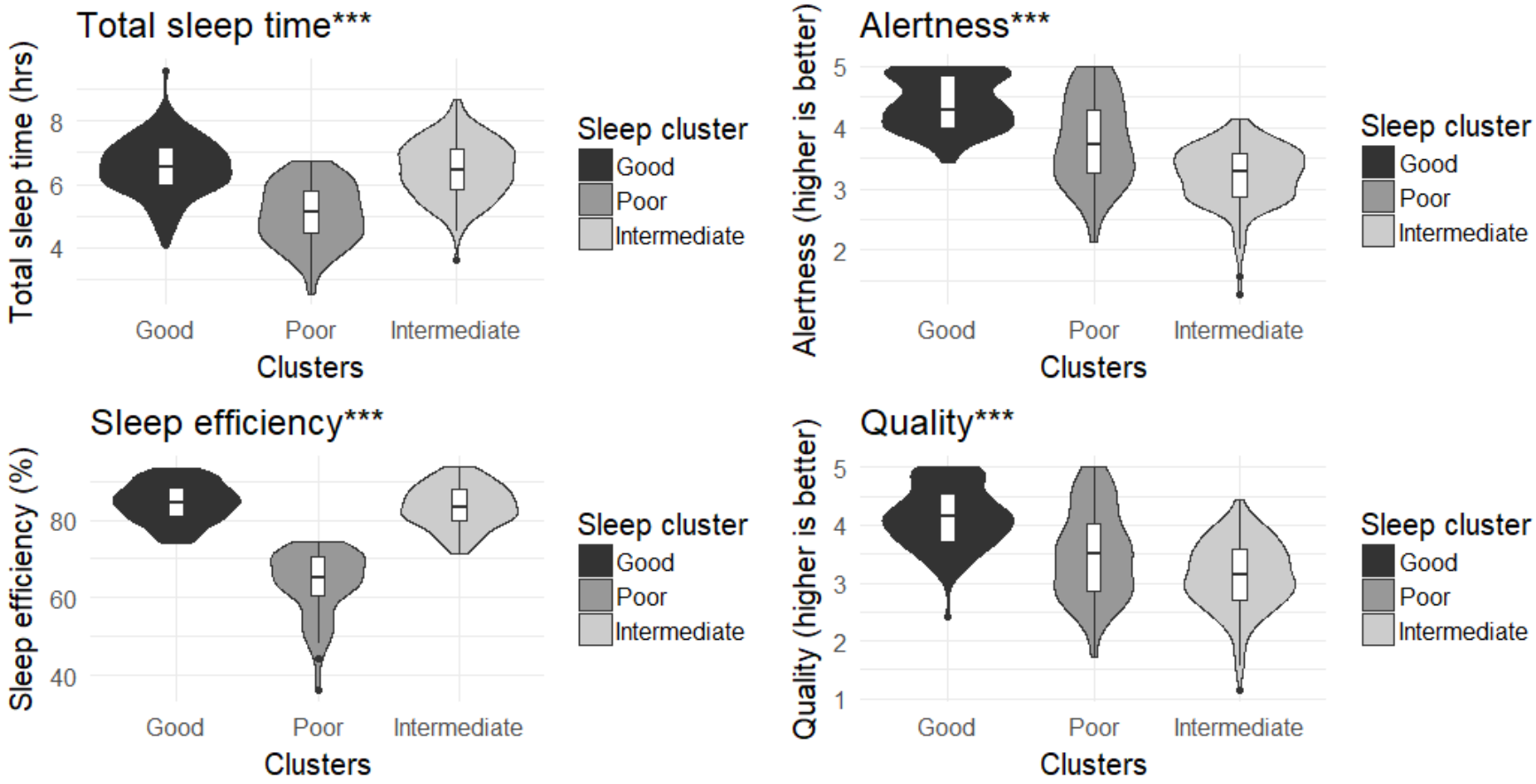
Note: Mean (sd) is reported for continuous variables. N (%) is reported for categorical variables.

Table A1. NbClust summary of optimal cluster analysis

Optimal k		**Additional information**
KL	13	Krzanowski and Lai, 1988
CH	2	Calinski and Harabasz, 1974
Hartigan	3	Hartigan, 1975
CCC	2	Sarle, 1983
Scott	3	Scott and Symons, 1971
Marriot	8	Marriot, 1971
TrCovW	4	Milligan and Cooper, 1985
TraceW	3	Milligan and Cooper, 1985
Friedman	3	Friedman and Rubin, 1967
Rubin	3	Friedman and Rubin, 1967
Cindex	2	Hubert and Levin, 1976
DB	3	Davies and Bouldin, 1979
Silhouette	2	Rousseeuw, 1987
Duda	2	Duda and Hart, 1973
PseudoT2	2	Duda and Hart, 1973
Beale	2	Beale, 1969
Ratkowsky	3	Ratkowsky and Lance, 1978
Ball	3	Ball and Hall, 1965
PtBiserial	3	Milligan 1980, 1981
Gap	2	Tibshirani et al., 2001
Frey	1	Frey and Van Groenewoud, 1972
McClain	2	McClain and Rao, 1975
Gamma	13	Baker and Hubert, 1975
Gplus	15	Rohlf, 1974; Milligan, 1981
Tau	3	Rohlf, 1974; Milligan, 1981
Dunn	3	Dunn, 1974
Hubert	0	Hubert and Arabie, 1985
SDindex	3	Halkidi et al., 2000
Dindex	0	Lebart et al., 2000
SDbw	14	Halkidi and Vazirgiannis, 2001

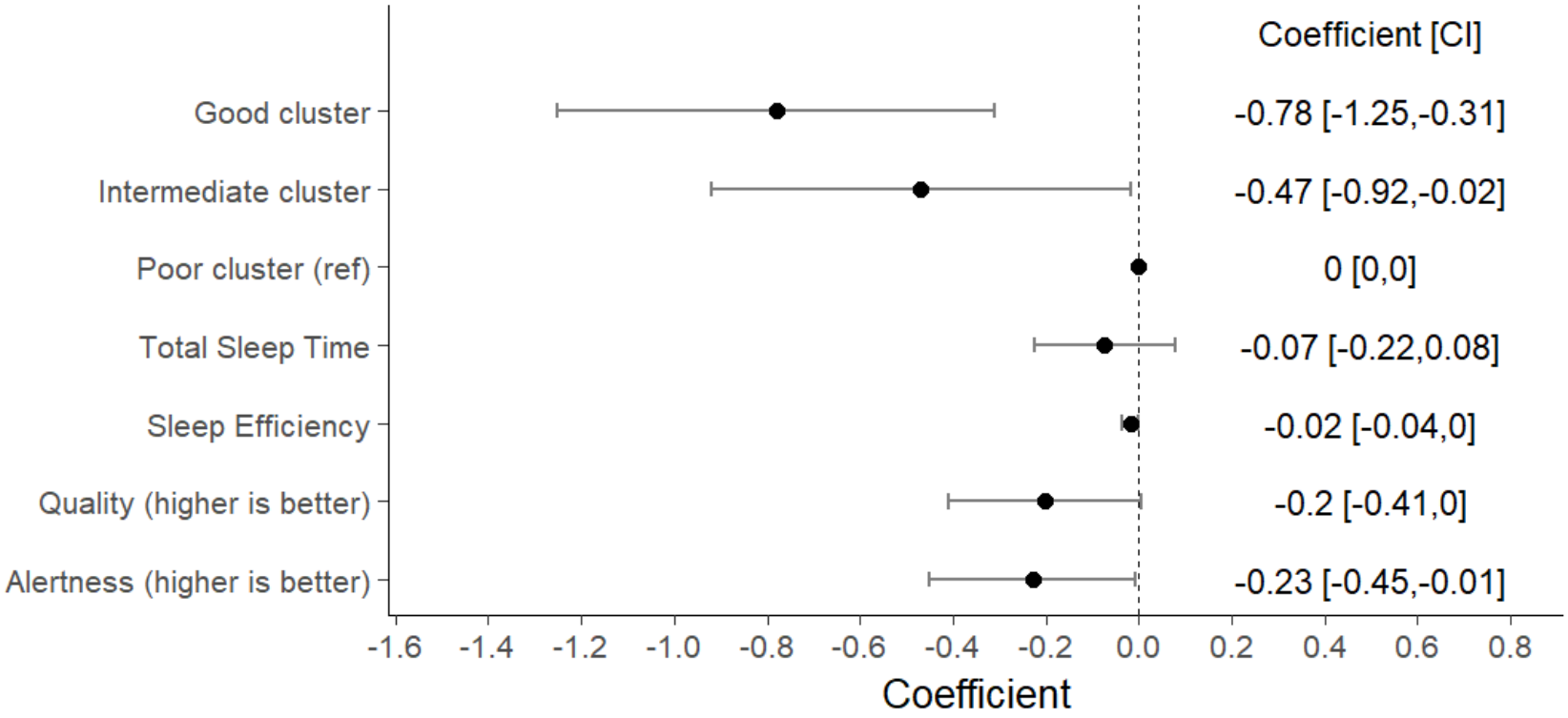
Figures

Figure 1. 7-day averages of total sleep time, sleep efficiency, sleep quality, and alertness decomposed by cluster, n = 330.



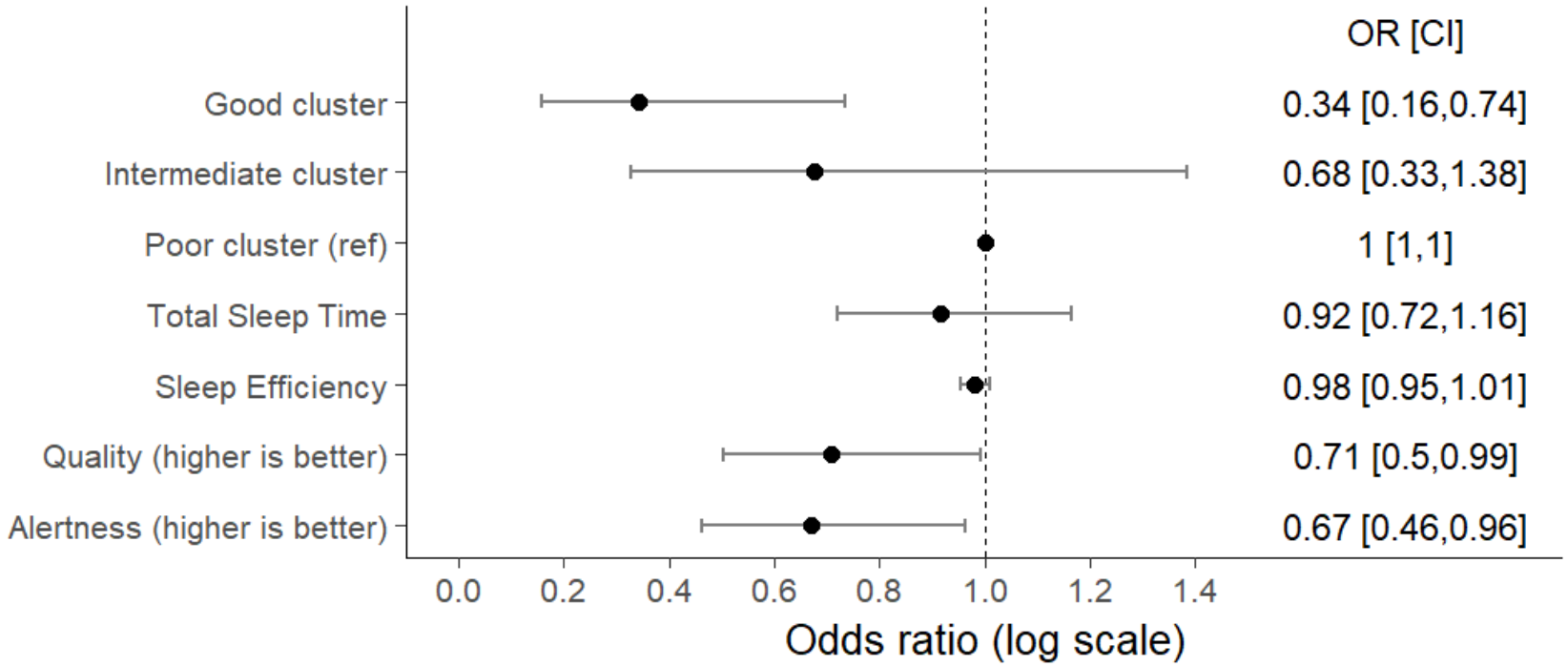
Note: Significance in ANOVA tests is denoted by * p< 0.05, ** p < 0.01, and *** p< 0.001.

Figure 2. Ordinary Least Squares regression on metS symptoms, n = 330.



Note: All regressions are adjusted for age (centered), sex, race, married, educational attainment, household income, depressive symptoms, smoking status, regular exercise, fast food consumption, and the use of cholesterol or bp lowering medications. Both the good and intermediate clusters were added in the same regression, with the poor category as the reference. All other regressions had no other sleep parameters except the sleep parameter of interest.

Figure 3. Logistic regression on metS, n = 330.



Note: All regressions are adjusted for age (centered), sex, race, married, educational attainment, household income, depressive symptoms, smoking status, regular exercise, fast food consumption, and the use of cholesterol or bp lowering medications. Both the good and intermediate clusters were added in the same regression, with the poor category as the reference. All other regressions had no other sleep parameters except the sleep parameter of interest.

Figure A1. K-means clustering within group sum of squares plot, N = 385.

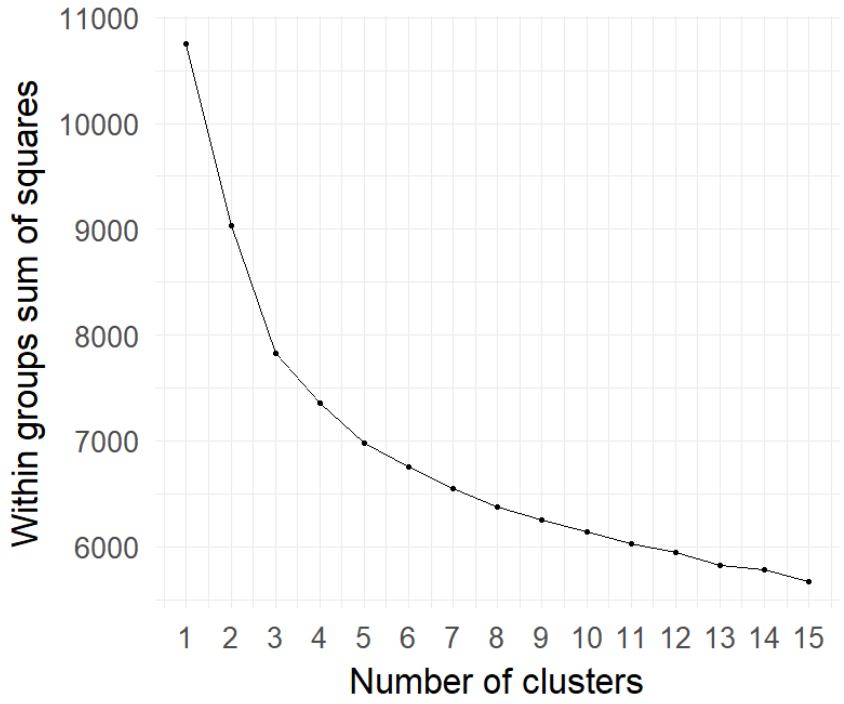


Figure A2. NbClust package results for optimal k. By majority rule, k = 3, N = 385.

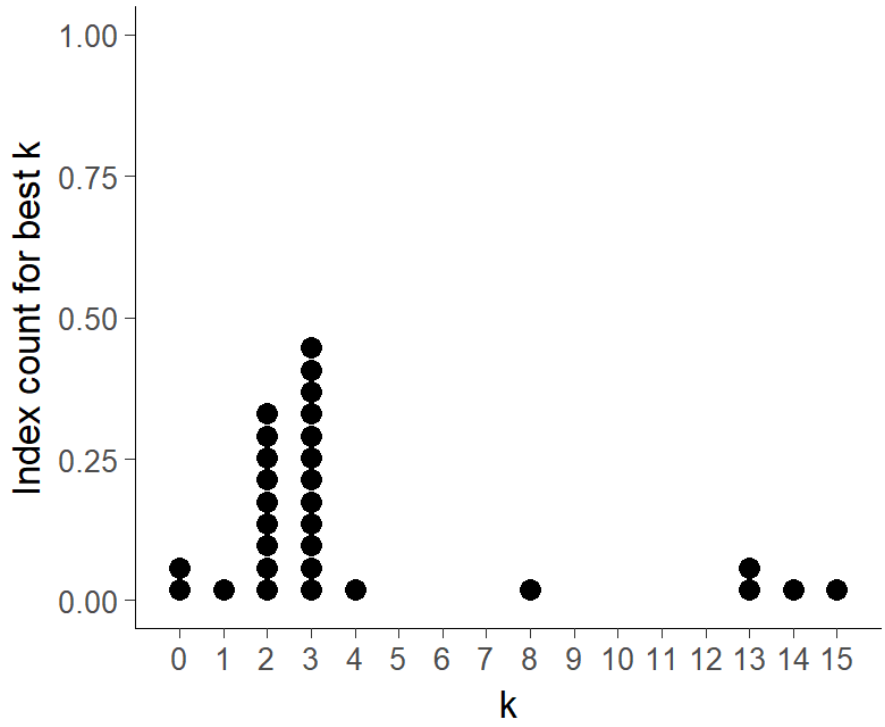
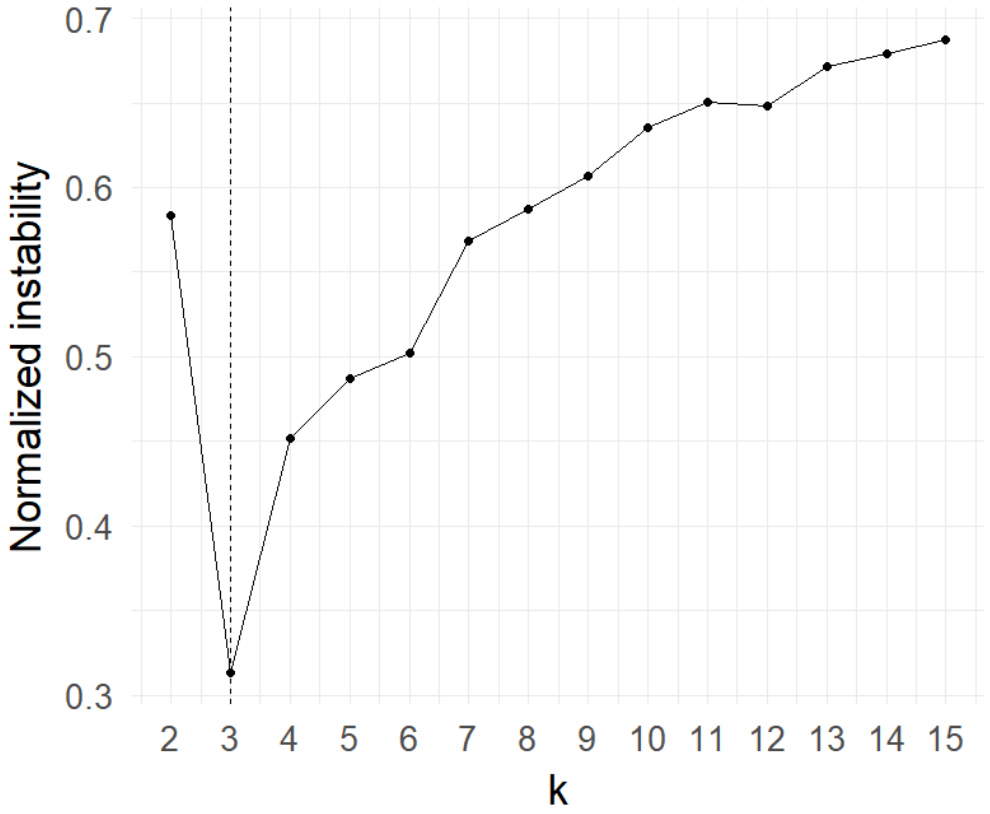


Figure A3. Normalized cluster instability; lowest instability at k = 3, N = 385.



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Chapter 5.

Sleep as embodied

Title: Social health and sleep health: Analyses of social integration, social well-being, and actigraphic and diary-reported sleep in a national survey of U.S. adults.

Abstract

While sleep has been established as essential for health, the social determinants of sleep remain unexplored. This article investigates 1) associations between social health (social integration and social well-being) and sleep; and 2) the potential effect of social integration on sleep through the mediating influence of social well-being. The sample consists of three linked datasets from the MacArthur Study of Successful Midlife Development: Wave II, the Milwaukee sample, and the biomarker supplement (linked sample size n = 320). Analyses suggest that social health is positively associated with sleep health. First, social integration is positively associated with social well-being ($\beta = 0.17$, $p < 0.01$). Second, social well-being is associated with increased odds of attaining good sleep (OR = 1.27, $p < 0.05$). Third, social integration does not display direct effects on healthy sleep but has an *indirect* positive effect on sleep through the mediating influence of social well-being; those who have integration scores of 2 or 4 have different Average Causal Mediated Effects (ACME OR = 1.014). Social health is important for sleep health, and increased social well-being may be a plausible mechanism by which social integration affects sleep.

Introduction

An expansive literature has linked sleep to health outcomes such as cardiovascular disease (Cappuccio et al. 2011), obesity (Cappuccio et al. 2008), cancer (Kecklund and Axelsson 2016; Verkasalo et al. 2005), and mortality (Dew et al. 2003; Kripke et al. 2002; Kurina et al. 2013). (see Czeisler 2015 for a review) While the downstream health effects of sleep are increasingly understood, the upstream social determinants of sleep remain unexplored. Because sleep health lies intermediate in hypothesized pathways between social determinants of health and variations in health outcomes, research into the upstream determinants of sleep has been identified as "the critical next step." (Knutson 2013: 7,8)

Among the earliest social determinants of health was "social health" itself, the extent and quality of an individual's social ties to others and the broader community. This article investigates the relationship between social health and sleep health. Specifically, it examines associations between sleep and two well-established social determinants of health, social integration and social well-being. It theorizes that social integration and social well-being can be considered as complementary indices of social health. It is hypothesized that a social health index composed of both integration and well-being is significantly associated with sleep health. This article presents a theoretical model further hypothesizing that social integration may operate through the mediating influence of social well-being to influence sleep.

Social integration

Among the earliest studies of upstream social determinants of health is Durkheim's *Suicide.* Based on suicide rates which varied by social ties such as group membership, Durkheim argued that suicide rates varied in accordance with a group's level of social integration. Modern studies of social integration have extended their focus beyond suicide to other health outcomes.

These studies operate at the objective social level, that is, at the level of measurable social ties and community participation rather than perception. The literature operating within this tradition tends to consider social integration as 1) frequency of interaction with social ties (e.g. family, friends, neighbors); 2) participation in social institutions such as marriage and church; or 3) involvement in community activities, and volunteer work. (Yang et al. 2016)

Some aspects of social integration appear to have positive effects on sleep. The most well-characterized social relationship with sleep is marriage. In large-scale surveys, married individuals report fewer sleep complaints (Grandner et al. 2010) and more sleep on both weekdays and weekends. (Hale 2005) The protective effect of marriage is generally also seen in objectively measured sleep: marriage is positively associated with wake after sleep onset and sleep duration. (Chen, Waite and Lauderdale 2015) Women who were stably partnered over 6-8 years show lower sleep latency, less sleep fragmentation, and less wake after sleep onset compared to those who were consistently unmarried. (Troxel et al. 2010a) It is theorized that spouses may function as 'social zeitgebers' or time-keepers who regularize sleep patterns via circadian rhythm entrainment. (Hasler and Troxel 2010)

Sleep also appears to be patterned by social participation. (Chen, Lauderdale and Waite 2016) Those with more social participation showed healthier objective measures of sleep parameters using actigraphy. (Chen, Lauderdale and Waite 2016) Exercise may also help to explain some of the relationship of social participation with sleep. That is, older US adults who participated in more social activities and engaged in low, moderate, or vigorous activity had lower odds of sleep troubles. (Endeshaw and Yoo 2016) Moreover, individuals who are more engaged in social participation may have greater access to protective resources such as social support as well as positive health information and influence (e.g. exercise). (Waite 2018)

On the other hand, some aspects of social integration appear to have detrimental effects on sleep. In one study it was observed that a particular aspect of social integration – frequency of family contact – was associated with increased risk of weekly or daily sleep troubles (Ailshire and Burgard 2012) When social support and social strain – the *perceptions* of the supportive or strained aspects of the social network – were included, increased family contact remained significant. At the same time, combinations of more social support and more strain were also predictive of weekly and daily sleep problems. This indicates that objective social ties and perceptions of those ties as supportive or strained are only modestly correlated and therefore are distinct in their effects on sleep.

The modest association amongst social ties, social participation, and perceptions of their quality has been noted in the past and form the basis for a more unified concept of social health. (Cornwell and Waite 2009; Larson 1993; Waite 2018) An early conception of social health consisted of both objective and self-reported aspects of one's relation to the social environment and network. (Larson 1993) These aspects were believed to belong to two larger concepts of 1) social adjustment, consisting of satisfaction with relationships, performance in social roles, and adjustment to environment; and 2) social support, consisting of number of contacts and satisfaction with contacts. Social health, in this view, was the ability of individuals to cope and adjust to their social environment, participate in that environment, and to have numerous relationships of high perceived quality.

Subsequent studies of social health and sleep appear to have focused predominantly on the second aspect, social support, and split along disciplinary lines: 1) a traditional sociological approach that focused on social integration or its components (Chen, Lauderdale and Waite 2016; Endeshaw and Yoo 2017; Troxel et al. 2010a), and 2) a social-psychological approach that

focused on perceptions of social network adequacy through constructs such as emotional support, loneliness, and social strain[i]. (Cacioppo et al. 2002; Chung 2017; Kang et al. 2012; Kent de Grey et al. 2018; Kurina et al. 2011; Troxel et al. 2010b) Missing from the sleep literature, however, are other aspects of social health identified by Larson (1993) such as adjustment to the social environment and performance in social roles, aspects identified as comprising social well-being or social functioning. Understanding how social health can affect sleep has been limited to the extent that unmeasured dimensions of social health are not studied.

Social well-being

One conception of social well-being addressed this oversight and came to prominence as a social psychological extension to social integration and as a corrective to the well-being literature which primarily considered the individual in isolation of his or her social environment. (Keyes 1998) Social well-being operationalizes *perceptions* of healthy social functioning through self-reports of the quality of an individual's relationship with other people and the community. (Keyes and Shapiro 2004) Social well-being is intended to capture "whether and to what degree individuals are functioning well in their social lives." (Keyes and Shapiro 2004: 352)

Social well-being is comprised of the domains of social integration, acceptance of others, social coherence, social contribution, and social actualization (i.e., growth). In contrast to objective social integration, social psychological integration is the feeling of belongingness to a community. Acceptance of others entails the belief that people are capable of being kind, altruistic, and caring. Social coherence is the feeling that one is able to understand what is happening in one's social world. Social contribution is the feeling that one can contribute things

[i] See Cornwell and Waite (2009) who make a similar distinction between social isolation and loneliness for health generally.

of worth or value to one's community, society, and world. Social actualization is the belief that society is or can progress and improve.

Together, these domains measure how well one is functioning socially from their own perspective. The resultant social well-being measure has proven consistent and valid. (Keyes 1998) Together with social integration, social well-being helps return the literature to the idea of social health as the presence of subjective as well as objective reports of social function, network size, and quality.

[Figure 1 about here]

To clarify associations between social integration, social well-being, and sleep, a theoretical model was constructed (Figure 1). It is theorized that social integration and social well-being together form social health. Furthermore, it is hypothesized that social health is positively associated with sleep.

Social integration and social well-being

Although related, social integration and social well-being are proposed to be distinct aspects of social health (Larson 1996) The literature has often treated integration as a potential cause of social well-being. As Larson (1996) notes, social well-being appears to be a "reaction to the environment," of which social ties and the broader community are a part. (p 187) Some have theorized, for example, that social participation can increase a sense of belonging by facilitating shared experiences. (Chen, Lauderdale, and Waite 2016)

Empirical support suggests this connection. Recent community involvement was found to associate significantly with all five components of social well-being (social integration, acceptance of others, social coherence, social contribution, and social actualization), whereas past community involvement was found to associate significantly with two of the five

components of social well-being (integration and contribution). (Keyes 1998) These results suggest that community participation may impart immediate effects on all aspects of social well-being as well as durable effects on sub-components of social well-being. A longitudinal study in a national sample found that volunteer work is predictive of social well-being 10 years later. The reverse seems to hold true as well, such that social well-being is predictive of volunteer work 10 years later (Son and Wilson 2012) Marital status may impact social well-being such that married individuals have higher well-being scores than cohabitating (but unmarried) individuals, although the effect of being married compared to those not-married, broadly defined, was not significant. (Shapiro and Keyes 2008) Finally, in a cross-national sample of college students, social participation (in groups such as political, sports, volunteering, and others) predicted social well-being, with a sense of community as a mediator. (Cicognani et al. 2008) The literature, in short, suggests that social integration is associated with, and may be a cause of, social well-being.

Social well-being and sleep

Although the literature on social relationships and sleep is growing, the relationship between social well-being and sleep is not well examined. Howell et al. (2010, 2008) report in two separate studies on undergraduates that social well-being is a mediator between mindfulness and 1) sleep quality and 2) self-regulation of sleep. (Howell et al. 2010; Howell et al. 2008) Another study provides evidence that social well-being interacts with sleep to produce differences in inflammatory biomarkers. (Friedman 2011) If it is true that social integration is a cause of social well-being, and social well-being in turn predicts sleep, one may hypothesize that social well-being a mediator between social integration and sleep.

[Figure 2 about here]

Figure 2 decomposes social health into social integration and social well-being. The model proposes that as social ties and participation (integration) increase, so does social well-being. As social well-being increases as a function of increased social integration, odds of achieving good sleep are also increased. The literature indicates conflicting evidence on the association between integration and sleep; some aspects of integration appear to have protective effects, while others somewhat detrimental ones. (see introduction) Thus, social integration may have weak or null direct effects on sleep. However, the model also allows for social integration to have an indirect effect on sleep, to the extent that it increases social well-being.

In summary, social health is proposed to be the combination of social integration and social well-being. The balance of evidence suggests that social integration has a positive effect on social well-being. It is not well known whether social well-being influences sleep. Aspects of social integration may have positive or negative associations with sleep. It is unknown whether social integration influences sleep through social well-being.

Accordingly, five hypotheses were constructed: 1) Social health (social integration + social well-being) is positively associated with sleep; 2) Social integration is weakly or un-associated with sleep; 3) Social integration is positively associated with social well-being; 4) Social well-being is positively associated with sleep; and 5) Social integration is associated with sleep through the mediating effect of social well-being.

Participants and Methods

Data are drawn from the MacArthur study on Midlife Development in the United States (MIDUS), a national probability sample of non-institutionalized English-speaking adults in the contiguous United States obtained by random digit dialing, aged 34-84 at Wave II. Of the several waves, the second wave of MIDUS (2004-2006), the Milwaukee subsample, and the Biomarker supplement (2004-2009) are utilized. Of the 7,108 respondents at Wave I, 4,963 also responded

at Wave II. At Wave II, Whites were over-represented and thus a separate project collected data on a sample of 600 black respondents Milwaukee county, Wisconsin. Subsamples of both populations (MIDUS main wave II and the Milwaukee), 1,255 respondents, were assessed for the Biomarker supplement; data were collected 5 to 64 months after Wave II. A further subsample participated in the sleep study. After exclusion of missing values on covariates and the outcome variable, the total number of observations is 320. Social integration, social well-being, and most covariates (except CES-D scores) were measured cross-sectionally; sleep was measured at least 5 to 64 months after Wave II.

Outcome variable

The outcome of interest is good sleep. Biomarker participants were invited to participate in a 7-day daily diary and actigraphy study. Sleep parameters were chosen for their significance to sleep health: sleep quality, alertness, total sleep time, and sleep efficiency. (Buysse 2014) In the daily diary, respondents rated the overall quality of their sleep the previous night on a scale of 1 (very good) to 5 (very poor). Similarly, alertness was assessed by 7 days of self-report. Each morning, respondents reported their alertness on a scale of 1 (very alert) to 5 (not alert at all). Scores for both domains were reverse coded such that higher scores reflect better quality and alertness. Total sleep time (TST) and sleep efficiency (SE) were assessed by actigraphy, a wrist-worn accelerometer that tracks movement. The actigraph used in MIDUS was the MiniMitter Actiwatch 64.

Good sleep was operationalized by k-means clustering. Cluster analysis suggested three clusters: good sleep, poor sleep, and intermediate sleep. However, a separate analysis showed that only the good sleep was significantly associated with metabolic syndrome, suggesting that poor or intermediate sleep health is insufficient for clinical significance. (Chung, Wallace, and

Buysse 2019 manuscript) Thus, good sleep was operationalized as a dichotomous outcome: good sleep versus less than good sleep (poor or intermediate).

Social Integration

The first component of social health is social integration. A summary index was constructed using the following domains: family contact, friend contact, neighbor contact, religious attendance, participation in social activities, volunteer work, and marriage. Responses were coded 1 if respondents were married, reported having family contact once a day or more, friend contact once a day or more, neighbor contact nearly every day, religious attendance once a week or more, and were in the top quartile for reported hours per month typically spent participating in church activities and reported any volunteer work. All other responses were coded 0. The domains for volunteer work include for political causes, school/youth causes, hospital or nursing homes, or other. Any time doing volunteer work was considered as 1 and was added to the integration scale. The index was summed. This index is consistent with previous approaches to social integration and health. (Yang et al. 2016)

Social well-being

The second component of social health is social well-being. Social well-being is comprised of the domains of social coherence, integration, acceptance of others, social contribution, and social actualization. (Keyes 1998) Respondents answered, on a 7-point Likert scale, the degree to which they agreed with statements such as “I cannot make sense of what’s going on in the world” (coherence); “I don’t feel like I belong to anything I’d call a community” (integration); “I believe people are kind” (acceptance); “society isn’t improving for people like me” (actualization). Each sub-scale was standardized and dichotomized at the upper tertile. (see

Shapiro and Keyes 2008) A social well-being score was constructed as the sum of the five domains.

Social health

A social health score was constructed as the sum of the integration and social well-being scores. Following previous conceptualizations, this scale presents social health as the presence of both objective and self-evaluated aspects of social engagement, quality, and functioning.

Control covariates

Control covariates were selected based on previous literature and four criteria, namely, whether the covariate could confound associations between: 1) social health and sleep health; and by extension for mediation analyses, 2) the exposure and outcome (social integration and good sleep); 3) the mediator and outcome (social well-being and good sleep); or 4) the exposure and mediator (social integration and social well-being). These relationships are visualized in Figure 2.

Thus, covariates were based on the need for standard demographic controls, and possible confounders of any of the relationships noted above. In particular, behavioral and physical and mental health controls were needed because these may affect individuals' ability to participate in social activities and relationships (integration), their perceptions of social well-being, and their sleep. Demographic controls include: age, sex, race (Black or White), education (less than high school vs at least high school), and household income (USD). (Blaine and Crocker 1995; Ellison 1995; Keyes 1998; Stamatakis, Kaplan and Roberts 2007; Taylor et al. 1996) Marital status was not included because it is included in the integration scale. Behavioral and physical and mental health controls include: regular exercise of at least 20 minutes, 3 times a week (dichotomous), number of chronic conditions (count of symptoms), self-rated health (5-point scale), and

depressive symptoms as measured by the Center for Epidemiological Studies Depression scale (CES-D). (Devins et al. 1993; Ellison 1995; Endeshaw and Yoo 2017; Foley et al. 2004; Keyes 2005; Koyanagi et al. 2014; Power et al. 2005) The CES-D includes a question on sleep; scores for this question were subtracted from the overall CES-D score. Covariates were tested for significance of association with the outcome (good sleep) and exposure (social integration) and mediator (social well-being) variables in bivariate tests.

Analytic strategy

The association between social health and good sleep was assessed by logistic regression. To assess mediation, each pathway in Figure 2 was first tested. Counterfactual mediation models were then used. (Imai, Keele and Tingley 2010) First, the association between the exposure and mediator (integration and social well-being) was assessed. Ordinary Least Squares (OLS) was used (social well-being ranges from 0-5). Model diagnostics suggested mild heteroskedasticity; consequently, robust standard errors are reported. Variance inflation factors were checked, and Ramsey RESET tests for functional form specification were performed. Social well-being is discrete-quantitative, and thus Poisson, negative binomial, and ordered logistic regressions were also run; the results agree with the OLS analysis and so OLS results are presented. Second, the association between the mediator and outcome (social well-being and good sleep) was assessed in logistic regressions. Third, the association between the exposure (social integration) and outcome (good sleep) was assessed by logistic regression.

Next, counterfactual causal mediation models were used. These models produce two estimates of interest to this analysis: an Average Direct Effect (ADE) and an indirect effect or Average Causal Mediated Effect (ACME). The direct effect is the difference in outcome (good sleep) if the exposure (social integration) changes between two levels, holding the mediator

(social well-being) constant at its natural levels (natural, that is, to the corresponding level of integration). The direct effect asks: How much do the odds of achieving good sleep change if only social integration changes, holding social well-being fixed at its natural levels and all else constant? The indirect effect or ACME denotes the difference in outcome (good sleep) at different levels of the mediator holding the exposure fixed. The indirect effect asks, counterfactually: Suppose those with lower integration scores had the social well-being scores of those of higher integration? How much would their odds of sleep increase, all else being equal?

The theoretical model dictated that social integration is the exposure, social well-being is the mediator, and sleep is the outcome. Contrasts of the exposure were initially set at integration scores of 2 and 4, which were both the modes of the distribution and one step below and above the mean, respectively. An additional contrast was set at 2 and 5, based on descriptive statistics which indicated that these two levels of integration had an approximately 1-unit difference in social well-being (see Figure 3). A final contrast was set between and 0 and 7 to assess the extremes of integration. The theoretical model suggests that the effect of social well-being changes depending on the level of social integration; as such, exposure-mediator interaction was assumed. (VanderWeele 2015)

To understand which sleep parameters are influenced, further mediation models were run with 7-day averages of tst, se, quality, and alertness as outcomes. OLS was used for exposure to mediator and mediator to outcome association. Integration contrasts of 2 and 4 are presented (the results do not substantively change with additional contrasts). Analyses were implemented in the R package 'mediation'. (Imai et al. 2010; Tingley et al. 2014) 2,000 simulations with bias-corrected bootstrapped confidence intervals were conducted[j].

[j] Simpler methods of causal mediation exist; however, if the outcome is dichotomous and non-rare (e.g. >10%), logistic regression for the mediation model will give biased estimates. (Vanderweele 2015)

Results

[Table 1: Descriptive statistics about here]

Overall, the sample averaged 6.24 hours of sleep, with sleep efficiencies of 80.37%, and self-reported quality and alertness scores of 3.64 and 3.83 out of 5, respectively.

A total of 137 out of 320 individuals (42.8%) met the criteria for good sleep. The average total sleep time, sleep efficiency, quality, and alertness scores for good sleepers were 6.52 hours, 84.5%, 4.15, and 4.40 out of 5, respectively. The scores for individuals with less than good sleep were significantly lower, averaging 6.03 hours, 77.27% efficiency, and 3.26 and 3.40 for quality and alertness. (see Table 1)

[Figure 3 about here]

Table 1 and Figure 3 show bivariate relationships among the variables of interest. Figure 3 shows the average level of social well-being by each level of social integration. The least integrated on average have social well-being scores of 0.82, whereas those who are most integrated on average have social well-being scores of 3.5 (ANOVA $p < 0.001$, Table 1). Appendix A shows correlations among integration and social well-being sub-components. Marital status is significantly associated with the social well-being components of integration ($p = 0.007$) and acceptance ($p = 0.001$). Family contact was not significantly associated with any social well-being components. Friend contact is associated with contribution ($p = 0.022$). Neighbor contact is associated with meaningfulness ($p = 0.017$) and integration ($p = 0.033$). Frequency of religious attendance is significantly associated with integration ($p = 0.001$) and contribution ($p = 0.014$). Church activities is significantly associated with contribution ($p = 0.012$). Finally, volunteer work associates significantly with all 5 dimensions of social well-being: meaningfulness ($p <0.001$), integration ($p = 0.006$), acceptance ($p < 0.001$), contribution ($p < 0.001$), and actualization ($p = 0.007$).

Those with good sleep tended to have social well-being scores of 2.22, whereas those with less than good sleep tended to have scores of 1.57 ($p < 0.001$; Table 1). Those with with good sleep tended to have integration scores of 3.24 whereas those with less than good sleep had an integration score of 2.83 ($p = 0.018$; Table 1).

[Table 2 about here: Regression results]

Social health is significantly associated with good sleep (Table 2). The 95% confidence interval indicates that the odds of achieving good sleep are expected to increase by anywhere from 2.7% to 30.2% (OR = 1.15, $p = 0.018$) with each unit increase in social health. However, social integration, the first component of social health, is not significantly associated with good sleep (OR = 1.11, $p = 0.240$). In the unadjusted model, social integration was significantly associated; however, after adjustment of demographics, social integration fell out of significance and remained so after addition of other covariates.

Furthermore, social well-being, the second component of social health, is significantly associated with good sleep. In the fully adjusted model, the 95% confidence interval indicates that odds of achieving good sleep are expected to increase by 6% to 54% with each unit increase of social well-being (OR = 1.27, $p = 0.011$).

Social integration is significantly associated with social well-being. In the fully adjusted model, the 95% confidence interval indicates that each unit increase in social integration is expected to result in a 0.07 to 0.28 unit increase in social well-being ($b = 0.17$, $p = 0.001$). This model explains approximately 24.65% of the variance.

[Table 3 about here]

Table 3 shows the results of the mediation analyses where social integration is the exposure, social well-being is the mediator, and sleep is the outcome. At integration levels of 2

compared to 4, the average causal mediated effect (ACME) of social integration as operating through social well-being on good sleep is 0.014. Based on Figure 3, an additional contrast was set at 2 and 5, for these contrasts have on average an approximately 1-unit difference in social well-being scores. Here, the ACME is 0.024. Finally, the extremes of social integration were investigated with contrasts set at 0 and 7. The ACME is 0.053. In sum, the difference in odds of achieving good sleep are 0.014 at integration levels of 2 and 4; 0.024 at integration levels of 2 and 5, and 0.053 at integration levels of 0 and 7.

Table 3 further shows mediation analyses on individual sleep parameters. Here linear regressions were used along with continuous variables, and thus the results are on the difference scale in units, not odds. Quality and alertness show significant indirect effects (ACME = 0.022, 0.019, respectively). If those with integration scores of 2 had the social well-being scores of those with integration scores of 4, the analysis suggests that their quality and alertness scores would increase by approximately 0.022 and 0.019 units.

Discussion

There are six conclusions from this research. First, social health – considered as the sum of social integration and social well-being – is associated with sleep health; as social health increases, sleep health also improves; 2) social integration is positively associated with social well-being; 3) social well-being is positively associated with good sleep; 4) social integration does not appear to exhibit direct effects on sleep; 5) under model assumptions, social integration has a positive indirect effect on sleep through the mediating influence of social well-being; and consequently 6) the theoretical model of social integration indirectly influencing sleep through social well-being is plausible.

Social health is positively associated with sleep health. Analyses suggest that social health owes its association with sleep primarily to social well-being. In contrast, social

integration was not found to be significantly associated with good sleep in fully adjusted models, despite significant bivariate association. A lack of association after adjustment holds true regardless of whether the integration scale excludes married individuals, and whether the integration scale is dichotomized at 1, 2, 3, 4, 5, or 6 (analyses available on request).

However, it remains possible for social integration to influence sleep through the mediating influence of social well-being. In descriptive statistics, it appears that those with the highest levels of integration on average have more than 4 times the social well-being scores of those least integrated. The association between integration and social well-being persisted after adjustment. It is important to recognize that a causal interpretation depends on the assumption that social integration precedes social well-being. The theoretical model and literature suggest that this is so; however, the cross-sectional measurement of integration and well-being does not permit strong claims of causality. Nonetheless, social integration is associated with social well-being.

Social well-being, in turn, is strongly associated with higher odds of attaining good sleep. Under the assumptions of the model, social integration appears to exert indirect effects on sleep through social well-being. In statistical terms, the effect of social integration as mediated through social well-being is significant for the contrasted integration scores of 2/4, 2/5, and 0/7. The Average Causal Mediated Effect (ACME) has the interpretation of the expected difference in odds of achieving good sleep if the contrasted integration scores had the social well-being scores corresponding to the higher level of social integration, holding levels of integration fixed. For instance, if those who had 2 out of the 7 domains of social integration had the social well-being of those who had 4 out of the 7 domains of social integration, how much higher would their odds

of achieving good sleep be even if their level of integration remained constant? These differences for the contrasts presented in this paper are significant at the 0.05 level.

In practical terms, the effects of social integration on sleep as mediated through social well-being appear to be modest. This suggests that interventions to increase social integration may exert statistically significant but practically small effects on sleep and do so purely through raising levels of social well-being. In contrast, the analysis suggests that good sleep might be reasonably achieved through interventions aimed at increasing social well-being. Longitudinal fixed-effects analyses would clarify how changes in social well-being might affect changes in sleep.

In theoretical terms, the evidence suggests that social well-being may lie in the mechanistic path between social integration and sleep. This model may plausibly extend to other health outcomes. Consider, for instance, mortality. The literature linking social integration with mortality is strong; the literature linking positive mental health (of which social well-being is a component) is strong; therefore, a natural extension of these analyses is to include social well-being as a mediator between social integration and mortality and other health outcomes. Future analyses may test this mechanism.

Finally, we revisit the social integration and sleep null findings. Bivariate analysis showed significant results, but the fully adjusted models did not. The findings are expected from the literature but unfortunately do not clarify previous work, which have found discordant associations between various aspects of integration and sleep. One explanation is that the different components of social integration may exert opposing effects, nullifying the total effect. For instance, social participation has been found to positively correlate with sleep, but frequency of family contact is associated with poor sleep. (Ailshire and Burgard 2012; Chen, Lauderdale

and Waite 2016) Given previous literature, it remains likely that aspects of integration or social participation are significantly associated with sleep. Another explanation for the lack of agreement in this study and others is that different samples and operationalizations of sleep were used.

This confusion might be clarified, in part, by approaching the problem in reverse: that is, beginning with sleep, then identifying mediators, then theorizing about social integration. First, healthy sleep consists of both objectively measurable and self-reported sleep parameters. Consequently, the ways in which sleep could be impacted by social integration might differ depending on whether the sleep parameters of interest are objective or subjective. Consequently, the mediator to be tested in the pathway between integration and sleep may depend greatly on the sleep parameters and aspects of integration of interest. Perhaps it is these particular aspects of social integration, rather than the whole, that should be tested in mediation models for sleep. Future analyses might consider using this reverse-method to identify aspects of integration and causal pathways to achieve healthy sleep.

The strength of this article is that it goes beyond association to theorize and test mechanisms and mediation. Social integration is among the earliest concepts in sociology to get at social health, but the way in which social health seems to protect physical health has been understudied. On the other hand, at least two limitations warrant consideration. First, the temporal ordering of the study variables should be taken into account. Social integration, social well-being, and most control covariates were measured cross-sectionally at Wave II; sleep was measured at least 5 to 64 months after. A longitudinal analysis of social integration and social well-being was not possible because Milwaukee respondents only had one wave of measurement. Thus, an assumption was required: it was assumed that social integration preceded

social well-being. However, to investigate the possibility of reverse causation, that social well-being causes social integration, ancillary analyses were run and are available in Appendix B. In these models, social well-being is assumed to be the exposure; social integration is the mediator; good sleep is the outcome. If it is true that social well-being precedes integration, the results suggest that social well-being exerts direct effects on sleep, but that social well-being does not operate through social integration to affect sleep. If it is true that social well-being and integration have a bi-directional relationship, the social health analysis still suggests that social well-being is important for healthy sleep. Thus, regardless of analysis, social well-being is significantly associated with sleep.

Conclusion

This article has given evidence that social health is associated with sleep health. Social integration is associated with social well-being; social well-being in turn is associated with good sleep. Furthermore, social well-being plausibly lies in the pathway between social integration and sleep. More broadly, social well-being may help explain the strong associations between integration and health.

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Tables

Table 1. Descriptive Statistics on sleep, socio-demographics, social health, sleep health, and covariates. Data from the MacArthur Study of Successful Midlife Development (n = 320).

	Overall	Good sleep	Less than good sleep	p
n	320	137 (42.8%)	183 (57.2%)	
Socio-demographics				
Age	54.19 (11.67)	57.31 (11.71)	51.85 (11.10)	<0.001
Female	193 (60.3%)	88 (64.2%)	105 (57.4%)	0.261
White	234 (73.1%)	110 (80.3%)	124 (67.8%)	0.018
More than HS	221 (69.1%)	87 (63.5%)	134 (73.2%)	0.082
Household income (USD)	63276.49 (51021.45)	66157.55 (54550.56)	61119.63 (48250.99)	0.383
Sleep characteristics				
Total sleep time (hrs)	6.24 (1.07)	6.52 (0.91)	6.03 (1.12)	<0.001
Sleep efficiency (%)	80.37 (9.52)	84.50 (5.05)	77.27 (10.83)	<0.001
Sleep quality	3.64 (0.74)	4.15 (0.51)	3.26 (0.66)	<0.001
Alertness	3.83 (0.73)	4.40 (0.43)	3.40 (0.60)	<0.001
Social health				
Social health index	4.85 (2.50)	5.46 (2.62)	4.40 (2.31)	<0.001
Social integration	3.00 (1.56)	3.24 (1.53)	2.83 (1.56)	0.018
Social well-being	1.85 (1.56)	2.22 (1.64)	1.57 (1.44)	<0.001
Covariates				
Regular exercise (3x per week)	230 (71.9%)	108 (78.8%)	122 (66.7%)	0.023
Number of chronic conditions	2.40 (2.22)	1.80 (1.86)	2.85 (2.37)	<0.001
Self-rated health	3.54 (0.99)	3.85 (0.88)	3.30 (1.01)	<0.001
CESD score	7.39 (7.07)	5.04 (4.92)	9.16 (7.88)	<0.001

Table 2. Regressions on good sleep and social well-being. N = 320.

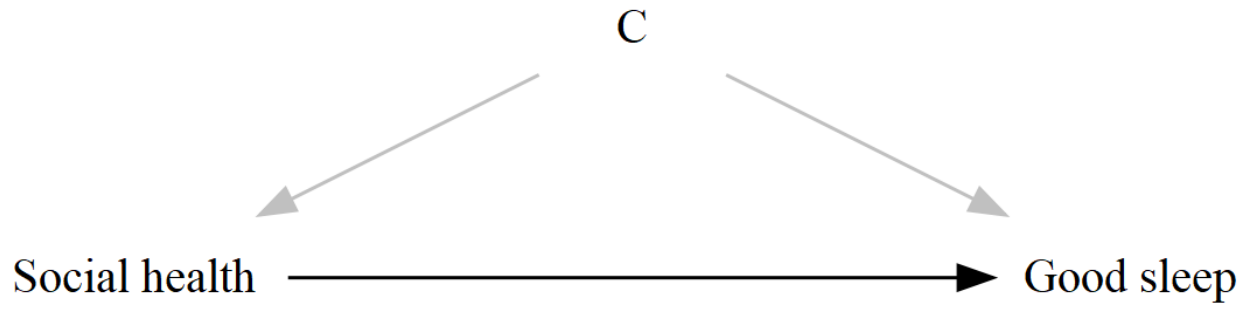
Outcome:	good sleep	good sleep	good sleep	good sleep	SWB
	OR [CI]	OR [CI]	OR [CI]	OR [CI]	β [CI]
Social Health	1.15* [1.03, 1.30]				
Social integration		1.11 [0.93, 1.32]		1.07 [0.89, 1.28]	0.17** [0.07, 0.28]
Social well-being			1.27* [1.06, 1.54]	1.26* [1.04, 1.53]	
Age	1.05*** [1.03, 1.08]	1.05*** [1.03, 1.08]	1.05*** [1.03, 1.08]	1.05*** [1.03, 1.08]	0.01 [-0.01, 0.02]
Female	1.66 [0.98, 2.86]	1.67 [0.98, 2.87]	1.76* [1.03, 3.02]	1.72* [1.01, 2.97]	-0.06 [-0.38, 0.26]
Black	0.78 [0.41, 1.49]	0.88 [0.46, 1.66]	0.78 [0.40, 1.48]	0.76 [0.39, 1.46]	0.65** [0.26, 1.04]
More than HS	0.46* [0.24, 0.83]	0.53* [0.30, 0.96]	0.45** [0.24, 0.82]	0.44** [0.23, 0.80]	0.77*** [0.42, 1.13]
Household income	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	0.00 [-0.00, 0.00]
CES-D	0.96 [0.91, 1.01]	0.94* [0.90, 0.99]	0.96 [0.91, 1.00]	0.96 [0.91, 1.01]	-0.06*** [-0.08, -0.03]
Number of chronic conditions	0.85* [0.72, 0.98]	0.85* [0.73, 0.98]	0.86* [0.73, 0.99]	0.85* [0.73, 0.99]	-0.05 [-0.14, 0.03]
Self-rated health	1.50* [1.08, 2.11]	1.51* [1.08, 2.12]	1.48* [1.07, 2.09]	1.49* [1.07, 2.10]	0.12 [-0.07, 0.32]
Regular exercise	1.78 [1.00, 3.23]	1.79* [1.01, 3.23]	1.84* [1.04, 3.34]	1.82* [1.02, 3.29]	-0.00 [-0.35, 0.34]
(Intercept)	0.01*** [0.00, 0.08]	0.01*** [0.00, 0.10]	0.01*** [0.00, 0.09]	0.01*** [0.00, 0.08]	0.19 [-1.11, 1.48]

Table 3. Causal mediation analyses. N = 320.

Outcome	**ACME**	**ADE**	**TE**
Good sleep*:			
Model 2-4	0.014*	0.025	0.039
	[0.003-0.034]	[-0.039-0.112]	[-0.025-0.126]
Model 2-5	0.024*	0.043	0.067
	[0.006-0.055]	[-0.061-0.159]	[-0.04-0.181]
Model 0-7	0.053*	0.091	0.144
	[0.01-0.113]	[-0.137-0.356]	[-0.092-0.391]
Individual sleep parameters:			
TST	0.002	0.064	0.066
	[-0.023-0.035]	[-0.106-0.214]	[-0.099-0.222]
SE	0.098	1.051	1.149
	[-0.085-0.422]	[-0.091-2.146]	[-0.002-2.262]
Quality	0.022*	-0.059	-0.037
	[0.001-0.051]	[-0.163-0.045]	[-0.141-0.066]
Alertness	0.019*	0.023	0.042
	[0.003-0.047]	[-0.076-0.121]	[-0.057-0.132]

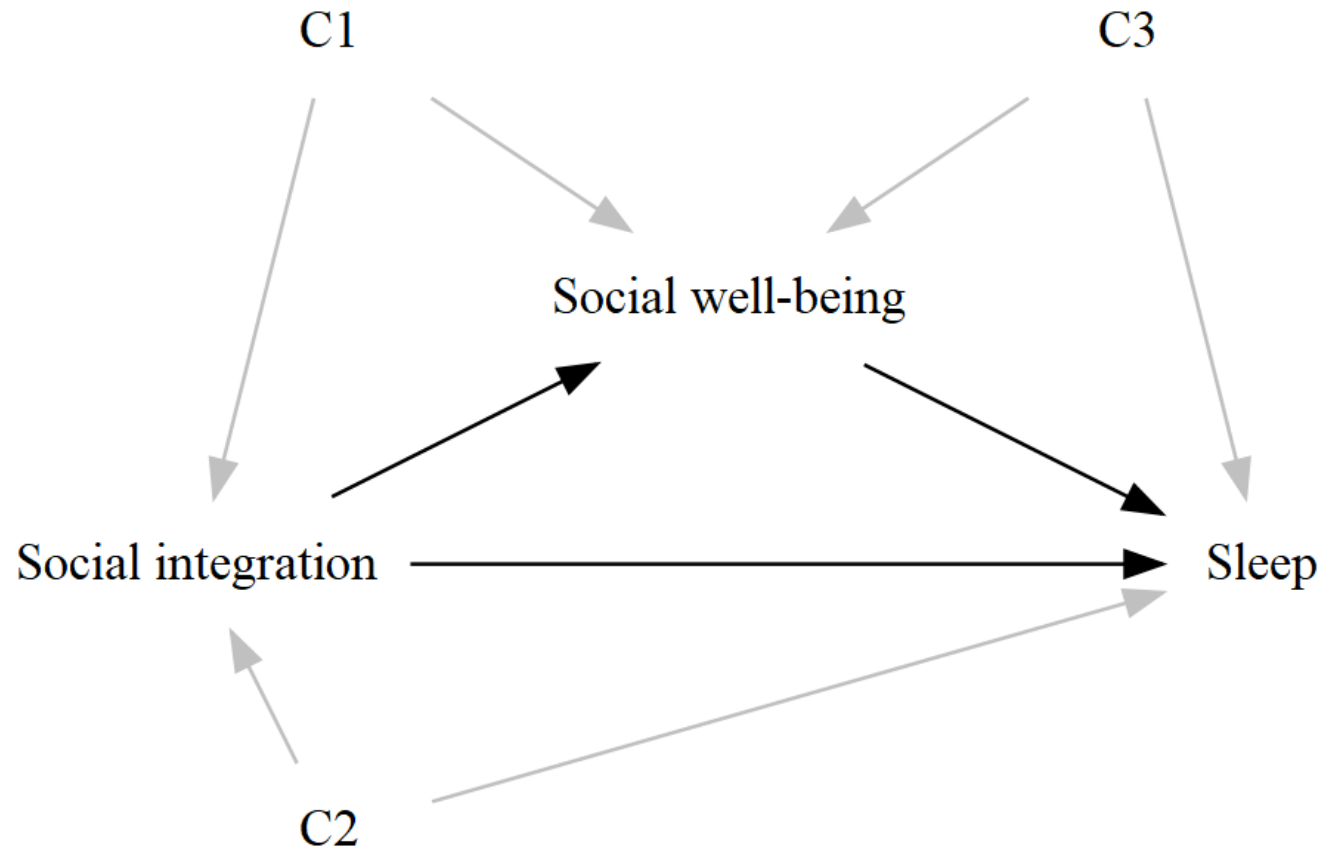
Note: model labels correspond to levels of integration. E.g. model 2-4 uses integration contrast levels of 2 and 4. TST = total sleep time. SE = sleep efficiency

Figure 1: Conceptual diagram of social health and sleep health



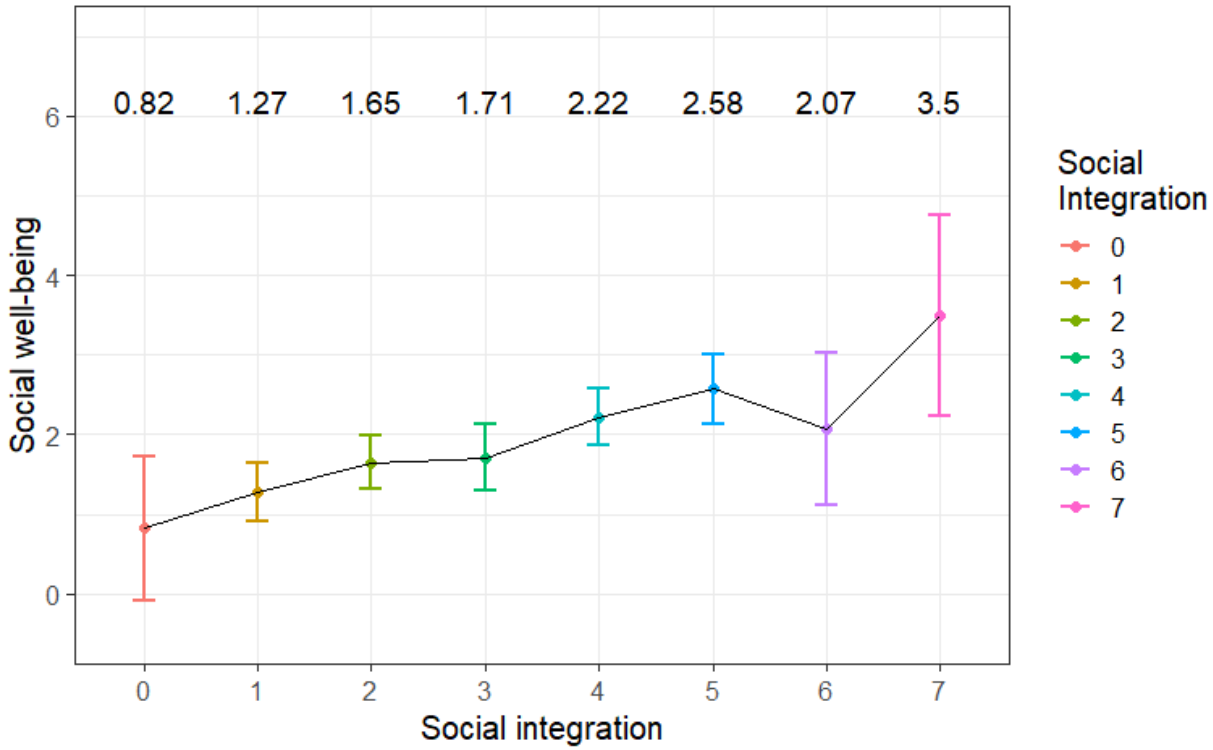
Note: Social health is the sum of social integration and social well-being. C is the confounders for demographics (age, sex, race, high school attainment, household income), physical health (self-rated health, regular exercise, number of chronic conditions), and mental health (CESD scores).

Figure 2. Conceptual diagram of social integration, social well-being, and sleep.



Note: C1, C2, and C3 are mediator-exposure, exposure-outcome, and mediator-outcome confounders, respectively. In subsequent analyses, C1, C2, and C3 are assumed to examine the same confounders for demographics (age, sex, race, high school attainment, household income), physical health (self-rated health, regular exercise, number of chronic conditions), and mental health (CESD scores).

Figure 3. Social well-being scores by level of integration. N = 320.



Note: The numbers refer to the mean level of social well-being within each level of social integration.

Appendix A: Social integration and social well-being components

Table A1. Associations between integration and social well-being components. N = 330.

		n	Social well-being	Meaningfulness	Integration	Acceptance	Contribution	Actualization
Marital status	Not married	126	1.75 (1.54)	8.97 (3.37)	13.87 (4.25)	13.10 (3.80)	16.10 (3.95)	12.23 (4.31)
	Married	194	1.92 (1.58)	9.47 (2.92)	15.12 (3.77)	14.46 (3.18)	16.21 (3.40)	13.08 (3.84)
	p		0.338	0.159	**0.007****	**0.001****	0.804	0.067
Family contact	Low	204	1.81 (1.59)	9.29 (3.08)	14.52 (4.09)	13.76 (3.52)	16.03 (3.68)	12.72 (4.05)
	High	116	1.92 (1.51)	9.23 (3.17)	14.81 (3.87)	14.20 (3.46)	16.41 (3.52)	12.78 (4.05)
	p		0.533	0.865	0.537	0.287	0.373	0.892
Friend contact	Low	224	1.73 (1.55)	9.12 (3.08)	14.42 (4.15)	13.96 (3.42)	15.86 (3.72)	12.68 (4.02)
	High	96	2.12 (1.56)	9.64 (3.16)	15.10 (3.63)	13.82 (3.68)	16.88 (3.30)	12.89 (4.12)
	p		**0.039***	0.171	0.163	0.741	**0.022***	0.671
Neighbor contact	Low	196	1.75 (1.54)	8.94 (3.18)	14.25 (4.23)	13.89 (3.37)	16.19 (3.79)	12.48 (4.16)
	High	124	2.01 (1.59)	9.79 (2.92)	15.23 (3.57)	13.97 (3.70)	16.13 (3.35)	13.15 (3.84)
	p		0.15	**0.017***	**0.033***	0.839	0.886	0.15
Religious attendance	Low	154	1.62 (1.52)	9.06 (3.14)	13.86 (4.19)	13.53 (3.36)	15.65 (3.61)	12.89 (3.91)
	High	166	2.06 (1.58)	9.46 (3.07)	15.34 (3.71)	14.28 (3.59)	16.64 (3.58)	12.61 (4.18)
	p		**0.012***	0.252	**0.001****	0.055	**0.014***	0.535
Church activities	Low	233	1.68 (1.50)	9.10 (3.07)	14.20 (4.09)	13.75 (3.53)	15.85 (3.59)	12.65 (3.99)
	High	87	2.31 (1.65)	9.72 (3.18)	15.77 (3.55)	14.39 (3.39)	17.00 (3.61)	13.01 (4.20)
	p		**0.001****	0.112	0.002	0.143	**0.012***	0.48
Volunteer (any)	Low	142	1.30 (1.43)	8.74 (3.17)	13.10 (4.18)	13.07 (3.47)	14.80 (3.71)	12.06 (4.14)
	High	178	2.29 (1.53)	9.70 (3.00)	15.84 (3.42)	14.60 (3.37)	17.25 (3.17)	13.29 (3.90)
	p		**<0.001*****	**0.006****	**<0.001*****	**<0.001*****	**<0.001*****	**0.007****

Appendix B. Mediation analyses with social well-being as the exposure and social integration as the mediator. The outcome is good sleep.

Table B.1 Social well-being and sleep with integration as a mediator

	ACME	ADE	TE
Integration 0/3	0.003	0.115*	0.119*
CI	[-0.016-0.027]	[0.004-0.223]	[0.011-0.229]
Integration 2/4	0.011	0.089*	0.100**
CI	[-0.003-0.036]	[0.016-0.163]	[0.025-0.174]

Social well-being exerts direct effects on sleep. Social integration shows no indirect effects.

Conclusion

What can the study of sleep offer sociology? Does sleep merely constitute another set of variables for sociologists to use? From this perspective, the primary utility of sleep is to broaden the scope of sociology to include the understudied links between sleep and the social world. Certainly, sleep can be just another outcome or predictor of interest, to be ported into an existing theoretical framework on health. The discussion in Chapter 4 on the social distribution of sleep health does exactly that. This is not a bad thing. Such work helps further establish the legitimacy of the social determinants of health and fills large gaps in sociological knowledge.

I would like to suggest, however, that sleep occupies – or could occupy – a distinctive place in sociology. First, sleep is one of the primary aspects of daily living. Above and beyond what people are or what they have, sleep is something that people *do* – every day. Furthermore, sleep is often in counter-position to other aspects of daily living such as work and leisure. To fully understand these domains, it may be necessary to study sleep, for experiences in one domain tend to bleed into another: work troubles are brought home, and sleep troubles affect work. Some sociological research has benefitted from examining the combination of work and sleep. (Burgard and Ailshire 2009) Other scholars could profit from this example and incorporate sleep into their inquiries about work and other aspects of daily life.

Sleep can also be a complex case that existing theories should accommodate. Sleep is not only an aspect of daily life, but also a health outcome, and yet traditional narratives of medicalization do not quite fit. Chapter 1 showed how the media have increasingly focused on the health consequences of poor sleep; however, sleep has not fully fallen under the dominion of medical professionals. When medical professionals do encourage a behavior, such as napping,

the data do not support widespread acceptance of this recommendation. I have argued that it is the deep-rooted Protestant work ethic which complicates a medicalization narrative.

More generally, embeddedness suggests that medicalization occurs within a cultural context. And when long-standing cultural attitudes, such as those derived from Protestantism, oppose the drive towards medicalization, it may not be medicalization which wins out. For instance, Peter Conrad (2005) suggested that while medicalization was once driven by the medical profession and interest groups, it has more recently been driven by technological advances, and "commercial and market interests." (p 3) However, it is possible that a more basic and necessary condition for medicalization to occur is the absence of cultural opposition, for medicalization rests largely on definitions of deviance. If a behavior has long been considered culturally normative, then resistance to its medicalization must be stronger, regardless of claims-making by professionals, advances in technology, or market forces (unless medicalization somehow enhances normativity). An account of culture, in other words, may be necessary to investigate those phenomena, like sleep, which appear to resist medicalization. If a phenomenon does become medicalized, it must be that the necessary condition of socially constructed deviance has been established. Sleep, and its resistance to medicalization, is therefore an anomaly for medical sociologists to explain.

Sleep is anomalous in a different sense as well. Along with positive mental health and self-rated health, sleep appears to be one of the few health concepts that can take an orientation towards health as more than the absence of disorder. This is important for two reasons. First, the literature continues to advance connections between social contexts and positive health. Second, sleep appears to be more commonly measured and an object of inquiry. In sleep, researchers will find a ready-made definition of – and, via chapter 3, a straightforward method to operationalize –

positive sleep health using objective and subjective sleep data. That is, should the social determinants of health continue to turn its focus more to positive health rather than absence of disorder, sleep may rank among the leading candidates for study.

This positive orientation was applied in Chapter 5 to social health. Social health was conceived as a positive scale. I argued that social health is not only the presence of objective social integration but also subjective social well-being. Moreover, in sleep we find a phenomenon that is both profoundly psychological as well as physical, objectively measurable as well as self-reported. These insights gleaned from sleep health and positive mental health were applied to social health. Similarly, sleep is not a single outcome but a composite of outcomes with potential associations with both objective and subjective social phenomena. In this way, sleep is again a prism through which sociological concerns can be refracted.

Final remarks

We are embedded in socio-historical and cultural contexts. As the great theorist Emile Durkheim put it, each individual "partakes of an age and a country; he has ideas and feelings which come not from himself but from those around him; he has prejudices and beliefs; he is subject to rules of action which he did not make but which he nevertheless respects" (Durkheim 1973: 38). We have partaken in an "age and a country" which have shaped our "prejudices and beliefs" about the napper, the late sleeper, and which should take priority: work or sleep. Embeddedness respects that our current beliefs and practices around sleep have been shaped by the Industrial Revolution.

I have used the notion of "Industrial Revolution" in a compressed sense, for we have actually undergone three and perhaps four Industrial Revolutions: the first from agrarian life to

mechanization aided by steam power; the second from steam power to electric power; and the third from electric power to complex technologies such as computers and smart-phones. (Schwab 2017) Already we are feeling the effects in the form of blue light emanating from our favorite distractions and enhancers of productivity (computers, smartphones, and e-readers). (Chang et al. 2015; Czeisler 2013) These devices have not been around long enough for us to chart their long-term effect on our sleep and health, but the evidence appears to judge them negatively. (Chang et al. 2015) Moreover, there is some evidence that we are undergoing a 4th Industrial Revolution in which technological advances such as artificial intelligence will reshape the way we work, play, and sleep. (Schwab 2017) If the previous Industrial Revolution is any guide, this latest iteration may have long-reaching consequences on our sleep, and consequently, our health.

Sleep is already attracting attention from health scientists. So far as I can tell, the reason for this is that the primary concerns of population health are those that are antecedent to the previous health outcome of significance. For instance, if mortality is the object of interest, the natural question is: what leads to mortality? If it is then established that cardiovascular disease is the leading contributor to mortality, one asks: what leads to that? If obesity is found to lead to cardiovascular disease, one asks: what leads to obesity? And since accruing evidence links sleep to obesity, the next obvious question is: what affects sleep? In the process of walking the cat back, we inevitably arrive at the social determinants of health and thus sociology. Central to this perspective is embodiment. We embody our social condition, and our bodies – as Nancy Krieger puts it – tell stories. (Krieger 2005)

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